Customer Service Quality and Incomplete Information in Mobile Telecommunications: A Game Theoretical Approach to Consumer Protection.*

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Abstract

There is growing evidence that low-quality customer service prevails in the mobile telecommunications industry. In this paper we provide theoretical support to this empirical observation by using simple game theoretical models where inefficient low-quality service levels are part of an equilibrium strategy for the firms. We also find that the inefficiency is due to a demand-side market failure generated by incomplete information, and that it does not necessarily vanish with competition or with repeated interaction. This is particularly important in terms of policy implications because it suggests that the inefficiency should be solved through regulation via consumer protection.

Key words and phrases: mobile telecommunications, consumer protection, game theory, customer services, competition, oligopoly, market failure, experience goods, incomplete information.

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1 Introduction

This work is part of an ongoing research project on consumer protection in mobile telecommunications. The main purpose of the project is to analyze if individual consumers of mobile telecommunications are subject to abuses by mobile operators, if these abuses might possibly arise due to market failures, and how improved regulation can increase overall welfare. In this paper we focus on a common situation, namely providing low-quality customer service, which seems to be spread among mobile operators worldwide (Sappington 2005, El País 2012, El Espectador 2012).

We rationalize this outcome by using simple game-theoretic models where low quality is obtained in equilibrium. We also show that the low-quality equilibrium is inefficient (i.e. overall welfare would improve by providing higher quality) and that the inefficiency may not be solved through repeated interaction or competition. This result is important in terms of policy implications because it suggests that competition may not solve the inefficiency and therefore justifies regulation via consumer protection (see Smith 2000, Cherry 2010).

Our basic model involves the following two-stage game: In the first stage, the firms (mobile operators) providing the good (phone contract) simultaneously choose a price-quality pair. The price refers to the whole mobile phone service while the quality refers solely to the post-sale customer service associated to the phone contract (which is unobservable for the consumer upon purchase) [1]. In the second stage, a single (representative) consumer makes his purchase decision after observing all the prices, but remains ignorant about the qualities of the services (which are only revealed at the end of the second stage). The consumer prefers higher quality over lower quality, but the former is more costly to firms than the latter. We consider variations of the model according to the number of participating firms (one, two, several) and whether the game is played just once (one-shot) or several times (finitely and infinitely repeated).

The crux of the problem is incomplete information: mobile phone contracts are what are known as experience goods (Nelson 1970), that is, goods that possess some features that are not observable by the consumer upon purchase and that can only be learned through experience. Costumer service in mobile telephony is such a feature: the mobile operator knows exactly the quality it provides but it is impossible for the consumer to observe its quality before actually using it, therefore the consumer has incomplete information about the service.

[1] To avoid confusion between these two services - the phone service and the customer service - we will refer to the former as the "good" and the latter as the "service". Therefore, the price refers to the whole good while the quality refers only to the customer service.

Although our work is motivated by empirical evidence in the mobile telecommunications industry, it applies to the general setting of an experience good with an unobservable quality and is thus related to the literature on vertical differentiation, adverse selection, and signaling games and reputation.

In their vertical differentiation models, Shaked and Sutton (1982) and Motta (1993) find that under complete information (i.e. when quality is observable for the consumer) firms choose to differentiate their products in order to relax price competition. This no longer holds under incomplete information: in our model we find equilibria where both firms choose the same low quality (i.e. no differentiation), although they may or may not relax price competition. In a similar vein to ours, Bester (1998) finds that when allowing for vertical as well as horizontal differentiation, incomplete information drives firms to no differentiation (i.e. they choose the same quality and locate at the same place) although he focuses on high-quality equilibria.

Our low-quality equilibria bear a resemblance to the "lemons" problem found by Akerlof (1970) in his adverse selection model for the used-car market, where only the bad cars (lemons) are traded. Despite this resemblance, the major difference is that in our model, quality is an endogenous variable (firms choose between high and low quality), while in his model it is exogenous (a used car owner either has a lemon or not).

Repeated purchases play an important role because they may allow for firms to signal their quality and build a reputation. Milgrom and Roberts (1986) show that when quality is exogenous, firms may use prices to signal their true quality and support separating equilibria (i.e. coexistence of different quality levels). In our model, separating equilibria are not possible, because when quality is endogenous, firms are driven to choose the same quality level. For finitely repeated purchases we show that the unique equilibrium outcome implies the low-quality choice (i.e. there is no possibility of building a reputation). However, with an infinite horizon there is equilibrium multiplicity: although the low-quality choice by all firms continues to be an equilibrium, we also show that there are price-signaling equilibria that support the high-quality choice (i.e. firms are able to build a reputation). This result goes along the same line of thought as the quality premium and reputation models by Shapiro (1983) and Klein and Leffler (1981). Nevertheless, the quality level obtained in equilibrium relies heavily on the consumers' expectations, and in particular we show that under pessimistic beliefs only the low-quality level may prevail.

The rest of the paper is organized as follows. In section 2 we present our benchmark monopoly model which is a generalization of Tirole (1988, pg. 96). In section 3 we analyze the duopoly case which also leads to an inefficient equilibrium outcome. In section 4 we show that the low-quality equilibrium continues to hold for a large number of firms. Section 5 offers concluding remarks. Proofs and examples are in the Appendix.

2 The Model (Monopoly)

We will consider a single representative consumer with utility function

$$U(p,q) = \begin{cases} \theta q - p & \text{if buying quality } q \text{ at price } p \\ 0 & \text{otherwise} \end{cases}$$

where p is the price of the good, q is the quality level, and θ is a taste parameter reflecting how much the individual values quality. This corresponds to the standard utility function used in models of vertical differentiation (i.e. when goods may differ only in their quality). For simplicity we assume that q can take only two values: h ("high") or l ("low"), with $h > l \geq 0$. In Tirole's model these levels take the particular values $h = 1$ and $l = 0$. As we will show later on, when $l > 0$, our generalization allows for equilibria that are not possible in that model.

There is only one firm producing the good and the per-unit cost of providing the qualities are, respectively, $c_h > c_l > 0$ (i.e. high quality has a higher cost). We assume that there are no fixed costs and therefore the per-unit profit of the firm is given by

$$\pi(p,q) = \begin{cases} p - c_q & \text{if selling quality } q \text{ at price } p \\ 0 & \text{if not selling} \end{cases}$$

Note that the social surplus of producing quality q is

$$W_q = U(p,q) + \pi(p,q) = \begin{cases} \theta q - c_q & \text{if trading takes place} \\ 0 & \text{otherwise} \end{cases}$$

Therefore, the high quality level is socially efficient whenever $\theta h - c_h > \max\{0, \theta l - c_l\}$. For our specific case of mobile telecommunications, it seems very natural to assume that providing the high-quality service is socially better than providing low-quality service which in turn dominates not providing the service at all. Therefore we will assume

$$\theta h - c_h > \theta l - c_l > 0$$

It is worth noticing that this assumption does not hold under Tirole's model since when $l = 0$ no production dominates providing low-quality service.

The time structure of the game is as follows: In the first stage the firm (player 1) chooses a price-quality pair (p, q). In the second stage, having observed p but ignoring q, the consumer (player 2) decides whether to buy or not. Let G be this one-shot game and denote by $G^T(\delta)$, the game G repeated during T periods with common discount factor δ. We turn now to study the equilibria of these games.

2.1 One-Shot Game

Notice that since player 2 doesn't know the level q when she decides her action and since player 1 doesn't know player 2's action when deciding the quality level q, the induced game is strategically equivalent to a game where player 1 chooses the price p in the first stage and in the second stage there is a simultaneous game where player 1 chooses quality q and player 2 chooses whether to buy or not, as illustrated in the following figure

[FIGURE 1 GOES HERE]

- **Assumption:** we will make the standard assumption that the consumer buys whenever indifferent.

Solving the game backwards we obtain a unique subgame-perfect Nash equilibrium ($SPNE$): for any p chosen in the first stage, the second stage game in strategic form is

	B	N
h	$p - c_h, \theta h - p$	$0, 0$
l	$p - c_l, \theta l - p$	$0, 0$

(1)

Notice that player 1 will play l because it is a dominant strategy. By eliminating strategy h from game (1) we observe that player 2 chooses to buy as long as

$$\theta l - p \geq 0 \tag{2}$$

(the assumption allows for the inequality not being strict). Knowing this, in the first stage the firm will choose the highest price p for which (2) holds, i.e.

$$p = \theta l$$

Therefore, in the unique $SPNE$ the firm chooses quality l and the payoffs are

$$U^* = 0 \qquad \text{and} \qquad \pi^* = \theta l - c_l > 0$$

The result is inefficient since by assumption $\theta h - c_h > \theta l - c_l = U^* + \pi^*$.

The $SPNE$ is characterized by the strategy profile $s^* = (s_1^*, s_2^*)$, where

$$s_1^* = (p, q) = (\theta l, l) \qquad \text{and} \qquad s_2^* = B \iff p \leq \theta l$$

2.2 Finitely Repeated Interaction

Let's consider now game $G^T(\delta)$ with finite T. Since the stage game G has a unique $SPNE$, solving by backward induction we obtain a unique $SPNE$ for $G^T(\delta)$ which consists of playing s^* unconditionally at each period. Therefore the firm chooses the low quality in every period and per-period payoffs are the ones corresponding to the one-shot game. Thus, we have shown that under a finite horizon and a single firm the inefficient low-quality outcome is not only an equilibrium but it is in fact the unique equilibrium.

2.3 Infinitely Repeated Interaction

Let's focus now on game $G^\infty(\delta)$. Once again, playing unconditionally in every period the strategy profile s^* constitutes a $SPNE$ of game $G^\infty(\delta)$ for any value of δ. However this is no longer the unique $SPNE$ of the repeated game. In fact there are infinitely many equilibria: applying the "Folk" theorems (see Fudenberg and Tirole 1991) it is possible to find a $SPNE$ supporting at each period any outcome yielding feasible per-period payoffs for both players higher than those of s^*, provided δ is sufficiently large (i.e. players are sufficiently patient). In the appendix we illustrate this result by constructing multiple $SPNE$ of $G^\infty(\delta)$ where in all of them the high quality is provided at each period. (they differ on how the social surplus is distributed between the firm and the consumer and in the minimum value of the discount factor that supports them).

We have thus shown that for the monopoly case and under the three scenarios (one-shot, finitely repeated and infinitely repeated) there exists an inefficient equilibrium where the low quality is produced. In the first two scenarios this is in fact the unique equilibrium while in the last it is the unique equilibrium that holds for any value of the discount factor δ. However, if δ is sufficiently large, there are also efficient equilibria where the high quality is produced. Notice that in all of the inefficient low-quality equilibria the utility obtained by the consumer is zero while all the social surplus is captured by the firm. In these equilibria, the inefficiency obviously calls for regulation and the fact that the consumer doesn't obtain any gains from trade calls for consumer protection. In the following sections we study the implications of allowing for multiple firms providing the good.

3 Duopoly

Consider now the extension of the previous model allowing for two firms. Let's label the firms as players 1 and 2, the consumer being player 3.

3.1 One-Shot Game

The time structure of the one-shot game G is as follows: in the first stage both firms simultaneously choose a price-quality pair. In the second stage, the consumer observes both prices (but doesn't observe the chosen qualities) and then decides whether to buy or not and from which firm. Contrary to the monopoly case, here we cannot find an equivalent game that may be solved by backward induction. In other words, there is no proper subgame of G and therefore subgame perfection is of no use. Of course, the consumer's decision must be based on the observed prices as well as on the expectations or beliefs he has on the chosen qualities. Let q_i^e be the quality the consumer expects from firm i. Since prices are the only information available at the time of the consumer's decision, the consumer can use them to form his expectations, therefore we define beliefs as functions of prices. Following Bester (1998) we can restrict to degenerate expectations since the firm's quality choices are nonrandom (i.e. we are looking for pure-strategy equilibria), then for any price pair (p_1, p_2), we have $\forall i = 1, 2$

$$q_i^e (p_1, p_2) \in \{h, l\} \tag{3}$$

Let's define a *beliefs system* $q^e (.)$ as the function that assigns to each possible observed price pair (p_1, p_2), the qualities the consumer expects from each of the two firms, i.e. $q^e (.) = (q_1^e (.), q_2^e (.))$, where $q_1^e (.)$ satisfies (3). The consumer's decision is straightforward given his beliefs system: he just chooses to buy from the firm that, according to his beliefs, offers him the highest utility (as long as this utility is nonnegative in which case he would prefer not to buy from any firm). Again, we will assume that the consumer buys whenever there is indifference between buying or not. We also assume that if there is indifference between buying from the two firms he buys from each with equal probability. Formally, given $q^e (.) = (q_1^e (.), q_2^e (.))$ the optimal strategy for the consumer is

$$s_3^* (p_1, p_2, q^e (.)) = \begin{cases} \text{buy from } i & \text{if} \quad \theta q_i^e (p_1, p_2) - p_i \geq \max\limits_{j \neq i} \left\{ \theta q_j^e (p_1, p_2) - p_j, 0 \right\} \\ \\ \text{not buy} & \text{if} \quad 0 > \max \{ \theta q_1^e (p_1, p_2) - p_1, \theta q_2^e (p_1, p_2) - p_2 \} \end{cases} \tag{4}$$

As solution concept for the game G we will use that of *rational-expectations equilibrium*, which explicitly states the consumer's beliefs and requires that they are confirmed in equilibrium and that all players respond optimally to them. Clearly, in any *rational-expectations equilibrium,* the consumer must play the strategy given by (4). Therefore we formally define it in terms of the firms' strategies:

- **Definition:** A beliefs system $q^{e*}(.) = (q_1^{*e}(.), q_2^{*e}(.))$ and a strategy profile $s^* = (s_1^*, s_2^*)$, with $s_i^* = (p_i^*, q_i^*)$ for $i = 1, 2$, constitute a *rational-expectations equilibrium* if, $\forall i = 1, 2$
  1. s_i^* is optimal given s_{-i}^* and beliefs $q^{e*}(.)$
  2. $q_i^{*e}(p_1^*, p_2^*) = q_i^*$

The first condition ensures that s^* is a Nash equilibrium for given beliefs q^{e*}, while the second condition guarantees rational expectations (i.e. beliefs are confirmed at equilibrium). Additionally, we will restrict to equilibria where the consumer buys the good with equal probability from any of the firms (otherwise at least one firm would leave the market).

We now show that in equilibrium both firms choose low qualities and set prices equal to marginal cost (and the consumer buys from any of them with equal probability) as stated in the following proposition

- **Proposition 1:** Let a strategy profile $s^* = (s_1^*, s_2^*)$ and a beliefs system $q^{e*}(.) = (q_1^{*e}(.), q_2^{*e}(.))$ constitute a *rational-expectations equilibrium.* Then

$$q_1^* = q_2^* = l$$
$$p_1^* = p_2^* = c_l$$

  Proof: the formal proof is in the appendix (for the general case with $n \geq 2$ firms). But the intuition is very simple: we first show that, as in the monopoly case, choosing l is a dominant strategy for each firm. In fact it is strictly dominant unless the firm doesn't sell. This means that the only reason should a firm choose high quality is because it's certain it won't sell which then implies that high quality would never be provided in equilibrium. Anticipating this, the consumer should have beliefs assigning low quality to both firms. But then we are in the same situation as in a Bertrand Duopoly with complete information, and therefore the unique equilibrium prices are $p_1^* = p_2^* = c_l$.

Notice that although there is a unique equilibrium outcome - firms provide low quality and set prices equal to marginal cost, and the consumer buys from any of them with equal probability - there are multiple equilibria (all yielding the same outcome). The reason for this is that our equilibrium concept requires that along the equilibrium path, beliefs should be pessimistic (in the sense that the consumer should expect low quality from both firms) but it poses no restriction on how beliefs are formed off the equilibrium path. In fact any off-equilibrium beliefs are admissible as part of a rational-expectations equilibrium, thus giving rise to multiple equilibria. Some equilibrium refinements have been proposed (e.g. perfect Bayesian, sequential, trembling-hand perfect, and proper equilibrium) in order to discard untenable beliefs off the equilibrium path, but all of those refinements will yield the same outcome since, in this case, the equilibrium outcome is unique. However, one may wonder what kind of beliefs could be accepted as tenable off the equilibrium path. The answer to this is imbedded in the fact that low quality is a dominant strategy for *any* possible price pair: therefore, the consumer should expect low quality upon observing any price pair (and not just equilibrium prices). This leads us to select a unique rational-expectations equilibrium, namely, the one involving pessimistic beliefs for any price pair as stated in the following definition

- **Definition:** in game G we say that the consumer has **pessimistic beliefs** if for any given price vector p he expects both firms producing low-quality, i.e. $\forall (p_1, p_2), \forall i = 1, 2$
$$q_i^e (p_1, p_2) = l$$

The corresponding payoffs in this unique equilibrium are

$$U^* = \theta l - c_l > 0 \qquad \text{and} \qquad \pi_1^* = \pi_2^* = 0$$

As in the monopoly case, this equilibrium is inefficient because of the low quality provided. However, in this case, the price competition between both firms drives the equilibrium price down to marginal cost so that all the gains from trade go to the consumer. As we shall see, this continues to hold if the game is repeated a finite number of times. However, with infinitely repeated interaction, firms may recapture the consumer's surplus by means of tacit collusion.

3.2 Finitely Repeated Interaction

Consider now game $G^T(\delta)$ for T finite and where G is the duopoly game of the previous section. For the finitely repeated game there is a unique equilibrium: the one-shot equilibrium under pessimistic beliefs repeated every period. To see this let's consider the last period. The consumer observes the period-T prices and makes his purchase decision depending on those prices and his period-T beliefs about qualities. Period-T beliefs are now much more complicated than the one-shot game beliefs. This is so, because the consumer has now more information from which to form his beliefs: he knows current T-period prices, he knows the prices from all previous periods and, if he bought from firm i in period $t \leq T$, he also knows q_i^t - the quality chosen by firm i in period t. Therefore, period-T beliefs may depend on all of that information. But no matter how complicated those beliefs may be, exactly the same argument used in the one-shot game shows that, period-T equilibrium beliefs should also be pessimistic and therefore firms should choose low quality and set $T-$period prices equal to marginal cost. The key reason for this is that period-T choices have no effect in future actions simply because there is no future beyond period T. Therefore, all players should behave in period T exactly as they do in the one-shot game. Since there is a unique equilibrium in the one-shot game (the one with pessimistic beliefs), that must be the predicted equilibrium in period T. Having obtained a unique equilibrium for the last period, the usual unwinding argument follows to obtain the same unique equilibrium played unconditionally in each of the preceding periods. Note that the beliefs supporting this equilibrium are constantly pessimistic in the sense that, for each period t, the consumer expects low quality no matter what the past history of the game has been up to that period. We therefore extend the pessimistic beliefs definition to the case of repeated games and state the result just obtained in the following definition and proposition.

- **Definition:** in game $G^T(\delta)$ the consumer has **pessimistic beliefs** if, for every period $t \leq T$, he expects low quality from every firm, independently of what the history of the game has been up to that period.

- **Proposition 2:** For game $G^T(\delta)$ the unique rational-expectations equilibrium with tenable beliefs implies
  1. The consumer has pessimistic beliefs.
  2. In every period t, firms choose low quality and set prices equal to marginal cost, i.e. $\forall t \leq T, \forall i = 1, 2$

$$\left(p_i^{*t}, q_i^{*t}\right) = (c_l, l)$$

The equilibrium intertemporal payoffs are

$$U^* = \frac{1-\delta^T}{1-\delta}(\theta l - c_l) > 0 \qquad \text{and} \qquad \pi_1^* = \pi_2^* = 0$$

The result is inefficient and, as in the one-shot game, all the gains from trade go to the consumer. We turn now to study the infinitely repeated game.

3.3 Infinitely Repeated Interaction

Infinitely repeated interaction allows for a myriad of equilibria arising in game $G^\infty(\delta)$. In particular, efficient equilibria may be obtained because firms are able to build and maintain a reputation by providing high quality. Notice that in the finitely repeated scenario no high-quality reputation could be formed because both firms have incentives to provide low quality in the last period and then, proceeding with a backward reasoning, firms provide low quality in each preceding period. The infinitely repeated game has no last period and therefore allows for building a reputation. Nevertheless, in this paper we are interested in finding low-quality equilibria that call for consumer protection, since that is the empirical evidence we are aiming at rationalizing. The duopoly cases we have analyzed (one-shot and repeated interaction) have produced inefficient low-quality equilibria where the consumer obtains all the gains from trade: although there is inefficiency there is not too much consumer protection needed so far! In the infinitely repeated version of the game, playing unconditionally in every period the unique rational-expectations equilibrium of the one-shot game is also a rational-expectations equilibrium of game $G^{\infty}(\delta)$. But all the gains from trade continue to go to the consumer. However, an infinite horizon allows for tacit collusion where the firms continue to provide low quality and they capture all the gains from trade. For our purposes, this is the interesting case because it is an inefficient equilibrium that calls for consumer protection. The following proposition provides such an equilibrium. The idea behind it is the standard trigger strategies used in infinitely repeated games of complete information: by assuming pessimistic beliefs, we may extend that idea to this incomplete information game.

- **Proposition 3:** Consider each firm $i = 1, 2$ following the strategy

$$\sigma_i^* = \begin{cases} t = 1 : s_i^1 = (p_i^1, q_i^1) = (\theta l, l) \\ \\ t > 1 : \begin{cases} s_i^t = (p_i^t, q_i^t) = (\theta l, l) & \text{if} \quad \forall \tau < t : (s_1^\tau, s_2^\tau) = (s_1^1, s_2^1) \\ \\ s_i^t = (p_i^t, q_i^t) = (c_l, l) & \text{otherwise} \end{cases} \end{cases}$$

Then the profile $\sigma^* = (\sigma_1^*, \sigma_2^*)$ constitutes a rational-expectations equilibrium under pessimistic beliefs for $\delta \geq 1/2$ (i.e. provided firms are sufficiently patient)

Proof: the formal proof is in the appendix (for the general oligopoly case) but the idea is a very simple "carrot-stick" argument: firms start by tacitly colluding in the first period (they set, independently, the low quality monopoly price θl). In the subsequent periods they continue to collude as long as both firms have colluded in all the previous periods. This is the "carrot" incentive. In case a firm deviates in some period t, it triggers an infinite punishment phase (the "stick") starting in period $t + 1$, because the other firm will permanently set its price equal to marginal cost. When considering an unilateral deviation in some period t a firm must weigh the immediate benefits (by setting its price slightly below θl it captures all the period-t market) against future losses (future profits are zero since the other firm will set the price equal to marginal cost forever after). The more a firm values the future (i.e. for higher values of δ) the least likely the unilateral deviation will be profitable. The key that allows us to use the same argument as in a complete information repeated game (i.e. the trigger strategies) is that under pessimistic beliefs there is no need in considering deviations that involve producing high quality.

This equilibrium is inefficient because the low quality is provided. But now all the gains from trade go to the firms because of the tacit collusion; the corresponding intertemporal payoffs are

$$U^* = 0 \qquad \text{and} \qquad \pi_1^* = \pi_2^* = \frac{1}{2}\left(\frac{1}{1-\delta}\right)(\theta l - c_l) > 0$$

We have thus obtained an inefficient equilibrium for the infinitely repeated game that may call for consumer protection.

The duopoly results we have obtained for the three scenarios rely heavily on the consumer having pessimistic beliefs. However, it is interesting to note that while pessimistic beliefs are an assumption for the equilibrium in the infinitely repeated game, they are a result for the other two: in the one-shot game and the finitely repeated game equilibria, the consumer must have pessimistic beliefs.

Also notice that only in the infinite horizon scenario do we obtain a low-quality equilibrium (provided firms are patient enough), where the consumer looses all his surplus, thus demanding consumer protection that could only be achieved by regulation. A mobile phone contract is indeed an indefinite repeated game and therefore the infinite horizon should be the appropriate setting to model the game. In the next section we show that these results continue to hold when allowing for several firms.

4 Oligopoly

Consider now game $G^{\infty}(\delta)$ with an arbitrary large number of firms $n \geq 2$. By using the same arguments as in the duopoly case we obtain the following results which are the counterparts to those obtained for the Duopoly case (in fact the formal proofs in the appendix are for this general oligopoly case). We also restate the definitions for this general case.

4.1 One-shot game

- **Definition:** we say that the consumer has **pessimistic beliefs** if for any given price vector p he expects all firms producing low-quality, i.e. $\forall i, \forall p = (p_1, p_2, ..., p_n)$

$$q_i^e(p) = l$$

- **Definition:** A beliefs system $q^{e*} = \left(q_1^{*e}(.), q_2^{*e}(.), ..., q_n^{*e}(.)\right)$ and a strategy profile $s^* = (s_1^*, s_2^*, ..., s_n^*)$, where $s_i^* = (p_i^*, q_i^*)$ for every i, constitute a *rational-expectations equilibrium* if, $\forall i = 1, 2, ..., n$

  1. s_i^* is optimal given s_{-i}^* and beliefs q^{e*}
  2. $q_i^{*e}(p_1^*, p_2^*, ..., p_n^*) = q_i^*$

- **Proposition 4:** let a strategy profile $s^* = (s_1^*, s_2^*, ..., s_n^*)$ and beliefs $q^{e*} = \left(q_1^{*e}(.), q_2^{*e}(.), ..., q_n^{*e}(.)\right)$ constitute a *rational-expectations equilibrium.* Then, $\forall i = 1, .., n$

$$q_i^* = l \qquad \text{and} \qquad p_i^* = c_l$$

  Proof: see Appendix.

The corresponding payoffs in this unique equilibrium implying pessimistic beliefs are

$$U^* = \theta l - c_l > 0 \qquad \text{and} \qquad \pi_1^* = \pi_2^* = ... = \pi_n^* = 0$$

4.2 Finitely Repeated Interaction

- **Definition:** in game $G^T(\delta)$ the consumer has **pessimistic beliefs** if, for every period $t \leq T$, he expects low quality from every firm, independently of what the history of the game has been up to that period.

- **Proposition 5:** For game $G^T(\delta)$ the unique rational-expectations equilibrium with tenable beliefs implies
  1. The consumer has pessimistic beliefs.
  2. In every period t, firms choose low quality and set prices equal to marginal cost, i.e. $\forall t \leq T, \forall i = 1, 2, ..., n$

$$\left(p_i^{*t}, q_i^{*t}\right) = (c_l, l)$$

  Proof: follows the same argument as in duopoly case.

The equilibrium intertemporal payoffs are

$$U^* = \frac{1 - \delta^T}{1 - \delta}(\theta l - c_l) > 0 \qquad \text{and} \qquad \pi_1^* = \pi_2^* = ... = \pi_n^* = 0$$

4.3 Infinitely Repeated Interaction

- **Proposition 6:** Consider each firm $i = 1, 2, ..., n$ following the strategy

$$\sigma_i^* = \begin{cases} t = 1 : s_i^1 = (p_i^1, q_i^1) = (\theta l, l) \\ t > 1 : \begin{cases} s_i^t = (p_i^t, q_i^t) = (\theta l, l) & \text{if} \quad \forall \tau < t : \left(s_i^\tau, s_{-i}^\tau\right) = \left(s_i^1, s_{-i}^1\right) \\ s_i^t = (p_i^t, q_i^t) = (c_l, l) & \text{otherwise} \end{cases} \end{cases}$$

  Then the profile $\sigma^* = (\sigma_1^*, \sigma_2^*, ..., \sigma_n^*)$ constitutes a rational-expectations equilibrium under pessimistic beliefs for

$$\delta \geq \frac{n-1}{n}$$

  Proof: see Appendix.

This equilibrium is inefficient because the low quality is provided and all the gains from trade go to the firms because of the tacit collusion; the corresponding intertemporal payoffs are

$$U^* = 0 \qquad \text{and} \qquad \pi_1^* = \pi_2^* = ... = \pi_n^* = \frac{1}{n}\left(\frac{1}{1-\delta}\right)(\theta l - c_l) > 0$$

- **Remark:** we have seen that all the results of the duopoly case apply to the general oligopoly case. However, notice an important difference: the minimum discount factor needed to support tacit collusion in the infinitely repeated game increases with the number of firms:

$$\delta \geq \frac{n-1}{n}$$

  This means that the higher the number of firms, the more patient they need to be in order for the tacit collusion to be an equilibrium. This is so because with a higher number of firms the immediate relative profits of deviating are higher and the future relative loses are smaller, therefore the deviation is more likely to be profitable. This implies that, the smaller the number of competing firms, the more consumer protection is likely to be needed.

5 Conclusions

There is growing evidence that low-quality customer service prevails in the mobile telecommunications industry. In this paper we provide theoretical support to this observation by using simple game theoretical models where low-quality service levels are part of an equilibrium strategy for the firms. We also show that the low-quality equilibrium is inefficient (i.e. overall welfare would improve by providing higher quality). We do so for three different scenarios of the game: one-shot, finitely repeated and infinitely repeated. Later we find that the inefficiency is due to the demand-side market failure generated by incomplete information, and that the inefficiency may not be solved through repeated interaction or competition. In the infinitely repeated scenario there are some high-quality equilibria. Nevertheless, the quality level obtained in equilibrium relies on the consumers' expectations. In particular we show that under pessimistic beliefs only the low-quality level may prevail.

Then we analyze the duopoly case. We show that under the same three scenarios described above, we obtain an inefficient equilibrium that entails both firms choosing the low-quality level. Next, we also consider the oligopoly case. We can show that the low-quality equilibrium continues to hold for a large number of firms. Again, in the infinitely repeated scenario, high-quality equilibria are also possible, but not under pessimistic beliefs.

In terms of policy implications, these results are important because they suggest that competition will not necessarily solve the inefficiency and therefore justifies regulation via consumer protection (for example, by means of imposing minimum quality standars, see Leland 1979).

Consumer protection regulations are partly in place in some industrialized countries. However, more specific rules may be needed in terms of, say, training call center operators, quality standards of call centers, possibilities of accessing supervisors in case of disconformities, and other regulations that are beyond the scope of this paper.

Certain countries have government services that mediate in unsettled customers complaints (SETSI 2012). However, in many cases they are unable to impose fines or penalties to those who fail to apply the remedies mandated by the mediator, which substantially reduces their effectiveness.

Although our work is motivated by empirical evidence in the mobile telecommunications industry, it applies to the general setting of an experience good with an unobservable quality, and is thus related to the literature on vertical differentiation, adverse selection, and signaling games and reputation.

6 Appendix

6.1 *Example: High-quality equilibria for the infinitely repeated monopoly game.*

Consider the stage game G with only one firm and let W_h and W_l be the social surpluses associated with providing high and low quality respectively, i.e.

$$W_h = \theta h - c_h \qquad \text{and} \qquad W_l = \theta l - c_l$$

So that the variation in social surplus Δ is given by

$$\Delta = W_h - W_l = \theta (h - l) - (c_h - c_l) > 0$$

Let $0 < x < \Delta$, we will construct a $SPNE$ where in each period the consumer obtains utility $x > 0$ and the firm gets profits $\pi_x = \pi_l + \Delta - x > \pi_l$. This is a "cooperation" situation in the sense that, if both players stick to the strategy profile, they will receive, in each period t, a higher payoff than the one obtained in the unique one-shot equilibrium. As is usually the case with infinitely repeated games, we do so by constructing a trigger strategy profile where both players earn the cooperation payoff as long as they stick to the strategy profile. In order to enforce this result, there must be a credible punishment in case some player deviates from the cooperation profile, and we do so by permanently punishing them (if there's deviation) with the unique one-period equilibrium (which is credible because it is a $SPNE$). That is exactly what the following profile does:

Consider the strategy profile $\sigma = (\sigma_1, \sigma_2)$ where

$$\sigma_1 = \begin{cases} t = 1 : s_1^1 = (p, q) = (\theta h - x, h) \\ \\ t > 1 : \begin{cases} s_1^t = (p, q) = (\theta h - x, h) & \text{if} \quad \forall \tau < t : (s_1^\tau, s_2^\tau) = (s_1^1, s_2^1) \\ s_1^t = (p, q) = (\theta l, l) & \text{otherwise} \end{cases} \end{cases}$$

$$\sigma_2 = \begin{cases} t = 1 : s_2^1 = (\text{buy} \iff p \leq \theta h - x) \\ \\ t > 1 : \begin{cases} s_2^t = (\text{buy} \iff p \leq \theta h - x) & \text{if} \quad \forall \tau < t : (s_1^\tau, s_2^\tau) = (s_1^1, s_2^1) \\ s_2^t = (\text{buy} \iff p \leq \theta l) & \text{otherwise} \end{cases} \end{cases}$$

If both players follow their strategy, they obtain the following intertemporal payoffs

$$\pi_1(\sigma_1,\sigma_2) = \frac{1}{1-\delta}(\pi_l + \Delta - x) = \frac{1}{1-\delta}(\theta h - x - c_h) \tag{5}$$
$$\pi_2(\sigma_1,\sigma_2) = \frac{1}{1-\delta}(x)$$

Clearly the consumer has no profitable deviation in any period. However at any period t the firm could obtain some extra profits in that period by providing low quality but sacrificing future payoffs by triggering the punishment: if he deviates at $t=1$, by maintaining the price but cutting quality he will obtain the following

$$\pi_1\left(\sigma_1^{'},\sigma_2\right) = (\theta h - x - c_l) + \frac{\delta}{1-\delta}(\theta l - c_l) \tag{6}$$

The deviation is not profitable as long as (5) is higher than (6), i.e.

$$\frac{1}{1-\delta}(\theta h - x - c_h) \geq (\theta h - x - c_l) + \frac{\delta}{1-\delta}(\theta l - c_l)$$

Solving for δ in the above inequality we obtain

$$\delta \geq \frac{c_h - c_l}{\theta(h-l) - x} > 0 \tag{7}$$

Hence, as long as the discount factor δ satisfies (7), the profile (σ_1,σ_2) constitutes a $SPNE$ of $G^{\infty}(\delta)$ yielding the stated per-period payoffs.

6.2 Proof of Propositions 1 and 4

Let a strategy profile $s^* = (s_1^*, s_2^*, ..., s_n^*)$ and beliefs $q^{e*} = (q_1^{*e}(.), q_2^{*e}(.), ..., q_n^{*e}(.))$ constitute a *rational-expectations equilibrium.* Then $\forall i = 1,..,n$

$$q_i^* = l \qquad \text{and} \qquad p_i^* = c_l$$

Proof: the following three Lemmas establish the proof.

- **Lemma 1**: choosing quality l is a dominant strategy for each firm i
  Proof: let q^e be any beliefs system for the consumer, $s_{-i} = (p_{-i}, q_{-i})$ be any strategy profile for all other firms except i, and p_i be any price chosen by firm i.We will show that

$$\pi_i((p_i,l), s_{-i}, q^e) \geq \pi_i((p_i,h), s_{-i}, q^e)$$

i.e. choosing low quality dominates high quality. Having observed prices (p_i, p_{-i}), the consumer makes his purchase decision according to his beliefs q^e. In terms of firm i, this purchase decision falls into basically three case types:

1. The consumer doesn't buy from i, in which case choosing high or low quality yield the same payoff (since the true quality chosen by firm i doesn't affect the consumer's purchase decision):

$$\pi_i((p_i, l), s_{-i}, q^e) = \pi_i((p_i, h), s_{-i}, q^e) = 0$$

2. The consumer buys only from firm i, in which case choosing low quality yields a strictly higher payoff (since the true quality chosen by firm i doesn't affect the consumer's purchase decision)

$$\pi_i((p_i, l), s_{-i}, q^e) = p_i - c_l > p_i - c_h = \pi_i((p_i, h), s_{-i}, q^e)$$

3. The consumer is equally likely to buy from firm i and m more firms, in which case choosing low quality yields a strictly higher payoff (since the true quality chosen by firm i doesn't affect the consumer's purchase decision):

$$\pi_i((p_i, l), s_{-i}, q^e) = \frac{1}{m+1}(p_i - c_l) > \frac{1}{m+1}(p_i - c_h) = \pi_i((p_i, h), s_{-i}, q^e)$$

Therefore choosing l is a dominant strategy.

Note from the three cases in the previous Lemma that the only case where a firm should choose high quality is if it were certain that it wouldn't sell. But then, why bother to choose high quality if it knows it is not going to sell? Therefore we can conclude that the firm will never optimally choose high quality. This proves the following lemma:

- **Lemma 2:** Let (s^*, q^{e*}) be a *rational-expectations equilibrium,* then $\forall i \in \{1, 2, ..., n\}$

$$q_i^* = l$$

Finally we show that in equilibrium all prices must equal marginal cost. This should not be surprising since now the game resembles a Bertrand game: players should anticipate low quality to be produced in equilibrium so that incomplete information vanishes resulting in a price competition game. Lemma 3 proves this.

- **Lemma 3:** Let (s^*, q^{e*}) be a *rational-expectations equilibrium,* then $\forall i \in \{1, 2, ..., n\}$

$$p_i^* = c_l$$

Proof: by Lemma 2, the consumer should anticipate all firms choosing low quality. Therefore the consumer's optimal decision should be to buy from the firm offering the lowest price p_i^* as long as

$$\theta l - p_i^* \geq 0$$

All firms should then set the same price in equilibrium (otherwise some firms would not sell). Clearly, it is not optimal for firms to set prices below marginal cost (since they would get negative profits). If all prices are above marginal cost any firm would find it profitable to unilaterally deviate by setting a slightly smaller price (just as in a regular Bertrand game), therefore, in equilibrium, we must have $\forall i \in \{1, 2, ..., n\}$

$$p_i^* = c_l$$

6.3 Proof of Propositions 3 and 6

In game $G^\infty(\delta)$ for the oligopoly case with $n \geq 2$ firms, consider the following strategy for each firm i

$$\sigma_i^* = \begin{cases} t = 1 : s_i^1 = (p_i^1, q_i^1) = (\theta l, l) \\ \\ t > 1 : \begin{cases} s_i^t = (p_i^t, q_i^t) = (\theta l, l) & \text{if} \quad \forall \tau < t : \left(s_i^\tau, s_{-i}^\tau\right) = \left(s_i^1, s_{-i}^1\right) \\ \\ s_i^t = (p_i^t, q_i^t) = (c_l, l) & \text{otherwise} \end{cases} \end{cases}$$

Then $\sigma^* = (\sigma_1^*, \sigma_2^*, ..., \sigma_n^*)$ constitutes a rational-expectations equilibrium under pessimistic beliefs for discount factor

$$\delta \geq \frac{n-1}{n}$$

- **Proof:** If all firms follow the strategy the intertemporal payoffs are, $\forall i$

$$\pi_i(\sigma_i, \sigma_{-i}) = \frac{1}{1-\delta}\left(\frac{1}{n}\right)(\theta l - c_l) \tag{8}$$

Suppose all firms except i stick to strategy profile σ_{-i} and let $\sigma_i^{'}$ be the best possible unilateral deviation for firm i. Since the future is discounted by factor δ, that deviation should occur at time $t = 1$. There is no need in considering deviations that involve producing high quality because since the consumer has pessimistic beliefs, those kind of deviations could never be the best possible deviation. So let's consider only deviations in the price set. All the other firms are setting their prices equal to θl: by slightly lowering its price, firm i would get all the market in period 1 (thus obtaining immediate profits of at most $\theta l - c_l$) but it triggers the punishment phase starting in period $t = 2$ and therefore will earn zero profits in all subsequent periods (since, starting in $t = 2$, all other firms will set prices equal to marginal cost on a permanent basis). Therefore the intertemporal payoff of the best possible deviation is at most

$$\pi_i\left(\sigma_i', \sigma_{-i}\right) = \theta l - c_l \tag{9}$$

This deviation is not profitable as long as (8) is higher than (9), i.e.

$$\frac{1}{1-\delta}\left(\frac{1}{n}\right)(\theta l - c_l) \geq \theta l - c_l$$

Solving for δ in the inequality above we obtain

$$\delta \geq \frac{n-1}{n}$$

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FIGURE1