Exchange markets with endogenous quality: When the “lemons problem” enhances trade*

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Abstract

A worrying feature of Akerlof’s (1970) model is that the existence of sufficiently many products of relatively low quality (“lemons”) in a market may not only drive those of high quality out of the market, but it may even “…*drive the market out of existence*” (p. 495). We discuss a two-sided market framework with endogenous quality and provide experimental evidence that the “lemons problem”, rather than driving the market out of existence, may lead to a more intense exchange of very low quality products.

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1. Introduction

In Akerlof's (1970) words, "*The presence of people in the market who are willing to offer inferior goods tends to drive the market out of existence*" (p. 495). The original framework assumes that quality is not observable by buyers before a product is purchased. Some early experiments by Holt and Sherman (1999) have replicated the basic lemons story in the classroom. Later, several authors have addressed reputation-related mechanisms which mitigate the lemons problem in a variety of local[1], online[2] and laboratory[3] markets. However, in many real world examples, the appearance of low quality products is associated with intense rather than scarce trade. For example, in many western countries, the entry of low quality products from China has been associated with increased consumption. Also, the tradition of car-boot exchange markets in many countries involves intense trade of rather low-quality products. We argue that in the case in which the quality of the products is a result of traders' choice and the information asymmetry regarding product quality affects both sides of the market, the existence of very low quality products enhances trade, rather than being detrimental to it as predicted by Akerlof (1970).

As suggested in the aforementioned quotation from Akerlof's (1970) seminal paper, we consider a more general framework, in which sellers decide on how much quality to embody in the goods they trade facing a quality-contingent unit cost. Furthermore, we assume that agents on both sides of the market possess an informational advantage regarding the quality of their own products. An interesting example could be a two-sided version of the information and evaluation markets described by Avery et al. (1999). Another case which can be described as a two-sided lemons market with endogenous quality is that of international currency markets, where countries may trade high volumes of low-value currencies. To our knowledge, the case in which agents on both sides of the market know the quality of their own product but ignore the quality of products offered by others has not been studied so far. Furthermore, there has been no analysis of the case in which agents can actually decide on the quality of the goods they are willing to exchange in the market.

An important feature of our framework is that, rather than sellers and buyers, there are two types of agents exchanging their goods in the market, as formalized in the seminal papers by Shubik (1973) and Shapley and Shubik (1977). In such market games, agents with different preferences and endowments individually decide on the quantity of the good they want to exchange, while the relative price of products is determined by their relative scarcity. We consider such a game, extending the framework to the endogenous quality case, allowing agents to decide not only on the quantity but also on the quality of the products they wish to exchange for the other product available in the market. Like in the original framework, individual traders receive shares of the other product available for exchange proportional to their contribution to the total output of their product type. With fixed qualities, such markets resemble perfect competition, when the number of players is sufficiently large[4]. Nash equilibria with trade usually coexist with a Pareto inferior zero-trade equilibrium. Duffy et al. (2011) show that agents systematically avoid such an equilibrium, whereas Barreda-

[1] Greif (1989, 1993).
[2] See Houser and Wooders (2006).
[3] Yamagishi and Matsuda (2002).
[4] See Postlewaite and Schmeidler (1978) and Koutsougeras (2009).

Tarrazona et al. (2015) observe intense exchange even in the absence of a Nash equilibrium with trade. Furthermore, Barreda-Tarrazona et al. (2015) have shown that intense trade and low quality are simultaneously observed in exchange markets with endogenous quality. However, our design establishes that the endogenous low quality of the products exchanged in the market actually enhances trade as compared to the exogenous quality case which is adopted here as the benchmark.

2. *The market game*

We outline first the theoretical framework introduced by Barreda-Tarrazona, et al. (2015). The exchange economy consists of two goods x, y and n agents, divided into two types. Agent i (j) of type I (II) possesses w units of good x (y) and zero units of good y (x). Preferences are described by the utility function $u(x,y)=\beta x+y$ for type I agents and by $v(x,y)=x+\beta y$ for type II agents, with $0<\beta<1$.

Agents individually submit quality and quantity bids in a single market. That is, each type I (*II*) agent can offer an amount $q_i \in [0,w]$ ($q_j \in [0,w]$) of good x (y) of quality $a_i \in [0,1]$ ($a_j \in [0,1]$) in exchange for good y (x). Hence, the action sets for agents are $S_h = \{(a_h, q_h) \in \Re^2_+ \mid 0 \le a_h \le 1, 0 \le q_h \le w\}$. In our setup, the higher the selected quality the higher the cost for the supplier and the higher the utility for the consumers (i.e., active traders of the other type). The average qualities of the two goods offered for exchange are quantity-weighted and are defined as $a_I = \sum_i a_i q_i / \sum_i q_i$ for good x and $a_{II} = \sum_j a_j q_j / \sum_j q_j$ for good y.

Given a profile of quality-quantity bids, the relative price of good y is

$$p = \begin{cases} \sum_i q_i / \sum_j q_j & \text{if } \sum_i q_i, \sum_j q_j > 0 \\ 0 & \text{otherwise,} \end{cases}$$

the final allocation of goods is $(x_i, y_i) = (w - a_i q_i, a_{II} q_i / p)$ for type I agents and $(x_j, y_j) = (a_I p q_j, w - a_j q_j)$ for a type II agents, where divisions over zero are equal to zero whenever they appear in the above expressions.

We define an equilibrium as a Nash equilibrium in quality-quantity bid strategies and we demonstrate that there exists no equilibrium in which an agent submits a pair of positive quality and quantity bids.

Proposition *Any equilibrium requires* $a_h^* q_h^* = 0$ *for all agents* h *of both types.*

Proof We start with the case where all agents submit zero quality bids and/or zero quantity bids. Then, the best response of an individual will definitely involve $a_h^* q_h^* = 0$, because any pair of positive bids leads to lower utility than the consumption of her initial endowment. We now move on to the case where we have a strategy profile that leads to active trading and let us select an agent (of any type) who submitted positive quantity bids. Given that this agent faces a maximisation problem with direct restriction on variables, partial differentiation of the objective function with respect to the quality variable always yields negative sign and hence any solution requires zero quality. That is, the best response for this agent involves zero quality. Consequently there is no equilibrium featuring an agent who submits a pair of positive quality and quantity bids. ■

Following this result, it is easily understood that all equilibria of the game involve zero exchanges, resulting in agents enjoying their initial utility.

Corollary *In equilibrium, all type* I *agents consume* $(x_i^*, y_i^*) = (w, 0)$, *all type* II *agents consume* $(x_j^*, y_j^*) = (0, w)$ *and all agents of both types enjoy utility* $u(x^*, y^*) = v(x^*, y^*) = \beta w$.

3. *An experiment*

The experiment took place between December 2014 and July 2015 at the LEE, Universitat Jaume I (Castellón) and at the LINEEX, University of Valencia. A total of 104 students from business and economics-related subjects were recruited following the standard online protocol. They were randomly assigned to two treatments, a baseline one with Exogenous Quality (48 subjects) and one with Endogenous Quality (56 subjects). In each session, they were divided into 6 (Exogenous Quality) and 7 (Endogenous Quality) independent matching groups respectively, each containing 8 players (4 of each type). In each period, 4 subjects (two of each type) were matched to form two markets per group.

At the beginning of each period, each subject was endowed with 20 units of a good whose unit consumption yields the owner $\beta = 0.6$ units of utility, whereas the same good, at maximal quality, yields 1 unit of utility to the other type of player. This case is implemented in the Exogenous Quality treatment. Following Cordella and Gabszewicz (1998) under maximal quality, Barreda-Tarrazona et al. (2015) observe that, for these values, it is collectively beneficial to engage in full trade, while the non-cooperative equilibrium involves minimal or zero trade. In the Endogenous Quality case, our framework unambiguously predicts either zero quality or minimal quantity trade or both in equilibrium, while full trade-full quality bids by all traders maximize welfare.

In each period (T=1-40), subjects simultaneously submit quantity (integers from 0, 1,…, 20) and –in the Endogenous Quality treatment– quality (from 0, 0.1, 0.2,…,1.0) bids. The experiment was computerized using z-Tree (Fischbacher, 2007). A profit calculator and a payoff table contingent on others' strategies was provided to the subjects to help them to accurately predict the consequences of their strategies for different strategies of their opponents[5]. Feedback was received on own and other's strategies and results from the market a subject had just participated in. The average duration of a session was approximately 100 minutes and average earnings were approximately 17.5€ per subject in the Exogenous Quality treatment and 13€ per subject in the Endogenous Quality treatment.

In Table 1, we provide descriptive statistics for quality and quantity bids throughout the experiment and for the initial and final 5 periods of the session. Whereas the zero- or minimal-trade prediction is strongly rejected by the significant amounts of trade observed, (mean 13.36, median 14 in the Exogenous Quality treatment; mean 16.30, median 20 in the Endogenous Quality treatment), the qualities chosen in the endogenous case are close to zero (mean 0.089, median 0 throughout the session). In Figures 1 and 2, we compare treatments with respect to the distribution of quantity bids pooled across all periods and matching

[5] Instructions and experimental data can be obtained from the authors upon request.

groups. A high concentration of bids is observed on the maximum amount of 20, when quality is endogenous, which is the main finding of our experiment. Clearly, in the Endogenous Quality treatment, trade is much more intense than in the Exogenous Quality treatment. Specifically, in the Exogenous Quality Treatment, 12.03% of all the quantity bids are exactly 20 units, coinciding with the collectively optimal, maximal trade bids, whereas in the Endogenous Quality treatment, 68.26% of all the quantity bids are exactly 20 units. However, this comes at the cost of very low or zero quality. Specifically, in the Endogenous Quality treatment 78.93% of all quality bids are 0. In the last 5 periods of the experiment, these percentages become 29.17% (maximal trade in the Exogenous Quality treatment), 86.43% (maximal trade in the Endogenous Quality treatment) and 96.79% (zero quality in the Endogenous Quality treatment), respectively. In the Endogenous Quality treatment, 85.36% of the bids in the last 5 periods involve both maximum trade and zero quality. In the Exogenous Quality treatment the mean quantity traded in the last 5 periods is 15.84 (rising from 10.13 in the initial 5 rounds), whereas in the Endogenous Quality treatment, the mean quantity traded in the last 5 periods is 18.28 (rising from 11.28 in the initial 5 rounds) with the median rising from 10 units in the first 5 periods to 20 in the last 5 periods and throughout the experiment. In the Endogenous Quality treatment, average quality falls from 0.32 in the beginning to 0.016 towards the end of the session, while the median falls from 0.2 to 0, which is also the median quality throughout the experiment.

Figures 3 and 4 show the evolution of median quantity, the former, and quality, the latter, bids over the 40 periods of the experiment. On one hand, in the Endogenous Quality treatment, before period 10, the median behaviour stabilizes to full (20 units) trade and zero quality. On the contrary, in the Exogenous Quality treatment, median quantity exhibits an increasing trend closer to full trade, without coinciding with it, even after 40 periods. On Figures 5, 6 and 7, a similar pattern can be observed for each independent matching group. In the Exogenous Quality treatment, all groups exhibit an increasing trend of quantity bids, whereas in matching groups of the Endogenous Quality treatment, median behaviour evolves fast to stabilize over the largest part of the session on the zero quality-full trade combination.

Figure 8 shows that the social dilemma emerging in the exchange market considered here is overcome by human subjects only in the Exogenous Quality treatment, in which increasingly intense trade gradually leads to significantly higher utility levels than those of the initial endowment. This is also confirmed for each one of the independent matching groups. On the contrary, the non-cooperative equilibrium prediction regarding final utility levels is strongly confirmed in the Endogenous Quality treatment.

Figures 9 and 10 show a striking coincidence between the theory and observed behaviour in the case of the Endogenous Quality treatment. After the initial periods, the median post-trade utility in each group converges exactly to 12, which is the initial, pre-trade utility. This is predicted by the corollary of our theory, confirming the intuitively appealing property that, in equilibrium, decision makers do not end up worse off than in the initial endowment. This is not the case with the exogenous quality treatment, in which subjects gradually learn how to substantially increase their overall utility above the initial endowment levels.

Finally, in the Endogenous Quality treatment, quality and quantity bids exhibit a strong negative correlation (independence strongly rejected in all cases, p=0.000) in all the sub-periods considered (Spearman's rho =-.5645 in periods 31-40; -.3322 in periods 1-10; -.5322 in the entire session). This is another way to confirm our finding that in the Endogenous Quality framework, the so called “lemons problem” enhances rather than restricts trade.

4. *Discussion*

In many modern economies, a common pattern of trade seems to link high volumes of trade with low quality products. This contradicts the concern inspired by the seminal paper of Akerlof (1970) that the existence of sufficiently many low quality products in a market may drive the market out of existence. We consider a two-sided extension of that seminal model, assuming that the information asymmetry regarding the quality of traded products does not imply an advantage in favour of one type of agent. Furthermore, we consider the case of endogenous quality, relaxing the assumption that the quality of “lemons” is exogenously given. In this two-sided, endogenous quality version of the market for lemons, the prevalence of low quality products leads to unprecedented levels of trade.

It has been known for years that, thanks to a variety of reasons, people overcome social dilemmas generated by divergent individual and collective goals. This has led to a fruitful empirical agenda obtaining positive contributions to public good games, cooperation in prisoner dilemmas, trust, altruistic donations, etc. Likewise, agents in our market game engage in more trade than predicted by the Nash equilibrium. We focus on the largely ignored interplay between quantity and quality strategies. We provide theory based on market games in which agents will either provide too little quantity or too low quality to the market. Our results inspire optimism on the ability of agents to overcome the social dilemma in terms of trade volumes, but not in terms of product quality. Hopefully, the pattern of high-volume/low-quality trade reported here will inspire more research from both a theoretical and an empirical point of view.

5. *Appendix: Figures and Tables*

	QUALITY (Only Endogenous case)			QUANTITY (Endogenous Quality)			QUANTITY (Exogenous Quality)		
	Median	Mean	St. Dev.	Median	Mean	St. Dev.	Median	Mean	St. Dev.
Periods 1-40	0	0.09	0.234	20	16.306	6.595	14	13.361	4.435
Periods 1-5	0	0.323	0.31	10	11.289	6.509	10	10.125	4.466
Periods 36-40	0	0.016	0.113	20	18.282	5.138	17	15.838	4.437

Table 1: Descriptive statistics of quality and quantity bids

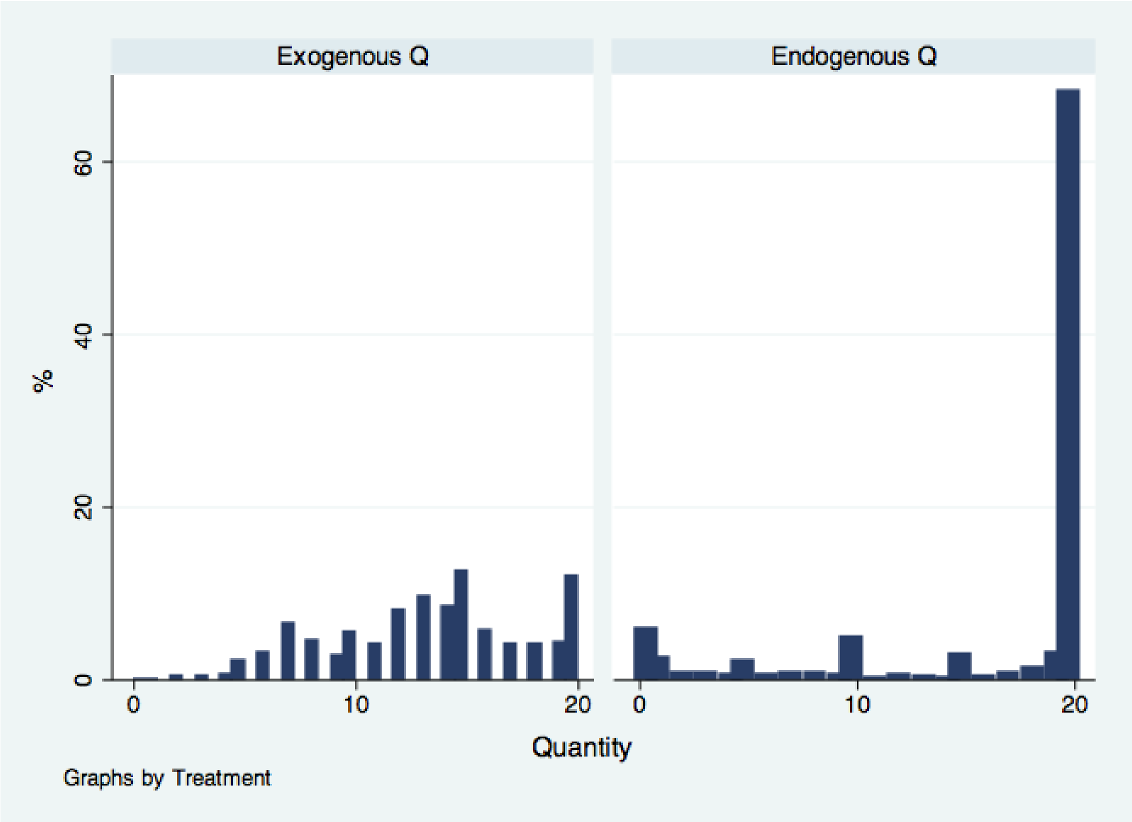

Figure 1: Distribution of Quantity bids by treatment

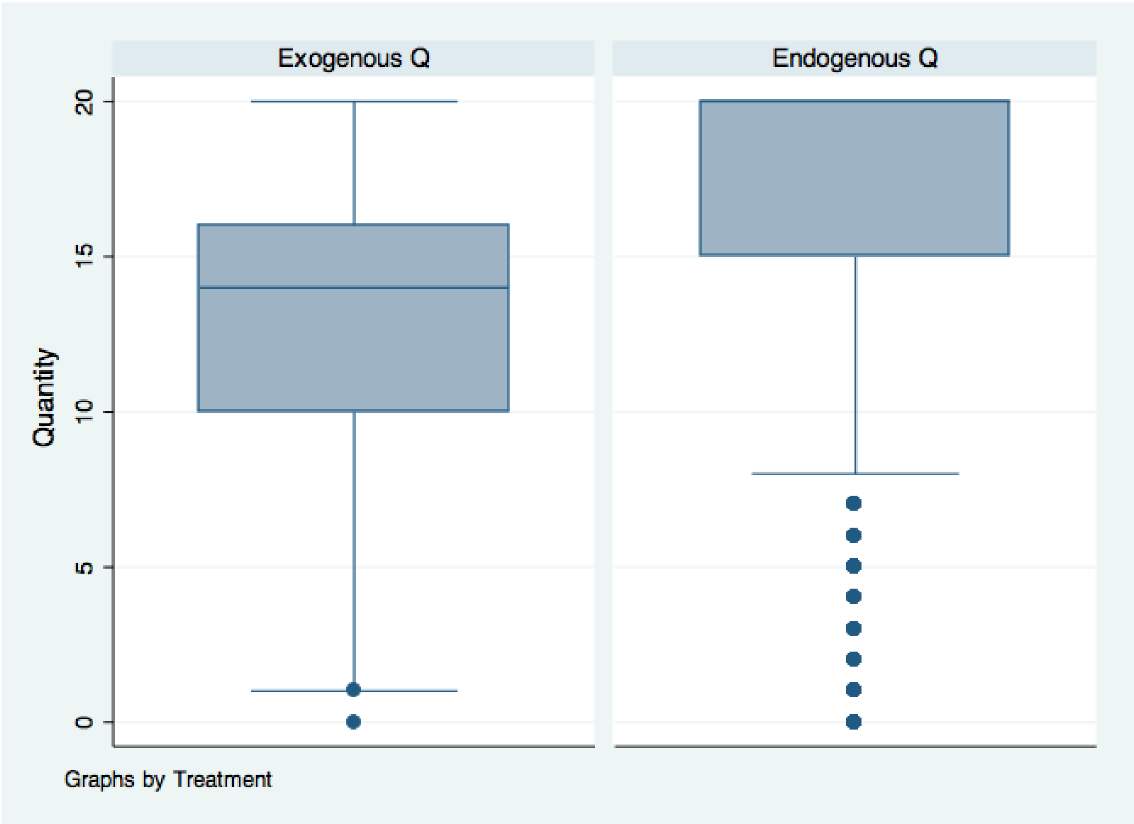

Figure 2: Boxplot of quantity by treatment

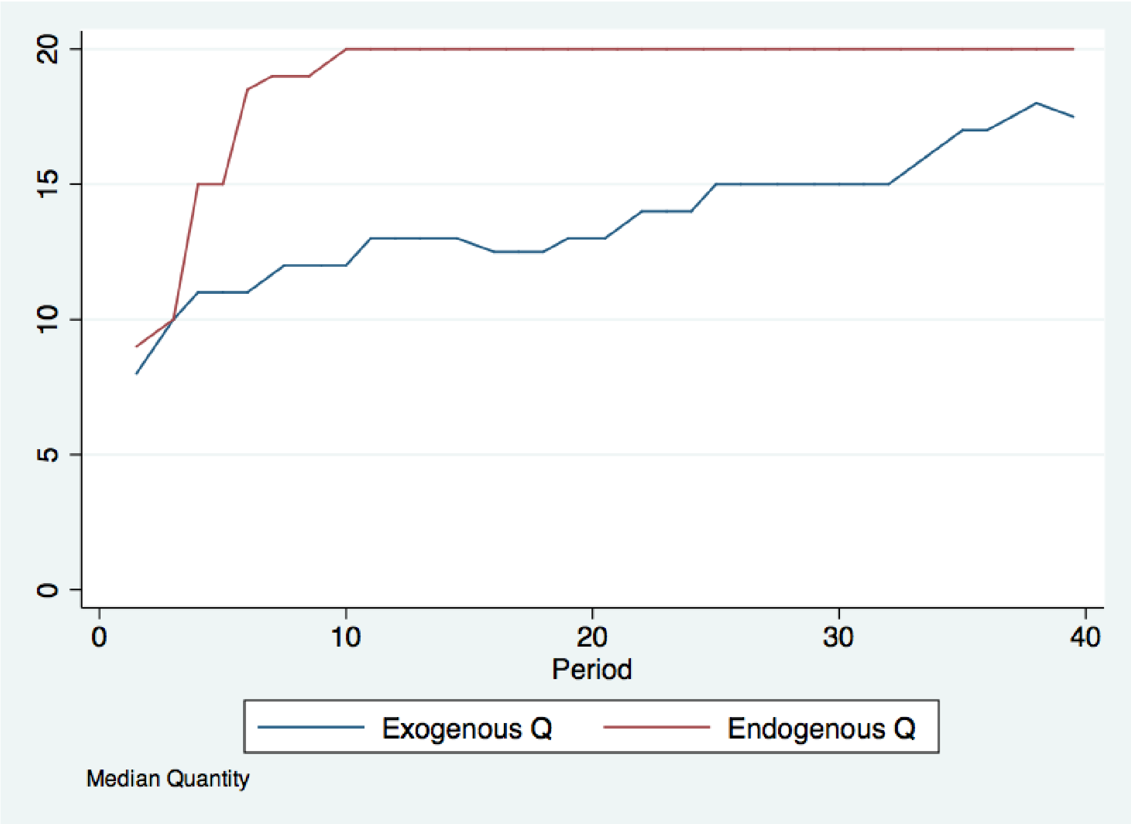

Figure 3: Evolution of median quantity bid by period and by treatment

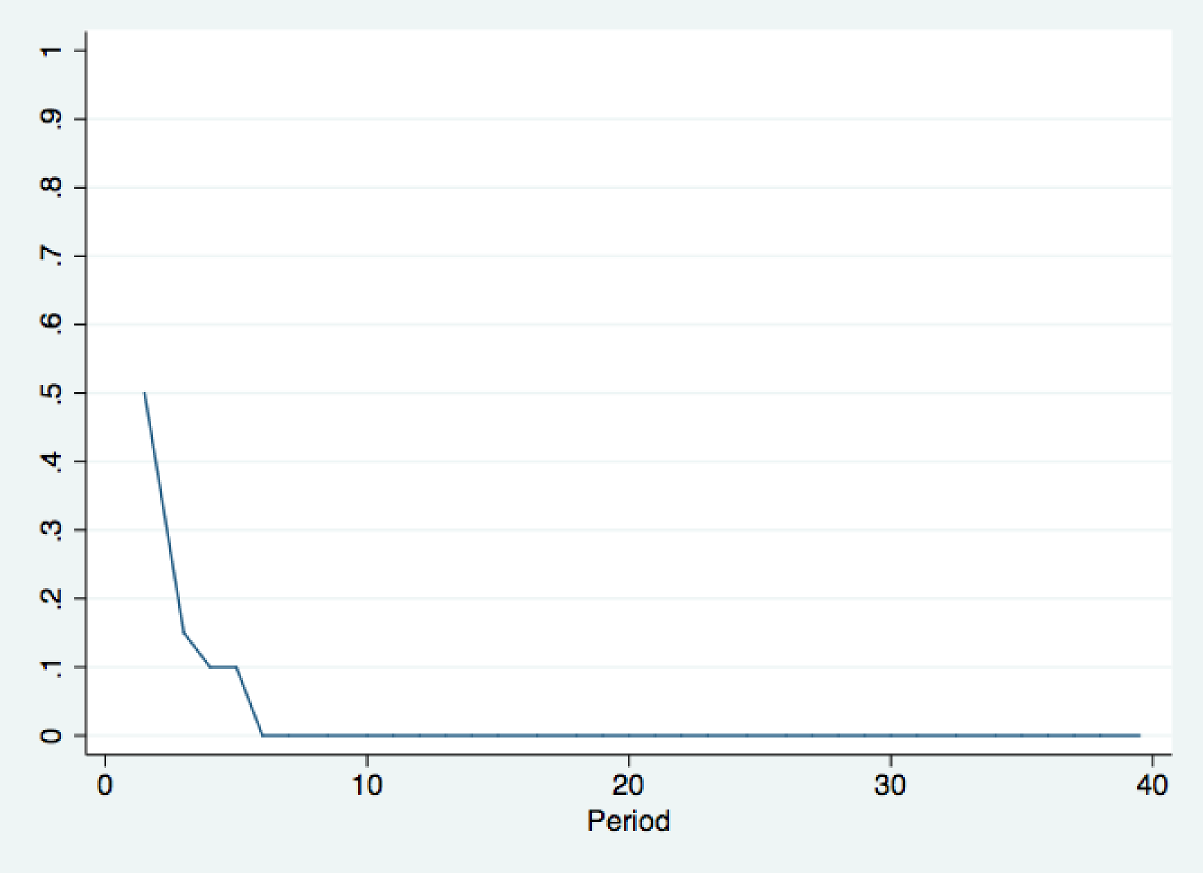

Figure 4: Evolution of median quality bid in the Endogenous Quality treatment

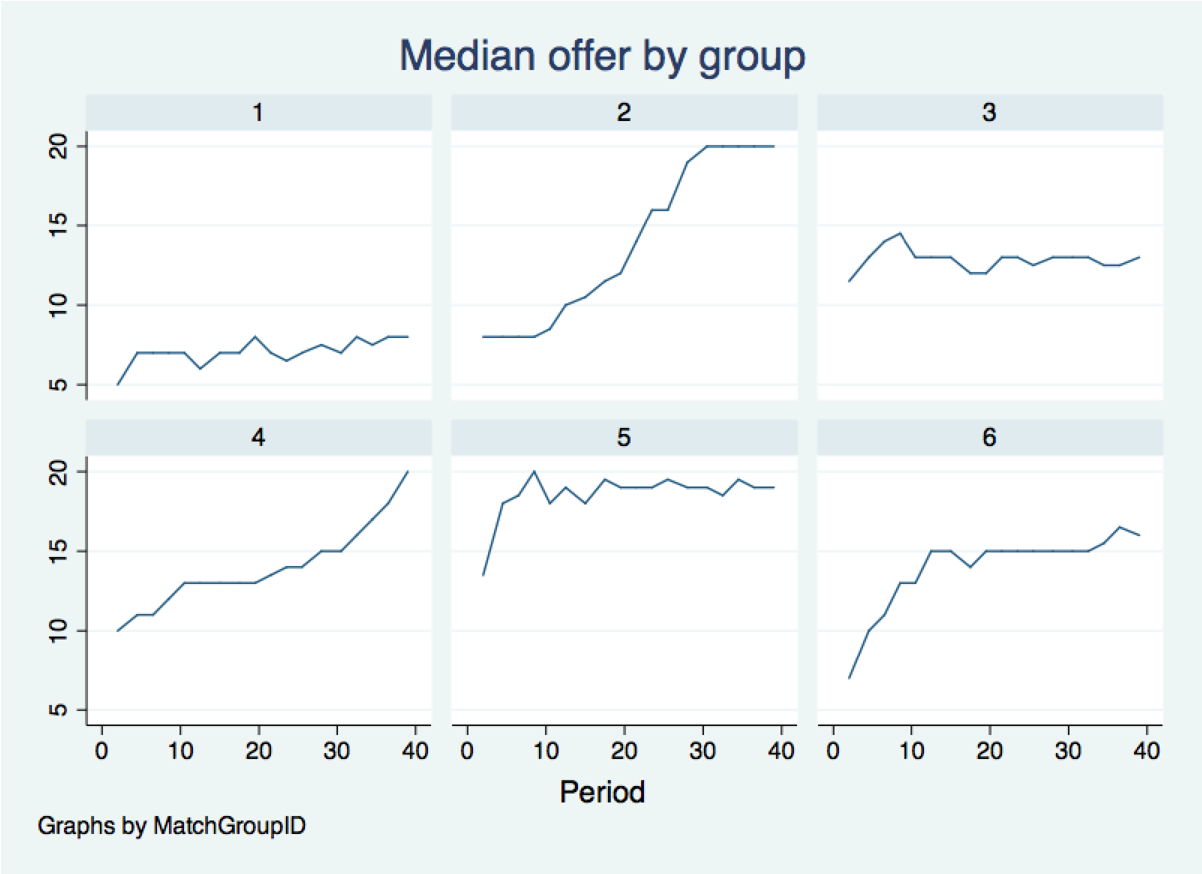

Figure 5: Evolution of the median quantity bid in the Exogenous Quality treatment by matching group

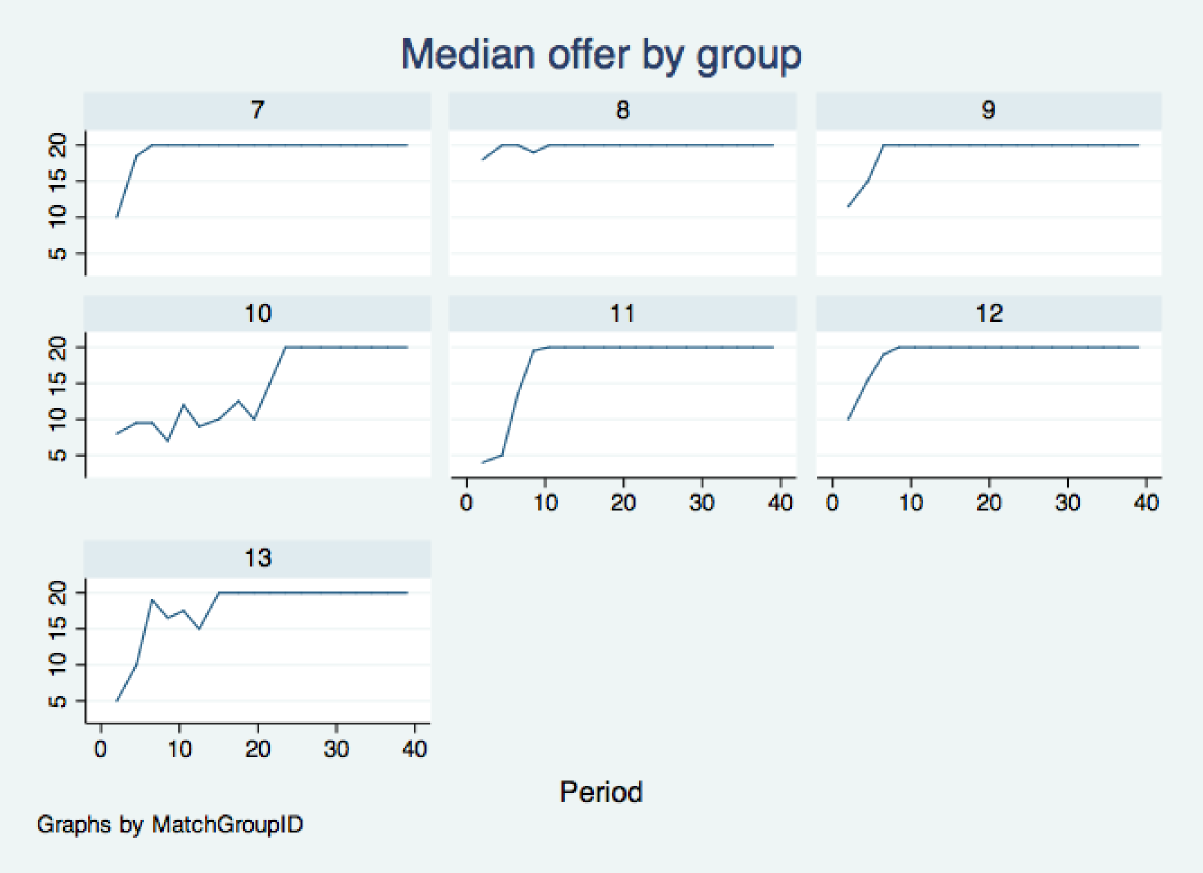

Figure 6: Evolution of the median quantity bid in the Endogenous Quality treatment by matching group

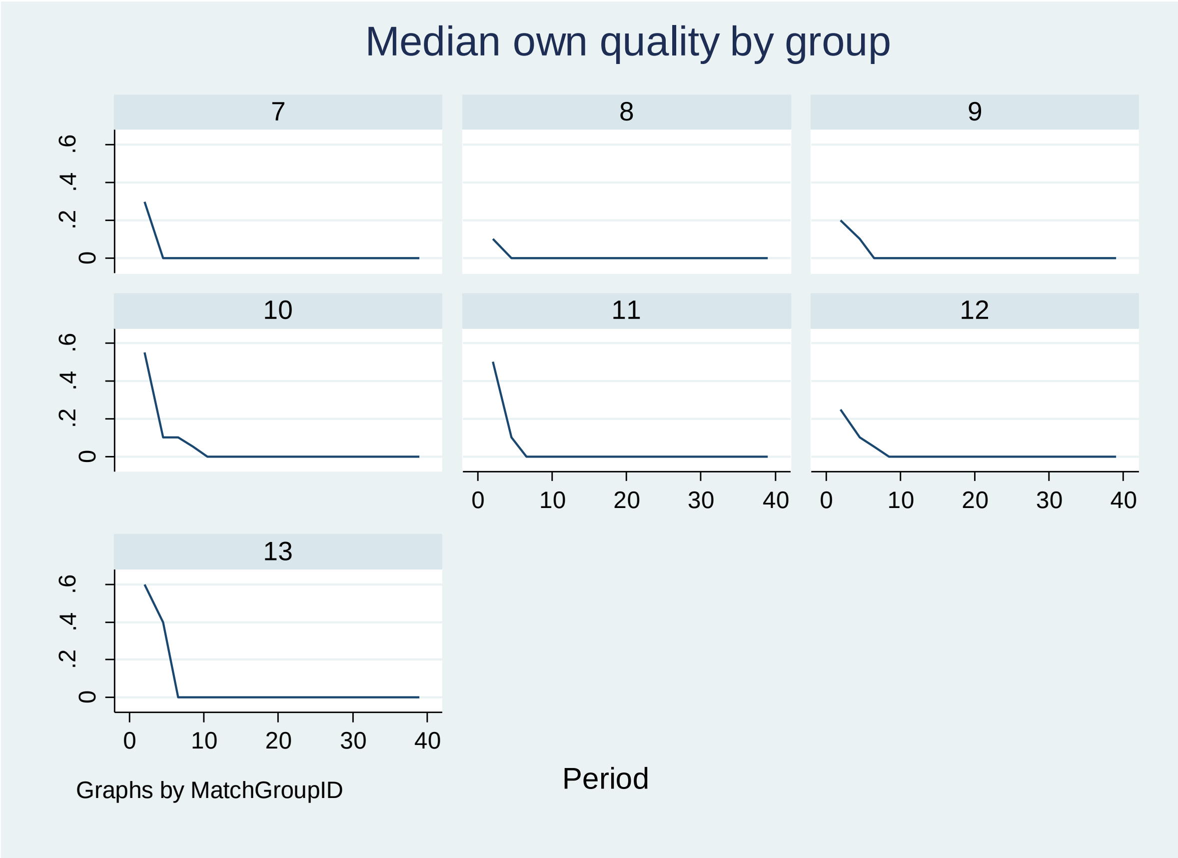

Figure 7: Evolution of the median quality bid in the Endogenous Quality treatment by matching group

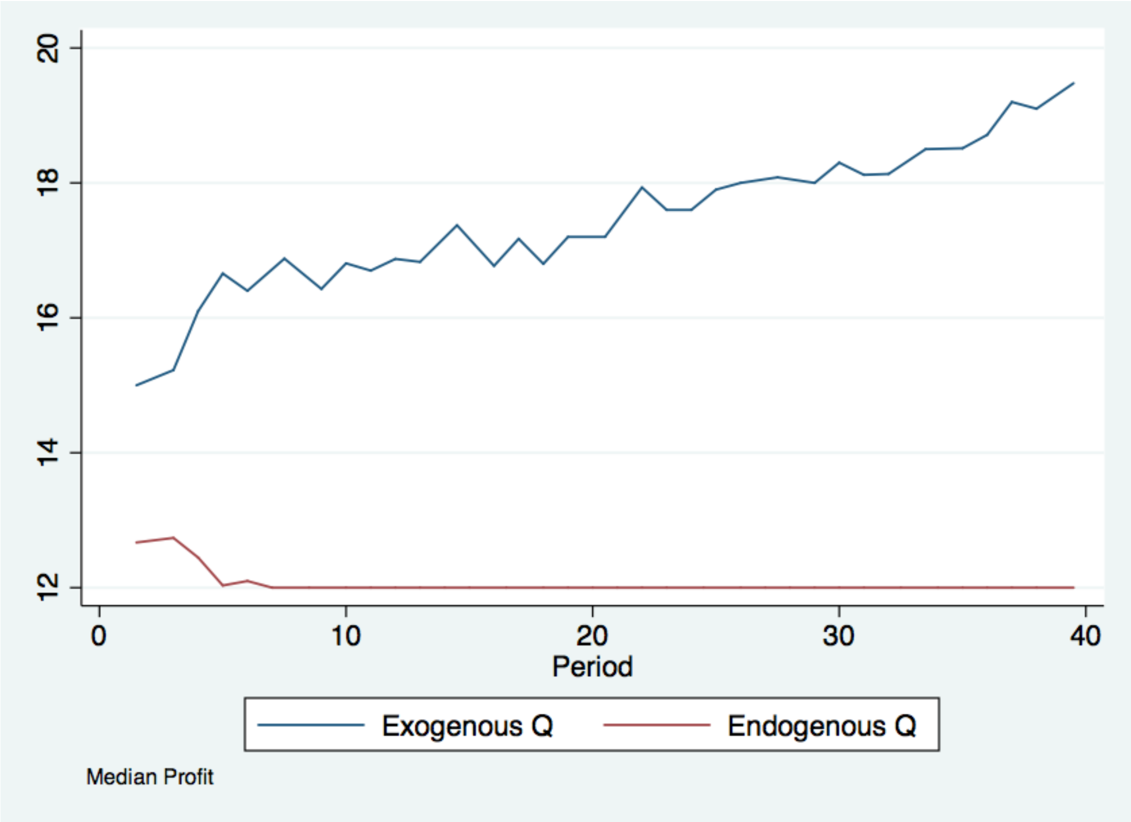

Figure 8: Evolution of median utility by treatment

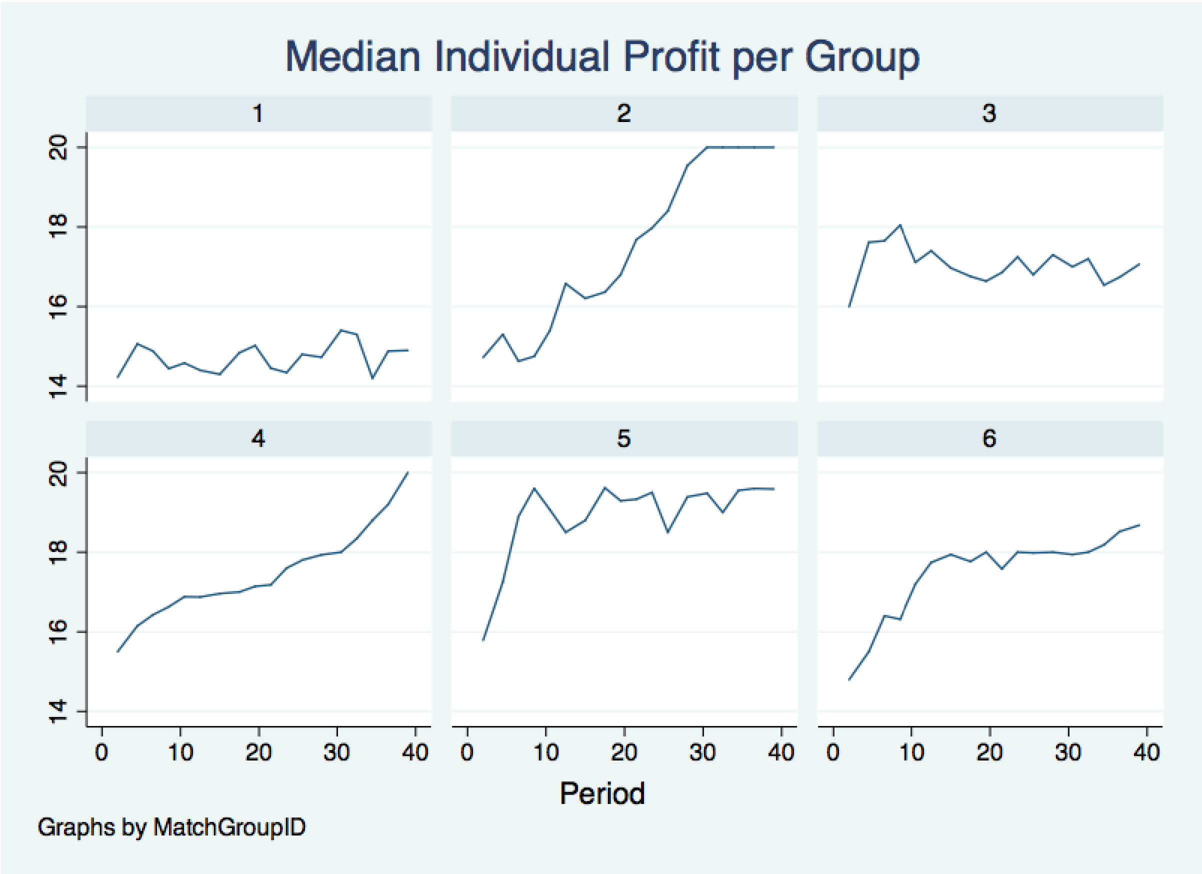

Figure 9: Evolution of median utility in the Exogenous Quality treatment by matching group

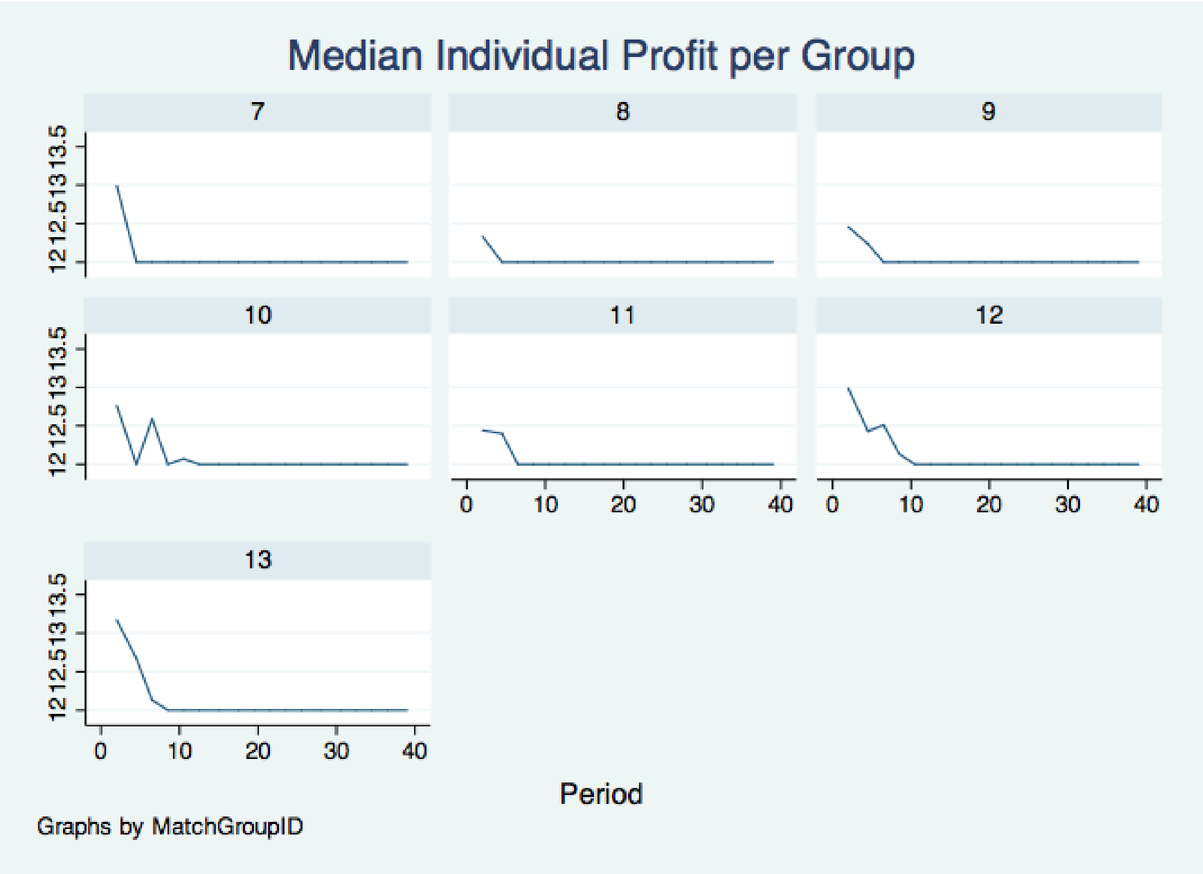

Figure 10: Evolution of median utility in the Endogenous Quality treatment by independent matching group. ("**Corollary** … *all agents … enjoy utility* $u(x^*, y^*) = v(x^*, y^*) = \beta w$.")

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