Network Regulation under Electoral Competition

Anke Leroux [a] and Magnus Söderberg [b]

[a] Monash University, anke.leroux@monash.edu
[b] Corresponding author. Ratio Institute & Halmstad University. magnus.soderberg@hh.se

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Abstract
Academics and policymakers generally agree that energy infrastructure should be subject to price regulation. However, modern regulatory approaches have been subject to increasing criticism for their apparent failure to achieve competitive pricing in practice. Some have suggested that customers ought to be involved in the regulatory process, but it is uncertain how customers' perspectives can best be incorporated. In this study, we evaluate how electoral competition influences monopoly pricing by extending well-known regulatory laboratory experiments. We show that electoral competition has a significant and negative impact on prices. When implemented jointly with incentive regulation our results indicate that electoral competition pushes the price down quicker to the welfare maximising level.

Keywords: regulation; monopoly; experiment

JEL: C91; D47; L51;

1. Introduction

Academics and policymakers generally agree that the service provision from energy infrastructure, such as transmission and distribution networks, should be subject to price or revenue caps and incentives to reduce cost and increase the service quality. This consensus is based on the well-developed theory of natural monopoly regulation for which Jean Tirole received the Nobel prize in 2014. From the early 1980s this theory has enjoyed wide implementation in the electricity sector, where networks continuing to be heavily regulated.

However, more recent practical experience points to incentive regulation having largely failed to achieve competitive pricing in the network sector (e.g. EU, 2014). Information asymmetries, moral hazard problems and generally sluggish price adjustment in response to incentive regulation have all been identified as culprits and have motivated a recent reversal toward greater local governance and re-municipalisation of electricity networks (Isaacs and Molnar, 2016; Julian, 2014). Moreover, rapid technological development and changing consumer behaviour is projected to lead to increasing decentralisation of the energy system, characterised by more small-scale renewable generation and demand-side management activity. Some have argued that these decentralised systems require local governance and management with broader ranging responsibilities than traditional centralised distribution network operators to effectively leverage the greater coordination opportunities (Energy UK, 2016; National Infrastructure Commission, 2016). Important questions arise with respect to the regulatory environment that these local entities should operate in.

It is in light of these recent developments that we explore electoral competition, a novel consumer-focused mechanism, as an alternative or complement to traditional incentive regulation. Electoral competition is a process by which customers vote on who should be in charge of the infrastructure and profit from it for a limited period of time. This form of governance is particularly suitable when the assets are owned by local or national governments, but it could also be an option under other forms of customer ownership, such as customer cooperatives. Moreover, elections can be relevant in jurisdictions where regulatory institutions have not yet reached an advanced level.

We test the effect electoral competition has on the price-setting behaviour of monopolies using laboratory experiments. We find that electoral competition exerts downward pressure on prices and that the average price under electoral competition is significantly lower than when there is no competition. When combined with incentive regulation our results show that electoral competition increases the efficiency of regulation: under certain types of regulation the average price converges to the welfare maximising level at twice the speed compared to when there is no electoral competition.

The power of the electorate rests in its ability to align the interests of an elected official with that of the public. Theoretical models of this concept (Barro, 1979; Peltzman, 1971) have been tested empirically in a variety of contexts. The complex regulatory environment and ownership structures in the context of networks, however, make it very challenging to isolate the effect of electoral pressure on prices. To our knowledge, we are the first to experiment with electoral competition in a controlled laboratory environment. The experimental approach allows us to identify and estimate with precision the effects of electoral competition on prices both on its own and when complemented by incentive regulation. In the absence of regulation, we find that firms do self-regulate as a result of electoral competition. Moreover, regulated monopolists subject to electoral competition reduce the price gap between the monopoly and welfare maximising price by an additional 5% compared with the price reductions achieved by incentive regulation alone.

Finally, we contribute to the literature that explores alternative incentive-based regulatory mechanisms in laboratory experiments (Harrison and McKee, 1985; Cox and Isaac, 1987). These mechanisms are based on decentralized price regulation and unlike other type of incentive regulation do not require that the regulator has any knowledge of the firm's costs or cost opportunities. Our experiment tests two decentralised pricing mechanisms in particular: Finsinger-Vogelsang and Cox-Isaac. In theory both mechanisms achieve price convergence but early experimentation with a small subject pool suggested that this convergence is either slow or hampered by a high risk of monopoly bankruptcy. Our experimental design tests the same regulatory mechanisms within the same decreasing cost environment and under full revelation of the demand curve to sellers as the early Cox and Isaac experiments. Unlike these early experiments ours benefited from a much larger subject pool, consisting of 162 students across 88 repeated, regulatory games. This feature enables us to provide statistical evidence in support of these early findings. Further we augment their experiment by adding electoral competition as a non-regulatory mechanism. We find that similar to the direct contestability environment tested in Harrison and McKee (1985) electoral competition results in prices that are lower than monopoly prices. In addition, we show that incentive regulation combined with electoral competition alleviates the problem of sluggish price convergence that were identified by Cox and Isaac (1987), with Cox-Isaac prices converging at twice the rate compared to a situation without electoral competition.

The remainder of this paper is structured as follows. Section 2 provides a brief background to network regulation, the institutional environment of networks and the concept of electoral competition. The experimental design is described in Section 3, followed by a section outlining the experimental predictions and hypotheses. The results are presented in Section 5 and Section 6 concludes.

2. Background

2.1 Network regulation

Electricity networks typically exhibit natural monopoly characteristics, whereby economies of scale make it inefficient for more than one firm to operate in a given market. To avoid welfare losses from the exploitation of monopoly market power, transmission and distribution services are among the most price regulated segments of the modern economy. Also, network costs represent a large share of the total cost of electricity, and wholesale and retail markets depend on the efficient and reliable provision of network services. Thus, it is of critical importance for the energy sector as a whole that regulation results in cost-effective and high-quality provision of these services (EC, 2014; Joskow, 2014).

Much of the early regulation of electricity networks was focused on their rate-of-return. Also referred to as cost-of-service regulation, this type of regulation is closely related to average-cost-pricing, whereby the regulator adds to the average cost of provision a rate of profit the network is allowed to earn. While rate-of-return regulation theoretically prevents the firm from charging monopoly prices, such regulation is much more difficult to achieve in practice. Identifying the drivers of energy transmission and distribution costs is challenging. Cost opportunities that are available to the regulated firm are unobserved by the regulator, as are individual firms' efforts in reducing costs. Incomplete information and information asymmetries between the regulator and the firm regarding the network's true costs and cost opportunities mean that network managers have no incentive to reduce costs and may even be tempted to over-invest and "gold-plate" their network.

The asymmetric information and moral hazard problems of rate-of-return regulation, identified formally by Averch and Johnson (1962), motivated the development of incentive-based regulation, most notably by Laffont and Tirole (1993). This class of regulatory mechanisms typically involve the regulator offering sliding scale contracts where price or revenue caps are determined by a fixed component as well as one that is contingent on the firm's realised costs. Such caps create direct incentives for firms to reduce their costs, which in turn provides opportunities for the regulator to reduce the cap gradually over time (Joskow 2014). While network regulation evolved to address the problems of moral hazard and information asymmetries between the regulator and the firm (see, for example, Shleifer, 1985; Schmalensee, 1989; Laffont, 1994; Bernstein and Sappington, 1998; Meade 2015), it has not been able to overcome these completely. For example, sliding scale contracts continue to assume that the regulator has some information about the firm's cost environment either in form of the ex-ante probability distribution over its cost opportunities or from being able to observe costs ex-post.[1]

In contrast, Loeb and Magat (1979) propose incentive-compatible decentralized price-regulation, whereby the regulator pays a subsidy equal to the consumer surplus to the regulated firm. They show that the regulated firm maximises after-subsidy profits by setting prices at the competitive level so as to maximise the consumer surplus and therefore the subsidy payment. This mechanism addresses moral hazard problems as realized cost reductions result in higher annual subsidy payments that allow firms to benefit indefinitely from cost reduction efforts. Importantly, relative to the price or revenue cap regulation, the decentralized price regulation reduces the information requirements for the regulator significantly. The regulator is no longer required to have any information about the firm's cost curve. However, knowledge of the firm's demand curve over the relevant output range is necessary to determine the incentive-compatible level of the subsidy. Harrison and McKee (1985) test the theoretical predictions in a laboratory experiment with 17 subjects. They conclude that decentralized price regulation is highly effective in constraining monopoly market power. This result also holds for an experimental variant where the size of the subsidy is effectively recouped by auctioning off the franchise rights to the monopoly at the beginning of each experimental round.[2] In comparison, an unregulated market that is characterised by direct contestability is found to also constrain monopoly power, but less effectively than the Loeb-Magat mechanism. This result raises the question of how the dead-weight loss under market contestability compares to that under Loeb-Magat regulation in the likely situation that the regulator does not know precisely the firm's demand curve.

Finsinger and Vogelsang (1981) devise a variant of the Loeb-Magat subsidy scheme that eliminates the requirement that the regulator has prior knowledge of the firm's demand curve. Instead, the regulator only needs to be able to observe current and past price-quantity points for this mechanism to work effectively. In the Finsinger-Vogelsang design, the regulated firm earns profits

$$pQ(p) - C\big(Q(p)\big) + S(p),$$

where p is the price charged by the firm, $Q(p)$ the quantity demanded at that price and the subsidy S received at each regulatory cycle is given by

$$S_t = S_{t-1} + Q_{t-1}(p_{t-1} - p_t).$$

[1] See Joskow (2014) for an excellent review of the evolution of regulation, including its shortcomings.

[2] In a deviation from the Loeb-Magat conditions, Harrison and McKee (1985) do not reveal the market demand to the monopoly seller nor is the seller required to fully satisfy it. This introduces an element of risk that is not present in other experimental studies of incentive regulation.

Finsinger and Vogelsang (1981) show that the optimal sequence of prices under this regulatory mechanism is monotonically decreasing and convergent to marginal cost. That the current subsidy depends on the size of the subsidy received in the previous period implies that pricing mistakes are penalized not only in the current but also in future periods. In an experimental test of the Finsinger-Vogelsang mechanism with five subjects, Cox and Isaac (1987) observe bankruptcy in four of the five regulatory games with only one game converging to efficient prices. These high bankruptcy and low conversion rates occur despite sellers having perfect knowledge of the market demand. Cox and Isaac (1987) argue that the enduring subsidy penalties for a one-off pricing mistake are the root cause of bankruptcy and the failure to converge. Retaining the theoretical property that prices converge to marginal cost, Cox and Isaac (1987) propose a modified subsidy rule, whereby price raises are only penalised in the current and not in future periods. A subsequent experiment of the Cox-Isaac mechanism reveals that price convergence to the efficient marginal cost level is achieved in 10 out of 10 games. However, the price adjustments are slow with convergence achieved on average only after 10-11 rounds.

While small subject pools are common to all these experiments they nevertheless suggest that alternative incentive mechanisms that do not require knowledge of firms' cost curves to be incentive compatible, are able to achieve price convergence. However, this convergence is not always guaranteed, being hampered either by a high risk of bankruptcy in the case of Finsinger-Vogelsang or sluggish price adjustments in the case of Cox-Isaac. It seems that incentive mechanisms so far have failed to create sufficiently strong and precise incentives for the monopoly to rapidly move towards the welfare maximising price. Admittedly a moderate pace for price adjustments may have several advantages in a real-world regulatory environment. These include avoiding major disruptions to the current capital stock and labour structure, and creating a buffer against, for example, data-driven pricing errors. However, to the extent that demand and supply conditions change rapidly, overly slow convergence rates could result in flat or even increasing prices over time.

2.2 Institutional Background

The practical experience with incentive regulation is a powerful demonstration of adverse selection and moral hazard problems seriously undermining the effective regulation of network services. The trend toward privatization and vertical disintegration in the electricity sector in the 1980s proceeded alongside stringent regulation of the transmission and distribution businesses. As documented by the EU (2014), Europe experienced substantial electricity network cost increases in just a few years around 2010 (up to 30% for some customer types), despite extensive fixed price and price cap regulations. It was claimed that price differences across jurisdictions was partially driven by differences in network tariff regulation. While inefficiently high network costs and prices are undesirable, setting network tariffs too low can also be problematic as they can adversely impact the quality of provision. For example, Reichl et al. (2008) find that in Austria lower network tariffs are associated with significantly longer blackouts.

Similar to price regulations failing to deliver the intended cost reductions, cost-of-service contracts seem to have failed to incentivize managerial effort to reduce costs. Amidst calls for improving network governance by another round of network tariff regulation adjustments, refinements of cost allocation practices and by tackling inefficiencies via incentive regulation (EC, 2014) the question emerges whether the price and revenue cap paradigm is simply outdated or in need of a fundamental make over.

Indeed, disappointment with the performance of price and revenue caps and other incentive schemes more generally set in motion the trend towards greater community governance or outright ownership of segments of the electricity sector. Since the early 2000s hundreds of German communities and municipalities moved to govern and manage their energy infrastructure locally so as to realise their energy vision. In 2012 there were about 900 energy co-operatives in Germany with 10% of these being in charge of local distribution, while about half of all energy generation and retail is now locally owned (Julian, 2014). Moves towards deregulation and re-nationalisation or re-municipalisation of networks services can also be observed in France and Hungary (Isaacs and Molnar, 2016). Comparing the productive efficiency of different ownership structures in the electricity sector during the 1880s, Hausman and Neufeld (1991) find that the municipally-owned utilities were significantly more efficient than their privately-owned counterparts. Similarly, Emmons (1997) finds for the period between 1930-1941 that while state regulation put some downward pressure on electricity prices they remained 10%-20% higher than when utilities were subject to competition or publicly-owned. Similarly, it has been observed that prices set by the public electricity distributors over the past two decades were lower by a sizeable margin than those set by investor-owned distributors: 5-15% in Finland (Lehto, 2011) and 22% in Sweden (Söderberg, 2008).

2.3. Electoral Competition

The practical experiences with regulation in the electricity sector raise several important questions. Firstly, what mechanisms may be responsible for the observed price dynamics and secondly, could alternative approaches to regulation reinforce those mechanisms that lead to lower prices? Thirdly, could the trend towards re-municipalisation of network industries open new doors and possibilities for achieving the objectives of lower prices and higher consumer surplus? We investigate electoral competition as a novel approach to utility regulation - both in its own right and in conjunction with incentive-based regulation.

The role of the power of the electorate in aligning the interests of an elected official with those of the public is explored in a seminal paper by Barro (1973). In this framework, the official is motivated by the political income that can be derived from being in an elected role. Assuming identical public preferences, the effectiveness of electoral power in aligning the elected official's interest with that of the public depends on factors such as the official's political income as well as renumeration and the frequency of elections. Subsequent papers test this theory in a variety of contexts. Within the context of the French National Assembly, Gavoille and Verschelde (2017) find that greater electoral competition is correlated with greater competence and intrinsic motivation, as measured by political activity by the elected official. Wilson and Damania (2004) find that while electoral competition is not always successful in curtailing corruption, higher levels of electoral competitions lead to more stringent environmental policy and higher fines for non-compliance.

Peltzman (1971) applies the concept of electoral competition to the electricity sector to explain the observed price differences between privately and publicly owned electric utilities. In this model, the management of publicly-owned utilities is more motivated to garner political support for their enterprise and to ensure their continued tenure than to maximise profits. The resulting pricing policies are thus designed to redistribute wealth within the political constituency. While Peltzman (1971) finds little evidence that publicly owned enterprises employ discriminatory pricing policies strategically, Kitchens and Jaworski (2017) argue that electoral competition was instrumental in limiting public rents in the electricity sector between 1935-1940. Hollas and Stansell (1988) investigate the price efficiency of electric utilities under different ownership structures and find that compared with privately-owned utilities, municipal utilities are furthest from being profit maximisers while customer owned cooperatives are somewhere in between.[3]

3. Experimental Design

Our experiment is designed to provide insight as to whether electoral competition can be used to increase the efficiency of incentive regulation. One of the criteria used when evaluating the performance of monopoly regulation is how fast it is able to bring the price down to the welfare maximising level.

The economic environment in our experiments is standard and one of a single-product monopoly subject to decreasing average costs and a known market demand curve. This monopolist can be thought of as the network provider. We implement a simple 3x2 between-subject experimental design as summarised in Table 1. The first treatment arm consists of the three regulatory contexts adopted for the experiment: the unregulated monopoly as well as two incentive-regulated monopolies based on the Finsinger-Vogelsang (FV) and Cox-Isaac (CI) mechanisms. The second treatment arm investigates the effect of electoral competition on the market outcome for each of the regulatory settings. Of the six resulting institutions, the unregulated monopoly without electoral competition represents the baseline treatment. The remaining five institutions represent variants of the baseline treatment, thereby enabling the comparison across different institutions.

The baseline treatment comprises a single seller (the monopolist) who is tasked with setting the product price in a repeated game, so as to maximise seller profits over at least 16 rounds. After round 16 the final round is determined at random. Both the market demand curve (see Appendix A Table 2 and Figure 2) of a simulated representative buyer and the seller's cost schedule (see Appendix A Table 1 and Figure 1) are known to the seller. Upon setting the product price for the round the seller is immediately informed of the number of units that were purchased at this price as well as the profits (sales revenue minus production costs) made. After this information is communicated, the seller proceeds to the next round.

For the incentive regulation treatments, the seller receives in addition to its market profit, a bonus that is calculated either according to the Finsinger-Vogelsang or the Cox-Isaac method. In each case, the seller receives immediate and detailed feedback on all individual components of the bonus payment, the size of the bonus and how it compares to the previous period. As in the baseline treatment the seller knows both the market demand curve and its own cost schedule. No such information is required by the regulator, as the bonus depends only on observable prices in the current and previous period and observed demand in previous period(s).

Treatments with electoral competition involve a second seller and a real buyer, with the game structure resembling that of an oligopoly with price leadership. The game rounds are divided in 'electoral cycles' or four-round blocks. The price-setting seller faces the same objective and constraints as sellers in the corresponding treatments without electoral competition.[4] In addition, the price-setting seller knows that at the end of the electoral cycle they may be voted out by the representative buyer

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[3] A cooperative membership composed of owner-consumers can theoretically ensure that pricing policies are welfare maximising, whereby resources are allocated efficiently and the shares of consumer and producer surplus are optimal (Enke, 1945). As such cooperatives incorporate consumer interest more directly than electoral competition.

[4] The student assigned as seller in the first electoral cycle is randomly determined.

in which case the price-setting authority is bestowed onto the second seller. The buyer purchases units according to the same, pre-determined demand schedule as the simulated buyer in treatments without electoral competition and decides every four rounds who of the two competing sellers should become the price-setting seller for the next 4-period electoral cycle. The profits for the price-setting seller are determined in the same way as for treatments without electoral competition. In each round, the seller without price-setting authority earns the price-setting seller's profits minus 10%.

Between 2016 and 2021, 162 economics and business undergraduate students in Gothenburg, Esbjerg and Halmstad were recruited to these experiments that were run over 45 sessions, with an average of 1.96 games per session, at the University of Gothenburg, University of Southern Denmark and Halmstad University. Participants were randomly assigned to treatment sessions. For treatments with electoral competition, participants were assigned randomly to a role and they kept that role for the duration of the experiment. All experiments were conducted free of any framing with the experimental instructions referring to sellers and buyers interacting in a market for a non-descript good. At the beginning of each experimental session each participant received a set of instructions to follow along while the experimenter read out the instructions aloud. Sellers and buyers were given several practice questions to test their understanding of how profits are calculated and, if applicable, how the price-setting seller is determined. As an example, the instructions for participants in the treatment of a Cox-Isaac regulated monopoly with electoral competition are given in Appendix A.

The participants were always shown their cumulative trading profit on the screen of their computer terminal, where they could enter different pricing decisions for the next round and receive feedback before confirming a price. A total of 88 regulatory games were played across the six treatment designs. At the end of the experiment the sellers with the three highest cumulative trading profits in the session received prizes of respectively 50, 30 and 10 euros. We deliberately chose this payment mechanism to encourage sellers to take a long-term perspective and maximise profits over the length of the game. This is particularly important in light of the path-dependency of profits under FV regulation. In treatments with electoral competition the same prize was also awarded to the three buyers with the lowest cumulative price for the session.[5] The winning participants were announced on a follow-up session, which all participants were invited to. The winners were paid their prizes privately at this occasion.

Table 1: Experimental Design – Number of regulatory games per treatment

Regulatory Regime	**Electoral Competition**		**Total**
	No	***Yes***	
Unregulated	20	20	40
Finsinger-Vogelsang	18	11	29
Cox-Isaac	13	6	19
Total	51	37	88

4. Theoretical predictions

[5] In treatments with electoral competition the price-setting seller was randomly determined for rounds 1-4. To make the payment incentives comparable across all treatments only profits and consumer surplus starting in round 5 were aggregated.

The experiment is designed to test several hypotheses. The first set of hypotheses relates to the properties of decentralized price regulation. Compared with previous experiments our experiment benefits from a much larger sample size. Similarly, the interactive, computerized interface employed in the experiment allows sellers prior to committing to a price to ‘try’ different prices and receive immediate and detailed feedback about the number of units that would be sold at that price, seller revenue, the size and composition of any applicable subsidy payment as well as seller profits.[6] We expect the latter to reduce the incidents of sellers making mistakes. These features allow us to conduct a compelling replication of previous experimental results. The second and third set of hypotheses relate to the effect of introducing electoral competition on prices and price dynamics.

Hypothesis 1a: Prices under decentralized price regulation converge to the welfare maximising price.

As has been shown by Finsinger and Vogelsang (1981) and Cox and Isaac (1987), the optimal price path for both FV and CI is monotonically decreasing until it converges to the welfare maximising price at which point the optimal number of units will be sold and the periodic profits are maximised. Given the starting price of 4.28 and initial quantity of 8 units, the theoretical prediction is that convergence to the optimal price and quantity is achieved by round 4, resulting in a profit path as shown in Figure 1.

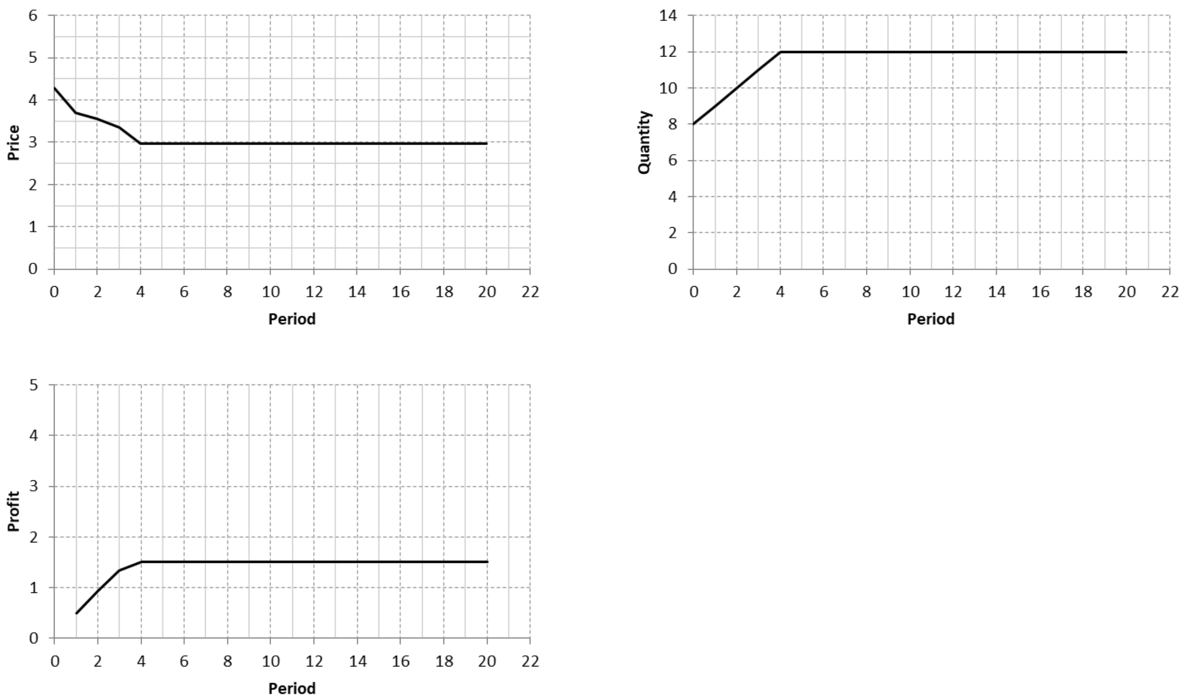

Figure 1: Optimal price, quantity and profit paths under Finsinger-Vogelsang and Cox-Isaac incentive regulation

[6] The Cox and Isaac experiment were conducted with pen and paper while subjects in the Harrison and McKee (1985) experiment of the Loeb-Magat mechanism did not know the market demand curve and received a more limited information set when taking turns on a single computer terminal under the supervision of the experimenter.

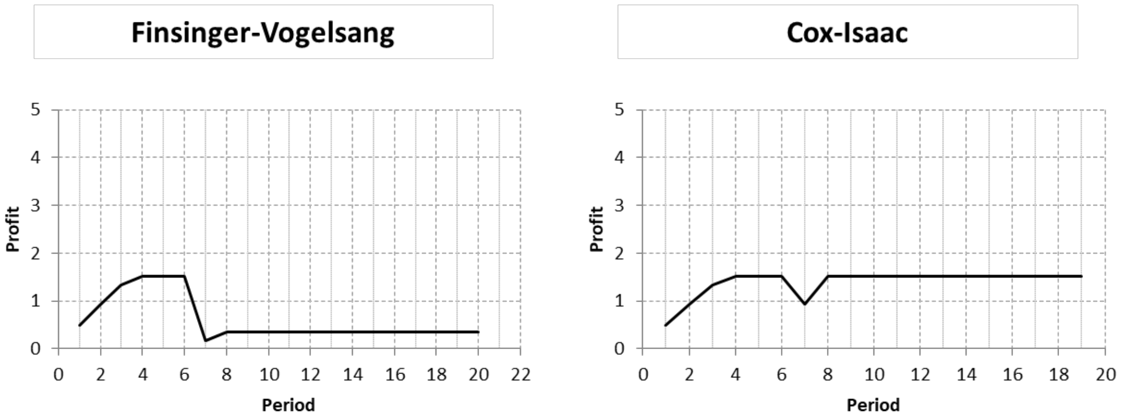

Figure 2: Profit implications under Finsinger-Vogelsang and Cox-Isaac of a one-off pricing mistake in period 7 (price raised from 2.97 to 3.55 and back to 2.97 again).

Hypothesis 1b: Seller are less susceptible to bankruptcy under CI than FV

Because subsidies under FV incentive regulation are path dependent this mechanism is less forgiving of pricing mistakes than CI. As shown in Figure 2, a pricing mistake made under FV results in reduced profits in all future periods. In contrast, pricing mistakes under CI are only reflected in the round's profits in which they are made. This difference in how pricing mistakes are penalised results in greater cumulative profits under CI regulation compared with FV regulation. In prior experiments a high incidence of bankruptcy under FV regulation was first noted by Cox and Isaac (1987), whereby four of five FV regulated sellers went bankrupt before the end of the game.

Hypothesis 2: In the absence of regulation, electoral competition results in prices that lie below the profit maximising price.

At the end of each electoral cycle the consumer determines whether or not the current price-setting seller is allowed to continue to set prices and earn higher profits over the next cycle. This increase in consumer market power induces the price-setting firm to share some of its surplus with the consumer, which it does by charging lower prices.

Hypothesis 3: Incentive regulation with electoral competition results in faster price convergence than in the absence of electoral competition.

Each electoral cycle provides an impetus for a price drop, while price rises are penalized under decentralized price regulation. Hence every four rounds the price can be expected to fall by more than in the absence of electoral competition. As long as subsequent potential price rises are smaller than the price drop, convergence will be faster.

5. Results

Next, we discuss the results of our analysis in the order of the posited hypotheses in Section 4. Figure 3 compares the mean price paths and their confidence intervals under FV and CI regulation, whereby the broken and continuous lines at 5.70 units and 2.97 units indicate respectively the profit maximising and welfare maximising prices as predicted by theory. This figure shows that, in line with hypothesis 1a, both types of incentive regulation result in prices converging to the welfare maximising level. Our results regarding average price convergence provide additional supporting evidence of the early experiments by Harrison and McKee (1985) and Cox and Isaac (1987) that decentralised pricing mechanisms are able to bring about price convergence to the welfare maximising level.

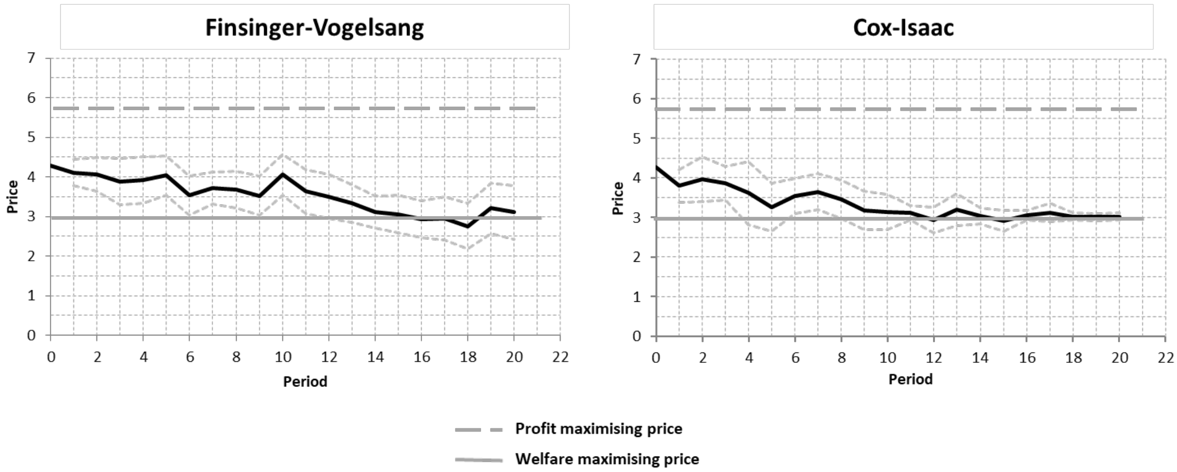

Figure 3: Average price paths under Finsinger-Vogelsang and Cox-Isaac incentive regulation.

However, closer inspection of Figure 3 shows that convergence is much slower than the round-4 conversion predicted by the theory. Moreover, the rates of conversion differ across the two mechanisms. Prices seem to converge faster under CI regulation whereby prices are no longer statistically different from the welfare maximising price from round eight and on average equal to this level by round 12. In contrast, average prices under FV regulation are significantly higher than the welfare maximising price until round 11 with the average mean price converging for the first time in round 15. Further inspection of Figure 3 reveals that convergence to the welfare maximising price is more precise under CI than FV. This result is compatible with Cox and Isaac (1987) who also observed convergence off the optimal path and overall a lower rate of convergence for FV than CI. A possible explanation for this phenomenon in our setting is that sellers under CI experimented more initially in order to find and settle on the profit maximising price path, whereas many FV sellers remained on suboptimal price paths for the duration of the game.

To understand the effect of different types of decentralized price regulation on firm profits, we adopt the profit index, as proposed by Harrison and McKee (1985). The index is constructed for each seller and provides a measure of the monopoly trading effectiveness in each round. It is computed as

$$I = \frac{\pi - \pi_w}{\pi_m - \pi_w},$$

where π is this round's observed seller profit, inclusive of any subsidies. The welfare maximising level of profit, π_w is the level of profit that corresponds to the price and quantity points where demand equals marginal cost, while π_m is the monopoly profit when the firm sets the price where marginal cost equals marginal revenue. An index value of $I = 1$, means that the firm is able to recover full monopoly profits, while $I = 0$ means that the firm's profits are at the welfare maximising level.

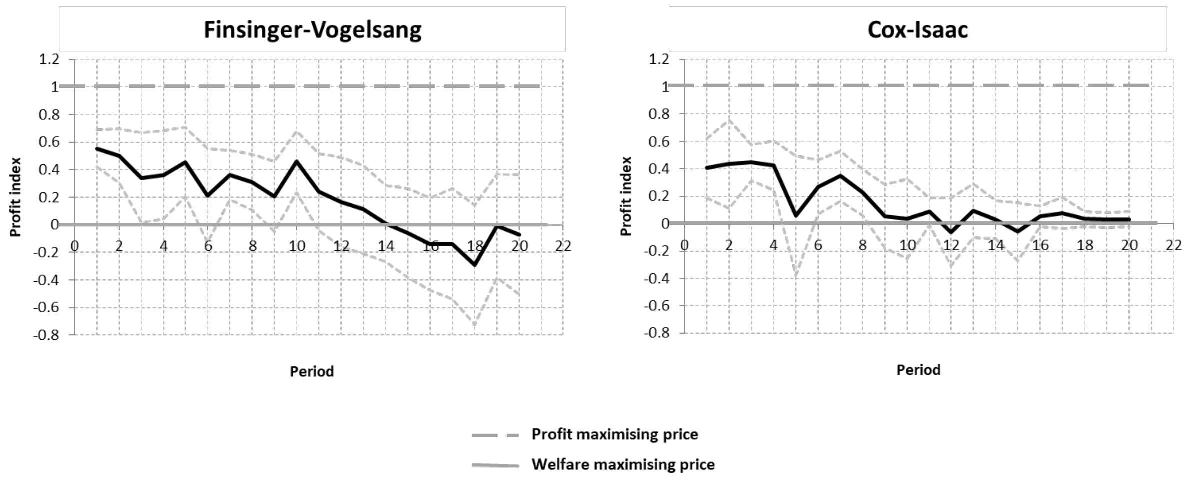

Figure 4: Average profit index under Finsinger-Vogelsang and Cox-Isaac incentive regulation.

The average monopoly trading efficiency under FV and CI is plotted in Figure 4. The average profit index for FV-regulated firms decreases steadily from its initial maximum level of just under 0.6, becoming negative from period 14 onwards. In contrast and in line with hypothesis 1b, the profit index for CI-regulated firms converges toward the welfare maximising index value around period 10 and remains there for the remainder of the game. Moreover, the profit index of CI-regulated firms is less dispersed over the latter half of the regulatory game than for FV-regulated firms. Together Figures 3 and 4 provide supporting evidence that similar price variation from period to period during the early rounds contributes to greater losses for FV-regulated firms than CI-regulated firms over the second half of the regulatory game.

Our next set of results relates to the effects of electoral competition on prices charged by the monopolist. Figure 5 shows the average price path for unregulated firms. The left-hand side panel shows that, without electoral competition, the price approaches the profit maximising price. In contrast, exposing unregulated monopolies to electoral competition results in prices that are significantly lower than the profit maximising price for the duration of the experiment. This result provides supporting evidence for our second hypothesis, that in the absence of regulation, electoral competition results in lower than profit-maximising prices.

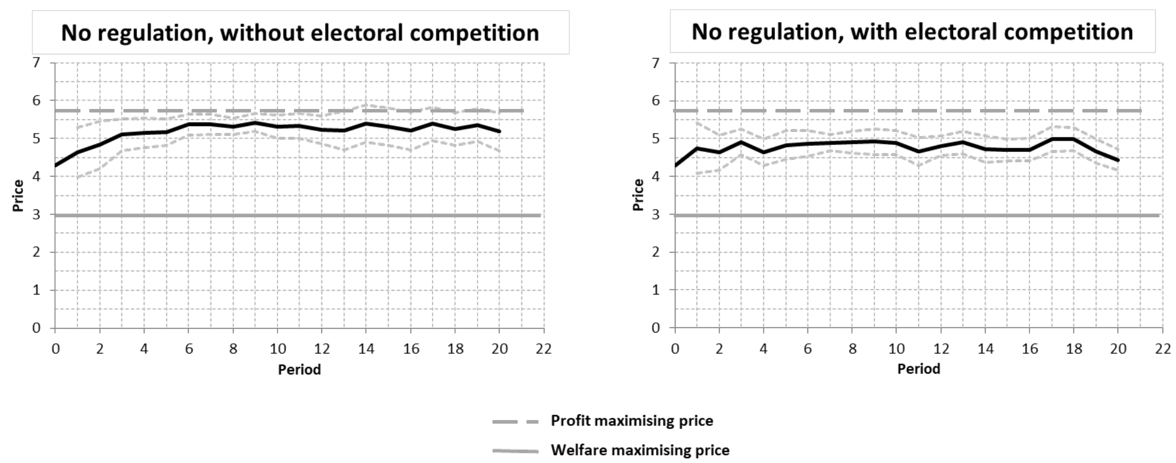

Figure 5: Average price path for unregulated monopolies without and with electoral competition

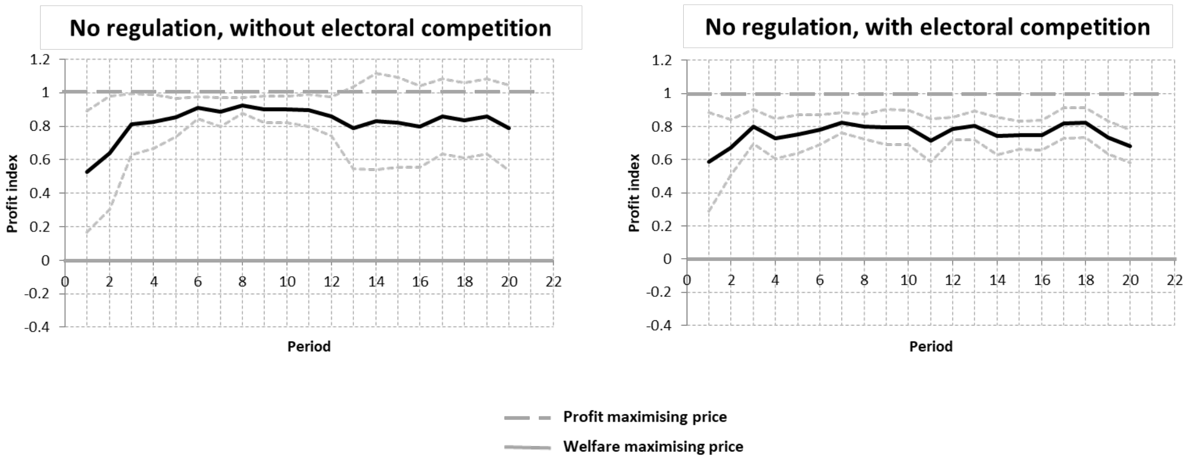

Figure 6: Average monopoly trading efficiency for unregulated monopolies without and with electoral competition.

In Section 4 we provide a heuristic argument that electoral competition increases consumer market power, which motivates the firm to share some of its surplus with the consumer. Figure 6 confirms this conjecture. The average profit indices of firms that are subject to electoral competition are clearly below 1 in all periods, while in profit indices in the absence of electoral competition lie much closer to the profit maximising index value. Despite electoral competition exerting significant downward pressure on prices and the monopoly trading efficiency, it is apparent from Figures 5 and 6 that both prices and the profit index remain above the welfare maximising levels. This is not surprising as electoral competition typically does not address the information asymmetry between the firm and the consumer. In line with actual market interactions the buyer in our experiment is ignorant of the firm's costs. Furthermore, if the price-setting firm goes bankrupt e.g. by setting prices too low, the second firm will automatically also go bankrupt. This is bad news not only for sellers but also for the buyers, who would lose any possibility of making a consumer surplus and may therefore be reluctant to exercise excessive electoral power.

The regression results reported in Table 2 allow us to quantify precisely the effect of electoral competition on mean prices. To control for issues related to time periods (e.g. fatigue) and individual characteristics (e.g. risk preference and other personality traits), all regressions include period fixed effects and player random effects. Model 1 reports the average effect of electoral competition on prices across all treatments and observations. It is shown that electoral competition reduces unit prices by 0.32 units on average compared with a price reduction of 1.55 units achieved by incentive regulation. Both effects are statistically significant at the 5% and 1% level respectively.

To understand how electoral competition interacts with incentive regulation, some treatments jointly implemented incentive regulation and electoral competition. Model 2 includes these interaction effects. The results show that without regulation present, electoral competition reduces unit prices by 44 cents, while regulation in the absence of electoral competition reduces prices by 1.79 units. Again, these effects are statistically significant at the 1% level. The interaction effect between electoral competition and regulation is not significant, which means that the individual effects of either mechanisms are neither heightened nor dampened when both operate together. Regulation with electoral competition results in a reduction in unit prices of 1.94 units on average.

Next, we analyse the interaction between electoral competition and the two different decentralised pricing mechanisms. Model 3 estimates the price effects separately for FV and CI. It is shown that CI is more effective than FV in reducing monopoly prices and that electoral competition added to CI leads to average price reductions of 2.32 units. In contrast, the regulation by FV in the presence of electoral competition reduces monopoly prices by 1.72 units on average across all periods.

Table 2: Estimation results.

	Model 1	**Model 2**	**Model 3**
	Mean (S.E.)	Mean (S.E.)	Mean (S.E.)
Electoral competition *(1=Yes)*	-0.3128** (0.1430)	-0.4360*** (0.1646)	-0.4360*** (0.1647)
Regulation *(either Finsinger-Vogelsang or Cox-Isaac)* *(1=Yes)*	-1.5465*** (0.1783)	-1.7941*** (0.1744)	
Finsinger-Vogelsang *(1=Yes)*			-1.6961*** (0.2139)
Cox-Isaac *(1=Yes)*			-1.9288*** (0.1674)
Elect. Comp. × Regulation		0.2941 (0.2341)	
Elect. Comp. × Finsinger-Vogelsang			0.4079 (0.2808)
Elect. Comp. × Cox-Isaac			0.0405 (0.2162)
Constant	5.3032*** (0.2339)	5.3856*** (0.1889)	5.3854*** (0.1890)
Period FE	Yes	Yes	Yes
Player RE	Yes	Yes	Yes
Observations	1 737	1 737	1 737
Games	88	88	88
R2 (overall)	0.286	0.458	0.471

Notes: Standard errors clustered at the game level. Statistical significance is reported at the 1%, 5% and 10% level, using ***, ** and *.

In addition to investigating the effect of electoral competition on average prices across all periods it is of interest to investigate its dynamic price effect. Recall that convergence toward the welfare maximising price under regulation was slower than the theoretical prediction. As hypothesised in Section 4, due to the impetus for price drops provided by the electoral cycle, price convergence may be faster when electoral competition is added to incentive regulation.

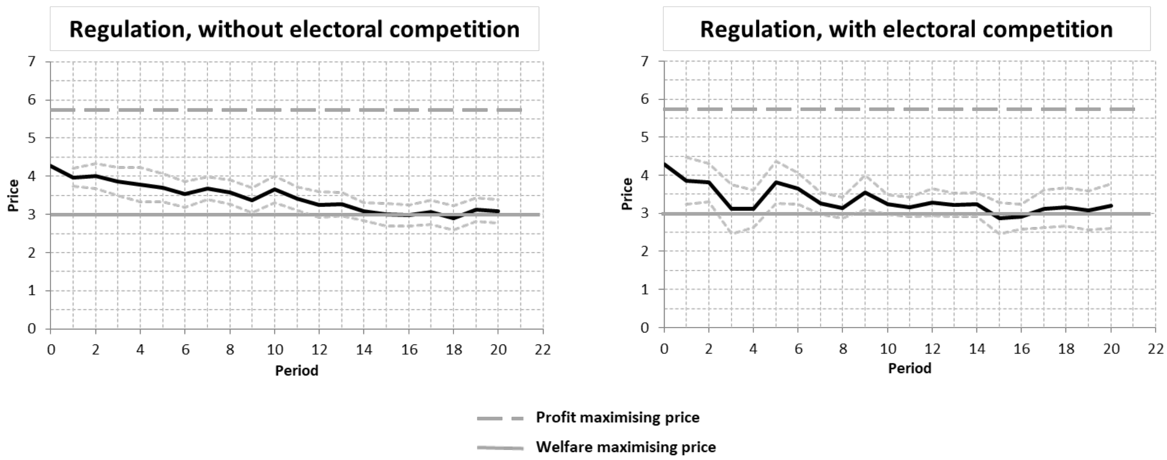

Figure 7: Average price paths under regulation, without and with electoral competition.

This third hypothesis is confirmed by the right-hand panel in Figure 7, which shows a large price drop leading up to the end of the first electoral cycle. Indeed, at that point the price is no longer significantly different from the welfare maximising price. The subsequent price rise at the beginning of the second electoral cycle is quantitatively smaller. This trend of decreasing price fluctuations around the electoral cycles continues until the end of the game. In comparison, in the absence of electoral competition, convergence is much slower and there are no clear price cycles.

An investigation of Figure 8, which plots the effect of electoral competition separately for each of the incentive regulation mechanisms, reveals that the four-round price cycles are much more pronounced under CI regulation than FV regulation.

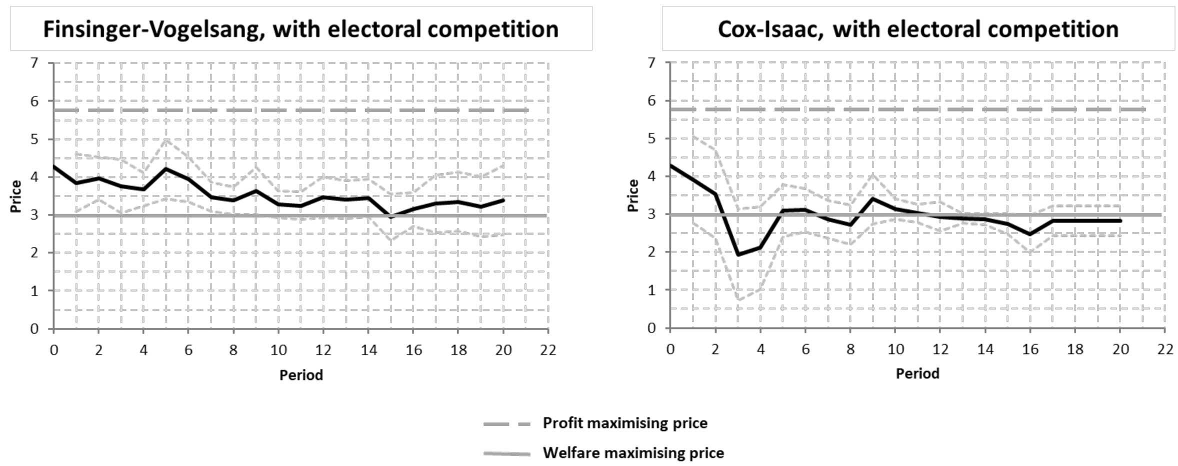

Figure 8: Average price paths under Finsinger-Vogelsang and Cox-Isaac regulation, with electoral competition.

Figure 8 confirms the results from the regression analysis. Electoral competition appears to be more effective when price increases are not punished as harshly. Specifically, CI-regulated firm seem to be 'daring' to lower the price more than FV-regulated firms. The quantitative estimates of these results are given in Table 3, which reports the individual and interaction effects of the regulatory regime, electoral competition and for each of the first 8 rounds of the game. None of the triple interaction terms are significant of FV regulated monopolies. In contrast, the results reveal that subjecting CI regulated monopolies to electoral competition leads to quantitatively and statistically significant price drops in the last two rounds of the electoral cycles. This provides evidence for hypothesis 3 whereby electoral competition can achieve faster price conversion when combined with incentive regulation.

Table 3: Dynamic price effects of electoral competition by regulatory mechanism

	Model 4
	Mean
Electoral competition *(1=Yes)*	-0.2383*
Finsinger-Vogelsang *(1=Yes)*	-1.7683***
Cox-Isaac *(1=Yes)*	-2.0717***
Finsinger-Vogelsang × Period 1	1.1484***
Finsinger-Vogelsang × Period 2	1.0558***
Finsinger-Vogelsang × Period 3	0.6041*
Finsinger-Vogelsang × Period 4	0.7641**
Finsinger-Vogelsang × Period 5	0.7664**
Finsinger-Vogelsang × Period 6	0.1457
Finsinger-Vogelsang × Period 7	0.3260*
Finsinger-Vogelsang × Period 8	0.3035*
Fin-Vog × Elect Comp × Period 1	-0.2493
Fin-Vog × Elect Comp × Period 2	-0.0770
Fin-Vog × Elect Comp × Period 3	-0.1147
Fin-Vog × Elect Comp × Period 4	-0.2351
Fin-Vog × Elect Comp × Period 5	0.1885
Fin-Vog × Elect Comp × Period 6	0.4273
Fin-Vog × Elect Comp × Period 7	-0.2379
Fin-Vog × Elect Comp × Period 8	-0.2937
Cox-Isaac × Period 1	1.0801***
Cox-Isaac × Period 2	1.1983***
Cox-Isaac × Period 3	0.8278***
Cox-Isaac × Period 4	0.7001*
Cox-Isaac × Period 5	0.2328
Cox-Isaac × Period 6	0.3974
Cox-Isaac × Period 7	0.4903**
Cox-Isaac × Period 8	0.3204
Cox-Isaac × Elect Comp × Period 1	0.2817
Cox-Isaac × Elect Comp × Period 2	-0.2551
Cox-Isaac × Elect Comp × Period 3	-1.7546***
Cox-Isaac × Elect Comp × Period 4	-1.3259**
Cox-Isaac × Elect Comp × Period 5	0.0160
Cox-Isaac × Elect Comp × Period 6	-0.2532
Cox-Isaac × Elect Comp × Period 7	-0.6031**
Cox-Isaac × Elect Comp × Period 8	-0.5606**
Constant	4.8110***
Period FE	Yes
Player RE	Yes
Observations	1 737
Games	88
R2 (overall)	0.4952

Notes: Standard errors clustered at the game level. Statistical significance is reported at the 1%, 5% and 10% level, using ***, ** and *.

6. Conclusions

We propose a novel consumer-focused mechanism to address the sluggish price response to incentive regulation in the electricity network market. Electoral competition leverages the recent trend toward more public management of electricity networks and gives consumers the power to decide who should have price-setting responsibilities over the course of the next electoral cycle.

We devise a novel laboratory experiment and show that firms self-regulate when faced with electoral competition: the average price set by firms over the length of the experiment is significantly lower than the monopoly price. Importantly, when implemented jointly with incentive regulation our results show that electoral competition increases the efficiency of incentive regulation: under some types of regulation, prices converge on average two times faster to the welfare maximising price than under regulation alone.

Our experimental investigations focused primarily on the price effects of electoral competition and its interaction with incentive regulation. A randomly assigned buyer decided at the end of each electoral cycle who of two sellers should be given price-setting authority for the next cycle. In future iterations of this experiment it would be interesting to exploit the seller role more extensively to understand how information about firm costs as well as withholding demand strategies may affect buyers' choices and market outcomes. Future experimental investigations could also test the effect of heterogenous buyers and sellers and the effect of exogenous cost or demand shocks on market outcomes.

Despite these caveats, our experiment offers early insights into the role of electoral competition in an institutional setting that is arguably moving away from a highly centralized and predominantly privatized, regulated system. The institutional and regulatory environments of the increasingly decentralised and localised energy systems that are emerging are still very much undecided. Here electoral competition on its own or in conjunction with a simple price control mechanism could potentially provide an opportunity to democratise their management and safeguard against these systems being captured by technocrats or ideologues.

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APPENDIX A.1: EXPERIMENTAL INSTRUCTIONS - SELLER

Regulatory Experiment (FV)

Summary

We are in a situation where there is one seller (a monopolist) and many buyers. You represent the seller. The seller wants to maximise his/her profit and the customer wants to pay as little as possible for what s/he purchases. The seller sets the price and the buyers respond by revealing how many units they want to purchase of the product. The seller has no right to refuse selling to a buyer willing to pay the price.

The seller knows:

- how many units s/he will sell at each price (Table 1 and Figure 1).
- what it will cost him/her to sell a certain number of units (Table 2 and Figure 2).

Each period begins with the seller recording, on his/her record sheet, the price s/he wishes to set in that period. The software shows how many units a population of competitive buyers would purchase at that price. This ensures that demand is defined by the demand curve (Table 2, and Figure 2). The software also gives the seller's profit (sales revenue less production cost) and the bonus payment according to the incentive mechanism.

Instructions

This is an experiment about market decision making. The better you perform in this experiment the more 'profit' you will get and that profit will earn you a financial reward. The individual that earns most profit across all experiments will be awarded 50 euros. The individual that earns the second most will be awarded 30 euros and the third most will be awarded 10 euros.

In this experiment you are the only seller (a monopolist). You will set the price in a sequence of trading periods and in each period, you are free to set whatever price you want. Everything you produce in given period, you must sell. Thus, there are no inventories. You can only set one price in each period. All the products you sell will be sold at this price. You are free to change your price from one period to the next, if you wish. The amount you sell will be determined by how many units the buyers are willing to purchase at the price you set. That is, you cannot refuse to sell to anyone who wishes to buy at the price you have decided.

How the buyers decide how many units to buy

The experimenter will make the purchasing decisions for the buyers. These decisions simulate a market with many buyers. In principle, you will sell more units the lower the price. In Table 2 and Figure 2 you can see exactly how much the buyers value each additional unit they purchase from you.

You have received two sheets in addition to these instructions:

1. <u>Sellers cost of production. (Table 1 and Figure 1).</u>

Column 1 displays the number of products sold, column (2) is total cost of production, and column (3) is another way of looking at the same information, it shows the additional cost to you of producing the last additional unit. Notice, for example, that the total cost of producing 15 units is equal to the total cost of producing 14 units plus the additional cost of producing the 15^{th} unit: 51.60 + 2.50 = 54.10.

2. <u>Buyers purchasing rule ('demand'). (Table 2 and Figure 2)</u>

Shows the number of units you will sell for different prices. For example, suppose that you set a price of 4.28. Notice that buyers' value is greater than or equal to 4.28 for units 1-8, but less than 4.28 for units 9 and above. Therefore, in this example, the buyers would purchase 8 units from you. So, if you set the price to 4.28, you will sell 8 units.

How many units would you sell at a price of 6.10?
How about a price of 0.30?

The profit you earn in each period consists of two parts:

1. **Trading profit.** If you make any sales, the trading profit is calculated as total sales revenue less total production cost. Your total sales revenue (line 3 on your record sheet) is calculated as price times number of sold units. Total costs are found in column (2) of the "Sellers cost of production" sheet and is entered on line 4 of your record sheet. Trading profit is then calculated as line 3 minus line 4.

   As an example, look at the column marked "example period" on you record sheet. Suppose you were to post a price of 4.28. The buyer's purchasing rule states that buyers would purchase 8 units. From your cost sheet, you find that your total cost of producing 8 units is 34.20. Thus, your total trading profits are 8*4.28 = 34.24 minus 34.20, or 0.04.

2. **Bonus profit.** In each period you may also receive a bonus profit (or bonus penalty), which is calculated based upon the price you set. The formula for calculating your bonus depends upon whether your price is greater than or less than €4.28.

- Price less than €4.28

When you set a price that is less than €4.28, each of the units you sell will have a "bonus value", which we shall refer to as the *B* value. You will receive a bonus profit on each unit you sell. This bonus will be the difference between that unit's *B* value and the price you charge. That is, for each separate unit:

unit bonus = (*B* - price)

The *B* values may differ, in general, from unit to unit, and the *B* values may increase from period to period. Here is how *B* values are calculated:

(1) The *B* values for each of units 1-8 is fixed at €4.28. This will not change from period to period.

(2) For units 9-20, the *B* value for any unit during a given period, say period *t*, is the maximum price buyers have paid for that unit in period *t* or any previous period. For example, the *B* value for unit 10 in period 5 will be the highest price buyers have actually paid for unit 10 in periods 1, 2, 3, 4 or 5.

Notice the following important attributes of *B* values:
- *B* values can stay the same or increase, but they can never decrease;
- *B* values can never be higher than the additional value to the buyers of a unit, which is given in on your chart.

To ensure you understand how B values are calculated, we shall show you a couple of purely illustrative examples on the board. To help you keep track of the B values, we shall provide them for you in each period.

- Prices greater than €4.28

If you set a price that is greater than €4.28, you will be charged a bonus penalty of eight times the difference between your price and €4.28. That is, if P_t is your price in period *t*, and $P_t > 4.28$, then you will be charged a penalty of $8(P_t - €4.28)$ in that period.

- Price equal to €4.28

If you set a price equal to €4.28, you will not receive a bonus payment, nor will you be charged a bonus penalty.

Buyer influence

There is a buyer/customer in the experiment. The buyer observes the prices in each period and knows that you (the seller) have information about demand and cost conditions but the buyer does not know the precise relationships, i.e. s/he does not observe the information you have in the two documents: 1) 'Sellers cost of production' and 2) 'Buyers purchasing rule ('demand')'. Of course, the buyer wants to pay as little as possible for the service that you sell to him/her.

At the end of every 4-period spell, i.e. period 4, 8, 12, …, the buyer can decide to replace you with another player. If s/he does replace you, you have to step aside and you do not participate in the experiment from the next period. If the buyer replaces the new seller in any future period, you will step in as seller again. *If you do not participate in the experiment, you earn 90% of the profit the active seller earns.*

Closing comments

Notice that for any period, your total profits may be positive even if your trading profits are negative, provided that you have sufficiently large positive bonus profits. Likewise, your total profits may be positive even if your bonus profits are not positive, provided that you have sufficiently large positive trading profit. Finally, before we begin the actual trading, we will start you off with an initial capital endowment of 5.

- The experiment will run for at least 16 periods. From period 17 termination of the experiment will be determined by a random number generator.

- All periods are part of the experiment, but the profits in the first four periods will not be counted towards your official aggregate profit.

Sequence of the game:

Step 1. The experiment starts at the beginning of period 1 (*t*=1).

Step 2. On the "Seller's Record Sheet" you will record your price on line 1, in column "t".

Step 3. The software calculates:

a) Number of units buyers have purchased
b) Trading profit
c) Bonus profit
d) Total profit
e)

Step 4. If we are at the end of a 4-period spell, i.e. period 4, 8, 12, …, the experimenter informs you if the customer will replace you or not.

Step 5. The experimenter informs if the game ends or continues. If it continues, you set *t*=*t*+1 and you go back to Step 2 and proceed as before.

Table 1. Seller's cost of production

(1) Units of production	(2) Total cost	(3) Additional/ marginal cost
1	5.15	5.15
2	10.05	4.90
3	14.70	4.65
4	19.10	4.40
5	23.25	4.15
6	27.15	3.90
7	30.80	3.65
8	34.20	3.40
9	37.45	3.25
10	40.55	3.10
11	43.50	2.95
12	46.30	2.80
13	49.00	2.70
14	51.60	2.60
15	54.10	2.50
16	56.55	2.45
17	58.95	2.40
18	61.60	2.65
19	64.60	3.00
20	68.25	3.65
21	72.50	4.25

Figure 1.

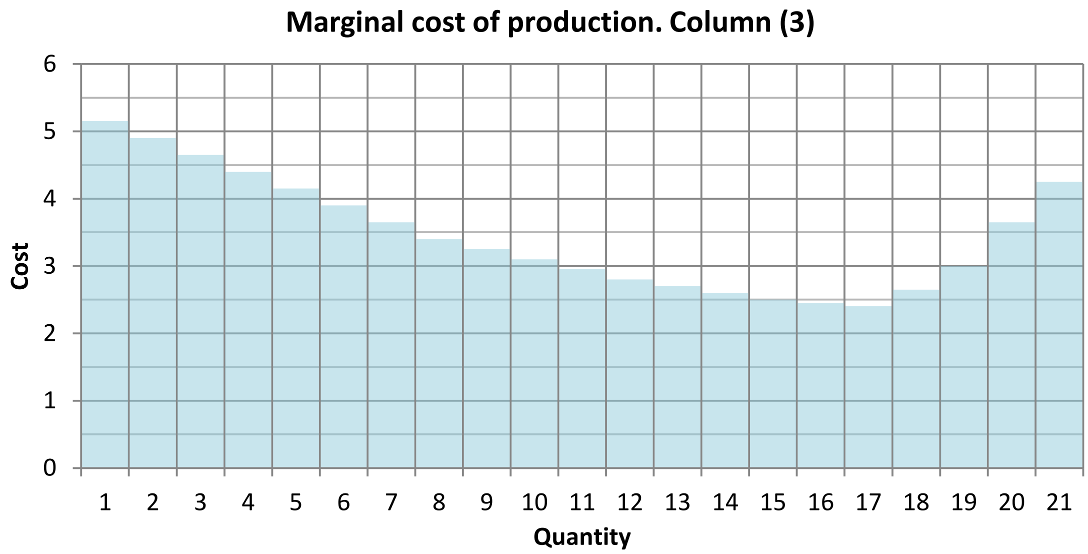
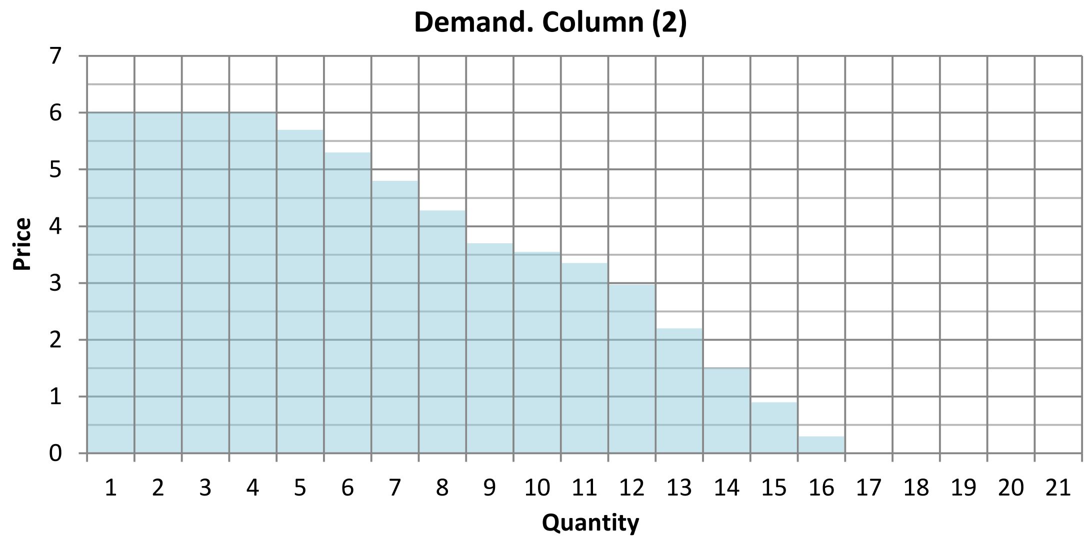


Table 2. Buyer's purchasing rule (demand)

(1) Demand	(2) Price / Additional value to buyers
1	6.00
2	6.00
3	6.00
4	6.00
5	5.70
6	5.30
7	4.80
8	4.28
9	3.70
10	3.55
11	3.35
12	2.97
13	2.20
14	1.50
15	0.90
16	0.30
17	0
18	0
19	0
20	0
21	0

Figure 2.



Regulatory Experiment (CI)

Summary

We are in a situation where there is one seller (a monopolist) and many buyers. You represent all buyers. The seller wants to maximise his/her profit and the customer wants to pay as little as possible for what s/he purchases. The seller sets the price and the customer responds by revealing how many units s/he wants to purchase of the product. The seller has no right to refuse selling to a buyer who is willing to pay the price set by the seller.

The seller knows:

- how many units s/he will sell at each price.
- what it will cost him/her to sell a certain number of units.

Demand and cost conditions are fixed throughout the experiment. The buyer, i.e. you, does not have information about the demand and cost conditions. At the end of each 4-period spell, the buyer decides whether s/he wants to replace the seller with another seller, or not.

A.2. EXPERIMENTAL INSTRUCTIONS – BUYER

Instructions

This is an experiment about market decision making. The lower the price set by the seller, the more points you will get. At the end of the experiment, all prices you paid will be added up and the buyer with the lowest total price will be ranked first; the buyer with the second lowest price will be ranked second, and so on. The individual ranked first will receive 50 euros; the individual ranked second will receive 30 euros and the individual ranked third will receive 10 euros.

The seller will set the price in a sequence of trading periods and in each period, s/he are free to set whatever price s/he wants. Everything that is produced in a given period is sold. Thus, there are no inventories. There can only be one price in each period. All the products will be sold at this price. Of course, the seller can change his/her price from one period to the next, if s/he wishes.

How market decisions are made

The seller sets the price and the software calculates the number of units sold, revenue and profit the seller gets, given the price s/he has chosen. The seller will sell more units the lower the price. The seller has specific knowledge about cost and demand. S/he knows:

- how many units s/he will sell at each price.
- what it will cost him/her to sell a certain number of units.

Both cost and demand conditions are fixed throughout the experiment.

Buyer influence

The buyer (i.e. you) can influence the experiment by deciding if the current seller should be allowed to continue as seller. You exercise this power at the end of each 4-period spell, i.e. at the end of period 4, 8, 12, ….

If you decide to replace the current seller, a new seller will step in and continue where the old seller left. As an example, if you, at the end of period 4, decide to replace the seller, a new individual playing the role of seller will be the seller from period 5 and at least until period 8. Then you will have the opportunity to replace the new seller at the end of period 8. In that instance, the old seller will come back and be the seller from period 9 and onwards.

Of course, you do not need to ever replace the seller if you do not want to.

Closing comments

Note that if the seller's accumulated profits falls below 0, s/he will be bankrupt and the experiment ends. If that happens, your points in the experiment will be calculated as if the price was 6 for all the remaining periods.

- The experiment will run for at least 16 periods. From period 17, termination will be determined by a random number generator.

Sequence of the game

<u>Step 1</u>. The experiment starts at the beginning of period 1 (t=1).

<u>Step 2</u>. On the "Seller's Record Sheet" the seller will record the price.

<u>Step 3</u>. The seller's software gives:

f) Number of units buyers have purchased

g) Profit

The experimenter informs the buyer what price the seller set and the buyer enters that price on his/her record sheet.

<u>Step 4</u>. Replacing sellers.

1. If we are at the end of a 4-period spell, i.e. at the end of period 4, 8, 12, …, the buyer will indicate on his/her Record Sheet if s/he wants to replace the seller.
2. The experimenter informs buyer and sellers in writing who is going to be seller in the next 4-period spell.

<u>Step 5</u>. The experimenter informs if the game ends or continues. If it continues, you set $t=t+1$ and you go back to Step 2 and proceed as before.