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Network Regulation under electoral competition

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ABSTRACT

Academics and policymakers generally agree that energy infrastructure should be subject to price regulation. More and more critics of modern regulatory approaches, however, point to the apparent failures of these mechanisms 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. This effect disappears when electoral competition is implemented jointly with incentive regulation, implying substitutability rather than complementarity of regulation and electoral competition.

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. From the early 1980s incentive-based regulation has enjoyed wide implementation in electricity network sectors.

However, more recent practical experience points to incentive regulation having largely failed to achieve competitive pricing in the network sector (e.g. European Commission, 2014; Orme, 2022). 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, 2017; 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 decentralized systems require local governance and management with broader ranging responsibilities than traditional centralized distribution network operators to effectively leverage the greater coordination opportunities (Energy, 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. 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, electoral competition can be relevant in new settings where regulatory institutions have not yet reached an advanced level. This includes emerging energy systems, such as embedded electricity networks, whereby private owners and operators buy electricity in bulk and then on-sell it to customers inside their network within a specific development or building. Despite the contestable nature of embedded networks, these may not work in the best interest of energy customers who are unable to choose their own electricity provider and who find themselves locked into long-term contracts, perhaps at high prices. In settings such as these, it could be beneficial for customers to be given the right to collectively vote on who should manage and operate the network for the next period. The length of the voting cycle could be optimised such that the economies of scale of embedded networks are appropriately shared with the network customers.

We test the effect of electoral competition on the price-setting behaviour of monopolies using laboratory experiments. We find that electoral competition exerts downward pressure on prices and that the

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average price under electoral competition is significantly lower than in the absence of voting. When combined with incentive regulation, our results show that electoral competition yields no additional benefit to incentive regulation. Therefore electoral competition can be considered an alternative regulatory mechanism, particularly in situations where the institutional quality is low or when the networks are too small to warrant formal involvement by a regulator. Our results should be viewed in light of the experimental design being stacked against electoral competition: buyers receive no information on the price-setting intentions of alternative sellers and alternative sellers are always guaranteed 90% of the profits made by the incumbent seller with the price-setting authority. Moreover, our economic environment of decreasing marginal costs in the relevant price range implies that the monopolist makes a loss when setting prices at the welfare maximising level.[1] These features make the economic environment relatively more unfavourable for electoral competition so our results can be interpreted as lower bounds of what this mechanism could potentially achieve in more favourable settings.

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, 1973; 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-compatible 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 decentralized pricing mechanisms in particular: Finsinger-Vogelsang (Finsinger and Vogelsang, 1985) and Cox-Isaac (Cox and Isaac, 1987). 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-Isaac experiments. Unlike these experiments, ours benefited from a much larger subject pool, consisting of 209 students across 109 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 electoral competition combined with incentive regulation carries no additional benefits for price convergence.

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 (European Commission, 2014; Joskow, 2014).

Much of the early regulation of electricity networks focused on the allowed rate-of-return. Hence, this type of regulation is closely related to average-cost-pricing, whereby the regulator takes the average cost of provision and adds a rate of profit the network is allowed to earn. While rate-of-return regulation theoretically prevents the firm from charging monopoly prices, cost reducing opportunities that are available to the regulated firm are unobserved by the regulator, as are individual firms' efforts to reduce 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 over-invest in their network.

The asymmetric information and moral hazard problems of rate-of-return regulation 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 realized 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, 1999; 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.[2]

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 the 'after-subsidy profit' by setting the price at the welfare maximising level, which maximises 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.

[1] Throughout, we assume that the regulator acts as in the standard textbook model where it seeks to maximise welfare, i.e. it sets price equal to marginal cost. However, we are agnostic about if that assumption best describes the actual behaviour of regulators. Future studies should explore alternative regulatory objectives, e.g. that the regulator seeks to ensure that the monopolist earns non-negative profit by setting price equal to average cost.

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

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.[3] 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 deadweight 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 (1985) 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.

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

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.

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

Finsinger and Vogelsang (1985) 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 penalized 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.

While small subject pools are common to all these experiments, they nevertheless suggest that alternative mechanisms that do not require the regulator's knowledge of firms' cost curves, are incentive compatible and able to achieve price convergence. While in theory any incentive regulation that achieves welfare-maximising price outcomes could be used in conjunction with, or in contrast to, electoral competition, we implement both the Finsinger-Vogelsang and the Cox-Isaac mechanisms. The main reason is that these mechanisms are easily implemented in lab experiments as they are easily explained and understood by participants, while they also achieve welfare-maximising price outcomes similar to incentive-based regulatory mechanisms. As such, we provide a laboratory test of the effectiveness of electoral competition relative to a textbook-type regulatory mechanism. The insights gained from this exercise are not diminished by the fact that the chosen regulatory mechanisms are unlikely to be implemented in practice as they require large transfers that are politically hard to accept. Nor are they, in our view, diminished by the fact that regulators that seek to maximise overall welfare may also take sunk investments made by consumers into account, as suggested by Biggar (2009, 2012) and Biggar and Heimler (2021a, 2021b).

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 (Armstrong and Sappington, 2007). 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 European Commission (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. Similarly, the regulated price of network service provision in Australia has recently been criticized as enabling providers of this service to make 'supernormal profits' (Orme, 2022). 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 (European Commission, 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 toward greater community governance or outright ownership of segments of the electricity sector.[4] 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 toward deregulation and re-nationalisation or re-municipalisation of networks services can also be observed in France and Hungary (Isaacs and Molnar, 2017). 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 III (1997) finds for the period between 1930 and 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).

The energy transition presents additional challenges for regulators. In its wake, new energy systems and structures are emerging at unprecedented rates, with the localised nature of their infrastructure and

[3] 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.

[4] Critique against incentive regulation has been raised by, for example, Joskow (2014) and, more recently, Orme (2022). In several parts of the world there has been a push to empower energy consumers in recent years (DellaValle and Czako, 2022). The re-nationalisation/re-municipalisation of energy networks, and other essential services, has been witnessed in several countries, including Germany, France, and the United States (The Guardian, 2014; Cumbers et al., 2022).

management representing difficult regulatory environments. Examples include community batteries, EV charging infrastructure as well as embedded electricity networks. The latter case involves private owners and operators buying electricity in bulk and then on-selling it to customers inside their network within a specific residential development or commercial precinct. Despite the contestable nature of the establishment phase of embedded networks, a recent review (DELWP, 2022) found that these are not working in the best interest of energy customers who are unable to choose their own electricity provider and find themselves locked into long-term contracts with high prices. These criticisms resulted in embedded networks now being banned in some jurisdictions.

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 toward 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 (2005) 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 and 1940.

3. Experimental design

Our experiment is designed to provide insights as to whether electoral competition can be used instead of, or in conjunction with, incentive regulation to reduce the deadweight loss from monopoly pricing. In the first instance, the pricing and deadweight loss outcomes from an unregulated monopoly and a monopoly subject to incentive-compatible regulation are used as the high and low benchmarks for electoral competition. Secondly, we implement both mechanisms jointly to test for complementarities.

The economic environment in our experiments is standard and one of a single-product monopoly subject to decreasing marginal costs over the relevant price range and a market demand curve that is known to the monopolist. This monopolist can be thought of as the network provider.

We implement a simple 3×2 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 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 price and deadweight loss outcomes 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 Fig. 2) of a simulated representative buyer and the seller's cost schedule (see Appendix A Table 1 and Fig. 1) are known to the seller. Upon setting the product price for the period 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 regulation treatments, the seller receives, in addition to its positive or negative 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 length of the game is divided into 'electoral cycles', each lasting four experimental periods. The price-setting seller faces the same objective and constraints as sellers in the corresponding treatments without electoral competition.[5] In addition, the price-setting seller knows that at the end of the electoral cycle they may be voted out by the representative buyer 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. The seller without price-setting authority earns the price-setting seller's profits minus 10%. In real markets, firms that are unsuccessful in some monopoly markets are likely to operate in other markets and so our design provides an alternative, market-dependent

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

Regulatory Regime	Electoral Competition		Total
	No	*Yes*	
Unregulated	20	20	**40**
Finsinger-Vogelsang	20	15	**35**
Cox-Isaac	19	15	**34**
Total	59	50	109

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

Table 2
Estimation results.

	Model 1	Model 2
	Mean (S.E.)	Mean (S.E.)
Electoral competition *(1 = Yes)*	−0.4360*** (0.1642)	−0.4360*** (0.1643)
Regulation *(either Finsinger-Vogelsang or Cox-Isaac) (1 = Yes)*	−1.8399*** (0.1659)	
Finsinger-Vogelsang *(1 = Yes)*		−1.7241*** (0.2024)
Cox-Isaac *(1 = Yes)*		−1.9611*** (0.1655)
Elect. Comp. × Regulation	0.5880*** (0.2214)	
Elect. Comp. × Finsinger-Vogelsang		0.6863** (0.2710)
Elect. Comp. × Cox-Isaac		0.4952** (0.2469)
Constant	5.4778*** (0.1739)	5.3854*** (0.1890)
Period FE	Yes	Yes
Seller RE	Yes	Yes
Observations	2158	2158
Games	109	109
R2 (overall)	0.423	0.435

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

Between 2016 and 2022, 209 economics and business undergraduate students in Gothenburg, Esbjerg and Halmstad were recruited to these experiments that were run over 54 sessions, with an average of 2.02 games per session, at the University of Gothenburg, University of Southern Denmark and Halmstad University.[6] 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 sellers were 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 109 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

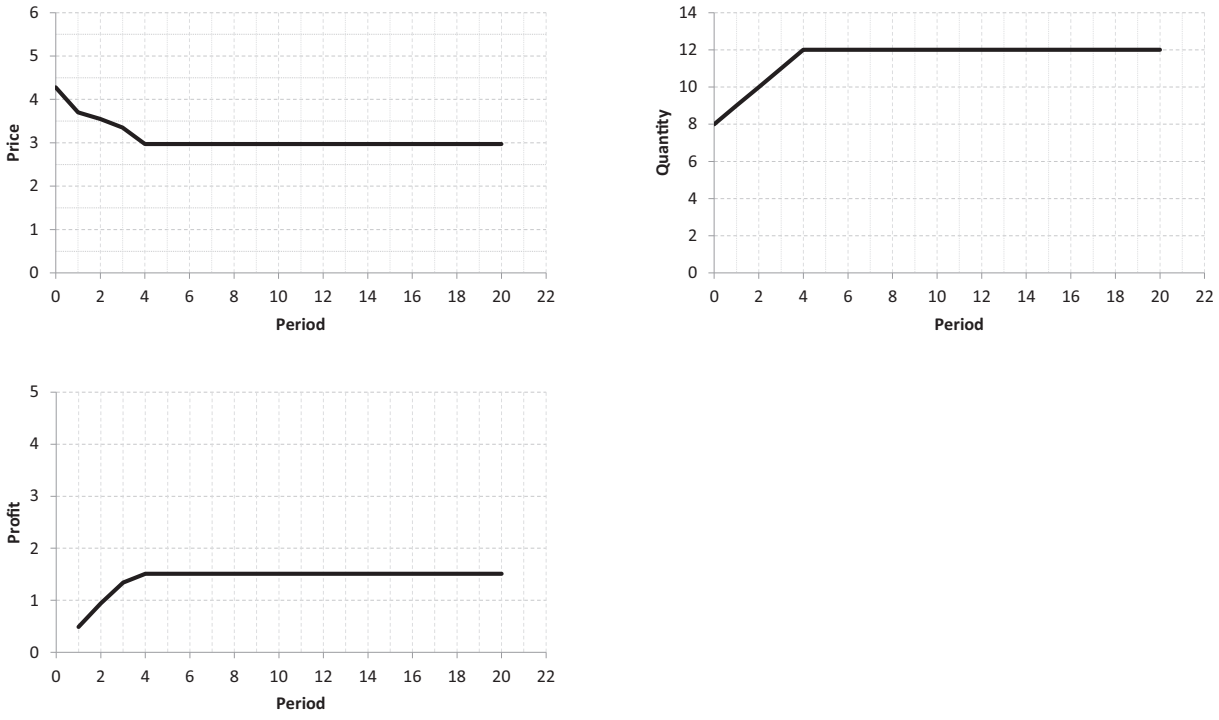

Fig. 1. Optimal price, quantity and profit paths under Finsinger-Vogelsang and Cox-Isaac incentive regulation.

income for the secondary seller, while at the same time encouraging this seller's continued interest in the price and profit outcomes of the market at hand.

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

[6] The experiments were conducted as part of undergraduate courses including pricing behaviour/theory. By selecting students from those courses, we ensured all were familiar with fundamental business and economic pricing challenges. All regressions include seller random effects that control for unobserved seller characteristics and any game-specific factor(s).

awarded to the three buyers with the lowest cumulative price for the session.[7] 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.

4. Theoretical predictions

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.[8] 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 (1985) 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 welfare-maximising price of 2.97 and quantity of 12 units is achieved by period 4, resulting in a net profit path as shown in Fig. 1.

Hypothesis 1b. *Sellers are less susceptible to bankruptcy under CI than FV.*

Decreasing marginal costs over the relevant price range, imply that seller's profits are negative over some range below the profit maximising and above welfare maximising price. Specifically, in the absence of bonus payments, selling more than 8 units results in net losses to the seller. The subsidy payments under incentive regulation are designed to compensate the seller for foregone profits from increasing the production to 12 units along the welfare maximising path. The main difference between the two mechanisms lies in how pricing mistakes are punished. Because subsidies under FV regulation are path dependent this mechanism is less forgiving of pricing mistakes than CI. As shown in Fig. 2, a single pricing mistake made under FV results in reduced profits in all future periods. For large or repeated pricing mistakes it is not difficult to see that future bonus payments would be inadequate to compensate for seller losses made along a subsequently social welfare maximising path and would ultimately result in seller bankruptcy. 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 penalized 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 the current price-setting seller should continue to set prices 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. However, two distinct features in our experimental design imply an optimal price above the welfare maximising price. Firstly, rational sellers will always set prices at or above 4.28 to ensure non-negative profits. Secondly, our generous payment rule for secondary sellers implies an opportunity cost of being secondary seller of merely 10% of monopoly profits. Hence in expectation no more than 10% of the producer surplus should be shared with the consumer in the bid to ensure incumbency.

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. Fig. 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 decentralized pricing mechanisms are able to bring about price convergence to the welfare maximising level.

However, closer inspection of Fig. 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 Fig. 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

[7] 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.

[8] 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.

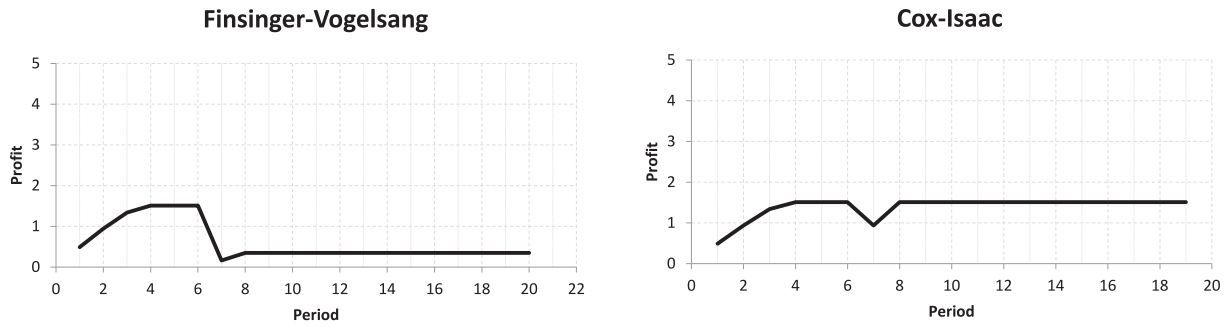

Fig. 2. Profit implications under Finsinger-Vogelsang and Cox-Isaac of a one-off pricing mistake in period 7 (price raised from 2.97 to 3.55 and back to 2.97 again).

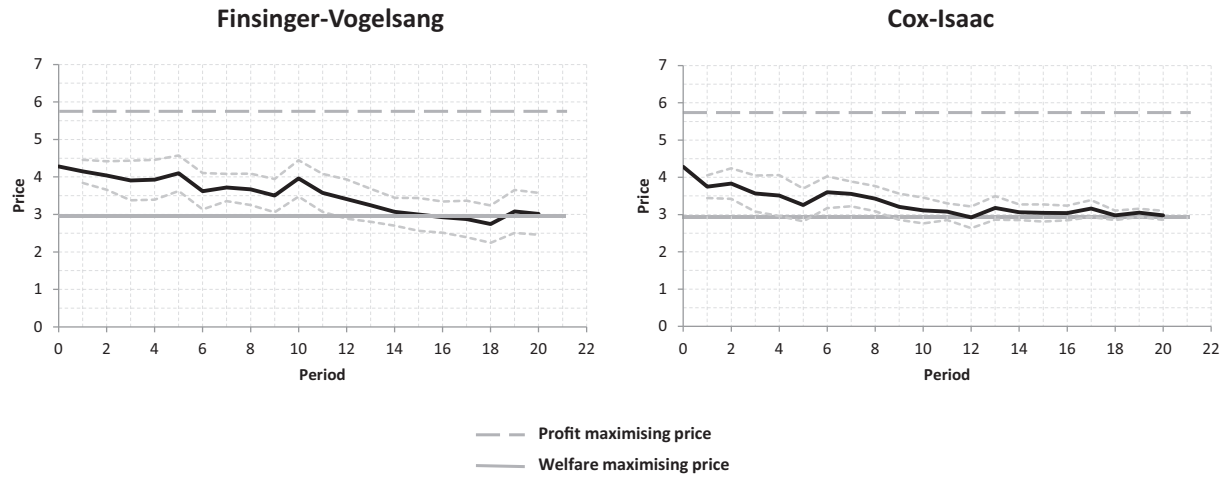

Fig. 3. Average price paths under Finsinger-Vogelsang and Cox-Isaac incentive regulation.

marginal cost, while π_m is the monopoly profit when the firm restricts its output to 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.

The average monopoly trading efficiency under FV and CI is plotted in Fig. 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 level 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, Figs. 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.

The tendency for FV regulated sellers to incur losses as the game progresses not only leads to a higher risk of bankruptcy for these firms, it also increases the deadweight loss compared with CI regulation as shown in Fig. 5. This figure depicts the average deadweight loss and its 95% confidence interval for each period as the difference between the sum of the consumer and producer surplus achieved at the average price in that period and the total welfare that can be achieved by setting the welfare maximising price. While the deadweight loss in a CI regulated monopoly converges steadily toward zero, the deadweight loss in a FV regulated monopoly remains positive and significant for the duration of the regulatory game.

Our next set of results relates to the effects of electoral competition on prices charged by the monopolist. Fig. 6 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.

Moreover, as can be seen from the right-hand-side panel of Fig. 6 the average price under electoral competition is below 5 and only one price step above the price of 4.28 at which the monopolist makes near-zero profits. 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. Fig. 7 confirms this conjecture. While the average profit indices of unregulated firms are close to the maximum value of one, the average profit indices of firms that are subject to electoral competition are clearly below 1 in all periods. Indeed, the right-hand-side of Fig. 7 shows that a monopoly seller subject to electoral competition foregoes on average slightly more than 20% of obtainable monopoly profits in order to retain the price-setting authority over the next electoral cycle. Considering that the secondary seller's opportunity costs is, in theory, capped at 10% of the monopoly profits, this result highlights the power of electoral competition in lowering prices, thereby significantly reducing the deadweight loss associated with this monopoly, as shown in Fig. 8.

Despite electoral competition exerting significant downward pressure on prices and reducing deadweight losses, it is apparent from Figs. 6 and 8 that prices remain above the welfare maximising level with deadweight losses never reaching zero. This is not surprising for the two experimental design features already mentioned: negative profits at prices above the welfare maximising price as well as only moderate

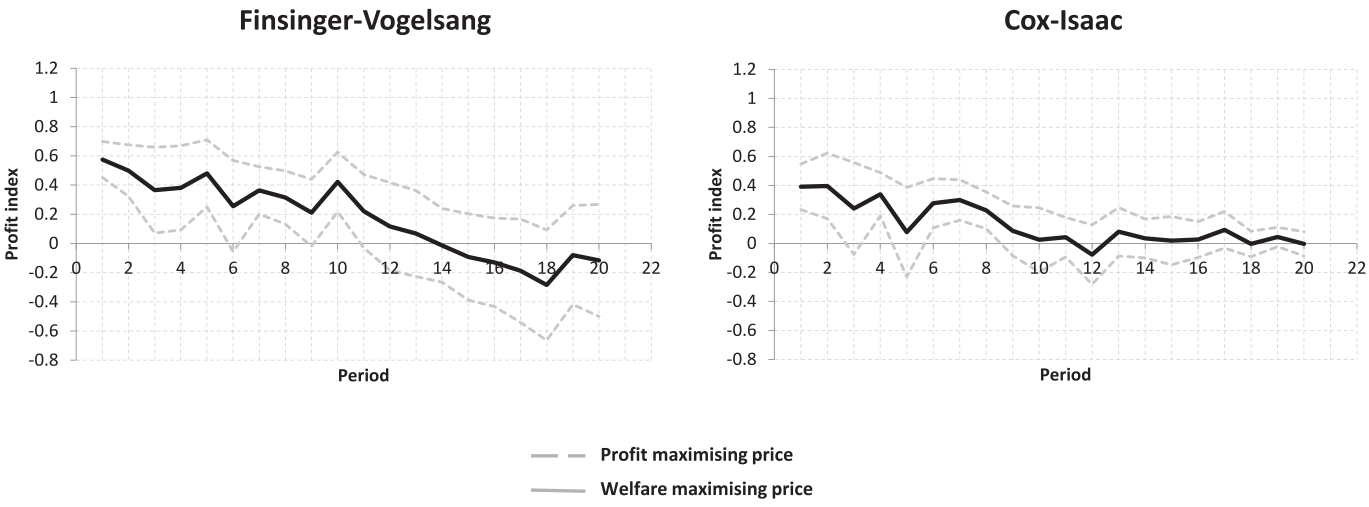

Fig. 4. Average profit index under Finsinger-Vogelsang and Cox-Isaac incentive regulation.

Fig. 5. Per period deadweight loss under Finsinger-Vogelsang and Cox-Isaac incentive regulation.

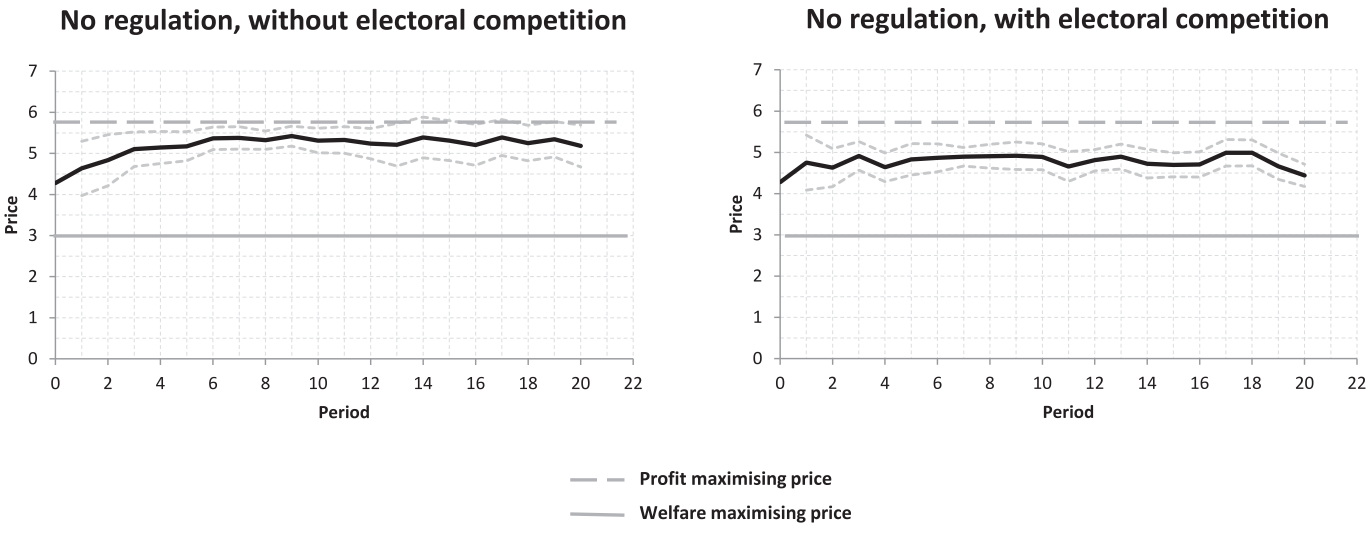

Fig. 6. Average price path for unregulated monopolies without and with electoral competition.

opportunity costs being incurred by the secondary seller. An important additional reason is that electoral competition in its purest form 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 and price setting intentions. For these reasons, one can interpret our experimental results with respect to electoral

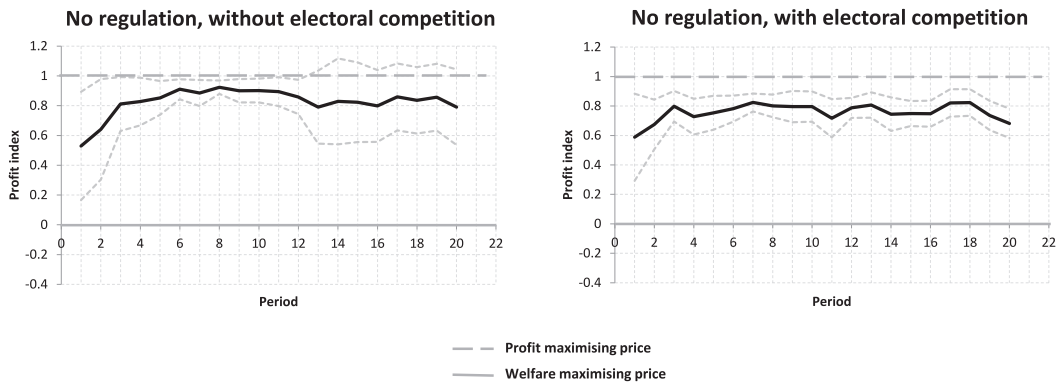

Fig. 7. Average monopoly trading efficiency for unregulated monopolies without and with electoral competition.

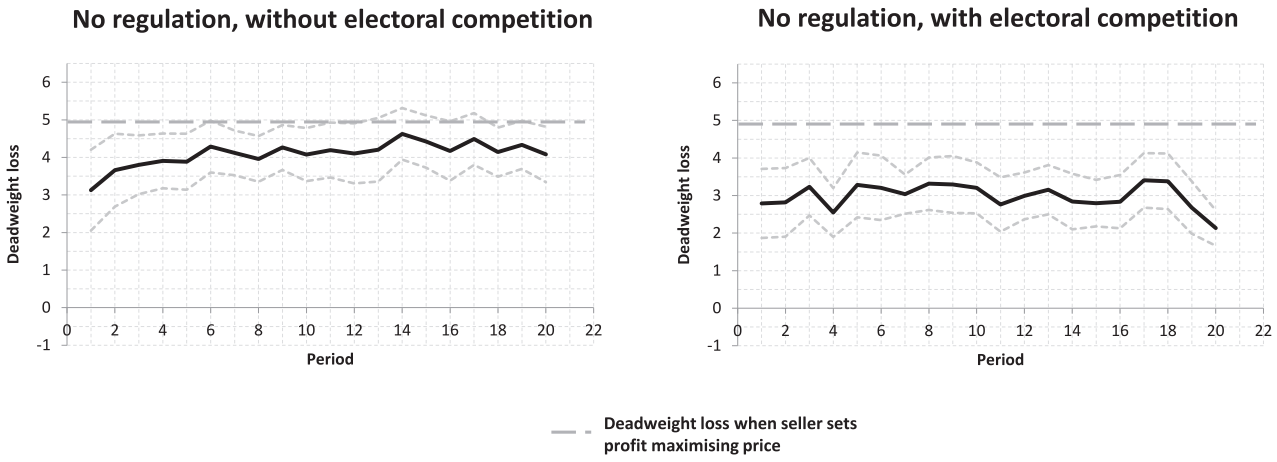

Fig. 8. Average deadweight loss for unregulated monopolies without and with electoral competition.

competition as conservative estimates of the price setting incentives that this mechanism creates. Electoral competition implemented in an environment where the monopoly seller retains positive profits at the welfare maximising price and the secondary seller earns less than the monopoly profits to be made at that price is likely to result in lower prices than we observe in our setting. Similarly, if buyers were able to observe the secondary sellers' prices in other, comparable markets or if sellers were allowed to post forward-looking price offers, this would lead to more informed voting and therefore greater consumer power, and in turn, lower prices.

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 when both regulatory mechanisms are treated equally. It is shown that without regulation, electoral competition reduces unit prices by 0.44 units on average, while regulation in the absence of electoral competition, reduced the price by 1.84 units. Both effects are statistically significant at the 1% level. To understand how electoral competition interacts with incentive regulation, we turn our focus to the treatments that jointly implemented incentive regulation and electoral competition. The results show that with regulation present, electoral competition increases the unit price marginally by $-0.436 + 0.588 = 0.152$ units. This result indicates that the benefits of electoral competition in terms of reduced average prices more than disappears if electoral competition is implemented jointly with incentive regulation. Instead of complementing each other these mechanisms can be viewed as substitutes.

This result remains when we analyse the interaction between regulation and electoral competition separately for each regulatory mechanism. Model 2 estimates the price effects separately for FV and CI. In line with the graphical results in Fig. 3 it is shown that CI is more effective than FV in reducing monopoly prices. Adding electoral competition to CI regulation leads to average price reductions of approximately 1.9 units. In contrast, the regulation by FV in the presence of electoral competition reduces monopoly prices by 1.47 units on average across all periods.

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.

The third hypothesis is not confirmed by our experiment as the right-hand-side panel in Fig. 9 shows. Indeed, electoral competition in conjunction with incentive regulation appears to hinder the convergence toward the welfare maximising outcome. This is confirmed by the regression results in Table 3, which reports the individual and interaction effects of the regulatory regime and electoral competition for each of the first 8 periods of the game. None of the three-way interaction terms are significant when FV is used and only one three-way interaction – that for period 7 – is significant when CI is used. In summary we find no evidence in support of hypothesis 3 whereby electoral competition can achieve faster price conversion when combined with incentive regulation. Instead of being complementary forces, electoral competition and regulation should be viewed as substitutes. That is, electoral competition appears to be suitable in settings that are challenging for the

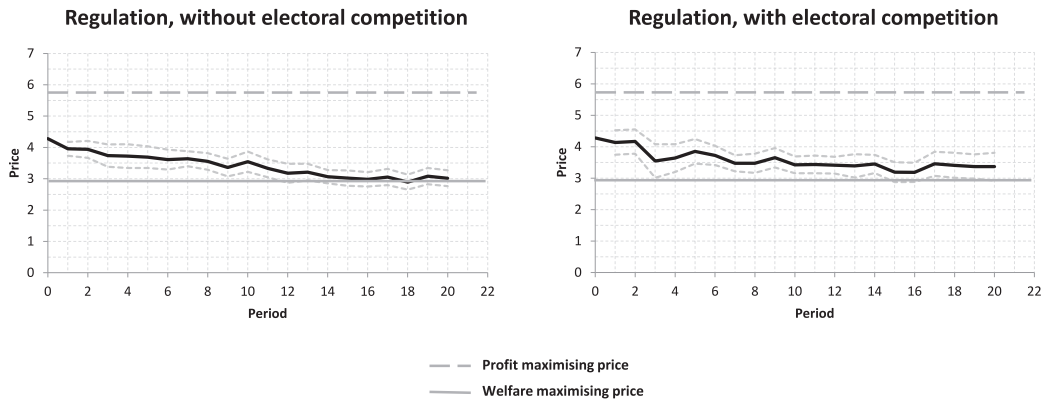

Fig. 9. Average price paths under regulation, without and with electoral competition.

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

	Model 3
	Mean
Electoral competition *(1 = Yes)*	−0.0131
Finsinger-Vogelsang *(1 = Yes)*	−1.6590***
Cox-Isaac *(1 = Yes)*	−1.9125***
Finsinger-Vogelsang × Period 1	1.2483***
Finsinger-Vogelsang × Period 2	1.0959***
Finsinger-Vogelsang × Period 3	0.6902**
Finsinger-Vogelsang × Period 4	0.8275***
Finsinger-Vogelsang × Period 5	0.8876***
Finsinger-Vogelsang × Period 6	0.2955
Finsinger-Vogelsang × Period 7	0.3739**
Finsinger-Vogelsang × Period 8	0.3467*
Fin-Vog × Elect Comp × Period 1	−0.3816
Fin-Vog × Elect Comp × Period 2	−0.0083
Fin-Vog × Elect Comp × Period 3	−0.4819
Fin-Vog × Elect Comp × Period 4	−0.1661
Fin-Vog × Elect Comp × Period 5	−0.1259
Fin-Vog × Elect Comp × Period 6	0.1489
Fin-Vog × Elect Comp × Period 7	−0.3114
Fin-Vog × Elect Comp × Period 8	−0.2774
Cox-Isaac × Period 1	1.0222***
Cox-Isaac × Period 2	1.0645***
Cox-Isaac × Period 3	0.5189*
Cox-Isaac × Period 4	0.5835*
Cox-Isaac × Period 5	0.2199
Cox-Isaac × Period 6	0.4485*
Cox-Isaac × Period 7	0.3852**
Cox-Isaac × Period 8	0.2802*
Cox-Isaac × Elect Comp × Period 1	0.3247
Cox-Isaac × Elect Comp × Period 2	0.0420
Cox-Isaac × Elect Comp × Period 3	−0.3250
Cox-Isaac × Elect Comp × Period 4	−0.4212
Cox-Isaac × Elect Comp × Period 5	0.0460
Cox-Isaac × Elect Comp × Period 6	−0.3505
Cox-Isaac × Elect Comp × Period 7	−0.4411**
Cox-Isaac × Elect Comp × Period 8	−0.3007
Constant	4.6984***
Period FE	Yes
Seller RE	Yes
Observations	2158
Games	109
R2 (overall)	0.442

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

regulator.

6. Conclusions

We propose a novel, consumer-focused mechanism to regulate electricity networks. Electoral competition leverages the recent trend toward more public involvement in 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. This effect, however, disappears when electoral competition is implemented jointly with incentive-compatible regulation, pointing to these mechanisms being alternatives to regulation in situations where institutional quality is low or networks are small.

Our experimental investigations focused primarily on the price and welfare effects of electoral competition and its interaction with regulation. However, this need not be the overarching objective of the consumer nor the regulator. Indeed, another benefit of electoral competition is that consumers through the voting process, can potentially communicate their preferences over a multitude of outcomes, including price stability and the quality of the service provision.

Our simple experimental design involved a randomly assigned buyer, who 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 buyer role more extensively to understand how information about firm costs, the possibility of offering forward-looking contracts, or information on seller performance in other markets may affect voting and price outcomes. Future experimental investigations could also test the effect of heterogenous buyers and sellers, different compensation mechanisms for the secondary seller and the effect of exogenous cost or demand shocks on market outcomes.

Another aspect that needs further attention in the future is how investments in the network is affected if electoral competition is used as the regulatory mechanism. In this context, electoral competition shares features with franchise bidding (Demsetz, 1968) that may lead to an underinvestment and a challenge to maintain the desired level of service quality.[9] Whether electoral competition leads to decreasing quality, and how that can be rectified, is a topic for future experimental studies.

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 decentralized and localised energy systems that are emerging are still very much undecided. Here electoral competition could provide an opportunity to democratise their management and

[9] The problem is that it is difficult to observe the precise state of the monopoly infrastructure asset. In this context, the payments to the franchisee cannot be made conditional on the state of the asset and the franchisee has little or no incentive to maintain the quality of the infrastructure (Williamson, 1976). We thank one of the reviewers for pointing this out.

safeguard against these systems being captured by technocrats or ideologues.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.eneco.2023.106614.

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