Online Appendix: "Spatial Competition in Fast-Charging Networks"

EC.1. Proofs for the Main Model

Proof of Lemma 1.

Total costs at source vertex $\mathrm{src}(e)$ and destination vertex $\mathrm{dst}(e)$ of edge e, respectively, for an infinitesimal consumer located at x are given by

$$C^\tau_{\mathrm{src}(e)}(x) = xt + x^\tau_e f^\tau_e \delta \kappa^{-1}_{\mathrm{src}(e)} + q\, p^\tau_{\mathrm{src}(e)} - a_{\mathrm{src}(e)}$$
$$C^\tau_{\mathrm{dst}(e)}(x) = (L_e - x)t + (L_e - x^\tau_e) f^\tau_e \delta \kappa^{-1}_{\mathrm{dst}(e)} + q\, p^\tau_{\mathrm{dst}(e)} - a_{\mathrm{dst}(e)},$$

assuming that x^τ_e is the indifferent infinitesimal consumer. Equating cost to find the consistent indifferent consumer results in

$$x^\tau_e = \frac{-q\Delta p^\tau_e + \Delta a_e + L_e(t + f^\tau_e \delta \kappa^{-1}_{\mathrm{dst}(e)})}{2t + f^\tau_e \delta \left(\kappa^{-1}_{\mathrm{src}(e)} + \kappa^{-1}_{\mathrm{dst}(e)}\right)}.$$

Here, for $\Delta p^\tau_e < \frac{\Delta a_e - L_e\left(t + f^\tau_e \delta \kappa^{-1}_{\mathrm{src}(e)}\right)}{q}$ or $\Delta p^\tau_e > \frac{\Delta a_e + L_e\left(t + f^\tau_e \delta \kappa^{-1}_{\mathrm{dst}(e)}\right)}{q}$, respectively, $x^\tau_e \notin [0, L_e]$. As the indifferent consumer must not lie outside edge e, we account for this saturation by defining the indifferent consumer as

$$x^{\tau *}_e = \min\left(L_e, \max\left(\frac{-q\Delta p^\tau_e + \Delta a_e + L_e(t + f^\tau_e \delta \kappa^{-1}_{\mathrm{dst}(e)})}{2t + f^\tau_e \delta \left(\kappa^{-1}_{\mathrm{src}(e)} + \kappa^{-1}_{\mathrm{dst}(e)}\right)}, 0\right)\right),$$

which is a piecewise-linear function of Δp^τ_e. □

Proof of Proposition 1.

As stated in the proof of Lemma 1, the indifferent consumer is a piecewise-linear function of Δp^τ_e. Its derivative with respect to Δp^τ_e is therefore piecewise constant outside the kinks, where the derivative is not defined. The kinks of $x^{\tau *}_e$ are located at $\Delta p^\tau_e = \frac{\Delta a_e - L_e\left(t + f^\tau_e \delta \kappa^{-1}_{\mathrm{src}(e)}\right)}{q}$ and $\Delta p^\tau_e = \frac{\Delta a_e + L_e\left(t + f^\tau_e \delta \kappa^{-1}_{\mathrm{dst}(e)}\right)}{q}$, respectively. Therefore, we obtain the derivative of the position of the indifferent consumer on edge e, $x^{\tau *}_e$, with respect to Δp^τ_e as

$$\frac{\mathrm{d}x^{\tau *}_e}{\mathrm{d}\Delta p^\tau_e} = \begin{cases} -\frac{q}{2t + f^\tau_e \delta \left(\kappa^{-1}_{\mathrm{src}(e)} + \kappa^{-1}_{\mathrm{dst}(e)}\right)}, & \text{for } \Delta p^\tau_e \in \left(\frac{\Delta a_e - L_e\left(t + f^\tau_e \delta \kappa^{-1}_{\mathrm{src}(e)}\right)}{q}, \frac{\Delta a_e + L_e\left(t + f^\tau_e \delta \kappa^{-1}_{\mathrm{dst}(e)}\right)}{q}\right) \\ 0, & \text{for } \Delta p^\tau_e \notin \left[\frac{\Delta a_e - L_e\left(t + f^\tau_e \delta \kappa^{-1}_{\mathrm{src}(e)}\right)}{q}, \frac{\Delta a_e + L_e\left(t + f^\tau_e \delta \kappa^{-1}_{\mathrm{dst}(e)}\right)}{q}\right] \end{cases} \quad \forall v, e.$$

Demands at the source and destination vertices of edge e are defined as $D^{\tau*}_{\mathrm{src}(e),e} = q f^\tau_e x^{\tau*}_e$ and $D^{\tau*}_{\mathrm{dst}(e),e} = q f^\tau_e (L_e - x^{\tau*}_e)$, respectively. The derivatives of $D^{\tau*}_{\mathrm{src}(e),e}$ and $D^{\tau*}_{\mathrm{dst}(e),e}$ are

$$\frac{\mathrm{d}D^{\tau*}_{\mathrm{src}(e),e}}{\mathrm{d}p^\tau_{\mathrm{src}(e)}} = \frac{\mathrm{d}D^{\tau*}_{\mathrm{src}(e),e}}{\mathrm{d}x^{\tau*}_e}\frac{\mathrm{d}x^{\tau*}_e}{\mathrm{d}\Delta p^\tau_e}\frac{\mathrm{d}\Delta p^\tau_e}{\mathrm{d}p^\tau_{\mathrm{src}(e)}} = q f^\tau_e \frac{\mathrm{d}x^{\tau*}_e}{\mathrm{d}\Delta p^\tau_e}$$
$$\frac{\mathrm{d}D^{\tau*}_{\mathrm{dst}(e),e}}{\mathrm{d}p^\tau_{\mathrm{dst}(e)}} = \frac{\mathrm{d}D^{\tau*}_{\mathrm{dst}(e),e}}{\mathrm{d}x^{\tau*}_e}\frac{\mathrm{d}x^{\tau*}_e}{\mathrm{d}\Delta p^\tau_e}\frac{\mathrm{d}\Delta p^\tau_e}{\mathrm{d}p^\tau_{\mathrm{dst}(e)}} = -q f^\tau_e \frac{\mathrm{d}x^{\tau*}_e}{\mathrm{d}\Delta p^\tau_e}(-1).$$

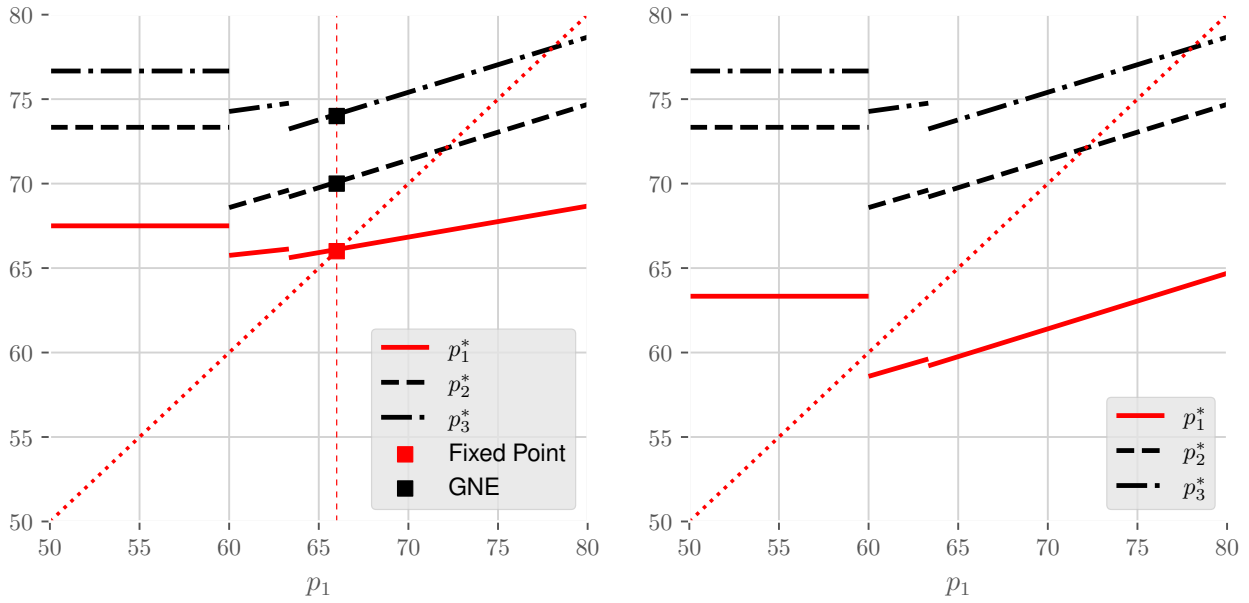
As both derivatives yield the same expression, we only have to determine $\frac{\mathrm{d}D^{\tau*}_{v,e}}{\mathrm{d}p^\tau_v} = q f^\tau_e \frac{\mathrm{d}x^{\tau*}_e}{\mathrm{d}\Delta p^\tau_e}$:

$$\frac{\mathrm{d}D^{\tau*}_{v,e}}{\mathrm{d}p^\tau_v} = \begin{cases} -\frac{q^2 f^\tau_e}{2t + f^\tau_e \delta\left(\kappa^{-1}_{\mathrm{src}(e)} + \kappa^{-1}_{\mathrm{dst}(e)}\right)}, & \text{for } \Delta p^\tau_e \in \left(\frac{\Delta a_e - L_e\left(t + f^\tau_e \delta \kappa^{-1}_{\mathrm{src}(e)}\right)}{q}, \frac{\Delta a_e + L_e\left(t + f^\tau_e \delta \kappa^{-1}_{\mathrm{dst}(e)}\right)}{q}\right) \\ 0, & \text{for } \Delta p^\tau_e \notin \left[\frac{\Delta a_e - L_e\left(t + f^\tau_e \delta \kappa^{-1}_{\mathrm{src}(e)}\right)}{q}, \frac{\Delta a_e + L_e\left(t + f^\tau_e \delta \kappa^{-1}_{\mathrm{dst}(e)}\right)}{q}\right] \end{cases} \quad \forall v, e.$$

This completes the proof. □

Proof of Proposition 2.

To prove Proposition 2, we only need a counterexample. Consider two three-vertex networks, A and B. Let $f_e, L_e = 1\ \forall e$, $p_{cap} = 100, \tilde{t} = 10$, $c_A = (50, 60, 70)^T$ and $c_B = (10, 60, 70)^T$, respectively. Figure EC.1 shows equilibrium plots.



(a) Conditions (C3) and (T3) are satisfied. p^*_1 intersects the identity function at the global Nash equilibrium $(p^*_1, p^*_2, p^*_3)^T = (66, 70, 74)^T$.

(b) Condition (C3) is not satisfied; condition (T3) is. p^*_1 and the identity function do not intersect; there is thus no global Nash equilibrium.

Figure EC.1 Equilibrium plots of two three-vertex networks, A (left) and B (right).

Here, the horizontal axis shows p_1, the price of the first vertex. On the vertical axis, the black lines represent the best-response equilibrium of CPO 2 (dashed) and CPO 3 (dash-dotted), i.e., the prices p_2^* and p_3^* that are in equilibrium when p_1 is given exogenously. The solid red line shows CPO 1's best response to the corresponding (p_2^*, p_3^*) pair. The dotted red line is the identity function. An intersection of the two red lines (i.e., the best response and identity) is a fixed point, and thus a global Nash equilibrium. As an example for the competitive regimes derived for two-vertex networks in Table 2, see $p_1 < 60$. Here, CPOs 2 and 3 concede on edges connecting to CPO 1, as they cannot fruitfully compete on these; the partial equilibrium p_2^*, p_3^* is thus independent of p_1. Clearly, we can see that while network A has a global Nash equilibrium, network B does not.

EC.2. Supplementary Results to Section 3

EC.2.1. Convex Delay Cost

In this extension, we replace the linear delay cost from the main model with a quadratic specification, where delay cost is proportional to the squared demand-to-capacity ratio, capturing non-linear congestion effects. For an infinitesimal consumer located at position $x \in [0, L_e]$ on edge e of length L_e, the total costs of charging at the source and destination vertices are:

$$C^\tau_{\mathrm{src}(e)}(x) = xt + \delta\left(\frac{x f_e^\tau}{\kappa_{\mathrm{src}(e)}}\right)^2 + q\, p^\tau_{\mathrm{src}(e)} - a_{\mathrm{src}(e)}$$
$$C^\tau_{\mathrm{dst}(e)}(x) = (L_e - x)t + \delta\left(\frac{(L_e - x) f_e^\tau}{\kappa_{\mathrm{dst}(e)}}\right)^2 + q\, p^\tau_{\mathrm{dst}(e)} - a_{\mathrm{dst}(e)}.$$

The indifferent consumer x_e^τ is the position where the costs are equal: $C^\tau_{\mathrm{src}(e)}(x_e^\tau) = C^\tau_{\mathrm{dst}(e)}(x_e^\tau)$. Expanding the terms and substituting the differences $\Delta p_e^\tau = p^\tau_{\mathrm{src}(e)} - p^\tau_{\mathrm{dst}(e)}$ and $\Delta a_e = a_{\mathrm{src}(e)} - a_{\mathrm{dst}(e)}$, the equilibrium condition is expressed as:

$$\delta(f_e^\tau)^2\left(\frac{1}{\kappa^2_{\mathrm{src}(e)}} - \frac{1}{\kappa^2_{\mathrm{dst}(e)}}\right)(x_e^\tau)^2 + 2\left(t + \frac{L_e\delta(f_e^\tau)^2}{\kappa^2_{\mathrm{dst}(e)}}\right)x_e^\tau + \left(q\Delta p_e^\tau - \Delta a_e - L_e t - \frac{L_e^2\delta(f_e^\tau)^2}{\kappa^2_{\mathrm{dst}(e)}}\right) = 0.$$

Solving this quadratic equation for x_e^τ yields the explicit position of the indifferent consumer:

$$x_e^\tau = -\frac{t + L_e\delta(f_e^\tau)^2\kappa^{-2}_{\mathrm{dst}(e)}}{\delta(f_e^\tau)^2\left(\kappa^{-2}_{\mathrm{src}(e)} - \kappa^{-2}_{\mathrm{dst}(e)}\right)} + \frac{\sqrt{\left(t + L_e\delta(f_e^\tau)^2\kappa^{-2}_{\mathrm{dst}(e)}\right)^2 - \left(\delta(f_e^\tau)^2\left(\kappa^{-2}_{\mathrm{src}(e)} - \kappa^{-2}_{\mathrm{dst}(e)}\right)\right)\left(q\Delta p_e^\tau - \Delta a_e - L_e t - L_e^2\delta(f_e^\tau)^2\kappa^{-2}_{\mathrm{dst}(e)}\right)}}{\delta(f_e^\tau)^2\left(\kappa^{-2}_{\mathrm{src}(e)} - \kappa^{-2}_{\mathrm{dst}(e)}\right)}.$$

For the specific case where capacities are symmetric ($\kappa_{\mathrm{src}(e)} = \kappa_{\mathrm{dst}(e)} = \kappa_e$), the quadratic term vanishes, and the solution simplifies to:

$$x_e^\tau = \frac{-q\Delta p_e^\tau + \Delta a_e + L_e\left(t + L_e\delta(f_e^\tau)^2\kappa_e^{-2}\right)}{2\left(t + L_e\delta(f_e^\tau)^2\kappa_e^{-2}\right)}.$$

When both vertices have equal capacity κ_e, the indifferent consumer still varies linearly with the price differential, i.e., the competitive dynamics are unaffected by the quadratic delay cost. Under heterogeneous capacities, however, the square-root term introduces a non-linear relationship between the price differential and the indifferent consumer. We illustrate this in a numerical example where $\kappa_{\mathrm{src}(e)} = 2\kappa_{\mathrm{dst}(e)}$, with the remaining parameters calibrated so that the quadratic and linear specifications yield identical outcomes under equal capacities, thereby isolating the effect of the delay cost curvature. Figure EC.2 shows the resulting relationship.

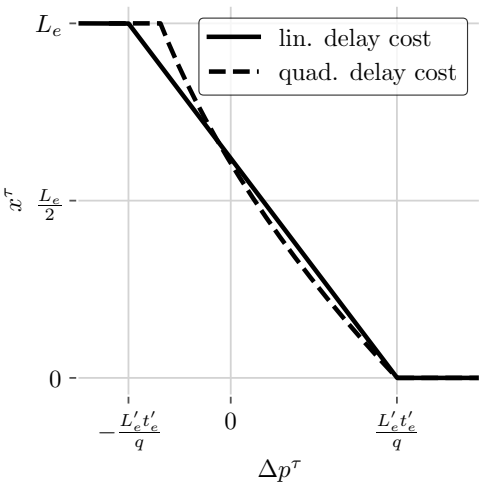


Figure EC.2 Position of the indifferent consumer dependent on price differential for linear and convex delay cost.

The higher capacity at the source vertex shifts the indifferent consumer toward it: at equal prices, most consumers charge at the source vertex, and this holds under both linear and quadratic delay cost. The two specifications differ, however, in how the indifferent consumer responds to the price differential. Given the relatively modest capacity disparities in practice, such a difference is small over the range of relevant price differentials, suggesting that the linear specification is appropriate, especially given its computational advantages.

EC.2.2. Globally Aware Consumers

In our main model, we assume that consumers are locally aware in estimating the waiting time without the cognitive overhead of a complete assessment of arrivals from all edges. Departing from this assumption, here, we consider the consumers' globally aware delay estimation of waiting time. Indifferent consumers with a globally aware delay estimation are characterized as follows:

$$\begin{aligned} &x_e^\tau t + \delta \kappa_{\mathrm{src}(e)}^{-1} \sum_{e' \in \mathcal{E}_{\mathrm{src}(e)}} \frac{D^\tau_{\mathrm{src}(e),e'}(\mathbf{p}^\tau)}{q} + q\, p^\tau_{\mathrm{src}(e)} - a_{\mathrm{src}(e)} \\ =&(L_e - x_e^\tau)t + \delta \kappa_{\mathrm{dst}(e)}^{-1} \sum_{e' \in \mathcal{E}_{\mathrm{dst}(e)}} \frac{D^\tau_{\mathrm{dst}(e),e'}(\mathbf{p}^\tau)}{q} + q\, p^\tau_{\mathrm{dst}(e)} - a_{\mathrm{dst}(e)} \qquad \forall e \in E. \end{aligned} \tag{EC.1}$$

In Eq. (EC.1), we highlight that demand $D^\tau_{v,e}$ from edge e at vertex v does not only depend on the price differential Δp^τ_e on that edge, but on all prices $\mathbf{p}^\tau$ in the network. When there is an interior solution to Eq. (EC.1), we can rewrite Eq. (EC.1) as a linear system of equations for $(\mathbf{p}^\tau, \mathbf{x}^\tau)$:

$$\begin{aligned} &x^\tau_e t + \delta \kappa^{-1}_{\mathrm{src}(e)} \left(\sum_{e' \in \mathcal{E}^-_{\mathrm{src}(e)}} f^\tau_{e'} x^\tau_{e'} + \sum_{e' \in \mathcal{E}^+_{\mathrm{src}(e)}} f^\tau_{e'} (L_{e'} - x^\tau_{e'}) \right) + q\, p^\tau_{\mathrm{src}(e)} - a_{\mathrm{src}(e)} \\ =&(L_e - x^\tau_e) t + \delta \kappa^{-1}_{\mathrm{dst}(e)} \left(\sum_{e' \in \mathcal{E}^-_{\mathrm{dst}(e)}} f^\tau_{e'} x^\tau_{e'} + \sum_{e' \in \mathcal{E}^+_{\mathrm{dst}(e)}} f^\tau_{e'} (L_{e'} - x^\tau_{e'}) \right) + q\, p^\tau_{\mathrm{dst}(e)} - a_{\mathrm{dst}(e)} \qquad \forall e \in E. \end{aligned} \tag{EC.2}$$

Let $\mathbf{x}^{\tau*}(\mathbf{p}^\tau) = (x^{\tau*}_e)$ be the solution to Eq. (EC.2). We have $D^{\tau*}_{\mathrm{src}(e),e}(\mathbf{p}^\tau) = q f^\tau_e x^{\tau*}_e(\mathbf{p}^\tau)$ and $D^{\tau*}_{\mathrm{dst}(e),e}(\mathbf{p}^\tau) = q f^\tau_e \left(L_e - x^{\tau*}_e(\mathbf{p}^\tau)\right)$. Each CPO $i \in N$ must now make pricing decisions considering not only the direct impact on adjacent edges of its controlled vertices, but also indirect effects that propagate through the network, which leads to the following decision problem:

$$\begin{aligned} \max_{\mathbf{p}^\tau_i} \quad & \Pi_i = \sum_\tau \Pi^\tau_i = \sum_\tau \sum_{v \in \mathcal{V}_i} \sum_{e \in \mathcal{E}_v} D^{\tau*}_{v,e}(\mathbf{p}^\tau) \left(p^\tau_v - c^\tau_v \right) \\ \text{s.t.} \quad & \mathbf{p}^\tau_i \preccurlyeq p_{cap} \quad \forall \tau. \end{aligned} \tag{EC.3}$$

The optimization problems defined in Eq. (EC.3) $\forall i \in N$ constitute an equilibrium problem (Gabriel et al. 2013), which can be solved with standard techniques using the corresponding linear system arising from the KKT conditions. If $\mathbf{p}^{\tau*} = (p^{\tau*}_v)_v$ solves Eq. (EC.3) $\forall i \in N$ and $\mathbf{x}^{\tau*}(\mathbf{p}^\tau)$ is an interior solution, $\mathbf{p}^{\tau*}$ is a (global) equilibrium price vector. Nevertheless, both consumer and operator decisions are significantly more complex under the assumption that consumers estimate delays by accounting for price information on all edges. Further, for general prices $\mathbf{p}^\tau$, $\mathbf{x}^{\tau*}(\mathbf{p}^\tau)$ might be a boundary solution, giving rise to intractable non-linear demand patterns in Eq. (EC.1). For the sake of tractability, we adopt the locally aware delay estimation for consumers in the large-scale case study presented in Section 4.

EC.2.3. Illustration of the Equilibrium Approximation

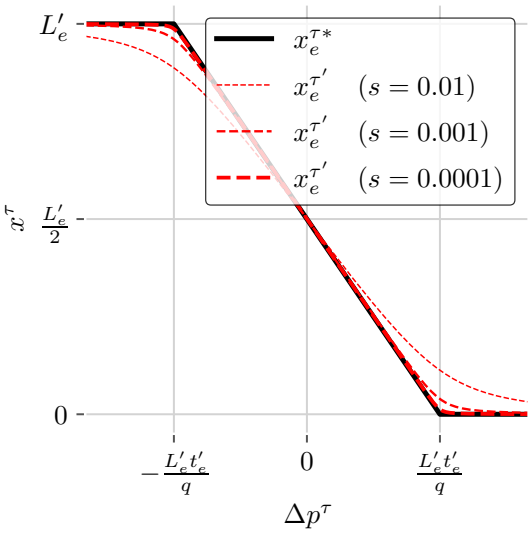
To speed up the calculation of local Nash equilibria, we propose an approximation method that smooths the demand function (see Section 3.4). Figure EC.3 provides an illustration of the asymptotic properties of our method, assuming no delay costs. We can observe that our proposed approximation method provides a close fit to the piecewise-linear demand when s (the smoothing parameter) is sufficiently small.

EC.3. Supplementary Materials to Section 4

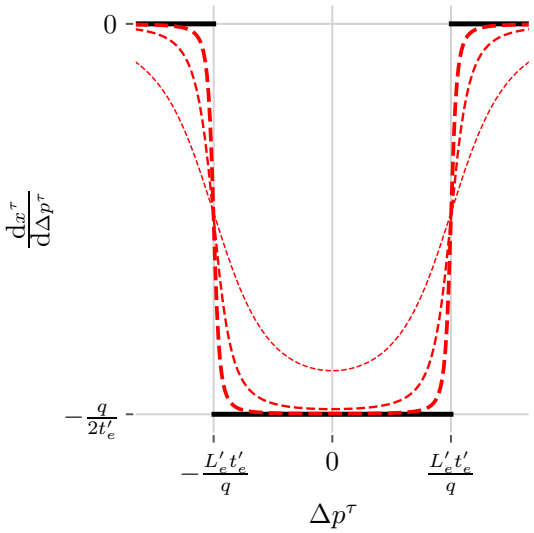
EC.3.1. Analysis of Attractiveness

Table EC.1 summarizes the amenities included in our analysis, following OSM's convention.[1]

[1] See `https://wiki.openstreetmap.org/wiki/Key:amenity` for details.



(a) Smoothing of the indifferent consumer x_e on edge e. The largest approximation errors are around the kinks of the exact x^*_e.



(b) Smoothing of $\frac{\mathrm{d}x_e}{\mathrm{d}\Delta p}$. The exact x^*_e is not differentiable at $\Delta p = \pm\frac{L'_e t'_e}{q}$; elsewhere the approximation is exact for $s \to 0$.

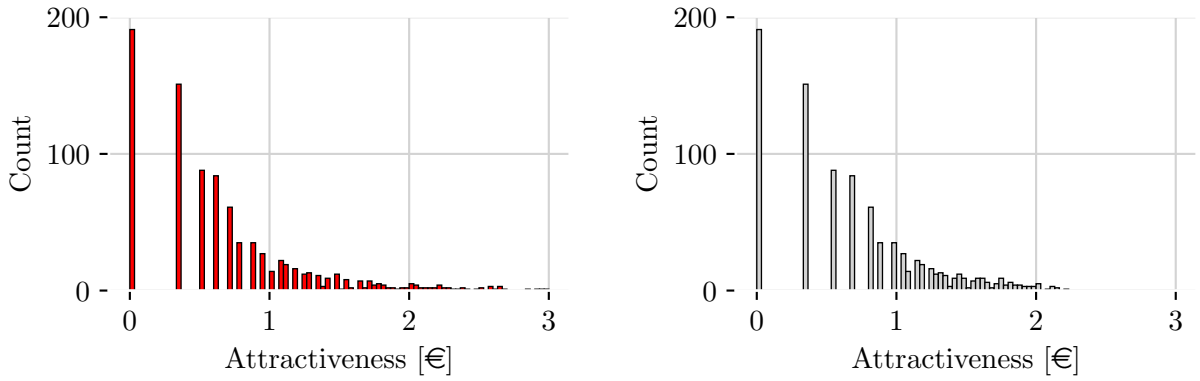
Figure EC.3 Plot of the continuously differentiable demand approximation and its derivative.

Table EC.1 Amenities clustered by OSM POI class.

OSM Category	Amenities
Sustenance	bar, biergarten, cafe, canteen, fast food, food court, hookah lounge, ice cream, pub, restaurant
Education	academy, college, dancing school, dojo, driving school, first aid school, kindergarten, language school, music school, prep school, school, training, tutoring, university
Transportation	bicycle rental, bicycle repair station, boat rental, car wash, compressed air, ferry terminal, loading dock, motorcycle parking, sanitary dump station, taxi, ticket validator, vacuum cleaner, vehicle inspection, vehicle workshop
Healthcare	clinic, dentist, doctors, hospital, nursing home, pharmacy, veterinary
Entertainment	arts center, casino, cinema, events venue, gambling, gambling hall, nightclub, studio, theater, vivarium
Public Service	archive, courthouse, fire station, graveyard, library, library dropoff, police, post box, post depot, post office, prison, public building, townhall
Financial	ATM, bank, money transfer, payment terminal
Facilities	bench, brothel, childcare, clock, clothes dryer, community center, device charging station, dressing room, drinking water, facility management, food sharing, fountain, funeral hall, greenhouse, grit bin, internet cafe, Kneipp water cure, lockers, lounger, luggage locker, marketplace, mortuary, parcel locker, photo booth, place of worship, public bookcase, public hall, shower, smoking area, social center, social facility, telephone, vending machine, waste disposal, water point

In the main analysis, we measure attractiveness using a log transformation of the amenity count. The log specification admits a natural economic interpretation: each proportional increase in ameni-

ties yields a constant utility increment. To assess sensitivity to this choice, we consider an alternative square-root transformation. Both are concave and thus capture diminishing marginal returns; they differ only in the degree of concavity, with the log compressing differences at higher counts more strongly. Figure EC.4a shows the distribution of attractiveness scores under the square-root transformation, normalized such that total utility from amenities is comparable to the log specification used in the main analysis (see Figure EC.4b). The two distributions are virtually identical, which is expected given that most stations in our network have fewer than 10 nearby amenities, a range over which the two transformations produce nearly identical rankings.

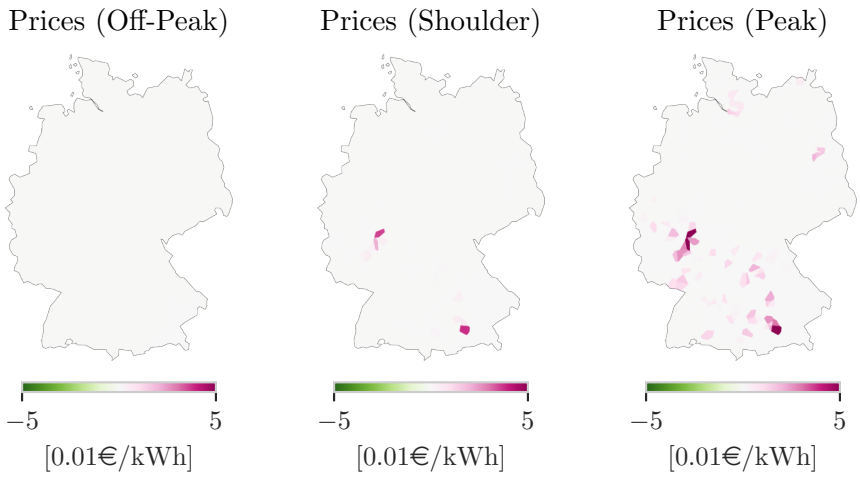


(a) Square-root utility. (b) Log utility.

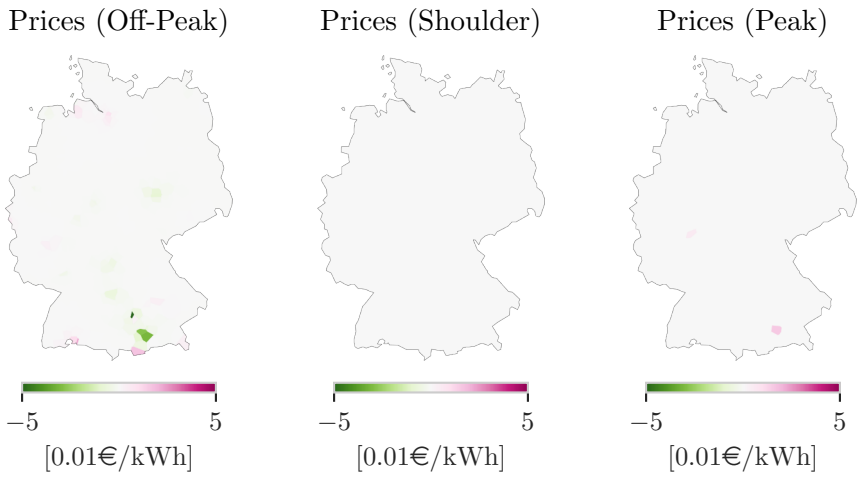
Figure EC.4 Distribution of attractiveness scores under alternative concave transformations.

EC.3.2. Impact of Heterogeneous Price Caps

Price cap regulation is primarily motivated by regional market power and CPOs' ability to extract monopoly rents. Differentiated price caps offer a natural approach to addressing this regional heterogeneity. Figure EC.5 shows equilibrium prices when a price cap is enforced only at nodes with below-average local competitiveness. In most rural areas, this price cap remains binding. In some moderately competitive yet high-demand regions, prices exceed the cap once it is lifted, whereas in highly competitive regions, prices remain below it regardless. These effects are most pronounced during peak hours, when delay-driven market power enables CPOs in high-demand regions to charge higher prices. Interestingly, enforcing a cap of 0.50 €/kWh only in low-competition areas while lifting it elsewhere (see Figure EC.5b) can lead to lower prices overall. This suggests that targeted caps alter competitive dynamics across the entire network, not just at directly affected nodes, through spatial spillover effects.



(a) Price cap of 0.44 €/kWh only in low-competition areas.



(b) Price cap of 0.50 €/kWh only in low-competition areas.

Figure EC.5 **Impact of heterogeneous price caps on pricing. Tight price caps are only enforced in lower-competition areas. Other areas have a price cap of 0.56 €/kWh to avoid unboundedness on monopoly edges.**

EC.3.3. Sensitivity Analysis of Travel and Delay Costs

An important driver of equilibrium prices is travel cost, which captures not only the direct expense of additional travel but also consumers' willingness to bypass closer stations to reduce charging expenditures. Figure EC.6 presents equilibrium prices under the *Deutschlandnetz* setting in 2030 with delay cost parameter $\delta = 2$ €/kWh as travel cost varies. At higher travel costs, the regulatory price cap becomes binding across nearly all regions; only in metropolitan areas with the highest charging station densities—where competitive pressure is strongest—does it keep prices below the cap. Eastern German regions are among the first where competition breaks down, as even the additional supply from the tender proves insufficient to overcome the lack of competitiveness.

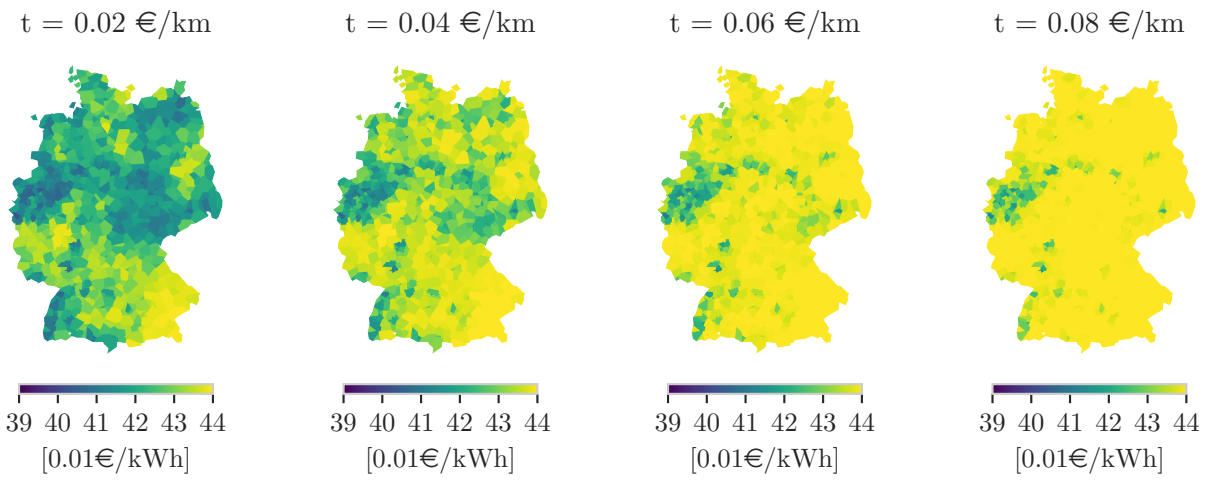


Figure EC.6 Sensitivity analysis of travel costs (*Deutschlandnetz* setting in 2030).

Figure EC.7 presents an analogous sensitivity analysis for delay cost. As delay costs increase, prices similarly converge toward the cap: extended waiting times at popular, lower-priced stations reduce their competitive advantage, lowering competitive pressure on rival CPOs.

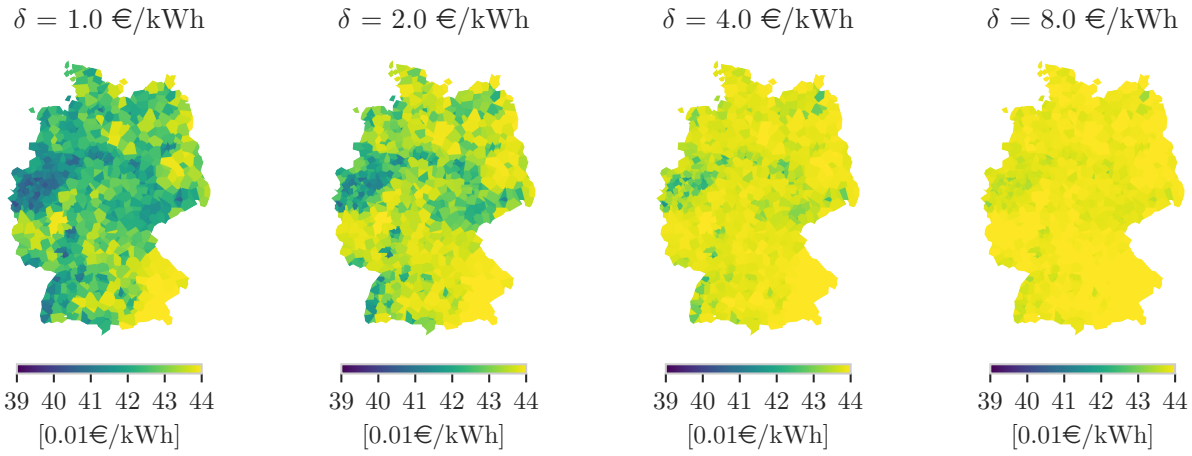


Figure EC.7 Sensitivity analysis of delay costs (*Deutschlandnetz* setting in 2030).

References

Gabriel SA, Conejo AJ, Fuller JD, Hobbs BF, Ruiz C (2013) *Complementarity Modeling in Energy Markets*, volume 180 of *International Series in Operations Research & Management Science* (New York: Springer).