Self-Selection in Retail Electricity Contracts

Competition, Regulation, and Welfare Implications

Léopold Monjoie[1,3], Julien Duc[2]

[1] Aalto University

[2] IAE Nantes, Nantes University, LEMNA

[3] leopold.monjoie@aalto.fi

Abstract.

We study equilibrium contract adoption in retail electricity markets in which consumers differ in their willingness to pay over time and can choose between a fixed-price contract (FP) and real-time pricing contract (RTP). Self-selection alters the consumption profile and, in turn, the cost of serving FP customers, creating an adverse-selection channel with endogenous costs. In a competitive retail segment, this channel unravels the FP contract: any private retailer that attracts FP customers is left with a pool that is too costly to serve at break-even. Under a regulated monopoly offering the FP contract, contract choice instead disciplines pricing: the monopoly internalizes consumer sorting to the RTP contract and may cut its price to retain low-cost customers. This pricing response can increase inefficient peak consumption and reduce welfare relative to a benchmark without an RTP contract. We characterize the monopoly's pricing rule, show how consumer heterogeneity governs the strength of the sorting incentive, and discuss regulatory instruments (two-part tariffs and loss-financing rules) that mitigate the welfare cost of opt-in RTP contracts.

We are grateful to Matti Liski, Iivo Vehviläinen and Juan-Pablo Montero for many illuminating discussions. We also thank Natalia Fabra, Mar Reguant, Stefan Ambec, R. Andrew Butters, Bertrand Villeneuve and Jacqueline Adelowo for their comments and suggestions.

1 Introduction

Economists have long advocated retail electricity contracts that replicate wholesale prices as a key policy to enhance the functioning of electricity markets. In a market for a non-storable homogeneous good with stochastic demand, transmitting the proper temporal price signal increases welfare by reducing intertemporal misallocation (Borenstein, 2005b), mitigating market power (Poletti and Wright, 2020), and lowering the need to keep peaking units available, which are typically among the most polluting generators (Borenstein and Bushnell, 2021). Building efficient demand-side incentives is all the more critical in the context of the energy transition. On the supply side, decarbonization entails moving from dispatchable but polluting fuel-based technologies to intermittent but clean renewable generation, whose stochastic nature raises new reliability challenges and makes accurate price signals more valuable (Imelda et al., 2024). On the demand side, electrification of end-uses (e.g., heat pumps, electric vehicles, and behind-the-meter storage) increases the scope for demand-side flexibility but also the risk of inefficient load shifting toward peak hours when incentives are misaligned (Bailey et al., 2024).

Yet the voluntary adoption of dynamic retail pricing remains limited. Recent surveys indicate that about 74% of European households and 81% of US households are enrolled in fixed-price contracts (ACER, 2024; Schittekatte et al., 2024). This persistence of fixed pricing is not primarily driven by a lack of metering technology or by the absence of contract choice.[1] Smart meter penetration is now high in significant markets, around 80% in Europe and 75% in the US (Kavulla, 2023; ACER, 2024), and dynamic contracts are widely available alongside fixed-price alternatives, yet switching into dynamic pricing remains low when consumers can choose (Fowlie et al., 2021).

This gap suggests that adoption may also be an *equilibrium outcome*: when consumers self-select across contracts, the composition of demand and the cost of serving each contract become endogenous, which shapes how retailers price the menu and, ultimately, which contracts consumers adopt. Behavioral explanations are often invoked to account for limited uptake of dynamic pricing. Still, there is comparatively little evidence, and limited theory, on how equilibrium pricing in retail markets can itself sustain (or deter) dynamic pricing adoption. One key contribution of this paper is to provide such a mechanism.

A key reason is that contract choice interacts with firms' incentives in a non-trivial way. Because dynamic pricing affects when consumers use electricity, contract selection generates a moral-hazard channel: the consumption profile induced by a contract changes retailers' procurement

[1] Smart metering and information provision are known to be important inputs for the effectiveness of dynamic tariffs (Jessoe and Rapson, 2014; Bollinger and Hartmann, 2020).

costs. As a result, retailers care not only about how many consumers they serve but also about which consumers they attract, since the composition of the customer base determines both the profitability and the cost profile of each contract. Moreover, retail markets differ widely in structure, from competitive environments populated by private retailers to settings dominated by a regulated public firm, and these institutions shape pricing incentives in distinct ways. A private retailer internalizes only the profitability of its customer base, whereas a public provider typically values consumer surplus subject to budget and regulatory constraints. These differences imply that the same contract menu can lead to sharply different equilibrium prices and, ultimately, different adoption patterns.

This paper develops a general-equilibrium model of self-selection in retail electricity contracts to examine how consumer sorting shapes firms' pricing responses across market structures.[2] We characterize contract demand in a two-dimensional type space (capturing heterogeneity in willingness to pay across two periods), and we derive equilibrium pricing when (i) private retailers compete for consumers with both FP and RTP contracts, and also face (ii) a regulated monopoly offering the FP contract.[3] The central message is that equilibrium adoption is not only a matter of consumers' preferences: it is the outcome of an interaction between sorting (which determines each contract's cost profile) and pricing (which feeds back into sorting).

Our main results can be summarized as follows. First, we provide a characterization of contract demand and the sorting pattern induced by a menu of FP and RTP contracts. Because consumers differ in their willingness to pay across periods, contract choice is determined by comparing utilities across three outside options: not consuming, enrolling in the FP contract, or enrolling in the RTP contract. This generates a distinct set of marginal consumers, *contract switchers*, in addition to the usual participation margin. The sorting pattern is intuitive but has sharp implications: consumers with relatively higher willingness to pay during off-peak periods tend to select the RTP contract, whereas those with relatively higher willingness to pay during on-peak periods tend to choose the FP contract.

Second, we study how this endogenous sorting affects equilibrium pricing. When competitive private retailers supply the FP contract, we show that no equilibrium can feature a demand for the FP contract: competition drives profits to zero, and adverse selection implies that any retailer

[2]In this paper, we derive the main results by assuming the set and characteristics of contracts as fixed. For future research, we leave the question of equilibrium regarding menu characteristics open. For instance, this issue concerns the representation of competition for non-linear tariffs (Stole, 2007), or how insurance companies can offer a menu of contracts given incomplete information (Rothschild and Stiglitz, 1976; Dosis, 2022).

[3]There is a significant diversity of contracts that introduce temporal variation in price. See Cabot and Villavicencio (2024) for a recent literature survey of current industrial practice. In this paper, we do not impose a dynamic contract to replicate the wholesale price perfectly. However, due to the perfect competition assumption, the equilibrium for the dynamic contract is always an RTP contract. Hence, we consider the term dynamic contract and RTP contract to be equivalent.

attracting consumers choosing this contract is left with a pool that is too costly to serve at break-even prices. In this case, competitive forces unravel the FP market and select the RTP contract, implementing the efficient allocation within the model environment. By contrast, when a regulated monopoly sets the FP contract price, an equilibrium with a demand for this contract can exist. We provide a pricing formulation for the regulated monopoly in which the equilibrium unit price reflects the sensitivity of contract demand to policy instruments, the consumers sorting toward the RTP contract,[4], and the way the firm's deficit is financed.

Third, we show that this general-equilibrium interaction between sorting and pricing is crucial for welfare. While the RTP contract improves allocative efficiency for consumers who switch, allowing contract choice can nevertheless reduce welfare under a regulated monopoly relative to a benchmark in which only an FP contract is offered. The reason is that the monopoly internalizes the consumer surplus loss from leakage to the RTP contract, and the consumers most likely to switch are also the least costly for the firm. This gives the monopoly an incentive to lower its unit price. The lower price, in turn, increases on-peak consumption among consumers whose willingness to pay is below wholesale cost, generating an additional inefficiency. Hence, the welfare gains from improved sorting into the RTP contract can be offset, and in some cases dominated, by induced overconsumption during peak periods. Significantly, equilibrium welfare depends on how consumer characteristics are distributed, and notably on which types become (i) *contract switchers* (moving to the RTP contract and adjusting consumption efficiently), (ii) *profile switchers* (remaining in FP but shifting demand across periods), and (iii) *marginal entrants/exiters* induced by the lower unit price.

A central policy implication is that the available tariff instrument and the loss-financing rule for the FP contract jointly shape the regulated monopoly's pricing distortion. We discuss allowing the public firm to use a two-part tariff compared to linear pricing, which can restore some efficiency by separating the intensive margin from the sorting margin: the unit price determines the consumption distortion. In contrast, the fixed fee can be used to manage enrollment and limit consumer leakage without compressing the unit price. At the same time, the regulated firm's practical objective depends on how deficits are financed within the electricity market. We capture this fiscal channel by introducing a market-wide unit levy whose incidence can fall partly on the public firm's own consumers and partly on consumers served by private retailers, and we show that it directly affects consumer sorting and its equilibrium consequences.

The paper is structured as follows. Section 2 introduces the model framework and the single-contract benchmark. Section 3 characterizes contract demand and consumer sorting. Section 4

[4]We also use the term consumers leakage to emphasize its negative role.

derives equilibrium pricing and presents the welfare analysis, and Section 5 studies the extension with fiscal policy. Section 6 concludes and discusses potential extensions.

Related Literature

This paper relates to several strands of the literature on real-time pricing and electricity markets. We contribute to two main questions: (i) how consumers sort across retail electricity contracts when contract choice is voluntary, and (ii) how this sorting shapes equilibrium pricing and welfare under different market structures.

Dynamic pricing and welfare in electricity markets. The idea that retail prices should reflect time-varying marginal costs is a classical theme in public economics and regulated pricing, going back to early analyses of peak-load and marginal-cost pricing (Boiteux, 1949). In electricity markets, some papers show that exposing consumers to time-varying prices can raise welfare by reducing intertemporal misallocation, lowering the need for expensive peaking capacity, and improving wholesale market performance (Borenstein and Holland, 2003; Borenstein, 2005b,a; Borenstein and Bushnell, 2021). Beyond the benchmark environment, subsequent work studies how the gains from adopting RTP contracts interact with investment decisions (including metering infrastructure), the integration of renewables, and consumer risk considerations (Borenstein, 2005b; Leautier, 2014; Ambec and Crampes, 2021; Boom and Schwenen, 2021). A common limitation of this literature, however, is that either consumers are homogeneous (demand profiles differ only by scale) or the share of consumers on dynamic tariffs is taken as exogenous. In contrast, our model delivers a micro-founded demand for contracts from heterogeneous consumers and treats adoption as an equilibrium outcome, which is central for evaluating welfare when dynamic pricing is offered on an opt-in basis.[5]

Contract choice, selection, and multidimensional heterogeneity. Empirically, an extensive literature evaluates dynamic pricing experiments and finds mixed evidence on the magnitude of average consumption responses (Fabra et al., 2021; Han et al., 2023; Enrich et al., 2024; Fu et al., 2024). Fewer papers study selection into dynamic tariffs and how selection interacts with welfare. Ito et al. (2023) provides evidence that consumers with larger potential efficiency gains are more likely to opt in. In contrast, Fowlie et al. (2021) documents that take-up can be weak even when

[5]Our approach is also related to the growing literature emphasizing heterogeneity and distributional impacts of time-varying pricing, both in theory and empirically (Blonz, 2022; Leslie et al., 2021; Levinson and Silva, 2022; Cahana et al., 2023). While these papers focus primarily on a single tariff, we study how welfare and adoption change when consumers can sort across contracts, which is precisely the context highlighted in policy discussions on opt-in RTP contracts and cross-subsidies (Borenstein, 2013; Joskow and Wolfram, 2012).

expected bill savings are significant, pointing to informational frictions and other demand-side mechanisms. Our paper complements this evidence by providing a theoretical foundation for selection into contracts in an electricity setting where costs depend on the induced consumption profile. We relate our results to the modern adverse-selection framework, distinguishing *selection on the level* and *selection on the slope* (Einav et al., 2012, 2021).

Methodologically, our self-selection problem is multidimensional: consumers differ in their willingness to pay across periods, so contract menus generate sorting along multiple margins. This connects our analysis to the multidimensional screening and nonlinear pricing literature, which emphasizes that comparative statics typically operate through composition effects rather than through a single marginal type as in one-dimensional models (Armstrong, 1996; Rochet and Chone, 1998; Veiga and Glen Weyl, 2016). In our context, this is precisely why it is helpful to distinguish *exiters*, *profile switchers*, and *contract switchers* when characterizing both contract demand and firms' best responses.

Finally, our paper is also related to the broader literature on equilibrium and welfare in selection markets, where endogenous sorting and pricing jointly determine outcomes. A key insight in this literature is that contracts and prices affect not only quantities, but also the composition of participants, so that market outcomes can be distorted even under competition when selection changes firms' effective costs (Veiga and Glen Weyl, 2016; Azevedo and Gottlieb, 2017). This equilibrium perspective is particularly relevant here because selection affects retailers' costs through moral hazard (load shifting), so that adoption and welfare depend on the feedback from sorting into firms' pricing incentives (Hendren et al., 2021).

Supply-side incentives, market structure, and public regulation. On the supply side, our focus is on how different retail market structures shape equilibrium pricing when consumers can choose between different contracts. This relates to the foundational discussion of retail restructuring and regulation in electricity markets (Joskow and Tirole, 2006), as well as to more recent work on competition and regulation in the presence of multiple contracts (Astier and Léautier, 2021). It is also closely related to recent work by Ancel (2025), who studies competition between flat tariffs and time-varying tariffs when consumers have heterogeneous reactions to dynamic pricing (in particular, heterogeneous willingness/ability to shift consumption), and analyzes how the coexistence of tariffs affects equilibrium pricing levels and adoption. Relative to these contributions, a distinctive feature of our framework is that consumer heterogeneity and self-selection make the cost of serving fixed-price consumers endogenous: because contracts distort the timing of consumption, sorting changes retailers' procurement costs by shifting consumption. This cost endogeneity is crucial for understanding why competitive provision can fail to sustain an active FP contract in equilibrium, and why the regulated monopoly's pricing incentives differ.

Our results on welfare under public provision also connect to the literature on public versus private supply, where objectives differ across firms and public pricing can respond strategically to competition and distributional concerns (Martimort et al., 2020; Kang, 2023). More generally, private information and incentive issues in electricity retail remain relatively sparsely studied. Existing contributions examine how dynamic contract design can induce strategic consumer responses and how incentive-compatible pricing schemes may be implemented (Chao and DePillis, 2013; Astier and Léautier, 2021). In contrast, we emphasize the general-equilibrium channel through which sorting affects costs and, in turn, pricing, and we use this mechanism to revisit policy questions about cross-subsidies and the welfare consequences of opt-in RTP contracts in regulated environments (Joskow and Wolfram, 2012; Borenstein, 2013).

2 The Model

2.1 The Environment

Consider a retail electricity market operating over two discrete periods, $t \in \{1, 2\}$. The economy consists of two types of agents: competitive *retailers* and a unit measure of *consumers*.

Contracts. Retailers acquire electricity from an upstream market at an exogenous marginal cost c_t in period t. We assume costs vary across periods, with $c_1 < c_2$. This cost differential captures the distinction between off-peak (period 1) and on-peak (period 2) generation, or the impact of renewable intermittency. As intermediaries, retailers resell electricity to consumers. We assume no other cost beyond c_t. A contract k constitutes a commitment to supply one unit of electricity in each period, defined by the tuple $k = (A^k, \mathbf{p}^k)$, where $A^k \geq 0$ is a fixed fee and $\mathbf{p}^k = (p_1^k, p_2^k)$ is a vector of unit prices. We restrict our analysis to the two contract structures most prevalent in electricity markets:

1. **Fixed-Price (FP) Contract (*r*):** The retailer provides price stability by setting a constant unit price across periods, such that $\mathbf{p}^r = (p^r, p^r)$.

2. **Real-Time Pricing (RTP) Contract (*s*):** The retailer sets unit prices that may vary across periods, denoted by $\mathbf{p}^s = (p_1, p_2)$.

Remark. While a fully general mechanism design approach would allow for arbitrary non-linear pricing schedules, we focus for now on these two contracts to capture the fundamental trade-off facing regulators: the choice between price stability (FP) and allocative efficiency (RTP). Furthermore, this restriction keeps the multidimensional screening problem tractable.

Consumers. Consumers have unit demand in each period and are characterized by a multidimensional type $\mathbf{v} = (v_1, v_2) \in V$, representing their willingness to pay for electricity in periods 1 and 2. The type space V is a bounded compact subset of $\mathbb{R}^2$. Types are distributed according to a continuous joint density $f(\mathbf{v})$, which is strictly positive on the support V. We assume that valuations are independent across periods, so $f(\mathbf{v}) = f_1(v_1)f_2(v_2)$.

Consumer utility is linear in money, implying risk neutrality. We model the consumer's problem as maximizing net surplus given the menu of contracts. A consumer of type $\mathbf{v}$ who chooses contract $k = (A^k, \mathbf{p}^k)$ selects a consumption vector $\mathbf{x} = (x_1, x_2) \in \{0, 1\}^2$ to solve:

$$U(\mathbf{v}, k) = \max_{\mathbf{x} \in \{0,1\}^2} \left\{ \mathbf{x} \cdot (\mathbf{v} - \mathbf{p}^k) - A^k \mathbb{I}_{\{\mathbf{x} \neq \mathbf{0}\}} \right\} \tag{1}$$

where $\mathbb{I}_{\{\cdot\}}$ is an indicator function equal to 1 if the consumer purchases at least one unit. The term $-A^k \mathbb{I}_{\{\mathbf{x} \neq \mathbf{0}\}}$ implies that consumers can always ensure non-negative utility by choosing not to consume $\mathbf{x} = \mathbf{0}$.

Retailers. The core of our analysis lies in the interaction between two distinct types of retailers, differentiated by their objective functions and budgetary constraints:

1. **Private Retailers** are perfectly competitive profit maximizing firms. For any contract k, profit is given by:

$$\pi^k = \mathbf{q}^k \cdot (\mathbf{p}^k - \mathbf{c}) \tag{2}$$

   where $\mathbf{q}^k := (q_1^k, q_2^k)$ is the aggregate consumption vector of the self-selected pool of consumers. Note that $\mathbf{q}^k$ is an equilibrium object determined by consumer self-selection described in section 2.2.

2. **The Public Retailer** acts as a regulated monopoly. For any contract k, the objective function is given by:

$$\Omega^k = CS^k + (1 + \lambda)\pi^k \tag{3}$$

   where CS^k is the aggregate surplus of consumers served by the public firm and π^k is the firm's profit. The parameter $\lambda \in \mathbb{R}_+$ represents the *shadow cost of public funds*. This objective creates a structural tension: the retailer seeks to lower prices to increase consumer surplus (CS^k), but is restrained by the penalty (λ) associated with the resulting deficit.

Remark. We derive the results under a specific objective for the public firm, namely, maximizing the surplus of consumers enrolled in its own FP contract. While stylized, this can be interpreted as a public option mandate, in which the utility is evaluated primarily on the welfare of its enrollees. One could alternatively micro-found an objective that aggregates welfare across all consumers in the market. For instance, if the public firm has redistributive motives when providing the FP contract, the consumer-surplus term in Ω^r would be weighted by social weights that vary across consumer types. In that case, the FP contract can serve as a redistribution instrument that facilitates consumption during the high-marginal-cost period by mitigating exposure to peak prices.

The informational structure is one of adverse selection. While the cost structure and the distribution of consumer types $f(\mathbf{v})$ are common knowledge, individual valuations $\mathbf{v}$ are private information known only to the consumer. There is no aggregate uncertainty in the model.

2.2 Consumer Choice

We characterize consumer behavior given an arbitrary menu of available contracts $\mathcal{K} = \{k_1, \ldots, k_n\}$. Each contract $k \in \mathcal{K}$ is defined by a tuple $(A^k, \mathbf{p}^k)$. In the following analysis, we focus on the specific FP and RTP contracts defined in the environment.

2.2.1 Optimal Contract Selection

Consumers face a two-stage optimization problem. First, for every contract $k \in \mathcal{K}$, the consumer determines the optimal consumption profile $\mathbf{x}^*(\mathbf{v}, k)$ and the resulting indirect utility $U(\mathbf{v}, k)$ as defined in (1). Second, consumers select the contract that yields the highest utility, provided it is non-negative.

This decision process partitions the type space V into disjoint regions of *active consumers*. The *participation set* for contract k is given by:

$$\mathcal{S}^k = \left\{ \mathbf{v} \in V : \mathbf{x}^*(\mathbf{v}, k) \neq \mathbf{0} \quad \text{and} \quad k \in \arg\max_{j \in \mathcal{K}} U(\mathbf{v}, j) \right\}. \tag{4}$$

The condition $\mathbf{x}^* \neq \mathbf{0}$ ensures that we only include consumers who actively purchase electricity. To ensure $\{\mathcal{S}^k\}$ forms a disjoint partition, we assume a consistent tie-breaking rule (e.g., favoring the contract with the lowest index) for the measure-zero set of indifferent consumers. Since the distribution of types $f(\mathbf{v})$ is continuous, the set of indifferent consumers has measure zero. Consequently, the choice of tie-breaking rule does not affect aggregate demand or welfare results; it merely ensures the sets $\mathcal{S}^k$ are mathematically disjoint. The collection $\left\{\mathcal{S}^k\right\}_{k \in \mathcal{K}} \cup \left\{\mathcal{S}^{\emptyset}\right\}$ forms a partition of V where $\mathcal{S}_\emptyset$ is the inactive consumer set. The aggregate demand for contract k is obtained by integrating the optimal consumption choice over this (Lebesgue measurable) set:

$$\mu^k = \int_{\mathcal{S}^k} f(\mathbf{v})\, d\mathbf{v}. \tag{5}$$

Similarly, aggregate demand for electricity in contract k in period t is:

$$q_t^k = \int_{\mathcal{S}^k} x_t^*(\mathbf{v}, k) f(\mathbf{v})\, d\mathbf{v}. \tag{6}$$

2.2.2 Marginal Consumers

In a competitive environment, demand responsiveness is driven by consumers located at the boundaries of these participation sets. We formally classify marginal consumers into three distinct categories based on the nature of their indifference.

1. The Extensive Margin (Exiters). Consumers are indifferent between accepting contract k and exiting the market entirely. They are located on the boundary between $\mathcal{S}^k$ and the inactive set:

$$\mathcal{M}_e^k = \left\{ \mathbf{v} \in \mathcal{S}^k : U(\mathbf{v}, k) = 0 \right\}$$

Geometrically, this boundary is defined by the hyperplane $\mathbf{x}^* \cdot (\mathbf{v} - \mathbf{p}^k) = A^k$. These consumers drive the aggregate market participation elasticity.

2. The Competitive Margin (Contract Switchers). Consumers are indifferent between contract k and a competing contract $j \in \mathcal{K}$. They are located on the internal boundaries of the market partition:

$$\mathcal{M}^\Delta = \left\{ \mathbf{v} \in \mathcal{S}^k : U(\mathbf{v}, k) = U(\mathbf{v}, j) > 0 \right\}$$

These consumers drive the cross-price elasticity between retailers. This margin is central to any sorting mechanism: a competitor can capture these consumers by offering a contract that slightly increases their surplus (see Veiga and Glen Weyl (2016) for a discussion).

3. The Intensive Margin (Profile Switchers). Consumers who strictly prefer contract k ($U > 0$) but are indifferent regarding the consumption of a specific unit t. They are located in the interior of $\mathcal{S}^k$:

$$\mathcal{M}_i^k = \left\{ \mathbf{v} \in \mathrm{int}(\mathcal{S}^k) : \exists t, v_t = p_t^k \right\}$$

These consumers are sensitive to unit prices $\mathbf{p}^k$ but locally insensitive to fixed fees or alternative contracts.

2.3 Single contract benchmark

We now recall the equilibrium and the sorting effect in the single-contract benchmark market. We begin by characterizing the equilibrium when only the RTP is offered to consumers by private firms; then, the equilibrium when only the FP is provided for consumers, either by private firms or by the public firm. We conclude by reformulating the comparison of equilibria across market structures in terms of how consumers sort and choose their consumption profiles. Note that consumers are allowed to exit the market.

To formalize the comparison between the instruments of a two-part tariff offered by a public firm[6], define for any outcome X

$$\delta_A(X) \;:=\; \frac{\partial X}{\partial A^r} \;-\; \frac{\partial X}{\partial p^r}. \tag{δ_A}$$

This expression captures a key element of the environment: the instruments of the two-part tariff do not have the same (marginal) effect on the model's outcome (such as mass or quantities, and ultimately equilibrium). The expression $\delta_A(X)$ measures how much more sensitive X is to the fixed fee than to the unit price. Note that $\sum_t \delta_A(q_t^r)/\delta_A(q^r) = 1$, and that $\delta_A(q_t^r) > 0$: both instruments induce a decrease in quantity, but the reduction is more substantial for p^r due to the effect on inframarginal consumers. Thus, the previous ratio of $\delta_A(X)$ indicates the proportional sensitivity of an outcome X.

Lemma 1. *i) When private firms offer the RTP contract, the unit-price equilibrium $\boldsymbol{p}^s$ is at the marginal cost: $p_t = c_t \; \forall t$ and $A^s = 0$. ii) When private firms offer the FP contract, the equilibrium unit price is equal to the average cost and $A^s = 0$, where*

$$p^r = \sum_t c_t \frac{q_t^r}{q^r}$$

iii) When the public firm offers the FP contract, then the pair (p^r, A^r) satisfies:

$$p^r - \underbrace{\sum_t c_t \frac{\delta_A(q_t^r)}{\delta_A(q^r)}}_{\textit{marginal cost}} \quad = \quad \underbrace{\frac{\lambda}{1+\lambda}\frac{q^r}{\delta_A(q^r)}\left(1 - \frac{\mu^r}{q^r}\right) - A^r \frac{\delta_A(\mu^r)}{\delta_A(q^r)}}_{\textit{Ramsey term}}$$

[6]The equilibrium prices with private firms lead in our setup to $A^s = 0$.

In the RTP-only benchmark with private firms, free entry and zero profit imply marginal-cost pricing in each period, $p_t = c_t$, and any fixed fee is null. This implements the efficient consumption profile given the wholesale costs. When only FP is available and supplied by private firms, zero profit instead pins down a single unit price equal to the average cost of the consumers in the contract.

When the public firm offers the FP contract, the first-order condition in part (iii) can be read as a decomposition of the markup over a marginal-cost benchmark. The term $\sum_t c_t \, \delta_A(q_t^r) / \delta_A(q^r)$ is a weighted marginal cost, where the weights reflect how a change in the tariff affects the period-by-period quantities through the differential responses to (A^r, p^r). The right-hand side is a Ramsey-type term induced by the public-fund constraint: the multiplier λ governs the overall strength of revenue needs. In contrast, the remaining terms capture that the unit price and the fixed fee affect (i) consumption q^r and (ii) participation μ^r differently.

We are now ready to characterize the selection effect for the firms. We first recall the definition of semi-elasticity.[7] Define for any outcome X and instrument Y

$$\sigma^Y(X) := -\frac{\partial X}{\partial Y}\frac{1}{X} \tag{σ}$$

We also distinguish between the semi-elasticity of exiters and profile switchers of an outcome X and write[8] $\sigma_e^Y(X)$ and $\sigma_i^Y(X)$. In our context of unit demand and unit mass consumers, semi-elasticity measures the density of marginal consumers in this period with respect to the density of inframarginal consumers. Hence, $\sigma_e^Y(X)$ and $\sigma_i^Y(X)$ measure, respectively, the shares of each type of marginal consumer. Finally, let p^* be the second-best fixed price:

$$p^* = \sum_t \omega_t^p c_t \quad \text{with} \quad \omega_t^p = \frac{\partial q_t^r / \partial p^r}{\partial q^r / \partial p^r} \quad \text{and} \quad \sum_t \omega_t^p = 1$$

It corresponds to the market outcome of maximizing welfare (under no public-fund constraints) when consumers face only an FP contract. The effect of sorting on the equilibrium is summarized below.

Lemma 2. *If private firms offer the FP contract, then $p^r \geq p^*$. (resp. $\leq$) iff $\sigma^p(q_1^r) \geq \sigma^p(q_2^r)$ (resp. $\leq$). If the public firm offers the FP contract, then sufficient conditions for $A^r \geq 0$ are*

$$\sigma^p(q^r) \geq \sigma^A(\mu^r) \qquad \textit{and} \qquad \frac{\sigma_i^p(q_1^r)}{\sigma_e^p(q_1^r)} \geq \frac{\sigma_i^A(q_2^r)}{\sigma_e^A(q_2^r)}$$

[7] See, for instance, the discussion in Veiga (2023) in a unidimensional framework.
[8] We formally define them in the Appendix available upon request.

If both inequalities reverse, then $A^r \leq 0$.

Lemma 2 shows that, under FP with private firms, the equilibrium deviation from the second-best price p^* is entirely governed by how the composition of demand varies across periods along the price margin. When $c_2 > c_1$, the price p^r exceeds p^* precisely when marginal consumers expand demand in the low marginal-cost period (period 1) relatively more than in the high marginal-cost period (period 2), i.e., when $\sigma^p(q_1^r) \geq \sigma^p(q_2^r)$. In that case, the average-cost schedule is locally increasing at p^r, so the set of marginal consumers attracted by a marginal price cut is, on average, cheaper than inframarginal consumers (adverse selection). When the inequality reverses, marginal consumers tilt relatively more toward the expensive period, the average-cost schedule is locally decreasing, and the equilibrium exhibits advantageous selection.

When the public firm offers the FP contract, the two instruments introduce an additional wedge between exiters and profile switchers. The first sufficient condition, $\sigma^p(q^r) \geq \sigma^A(\mu^r)$, states that the unit price moves consumption relatively more than the fixed fee moves participation, so p^r is the instrument that most strongly affects quantities. The second condition is cross-period: it requires that p^r tilts quantities toward period 1 (relative to period 2) more strongly than A^r does, in the sense that the intensive-margin response among switchers dominates under p^r compared with the extensive-margin response under A^r. When both conditions hold, it is optimal to rely relatively more on the fixed fee for revenue extraction, which corresponds to $A^r \geq 0$; if both inequalities reverse, the public firm instead finds it optimal to subsidize entry, so $A^r \leq 0$.

3 Demand for contracts

In this section, we derive the contract choices from consumers when they can choose between an RTP contract $\mathbf{p}^s = (p_1, p_2)$ with fixed part A^s and an exogenous fixed-price contract p^r with fixed part A^r. We assume that $p^r \in [p_1, p_2]$. Throughout this section, we focus on the following region to ensure a positive demand for all contracts

$$p_1 + A^s \;\leq\; p^r + A^r \;\leq\; p_2 + A^s, \tag{7}$$

The key result is a specific sorting based on relative valuations across periods and on consumption profiles. There are three consumption profiles with positive demand: a consumer can consume (i) one unit only in period 1, (ii) one unit only in period 2, or (iii) two units (one in each period). Define

$$\overline{p} \;:=\; \frac{p_1 + p_2}{2} + \frac{\Delta A}{2}, \qquad \Delta A := A^s - A^r,$$

In other terms, $\overline{p}$ is the cutoff of the FP unit price such that a two-unit consumer is indifferent between the two contracts.

Lemma 3. *Fix (p_1, p_2) with $p_1 < p_2$ and $p^r \in [p_1, p_2]$, and consider the region* (7)*. Consumers sort across contracts according to their relative valuations:*

- *If v_1 is relatively high and v_2 relatively low, the consumer selects RTP and consumes only in period* 1.
- *If v_2 is relatively high and v_1 relatively low, the consumer selects FP and consumes only in period* 2.
- *If both v_1 and v_2 are high, the consumer consumes in both periods and selects FP if $p^r < \overline{p}$, and RTP otherwise.*

Intuitions for the proof. The result stems from comparing the indirect utility that each consumer receives under each contract option (FP, RTP, or exit). Under (7), no consumer strictly prefers to consume only in period 1 under the FP contract, and no consumer strictly prefers to consume only in period 2 under the RTP contract. Hence, the relevant indirect utilities are

$$U_b^r := v_1 + v_2 - 2p^r - A^r, \qquad U_2^r := v_2 - p^r - A^r,$$

under the FP contract, and

$$U_b^s := v_1 + v_2 - p_1 - p_2 - A^s, \qquad U_1^s := v_1 - p_1 - A^s,$$

under the RTP contract. Three boundaries are then immediate. First, within the FP contract, consumers are indifferent between consuming two units and only one unit in period 2 when $v_1 = p^r$ from $U_b^r = U_2^r$, which is the profile-switching boundary if it exists. Second, the contract-switching boundary between consuming one unit in period 2 under FP and consuming one unit in period 1 under the RTP contract is given by $v_2 = \phi(v_1)$, with $\phi(v_1) := v_1 - p_1 + p^r - \Delta A$ from $U_2^r = U_1^s$. Third, the contract choice of two-unit consumers is governed by comparing U_b^r and U_b^s such that $U_b^r > U_b^s$ if $p^r < \overline{p}$ and $U_b^r < U_b^s$ otherwise. If $p^r < \overline{p}$, then two-unit consumers select into the FP contract, and the additional contract-switching boundary is given by $v_2 = v_2^\Delta$, with $v_2^\Delta := 2p^r - p_1 - \Delta A$ from $U_b^r = U_1^s$. If $p^r > \overline{p}$, two-unit consumers select into the RTP contract, and the relevant boundary becomes $v_1 = v_1^\Delta$, with $v_1^\Delta := p_1 + p_2 - p^r + \Delta A$ from $U_b^s = U_2^r$. Therefore, the FP demand region is the set of types that lie above (and/or to the left of) these boundaries.

Importantly, the comparison between p^r and $\overline{p}$ governs consumers who would like to consume in both periods. If $p^r > \overline{p}$, then a two-unit consumer pays less under the RTP contract than under the FP contract, so high-(v_1, v_2) consumers choose the RTP contract and consume two units. If $p^r < \overline{p}$, the reverse holds, and high-(v_1, v_2) consumers choose the FP contract and consume two units. In the remainder of the paper, we do not study the case $p^r = \overline{p}$, as it depends on the allocation rule for the set of indifferent consumers with positive mass. This does not entail a significant loss, as consumers in this region do not generate negative welfare in the model.

Adding a second contract provides consumers with a second outside option. In that case, it changes the set of possible indifferent consumers. For a firm offering a contract $k \in \{r, s\}$, there are now three possible subsets: i) *exiters* that stop consuming from contract k and do not choose the other contract (with the set $\mathcal{M}_e^k$), ii) and iii) *contract switchers* that are indifferent between a specific consumption pattern in one contract and a specific consumption pattern in the other contract. We denote this set by M^{Δ}. In the two-contract environment, this set is the same for firms offering either the FP or the RTP contract. Hence, $\mathcal{M}^k = \mathcal{M}_e^k \cup \mathcal{M}_i^k \cup \mathcal{M}^{\Delta}$. The set of *contract switchers* can be characterized as follows:

- it always includes consumers indifferent between consuming in period 1 under RTP and consuming in period 2 under FP (the boundary $v_2 = \phi(v_1)$);
- when $p^r < \overline{p}$ (resp. $p^r > \overline{p}$), it also includes consumers indifferent between consuming in both periods under FP (resp. RTP) and consuming only in period 1 under RTP (resp. only in period 2 under FP), i.e. $v_2 = v_2^{\Delta}$ (resp. $v_1 = v_1^{\Delta}$).[9]

We illustrate the different zones in Figure 1. The sorting pattern also has clear implications for the timing of consumption. Under FP, consumption in period 2 is always (weakly) higher than in period 1, whereas under RTP, consumption in period 1 is always (weakly) higher than in period 2.

The effect of p^r on contract demand is intuitive. Increasing p^r decreases the mass of consumers in the FP contract and increases the mass in the RTP contract, since it makes the other contract less attractive. For any $p^r \in [p_1, p_2]$, the function $\phi(v_1)$ is strictly increasing in p^r: consuming only in period 2 under the FP contract becomes less attractive relative to consuming only in period 1 under the RTP contract. When $p^r < \overline{p}$, an increase in p^r also raises v_2^{Δ}, which makes it more likely that high-(v_1, v_2) consumers switch to the RTP contract. When $p^r > \overline{p}$, an increase in p^r decreases v_1^{Δ}, which expands the set of two-unit consumers under the RTP contract.

The effect of p^r on q_2 is always negative: consumers switching from FP to RTP either keep consuming in period 2 (two-unit switchers) or stop consuming in period 2 and consume only in period 1. The effect on q_1 is instead ambiguous when $p^r < \overline{p}$: increasing p^r reduces period-1 consumption by FP profile switchers, but increases period-1 consumption by contract switchers who move to the RTP contract. Therefore, the net effect depends on the relative mass of consumers on these

[9]The first type of contract switchers is described by the linear boundary $\mathcal{M}_a^{\Delta} := \{\mathbf{v} : \ v_2 = \phi(v_1)\}$. The second type depends on whether p^r is below or above $\overline{p}$: $\mathcal{M}_b^{\Delta} \equiv \{\mathbf{v} : \ v_2 = v_2^{\Delta}\}$ if $p^r < \overline{p}$, $\mathcal{M}_b^{\Delta} \equiv \{\mathbf{v} : \ v_1 = v_1^{\Delta}\}$ if $p^r > \overline{p}$.

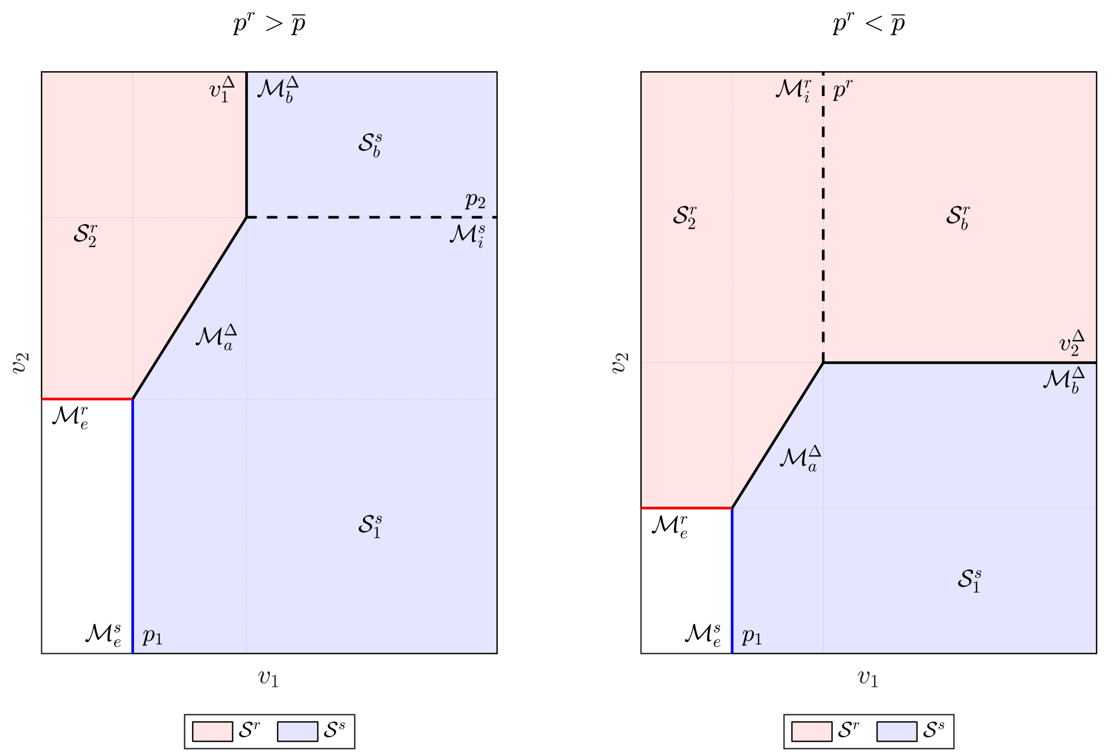

Figure 1: Demand zones for the two contracts. The boundary $v_2 = \phi(v_1)$ is represented by the relevant segment. When $p^r < \overline{p}$, the additional boundary is $v_2 = v_2^\Delta$; when $p^r > \overline{p}$, it is $v_1 = v_1^\Delta$.

margins. Figure 2 illustrates the induced change in contract demand (left) and in consumption by period (right).

4 Equilibrium with multiple contract choices

In this section, we use the previous demand system to determine the general equilibrium in the retail market.[10] We define the general (mixed) equilibrium as follows.

Definition 1. *A mixed-equilibrium contract is a pair of contracts* (s, r) *and participation sets* $\{\mathcal{S}^r, \mathcal{S}^s\}$ *that satisfy* $\pi^s = \pi^r = 0$*, with* (p^r, A^r) *that solves* $\max_{\{p^r, A^r\}} \Omega^r$ *and consumers' optimal consumption decisions.*

[10]We showed how the set of subscriber types and hence contract demand is affected by contract options. So far, the analysis has focused on sorting decisions in which contract prices are taken as given. Here, we examine contract markets and the interaction between consumer contract demand and firm pricing decisions.

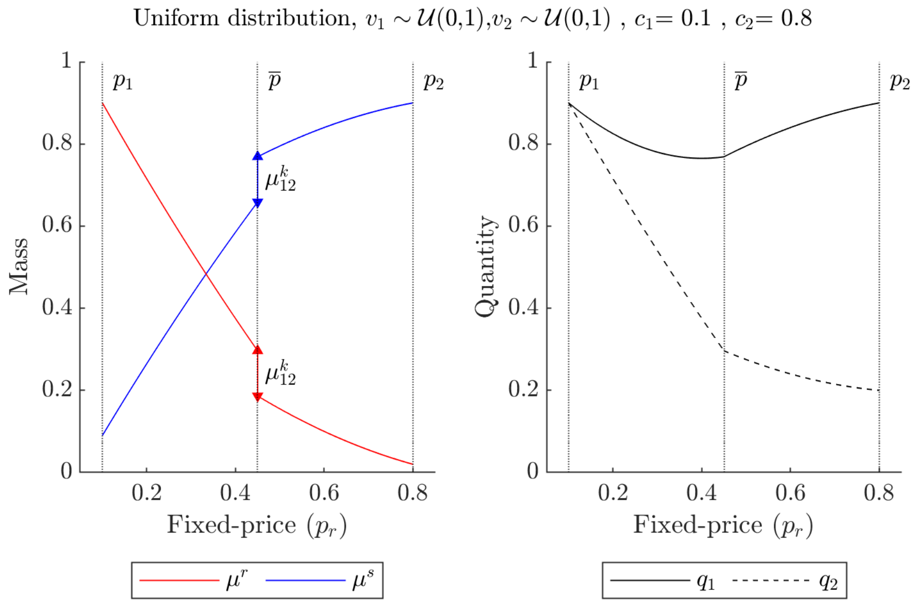

Figure 2: Demand for the two contracts and quantities by period as functions of p^r. In the left panel, the red line represents demand for the FP contract, and the blue line represents demand for the RTP contract. The jump at $p^r = \overline{p}$ corresponds to the mass of two-unit consumers who switch to the contract under which they purchase both units. In the right panel, the solid line represents period-1 consumption, and the dashed line represents period-2 consumption (aggregated across contracts).

4.1 Private firm equilibrium

Notice that we do not let firms cross-subsidize between contracts. For example, a firm could offer an RTP contract with a tax, $A^s > 0$, to subsidize its FP contract. However, any form of cross-subsidization between the different contracts is excluded (See Azevedo and Gottlieb (2017) for a discussion in the context of adverse selection). Furthermore, we can show the following standard result.

Proposition 1. *A mixed-equilibrium contract in which consumers have a strict preference for an FP contract offered by private firms does not exist. The unit-price equilibrium of the RTP contract $\boldsymbol{p}^s$ is at the marginal cost: $p_t = c_t$ $\forall t$ and $A^s = 0$.*

Proposition 1 states that private retailers offering the FP contract cannot compete with RTP contract providers. The intuition is driven by adverse selection, as illustrated in the left panel of Figure 3.

To understand why, consider a retailer attempting to offer a fixed price p^r slightly below the peak cost c_2. This contract is attractive to on-peak consumers who are costly to serve since they entail a cost c_2. On the other hand, low-cost consumers who value off-peak consumption prefer the RTP contract, where they pay the much lower price $c_1 < p^r$. Because the low-cost consumers self-select into RTP, the FP retailer is left with a pool of high-cost consumers. The average cost of serving this specific pool strictly exceeds the price p^r. To break even, the retailer must raise p^r (or A^r). But raising the price drives away the few remaining moderate consumers, further deteriorating the pool's quality. Thus, the average cost curve for the FP contract lies strictly above the demand curve for all relevant prices ($p^r < c_2$), rendering the contract inessential in equilibrium.

Figure 3 illustrates how providing the FP contract when an RTP contract is available as an outside option always entails a higher average cost for retailers relative to inverse demand (i.e, the willingness to pay for the contract). This is because of the selection effects discussed previously. Notice that when the sole outside option is to exit the market (dashed lines), a private FP contract can emerge in equilibrium for sufficiently low prices.

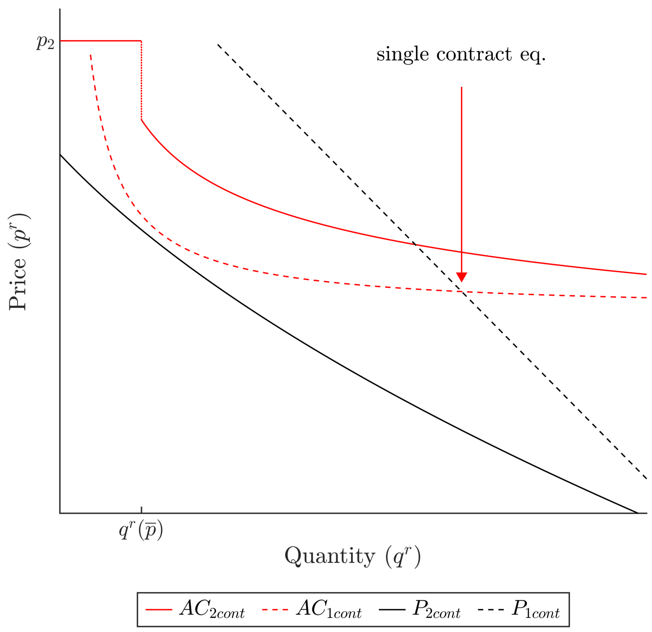

Figure 3: Aggregate demand over the two periods of electricity from consumers with the FP contract, and the average cost of providing them. The solid lines illustrate the case when the consumer can also choose the RTP contract. The dashed lines illustrate the case in which the consumer faces only the FP contract. In the first case, the average cost is always above the demand, leading to market unraveling. In the second case, there exists an equilibrium with private firms at the intersection of the average cost and the inverse demand. The discontinuity of the average cost function is due to the condition on p^r with respect to $\overline{p}$.

4.2 Regulated monopoly

4.2.1 Incentives for fixed-price contracts

We start by examining the effect of introducing an FP contract for the public firm in a market where all consumers are under an RTP contract with prices $\{p_1, p_2, A^s\}$ where at the equilibrium we have $A^s = 0$, $p_1 = c_1$ and $p_2 = c_2$. To ensure that at least some consumers select into the FP contract, a sufficient condition for entry, we consider a deviation indexed by $\epsilon > 0$ such that the FP total cost for a consumer satisfies.

$$\epsilon \;\equiv\; p_2 - (p^r + A^r) \;>\; 0, \qquad \text{i.e.} \qquad p^r + A^r \;=\; p_2 - \epsilon.$$

We study the marginal incentive to introduce the FP contract as $\epsilon \downarrow 0$. Such deviation leads to a distinct selection pattern among consumers in FP contracts. Namely, consumers switch contracts but keep the same consumption profile (consume only in period 2), consumers switch contracts and stop consuming in period 1 (whether they are consuming in period 2 or not), and consumers who weren't consuming under an RTP contract and start consuming in period 2. We illustrate such a pattern in Figure 4.

We have shown that when retailers' unit prices are equal to marginal costs and $A^s = 0$, such a deviation always decreases welfare. This is a canonical result from peak load theory as a fixed price contract generates over-consumption during high-price periods (corresponding to the red area in Figure 4, where $v_2 < p_2$), under-consumption during low-price periods (corresponding to the blue area in Figure 4, where $v_1 > p_1$) and temporal misallocation (corresponding to the green area in Figure 4, where $v_1 > p_1$ and $v_2 < p_2$).

The effect of an entry of the FP contract on the public firm is less straightforward.[11] The two main effects of the deviation can be understood via the change of surplus and of profit. By construction and revealed preferences, the consumer surplus component of the public firm's objective increases with the deviation: any consumer who switches to the FP contract attains a positive individual surplus under it. Let S^ϵ be the set of consumers that switch to the FP contract [12]. The per consumer gain from attracting consumers is $v_2 - p_2 + \epsilon$, and the expected gain compared to the benchmark case in which the public firm is absent (and the objective value is null) is

[11]Note that a strategy to fix $\epsilon = 0$ may constitute an entry depending on the allocation rule of the indifferent consumer,s that is, how they are sorting among firms. We show in the Appendix that, while it changes the entry's absolute value, the allocation rule does not affect the marginal incentive to offer an FP contract.

[12]formally $S^\epsilon := \{\mathbf{v} \in \mathbf{V} : U(\mathbf{v}, r) \geq U(\mathbf{v}, s) \textit{ and } U(\mathbf{v}, s) \geq 0 \textit{ and } p^r + A^r = p_2 - \epsilon\}$

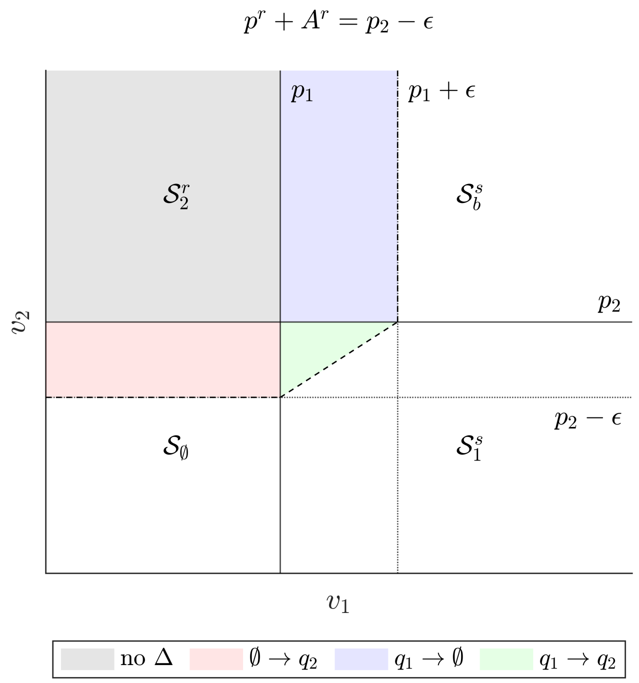

Figure 4: Sorting with a fixed-price entry. The gray, blue, and green areas correspond to consumers switching contracts: no change in consumption; stopping consumption in period 1 but continuing to consume in period 2; and switching consumption between period 1 and period 2. The red area corresponds to consumers not initially in an RTP contract.

$$\Delta CS^r = \int_{S^\epsilon} (v_2 - p_2 + \epsilon) f(\mathbf{v}) d\mathbf{v}$$

From the profit perspective, as the sorting is such that consumers only consume in the second period and the deviation is such that $p^r + A^r = p_2 - \epsilon$, the public firm always sustains a loss. Let q^r be the quantity of consumers switching to the FP contract due to the price deviation (given by the mass in the four zones of Figure 4), then the loss is

$$\Delta\pi^r = -\epsilon q^r$$

The change in the public firm's objective is then $\Delta\Omega = \Delta CS^r + (1+\lambda)\Delta\pi^r$. The following proposition provides a sufficient condition for a public firm to offer a fixed-price contract, starting from a situation in which all consumers are enrolled in an RTP contract. Recall that $\mathcal{M}^\Delta$ corresponds to the blue and green areas in Figure 4.

Proposition 2. *A public firm has a strict incentive to offer a fixed price contract if:*

$$\underbrace{\int_{\mathcal{M}^\Delta|_{\epsilon=0^+}} (v_2 - p_2) f_1(p_1) f_2(v_2) dv_2}_{\textit{marginal benefit}} > \underbrace{\lambda q^r|_{\epsilon=0^+}}_{\textit{inframarginal cost}} \tag{8}$$

The condition in the proposition has a natural interpretation. When the marginal benefit at the extensive margin brought by contract switchers exceeds the marginal loss due to inframarginal consumers, then the public firm can profitably enter the market by offering an FP contract (i.e., the objective function is strictly increasing in ϵ in a right-neighborhood of 0.). When ϵ is small, then the mass of consumers in the green area of figure 4 is a second-order effect. Therefore, the set of contract switchers is defined by the blue rectangle. When ϵ is small, it coincide with the set $\{\mathbf{v} : v_1 = p_1 \textit{ and } v_2 = [p_2, \overline{v}_2]\}$. The left-hand term of the condition gives the surplus brought by those consumers. Note that the exiters (the red area) do not have a net marginal effect, as the additional surplus is null ($v_2 = p_2$) and the profit loss cancels at $\epsilon = 0$. Finally, by construction, the set of consumers in the gray area does not depend on ϵ. Therefore, the marginal effect is solely given by the marginal cost of providing the good, which is evaluated at ϵ.

The strength of the condition depends on the primitives, notably the cost of public fund λ, the marginal costs $\mathbf{c}$ via the RTP option, and the distribution of the consumers and their types. It is straightforward that an increase in λ always reduces the incentive to enter the market. In the following corollary, we present comparative statics based on closed-form solutions for two distribution functions.We assume that each density f_t is either (i) uniform on $[\underline{v}_t, \overline{v}_t]$, or (ii) exponential with rate $l_t > 0$.

Corollary 1. *Let $\overline{\lambda}$ be the cutoff such that condition* (8) *holds with equality. i) (Uniform.) If $v_t \sim \mathcal{U}[\underline{v}_t, \overline{v}_t]$, then an increase in p_1 or in p_2 decreases $\overline{\lambda}$, and an increase in $\overline{v}_2$ or in $\underline{v}_1$ increases $\overline{\lambda}$. ii) (Exponential.) If $v_t \sim \mathrm{Exp}(l_t)$ with $l_t > 0$, then an increase in l_1, l_2 or in p_1 decreases $\overline{\lambda}$.*

Proof. Under the uniform and exponential specifications, the cutoff is given by

$$\overline{\lambda} = \frac{1}{2}\frac{\overline{v}_2 - p_2}{p_1 - \underline{v}_1}, \qquad \overline{\lambda} = \frac{l_1}{l_2\left(\exp(l_1 p_1) - 1\right)}.$$

The result follows from differentiation. □

If the cutoff decreases, then the interval over which the sufficient condition is reduced; that is, only a relatively lower cost of public funds can sustain an equilibrium. From the expression (8), two opposite forces drive the change in the cutoff: i) the surplus brought by marginal consumers (contract switchers), ii) the quantity of inframarginal consumers of the public firm. In the uniform case, a rise in p_1 only affects the latter as the gray area in figure 4 expands on its right (the FP contracts become more valuable than the RTP contract). Under the assumption about f, the surplus of the switchers remains unchanged. Therefore, the (marginal) cost increases while the benefit is constant, which decreases the cutoff. In the exponential case, this effect is reinforced by lowering the mass of marginal consumers. The effects of the other primitives are less clear, as they can reduce or increase the surplus and the mass of consumers, both marginal and inframarginal. However, we find that the proportional change for each primitive is greater for either inframarginal consumers or marginal, resulting in a net negative effect.[13]

4.2.2 Equilibrium prices

We now characterize necessary conditions for (p^r, A^r) to be an equilibrium (as defined in Proposition 3). As in the previous subsection, we study the public firm's first-order conditions by evaluating the gains and losses from local deviations around a benchmark in which the public firm already offers an FP contract.

A first key element is how a deviation in the unit price p^r differs from a deviation in the fixed part A^r. When $p^r > \overline{p}$, consumers enrolled in the FP contract consume only in period 2, so that p^r and A^r affect both consumer choices and the firm's objective only through the total payment

[13]For instance, an increase in $\overline{v}_2$ with the uniform distribution has two effects on each part of the conditions: it expands the set via the upper boundaries of the integral. Still, it reduces mass by decreasing f. In terms of proportional change, it can be shown that the change of f on each part of the condition compensates. The upper-boundary effect is strictly greater for the inframarginal benefit than for the marginal cost. This net effect strictly increases the cutoff.

$p^r + A^r$. We therefore focus on the case $p^r < \overline{p}$, in which the two instruments have distinct marginal effects.

Figure 5 illustrates the difference between an equal increase in p^r (left panel) and in A^r (right panel). Two dimensions matter: (i) only the unit price affects the set of profile switchers (gray area), and (ii) the set of contract switchers (blue area) expands more under a change in p^r than under a change in A^r. The first dimension is a canonical result when comparing the effect of the fixed part with that of the unit price, as the former affects only marginal consumers. In contrast, the latter affects both inframarginal and marginal consumers. The second dimension follows from the indifference cutoff $v_2^\Delta = 2p^r + A^r - p_1$, so that $\partial v_2^\Delta / \partial A^r - \partial v_2^\Delta / \partial p^r = -1$. In other words, the cutoff v_2^Δ is more sensitive to p^r than to A^r.

Using the expression (δ_A), the difference in marginal quantity responses between A^r and p^r can be written as

$$\delta_A(q_1^r) := \underbrace{\int_{\mathcal{M}_i^r} f(\mathbf{v})\, d\mathbf{v}}_{\text{profile-switching margin}} - \underbrace{\delta_A(v_2^\Delta) \int_{\mathcal{M}_b^\Delta} f(\mathbf{v})\, d\mathbf{v}}_{\text{contract-switching margin}}, \qquad \delta_A(q_2^r) := -\underbrace{\delta_A(v_2^\Delta) \int_{\mathcal{M}_b^\Delta} f(\mathbf{v})\, d\mathbf{v}}_{\text{contract-switching margin}}.$$

The expression is positive as $\delta_A(v_2^\Delta) = -1 < 0$. It captures that the unit price has a larger (in absolute value) marginal effect on quantities than the fixed part (recall that both quantities are strictly decreasing in the price instruments). We also write $\delta_A(q^r) := \delta_A(q_1^r) + \delta_A(q_2^r)$. Finally, in the region $p^r < \overline{p}$, the marginal effect of either instrument on the mass of FP customers μ^r is the same as its effect on q_2^r, so that $\delta_A(\mu^r) = \delta_A(q_2^r)$.

A second key element, relative to the canonical regulation model of Laffont and Tirole (1993), is that the public firm faces two distinct margins: exiters and contract switchers. This yields an additional leakage term in the marginal effect on consumer surplus. For the unit-price instrument, the marginal effect on the (public-firm) consumer-surplus component can be written as

$$-q^r + \partial_{p^r}\mathcal{C}$$

where $\partial_{p^r}\mathcal{C}$ denotes the sorting leakage component of the consumer-surplus derivative due to contact switchers:

$$\partial_{p^r}\mathcal{C} := -\underbrace{\frac{\partial \phi(v_1)}{\partial p^r} \int_{\mathcal{M}_a^\Delta} (\phi(v_1) - p^r - A^r) f_1(v_1) f_2(\phi(v_1)) dv_1}_{\text{sorting effect \#1}} - \underbrace{\frac{\partial v_2^\Delta}{\partial p^r} \int_{\mathcal{M}_b^\Delta} (v_2^\Delta - p^r - A^r) f_1(v_1) f_2(v_2^\Delta) dv_1}_{\text{sorting effect \#2}}$$

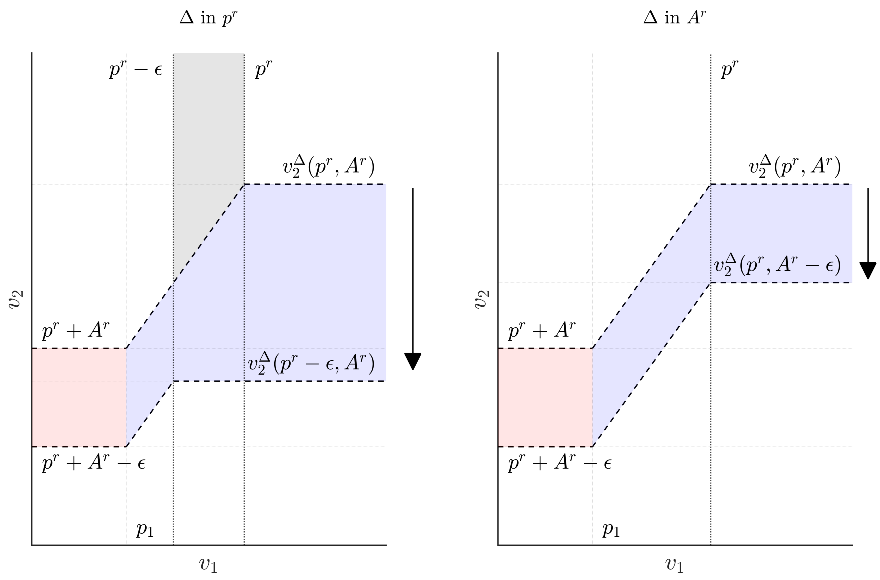

Figure 5: Change in consumption and contract choice after an equal deviation in the unit price p^r (left) and in the fixed part A^r (right). The gray zone indicates profile switchers. Blue zones indicate contract switchers. Red zones indicate exiters.

The expression for the fixed part A^r, which we note $\partial_{A^r}\mathcal{C}$, is similar to the derivatives in the sorting terms, which are taken with respect to A^r. The term q^r in the first expression is the canonical part of the model: an increase in p^r decreases the surplus of all consumers, which amounts to q^r. As the price p^r increases, some consumers switch to the RTP contract and modify their consumption behavior (the first term represents consumers switching from consuming only in period 2 to only in period 1, and the second term represents consumers ceasing to consume in period 2). This leakage is always costly for the public firm, as the marginal consumers who leave it have strictly positive welfare gains: both $\partial_{p^r}\mathcal{C}$ and $\partial_{A^r}\mathcal{C}$ are negative. Indeed for $v_1 \in \mathcal{M}_a^\Delta$,

$$\phi(v_1) - p^r - A^r \;=\; v_1 - p_1 \;>\; 0,$$

and for $v_1 \in \mathcal{M}_b^\Delta$,

$$v_2^\Delta - p^r - A^r \;=\; p^r - p_1 \;>\; 0.$$

In other words, only consumers with a positive surplus leave the public firm. Moreover, the magnitude of the sorting effect #2 differs across instruments because v_2^Δ is more sensitive to p^r than to A^r. Define the additional leakage generated by p^r relative to A^r on this margin as

$$\delta_A(\mathcal{C}) \;:=\; \partial_{A^r}\mathcal{C} - \partial_{p^r}\mathcal{C} = -\delta_A(v_2^\Delta) \int_{\mathcal{M}_b^\Delta} \left(v_2^\Delta - p^r - A^r\right)\, f_1(v_1)\, f_2\!\left(v_2^\Delta\right)\, dv_1 \;>\; 0. \qquad (\delta_A(\mathcal{C}))$$

Again, this term is positive as $\delta_A(v_2^\Delta) < 0$. Sorting effect#1 has the same marginal value under both instruments (consumers consume one unit under either contract along that boundary), hence it cancels when taking the difference across instruments.

Combining the first-order conditions for p^r and A^r yields the following modified Ramsey pricing rule.

Proposition 3. *If an interior equilibrium with $p^r < \overline{p}$ exists, the unit price p^r and fixed part A^r of the FP contract offered by the public firm satisfy*

$$p^r \; - \underbrace{\sum_t c_t \frac{\delta_A(q_t^r)}{\delta_A(q^r)}}_{\textit{marginal cost}} \; = \; \underbrace{\frac{\lambda}{1+\lambda}\,\frac{q^r}{\delta_A(q^r)}\left(1-\frac{\mu^r}{q^r}\right) - \frac{\delta_A(\mu^r)}{\delta_A(q^r)}\,A^r}_{\textit{Ramsey term}} \; - \; \underbrace{\frac{1}{1+\lambda}\,\frac{\delta_A(\mathcal{C})}{\delta_A(q^r)}}_{\textit{sorting correction}} \tag{9}$$

If an interior equilibrium with $p^r > \overline{p}$ exists, the unit price p^r of the FP contract offered by the public firm satisfies

$$p^r - c_2 \; = \; \underbrace{\frac{\lambda}{1+\lambda}\,\frac{q_2^r}{\partial_{p^r}(q_2^r)}}_{\textit{Ramsey term}} \; - \; \underbrace{\frac{1}{1+\lambda}\,\frac{\partial_{p^r}\mathcal{C}}{\partial_{p^r}(q_2^r)}}_{\textit{sorting correction}}.$$

where $\partial_{p^r}(q_2^r) := \frac{\partial q_2^r}{\partial p^r} < 0$ and $\partial_{p^r}\mathcal{C} < 0$, both evaluated in the $p^r > \overline{p}$ region.

Because the objective differs depending on whether p^r lies above or below $\overline{p}$, there can be two local maxima even if the objective is strictly concave within each region.[14] Moreover, the interaction between sorting and inframarginal effects generally prevents a simple condition guaranteeing the uniqueness of an interior solution.

The equilibrium conditions in Proposition 3 echo Ramsey pricing: they specify how the unit price departs from marginal cost. When $p^r > \overline{p}$, the fixed part A^r can be discarded since it affects the objective only through $p^r + A^r$. Dividing the expression by p^r yields the usual inverse-elasticity logic: the markup over marginal cost is higher when demand is less elastic, as it is less costly to raise price and reduce the deficit. When $p^r < \overline{p}$, the markup is taken over a weighted marginal cost, where the weights depend on the relative quantity responses across periods.[15] In addition, the Ramsey term accounts for the role of the fixed part in raising revenue; i.e., how adjusting A^r can offset, at the margin, a change in p^r while holding participation fixed.[16] Finally, the equilibrium condition accounts for sorting-induced leakage: consumers who self-select into RTP make a

[14]Corner solutions are also possible, e.g. $p^r + A^r = p_1$ or $p^r = \overline{p}$. In the latter case, the public firm slightly undercuts $\overline{p}$ to retain two-unit consumers who would otherwise switch to RTP, since they always have positive individual surplus.

[15]A weighted marginal cost also arises in canonical single-contract settings when the second best equates price to a weighted average of marginal costs; see, for instance, (Joskow and Tirole, 2006).

[16]The specific form reflects unit demand and multidimensional heterogeneity. The operator $\delta_A(\cdot)$ is needed because the marginal effects of A^r and p^r are not proportional in this environment (in contrast to the proportionality often exploited in (Laffont and Tirole, 1993)).

positive contribution to the public firm's objective; therefore, the associated sorting term reduces the optimal markup.

We have not assumed any condition on the fixed part A^r; it can be positive or negative. In this environment, its sign has a clear implication: if A^r is positive, then the public firm relies more on the fixed component to raise revenue, thereby deterring consumer entry under the RTP contract. On the other hand, if A^r is negative, the firm uses a subsidy to attract/retain FP consumers, shifting revenue recovery onto the unit price p^r. We summarize, in the following corollary, sufficient conditions for determining the sign of A^r. For that, recall the definition of semi-elasticity from equation (σ). All expressions are positive and recall that $\partial_{A^r}\mathcal{C} < 0$ and $\partial_{p^r}\mathcal{C} < 0$. A similar result is obtained when $p > \overline{p}$. Note that this corollary extends the result from the single benchmark case in Lemma 2

Corollary 2. *Assume that there exists a unique equilibrium (p^r, A^r) and $p^r < \overline{p}$, then sufficient conditions for $A^r \geq 0$ are*

$$(\frac{\partial_{A^r}\mathcal{C}}{\mu^r} + \lambda)\frac{1}{\sigma^A(\mu^r)} \geq (\frac{\partial_{p^r}\mathcal{C}}{q^r} + \lambda)\frac{1}{\sigma^p(q^r)} \qquad \text{and} \qquad \frac{\sigma^p(q_2^r)}{\sigma^p(q_1^r)} \geq \frac{\sigma^A(q_2^r)}{\sigma^A(q_1^r)}$$

If both inequalities reverse, then $A^r \leq 0$.

The first inequality compares the (average) surplus cost due to the leakage effect (e.g. $\frac{\partial_{A^r}\mathcal{C}}{\mu^r}$) of raising one of the instruments to the marginal fiscal cost (λ) scaled by the average marginal consumer of the same instrument (represented by the semi-elasticity $\sigma^p(q^r)$, which in our environment is the marginal mass relative to the inframarginal mass, per unit of the instrument). This condition emerges as we have shown that the unit-price generate higher variation in the sorting effect, which yields $|\partial_{p^r}\mathcal{C}| > |\partial_{A^r}\mathcal{C}|$ and $|\frac{\partial\mu^r}{\partial p^r}| > |\frac{\partial\mu^r}{\partial A^r}|$. However, $q^r > \mu^r$, which introduces ambiguity in the comparison between the two instruments. The second inequality is the same condition as in Lemma 2.

4.3 Welfare analysis

The equilibrium unit price p^r set by the regulated monopoly can be either greater or smaller than the price set by the same firm in the single-contract environment in which consumers face only an FP contract (denoted p^r_{fp}). The key mechanism for understanding why p^r can be lower under contract choice follows from the previous section. In the presence of an RTP outside option, the regulated monopoly faces the risk of losing consumers who contribute substantially to its objective, notably consumers with relatively high values of v_1. The public firm can only respond by reducing the FP unit price, p^r, to make the FP contract more attractive and limit consumer leakage. In this section, we discuss the welfare consequences of this equilibrium behavior and, more specifically, the welfare ranking between an environment in which consumers optimally choose between the FP and RTP contracts and the benchmark case in which consumers are offered a unique FP contract. Note that the welfare is defined as consumer surplus in all contracts minus the production cost of the public firm (private firms make zero profit at the equilibrium), including public funds. When comparing the mixed equilibrium to the single contract equilibrium, we assume that it is the public firm that fixed p^r_{fp} and satisfies the same objective.

4.3.1 Sorting decision

For now, we analyze this comparison from a sorting perspective, treating contract prices as given. For simplicity, assume that $A^r = 0$ and use our previous result, under which private firms offer the RTP contract at marginal cost. In Figure 6, we illustrate the set of prices p^r (under contract choice) for which welfare is lower than in the benchmark single-contract case (evaluated at p^r_{fp}). This set lies below a threshold p^r_0, which highlights that having a lower equilibrium price is not, by itself, sufficient to generate lower welfare. Formally, let DW^{mixed} be the deadweight-loss under the mixed equilibrium, DW^{single} be the deadweight-loss under the single contract equilibrium, and $\Delta DW = DW^{mixed} - DW^{single}$. The welfare is lower under the mixed equilibrium if $\Delta DW > 0$. Hence, p^r_0 is such that for given equilibrium price p^r and p^r_{fp} it yields

$$\Delta DW(p^r_0) = 0$$

Two effects are at play when comparing welfare across the two environments: *i*) some consumers choose the RTP contract, and *ii*) the equilibrium FP unit price p^r may be lower than in the benchmark. The first effect is always positive, since consumers who select into RTP better align their consumption with marginal costs. The second effect is ambiguous: a lower p^r reduces the deadweight loss in period 1 but can increase it in period 2. The key idea is that if p^r becomes sufficiently low, the increase in deadweight loss in period 2 can dominate the positive selection effect of RTP. Therefore, p^r_0 is the unit price such that, holding the benchmark fixed, the gain from RTP sorting equals the extra deadweight loss induced by the lower FP price.

To organize the discussion, recall the allocation inefficiencies created by having some consumers in the FP contract: *i*) consumers may consume in period 2 while they should not (overconsumption at high marginal cost), *ii*) consumers may consume in period 2 instead of period 1 (intertemporal misallocation), and *iii*) consumers may not consume in period 1 while they

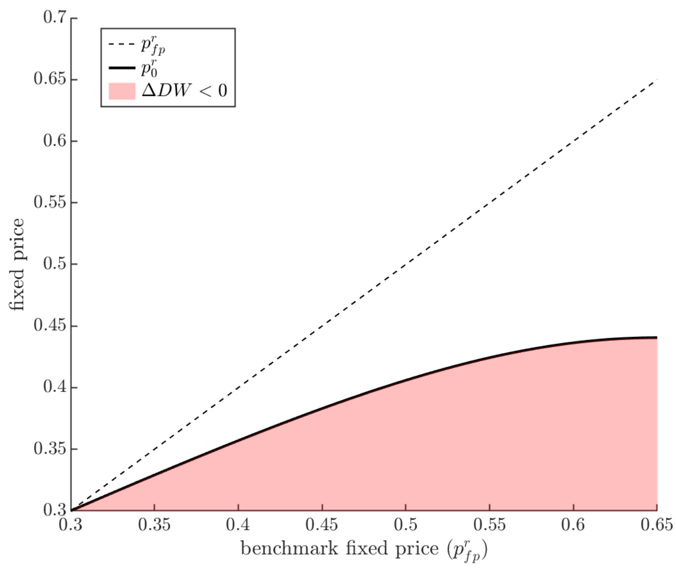

Figure 6: Price threshold p^r_0 (solid black line) and zone (in red) such that the deadweight loss under the choice equilibrium with multiple contracts is higher than the deadweight loss in the single fixed-price benchmark (with equilibrium price p^r_{fp}). Deadweight loss is computed relative to the first best (prices at marginal cost).

should (under-consumption at low marginal cost). The first and third inefficiencies correspond to the canonical peak-load logic: fixed prices induce over-consumption when production costs are high (period 2) and under-consumption when production costs are low (period 1). The second inefficiency captures the misallocation of consumption across periods induced by differences in marginal costs.

We summarize the net welfare comparison by decomposing the change in deadweight loss between the choice environment and the single-contract benchmark as

$$\begin{aligned}\Delta DW \;=\; \Delta DW^s(\text{selection into RTP}) \;+\; \Delta DW^r_1(\text{period-1 misallocation})\\ +\; \Delta DW^r_2(\text{period-2 misallocation}),\end{aligned}$$

where $\Delta DW^s \leq 0$ captures the (positive) selection effect of consumers switching to RTP, while ΔDW^r_1 and ΔDW^r_2 capture how the FP outcome changes in each period due to the difference between p^r and p^r_{fp} and the resulting adjustment in consumer behavior. In the case where the equilibrium price p^r is lower than the benchmark price p^r_{fp} we have $\Delta DW^r_1 \leq 0$ as consumers under the FP contract increase their demand when the marginal cost is low and $\Delta DW^r_2 \geq 0$ as consumer also increase their demand when the marginal cost is high.

We illustrate in Figure 7 how the net welfare change depends on consumer types. The red line corresponds to the benchmark equilibrium price p^r_{fp} when only the FP contract is available. The other black lines correspond to contract-demand limits as shown in Figure 1. The white areas correspond to consumers whose allocations are unchanged; hence, there is no direct welfare effect. The blue regions correspond to consumers who experience a net welfare gain from switching to the RTP contract (contract switchers). The green areas correspond to consumers who generate a net welfare gain by changing their consumption profile (profile switchers). Finally, the red regions correspond to consumers for whom welfare decreases because the lower FP unit price, p^r, relative to the benchmark price, p^r_{fp}, increases consumption in the high-cost period.

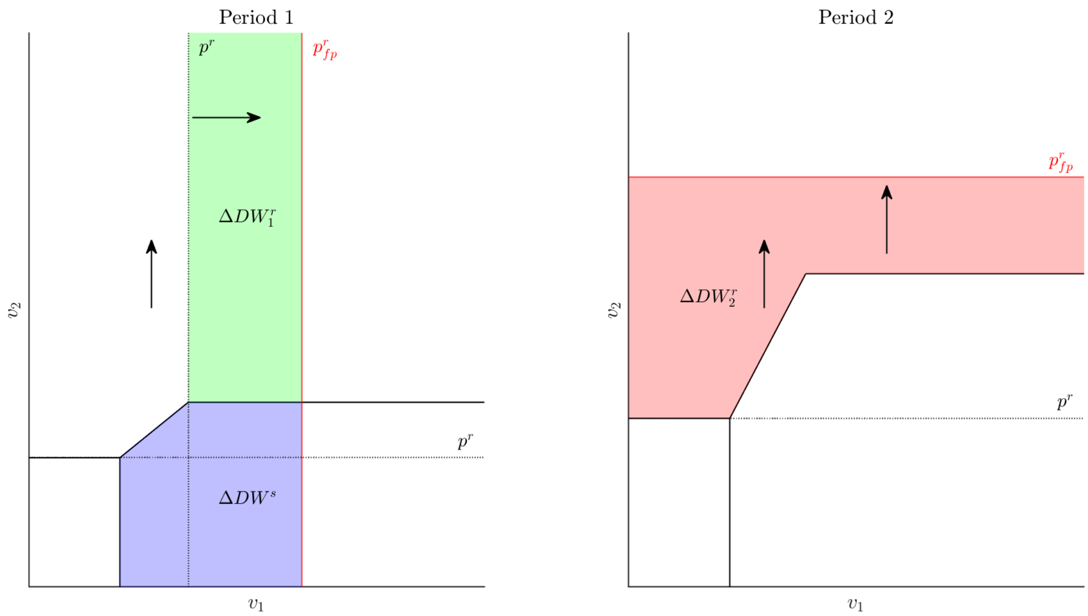

Figure 7: Comparison of welfare change between the equilibrium with multiple contracts and the single FP benchmark. Blue = welfare gain due to switching to RTP. Green = welfare gain from changing the profile while remaining FP. Red = welfare loss from extra period-2 consumption caused by lower p^r. Arrows indicate the direction of marginal consumers when p^r increases in the multiple-contract environment.

We conclude this subsection by analyzing how the welfare ranking changes when p^r varies in the contract-choice equilibrium, holding the benchmark price p^r_{fp} fixed. Figure 7 illustrates that increasing p^r reduces the adverse impacts in period 2, as more consumers switch to RTP and therefore reduce inefficient on-peak consumption. However, the effect is ambiguous in period 1. On the one hand, a higher p^r increases efficient period-1 consumption through contract switching. On the other hand, it reduces the welfare gain generated by profile switchers, since a higher p^r reduces the incentive to consume in period 1 for consumers who remain in the FP contract.

4.3.2 General equilibrium

The previous discussion isolates the welfare mechanism at given prices: the RTP outside option improves efficiency through sorting, but it can also induce the public firm to adjust the FP price in a way that increases misallocation during the high-marginal-cost period. We now study this trade-off after endogenizing prices. In general equilibrium, contract demand, elasticities, and the sorting-leakage margin all move with primitives, so the welfare ranking becomes a joint outcome of (i) how consumer types sort across contracts, and (ii) how the public firm responds to the resulting leakage incentives.

Our goal here is not to provide a complete comparative statics theorem. Instead, we use illustrations to connect it back to the pricing condition in Proposition 3. Two questions are central. First, how do primitives — most importantly, the distribution of consumer types — shape the welfare comparison between the mixed-equilibrium (FP + RTP) and the single-contract equilibrium (only FP)? Second, can this welfare comparison tell about the pricing rule implemented by the public firm, in particular, the choice between a linear tariff and a two-part tariff? Throughout, we keep the benchmark single-contract price, p^r_{fp}, as the equilibrium outcome for the same public firm when the RTP outside option is removed.

Consumer distribution. To illustrate the mechanism, assume that in each period t consumer values follow an exponential distribution, $v_t \sim \text{Exp}(l_t)$, where $l_t > 0$ is the rate in period t.[17] We examine how changes in (l_1, l_2) affect the public firm pricing, and whether the effect differs across periods. For simplicity, we restrict the public firm to a linear tariff, i.e., $A^r = 0$. The equilibrium condition under linear pricing can be written as the markup rule

$$\underbrace{\frac{p^r - \sum_t c_t \omega_t^p}{p^r}}_{\text{markup}} = -\underbrace{\frac{\lambda}{1+\lambda}\frac{1}{\varepsilon_{p^r}}}_{\text{Ramsey term}} - \underbrace{\frac{1}{1+\lambda}\frac{\partial_{p^r}\mathcal{C}}{q^r}\frac{1}{\varepsilon_{p^r}}}_{\text{sorting correction}},$$

where

$$\omega_t^p := \frac{\partial q_t^r / \partial p^r}{\partial q^r / \partial p^r}, \qquad \varepsilon_{p^r} := \frac{\partial q^r}{\partial p^r}\frac{p^r}{q^r} < 0,$$

and $\partial_{p^r}\mathcal{C} < 0$ is the sorting-induced leakage component (defined in the previous subsection). The Ramsey term is positive (since $\varepsilon_{p^r} < 0$). At the same time, the sorting correction is negative: raising p^r strengthens welfare-improving sorting into RTP, which reduces the optimal markup relative to the standard Ramsey benchmark.

[17] If values are bounded in the rest of the paper, this can be interpreted as a truncated exponential on $[0, \overline{v}_t]$.

We report in the first panel of Figure 8 the equilibrium FP price p^r as we vary l_1 (blue) and l_2 (red). The second panel illustrates the interpretation of a change in the rates. An increase in l_t shifts mass toward lower types in period t (and away from higher types). The key point is that changes in the relative composition across periods matter for the public firm. In the illustration, when the first-period distribution becomes relatively more concentrated among low-willingness-to-pay consumers (i.e., higher l_1 relative to l_2), the equilibrium price p^r increases. On the other hand, when the second-period distribution becomes relatively more concentrated on low willingness-to-pay consumers (higher l_2 relative to l_1), the equilibrium p^r decreases.

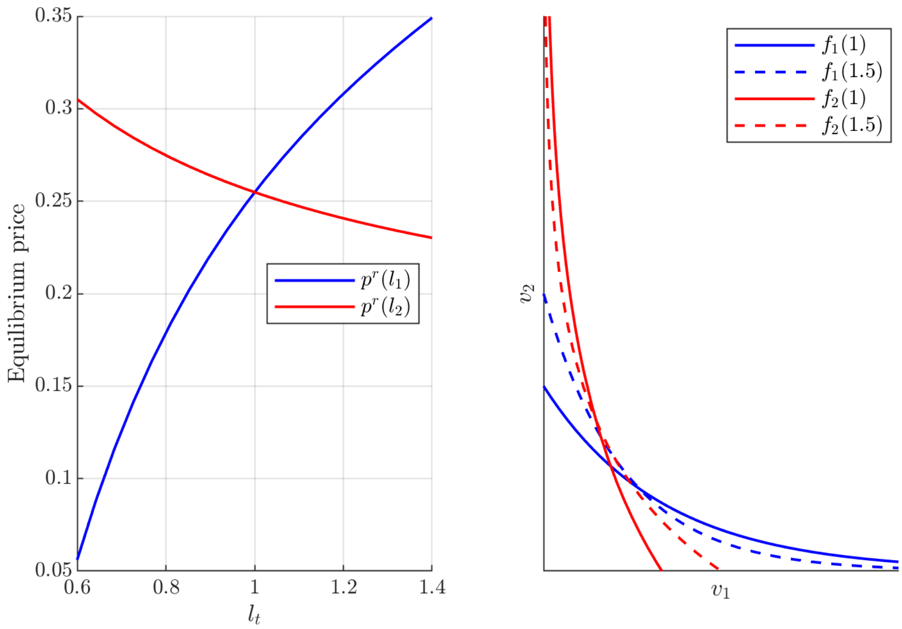

Figure 8: First panel: equilibrium FP price p^r under the mixed equilibrium with linear pricing ($A^r = 0$) as a function of l_1 and l_2. Second panel: illustration of how an increase in l_t shifts mass toward lower types.

Closed-form comparative statics are generally not available in this environment.[18] Still, we find that the evolution of the price response corresponds to the change in the sorting correction. When l_1 increases, $-\partial_{p^r}\mathcal{C}$ decreases: the public firm faces a smaller leakage margin and is therefore willing to raise p^r. When l_2 increases, $-\partial_{p^r}\mathcal{C}$ increases: the leakage margin is stronger, and the public firm is incentivized to reduce p^r.

The exponential case also provides a way to interpret these changes because the shift in mass has a single-crossing structure. To make this explicit, consider a change from l_1 to l_1' and define

$$\Delta f_1(v_1) \;:=\; f_1(v_1 \mid l_1') - f_1(v_1 \mid l_1).$$

[18] Demand for each contract is endogenous, so changes in (l_1, l_2) affect both the elasticities and the leakage term, hence all components of the equilibrium condition.

There exists a cutoff v_1^* such that $\Delta f_1(v_1) > 0$ for $v_1 < v_1^*$ and $\Delta f_1(v_1) < 0$ for $v_1 > v_1^*$ (mass shifts from high to low types). Recall that $\mathcal{M}_a^\Delta$ is the boundary given by $v_2 = \phi(v_1)$ for $v_1 \in [p_1, p^r]$, while $\mathcal{M}_b^\Delta$ is the boundary relevant for contract switching on $v_1 \in [p^r, \overline{v}_1]$. Assume, for illustration, that $v_1^* > p^r$, the induced change in the sorting term can be decomposed as

$$\begin{aligned}
\Delta\partial_{p^r}\mathcal{C} = & -\frac{\partial\phi(v_1)}{\partial p^r}\overbrace{\int_{p_1}^{p^r}(v_1 - p_1)\,\Delta f_1(v_1)\,f_2(\phi(v_1))\,dv_1}^{\text{sorting effect \#1 with } \Delta f_1>0} - \frac{\partial v_2^\Delta}{\partial p^r}\overbrace{\int_{p^r}^{v_1^*}(p^r - p_1)\,\Delta f_1(v_1)\,f_2(v_2^\Delta)\,dv_1}^{\text{sorting effect \#2 with } \Delta f_1>0} \\
& - \frac{\partial v_2^\Delta}{\partial p^r}\underbrace{\int_{v_1^*}^{\overline{v}_1}(p^r - p_1)\,\Delta f_1(v_1)\,f_2(v_2^\Delta)\,dv_1}_{\text{sorting effect \#2 with } \Delta f_1<0}.
\end{aligned}$$

The first two terms capture the increase in mass on the relevant margins ($\Delta f_1 > 0$), which tends to make $\partial_{p^r}\mathcal{C}$ more negative (a stronger leakage effect). The last term captures the loss of mass at higher v_1 ($\Delta f_1 < 0$), which tends to make $\partial_{p^r}\mathcal{C}$ less negative (a weaker leakage effect). The net impact depends on the parameters, but this decomposition clarifies why changes in (l_1, l_2) map to changes in the leakage margin and, therefore, to changes in the equilibrium price p^r.

Public firm pricing. The key idea of this discussion is that, in this environment, the two instruments of a two-part tariff affect consumer sorting differently. In turn, they affect market welfare directly (through consumption profiles) and indirectly (through the public firm's marginal incentive to adjust prices when facing the RTP outside option). To highlight this mechanism, we compare outcomes under a two-part tariff with those under a linear tariff for the public firm.

We illustrate the welfare implications of this general-equilibrium mechanism in Figure 9. The left panel reports the equilibrium FP price as a function of the marginal cost of public funds λ. In line with the mechanism above, allowing consumers to choose RTP tends to reduce the equilibrium FP price relative to the single-contract benchmark. The right panel shows that this equilibrium price response can be strong enough to generate a welfare loss relative to the benchmark. By lowering p^r, the mixed equilibrium may increase inefficient consumption during the high marginal-cost period. However, this does not hold uniformly across parameters. In particular, when λ is sufficiently high, the mixed-equilibrium price increases faster than in the single-contract case. Intuitively, a higher λ strengthens the revenue motive and reduces the extent to which the public firm is willing to compress the FP price to limit leakage. As a result, the adverse sorting through over-consumption in period 2 is relatively weaker at high values of λ.

A second observation from Figure 9 is that allowing the public firm to use a two-part tariff can be welfare-improving relative to restricting it to linear pricing.[19] The reason is that the two-part

[19]The illustration also shows that the public firm's objective is higher under a two-part tariff.

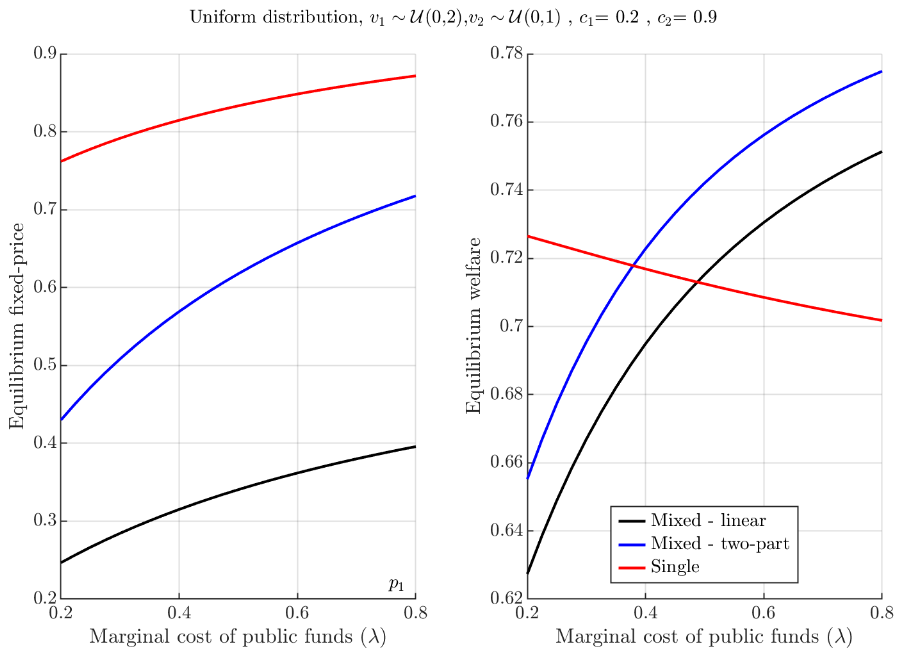

Figure 9: First panel: equilibrium prices as a function of λ. Red: single-contract equilibrium (only FP). Black: mixed-equilibrium with RTP when the public firm is restricted to linear pricing. Blue: mixed equilibrium with RTP when the public firm uses a two-part tariff. In the two-part case, the relevant equilibrium price is the total payment $p^r + A^r$.

tariff changes sorting: it increases enrollment into RTP and reduces consumption in period 2 by raising the price faced by marginal consumers. The effect on period 1 consumption in the FP contract is instead ambiguous, because the same change in tariff that discourages inefficient period 2 consumption can also reduce incentives to consume in period 1 for consumers who remain under FP. We summarize these channels in Figure 10.

5 Endogenous budget and fiscal policy

In the previous sections, the public firm's budget constraint was fully exogenous and financed outside the electricity market. To capture the firm's public nature more explicitly, we now allow it to raise resources from all electricity consumers through a unit tax. The public firm chooses this tax to cover any deficit generated by the fixed-price contract.[20]

Formally, let τ denote a unit tax levied on all electricity consumption. We assume that the tax burden is split between the public firm's consumers and the rest of the market as follows:

$$\tau^r = \alpha\tau, \qquad \tau^s = (1-\alpha)\tau, \qquad \alpha \in [0,1].$$

[20]In the current setting, as a full RTP is the first-best, if the regulator acting as a social planner sets a tax, then it would be optimal to implement such that no consumer self-selects into the FP contract.

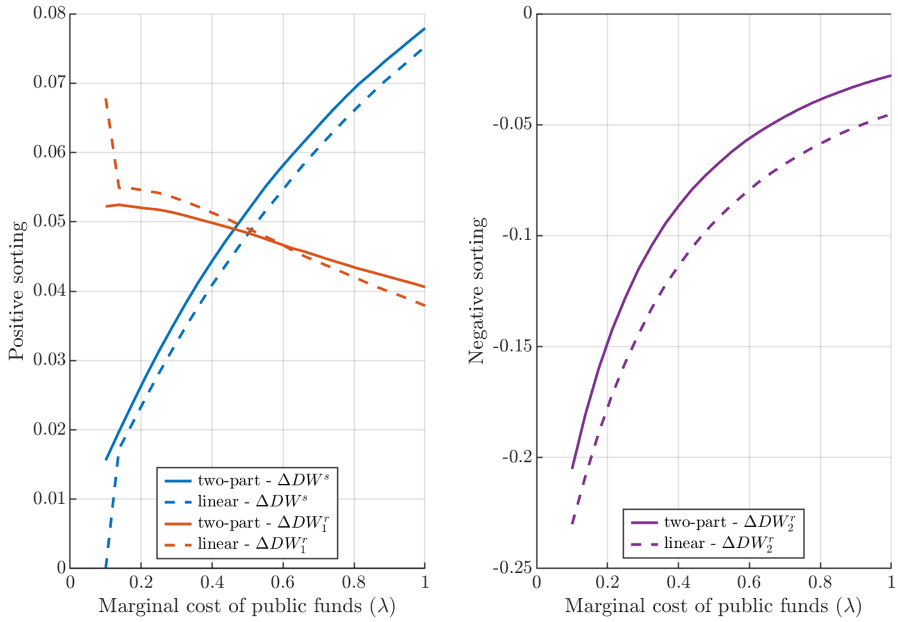

Figure 10: Welfare decomposition under contract choice. First panel: gains from the RTP option, arising from consumers switching to RTP (blue) and from the lower FP equilibrium price increasing consumption during the low-marginal-cost period (red). Second panel: losses from the lower FP price increase consumption during the high-marginal-cost period. Solid lines: two-part tariff. Dashed lines: linear pricing.

Hence τ^r is the increase in the unit price paid by consumers enrolled with the public firm, while τ^s is the increase in the unit price paid by consumers enrolled with private firms. The parameter α measures the degree of self-financing: $\alpha = 1$ corresponds to full self-financing, whereas lower values of α indicate a greater ability to raise revenue from outside the public firm's consumer base. Setting $\alpha = 0.5$ implies that consumers in both contracts face the same levy.

Definition 2. *A triple $(p^r, \tau, \boldsymbol{p}^s)$ is a mixed-equilibrium contract with fiscal policy if, given consumers' optimal contract choice, $\pi^s(p^r, \tau, \boldsymbol{p}^s) = 0$ and (p^r, τ) solves*

$$\max_{\{p^r,\tau\}} \quad CS^r(p^r,\tau) \qquad (\Omega^F)$$
$$\text{s.t.} \quad \pi^r(p^r,\tau) + \tau^r q^r + \tau^s q^s = 0,$$

where $\pi^r(p^r, \tau)$ is the public firm's operating profit from serving its consumers at tariff p^r (excluding the unit tax), and $\tau^r q^r + \tau^s q^s$ is the fiscal transfer financing the public firm.

We begin with the special case $\alpha = 1$, i.e., a fully self-financing levy.

Lemma 4. *With a public firm and a full self-financing levy $(\alpha = 1)$, there is no equilibrium with an active FP contract.*

This result highlights the symmetry between the public and private market structures once consumers self-select. Under full self-financing, the public firm cannot rely on an external tax base: any deficit created by the FP contract must be covered by the same consumers who select into FP. Since the more costly consumers remain in FP at equilibrium, the break-even requirement forces an average unit payment that exceeds what any FP-selecting consumer is willing to pay without deviating to RTP.

We next consider the general case $\alpha \in [0, 1)$. In the region $p^r < \overline{p}$, contract choice is driven by the effective price distortion in period 1, while p_2 does not affect the selection margin. A similar result can be obtained in the region $p > \overline{p}$.

Lemma 5. *Fix $\alpha \in [0, 1)$ and assume $p^r < \overline{p}$. Define the full price paid by consumers enrolled in FP as $P^r \equiv p^r + \alpha\tau$, and the full price paid by consumers enrolled in RTP in period 1 as $P_1^s \equiv p_1 + (1 - \alpha)\tau$. The problem (Ω^F) can be written equivalently as*

$$\begin{aligned} \max_{\{P^r, P_1^s\}} \quad & CS^r(P^r, P_1^s) \\ s.t. \quad & \pi^r(P^r, P_1^s) \;+\; (P_1^s - p_1)\; q^s(P^r, P_1^s) \;=\; 0, \end{aligned} \tag{$\overline{\Omega}^F$}$$

In particular, the feasible set and the equilibrium pair (P^r, P_1^s) are independent of α.

Lemma 5 highlights that what matters for the public firm is the sorting of consumers across contracts, which is entirely pinned down by the full prices (P^r, P_1^s). In particular, for any $\alpha \in [0, 1)$, holding (P^r, P_1^s) fixed leaves consumers' contract choices unchanged. Thus, varying α only changes how the same full-price profile is decomposed between the tariff component p^r and the tax wedge τ, without affecting equilibrium sorting.

For characterizing the equilibrium, we define, similarly to Proposition 3, the operators

$$\delta_\tau(X) \;:=\; \frac{\partial X}{\partial P_1^s} \;-\; \frac{\partial X}{\partial P^r}.$$

An increase in P^r always decreases demand for the FP contract, but an increase in P_1^s always increases it; it follows that $\delta_\tau(q^r) > 0$. We also define $\delta_\tau(\mathcal{C})$ that captures the difference in the leakage effect between P_1^s and P^r. However, compared to the two-part tariff case, the instruments change in the opposite way, contract switchers (increasing P_1^s attracts consumers, and increasing P^r deters consumers). Therefore, $\delta_\tau(\mathcal{C}) > 0$.

Proposition 4. *For $\alpha < 1$, there always exists an equilibrium (p^r, τ) such that some consumers strictly prefer the FP contract. The full price set by the firm solves the following:*

$$P^r - \underbrace{\sum_t c_t \frac{\delta_\tau(q^r_t)}{\delta_\tau(q^r)}}_{\text{marginal cost}} = (1-\alpha)\underbrace{\frac{\lambda}{1+\lambda}\frac{q^r}{\delta_\tau(q^r)}}_{\text{Ramsey}} - \underbrace{\frac{1}{1+\lambda}\frac{\delta_\tau(\mathcal{C})}{\delta_\tau(q^r)}}_{\text{sorting correction}} - \underbrace{\frac{T}{\delta_\tau(q^r)}}_{\text{levy effect}}$$

where $\lambda \geq 0$ is the Lagrange multiplier from the budget constraint and $T = q^s + t^s\delta_\tau(q^s)$

Proposition 4 delivers a sharp existence result: as soon as the public firm can raise part of the required revenue outside its own consumer base ($\alpha < 1$), the mixed equilibrium yields that a set of consumers strictly prefers FP in equilibrium. The equilibrium full price P^r is characterized by a markup condition, which decomposes the deviation from weighted marginal cost into three terms. First, the term proportional to $1-\alpha$ is a standard Ramsey component. Because only a fraction α of the levy is borne by FP consumers, the public firm internalizes the outside tax base, thereby relaxing its budget constraint. Second, the sorting correction $\delta_\tau(\mathcal{C})$ captures that both a change in the unit price p^r and the unit tax τ affect not only quantities but also the composition of the FP consumers, and hence the cost of serving inframarginal FP consumers. Third, the levy effect T reflects the marginal fiscal gain from taxing consumption in the RTP contract, which affects the FP price through the budget constraint. As α increases toward 1, the Ramsey term vanishes, and the ability to shift negative profit to consumers under RTP disappears, consistent with Lemma 4 in which no equilibrium can sustain an active FP contract under full self-financing.

6 Conclusion

This paper develops a theoretical framework to study how end-user consumers in retail electricity markets self-select into a menu of contracts and how this endogenous sorting shapes equilibrium pricing. We focus on a simple but empirically relevant menu: a fixed-price (FP) contract and a real-time pricing (RTP) contract that transmits the wholesale price signal. In the context of an energy transition where dynamic pricing is often implemented through voluntary choice, understanding adoption requires modeling contract demand and firms' pricing incentives jointly.

Consumers differ in their willingness to pay across periods, so contract choice affects not only quantities but also the timing of consumption. This generates a moral-hazard channel: the induced consumption profile changes retailers' procurement costs. Hence, equilibrium outcomes depend on who selects each contract, not only on aggregate demand.

Using this micro-founded demand for contracts, we characterize equilibrium pricing under two market structures for the FP contract. The RTP contract is supplied competitively, so consumers on this contract face the wholesale prices. For the FP contract, we compare competitive provision by private retailers with that of a regulated monopoly that maximizes its consumers' surplus subject to a budget constraint. We show that no equilibrium can feature a demand for the FP contract when private firms provide it: consumers who select it are more costly to serve, so adverse selection makes this contract unprofitable at break-even prices, and competitive forces unravel the FP market. By contrast, under a regulated monopoly, an equilibrium with a demand for the FP contract can exist; the optimal FP price then reflects the elasticity of contract demand, sorting to the RTP contract, and the financing of losses on the FP contract.

A central welfare implication is that contract choice can reduce welfare under a regulated monopoly once the pricing response to sorting is taken into account. While the RTP contract improves allocative efficiency for consumers who switch, the monopoly has an incentive to lower its unit price to retain the consumers most likely to leave for the RTP contract, who are also the least costly to serve. This price response increases peak consumption among consumers whose willingness to pay is below the wholesale marginal cost, thereby offsetting, and in some cases dominating, the welfare gains from enrolling in the RTP contract. The magnitude (and sign) of this effect depends on the distribution of consumer characteristics, as reflected in the mass and composition of contract switchers and marginal FP entrants.

The paper also discusses the regulation of the public firm. Indeed, we show that the equilibrium distortions depend jointly on the available tariff instrument and the financing rule for FP losses. Allowing a two-part tariff, rather than linear pricing, separates the intensive margin from the sorting margin, while financing deficits through a market-wide levy changes the sorting effect and, therefore, the pricing response.

We view the model and its results as a mechanism for the equilibrium effects of contract choice in electricity markets. It called for various extensions. First, there is significant heterogeneity in dynamic tariff designs. A growing literature studies the welfare gains from contracts that approximate the RTP contract while preserving simplicity of implementation (Hinchberger et al., 2024), and raises the question of how retailers choose among alternative designs in the presence of frictions and market power (Fabra and Reguant, 2020). Second, the assumption that a regulated monopoly maximizes only its own consumers' surplus is stylized. In practice, regulators may also value aggregate surplus. Yet, regulated prices are unlikely to be fully efficient because they are shaped by redistribution objectives and political constraints, which can generate distortions similar in spirit to those highlighted here (Martimort et al., 2020). Finally, consumers may display behavioral biases when selecting electricity contracts (Fowlie et al., 2021; Gibbard and Remmy, 2024). While such forces are likely important empirically, we argue that the foundations of contract demand, even with rational consumers and private information, remain underexplored. We view this paper as a first step toward a more systematic analysis of consumer sorting, market structure, and regulation in retail electricity markets.

References

ACER (2024). Energy retail - Active consumer participation is key to driving the energy transition: how can it happen? 2024 Market Monitoring Report. Technical Report September, ACER.

Ambec, S. and Crampes, C. (2021). Real-time electricity pricing to balance green energy intermittency. *Energy Economics*, 94:105074.

Ancel, J. (2025). Tariffs time-dynamics in competitive electricity retail markets with differentiated consumer reactions. *Energy Economics*, 148(May):108615.

Armstrong, M. (1996). Multiproduct Nonlinear Pricing. *Econometrica*, 64(1):51.

Astier, N. and Léautier, T.-O. (2021). Demand Response: Smart Market Designs for Smart Consumers. *The Energy Journal*, 42(3):153–176.

Azevedo, E. M. and Gottlieb, D. (2017). Perfect Competition in Markets With Adverse Selection. *Econometrica*, 85(1):67–105.

Bailey, M., Brown, D., Myers, E., Shaffer, B., and Wolak, F. A. (2024). Electric Vehicles and the Energy Transition: Unintended Consequences of a Common Retail Rate Design. *SSRN Electronic Journal*.

Blonz, J. A. (2022). Making the Best of the Second-Best: Welfare Consequences of Time-Varying Electricity Prices. *Journal of the Association of Environmental and Resource Economists*, 9(6):1087–1126.

Boiteux, M. (1949). *La tarification des demandes en pointe: Application de la théorie de la vente au coût marginal*. place Henri-Bergson.

Bollinger, B. K. and Hartmann, W. R. (2020). Information vs. Automation and implications for dynamic pricing. *Management Science*, 66(1):290–314.

Boom, A. and Schwenen, S. (2021). Is real-time pricing smart for consumers? *Journal of Regulatory Economics*, 60(2-3):193–213.

Borenstein, S. (2005a). The Long-Run Efficiency of Real-Time Electricity Pricing. *The Energy Journal*, 26(3).

Borenstein, S. (2005b). Time-varying retail electricity prices: Theory and practice. *Electricity deregulation: choices and challenges*, pages 317–356.

Borenstein, S. (2013). Effective and Equitable Adoption of Opt-In Residential. *Review of Industrial Organization*, 42:127–160.

Borenstein, S. and Bushnell, J. (2021). Headwinds and Tailwinds: Implications of Inefficient Retail Energy Pricing for Energy Substitution. *SSRN Electronic Journal*, 3.

Borenstein, S. and Holland, S. (2003). On the Efficiency of Competitive Electricity Markets With Time-Invariant Retail Prices. Technical report, National Bureau of Economic Research, Cambridge, MA.

Cabot, C. and Villavicencio, M. (2024). The demand-side flexibility in liberalised power market: A review of current market design and objectives. *Renewable and Sustainable Energy Reviews*, 201(January).

Cahana, M., Fabra, N., Reguant, M., and Wang, J. (2023). The Distributional Impacts of Real-Time Pricing. A.

Chao, H. p. and DePillis, M. (2013). Incentive effects of paying demand response in wholesale electricity markets. *Journal of Regulatory Economics*, 43(3):265–283.

Dosis, A. (2022). Price caps and efficiency in markets with adverse selection. *Journal of Mathematical Economics*, 99:102591.

Einav, L., Finkelstein, A., and Mahoney, N. (2021). *The IO of selection markets*, volume 5. Elsevier B.V.

Einav, L., Jenkins, M., and Levin, J. (2012). Contract Pricing in Consumer Credit Markets. *Econometrica*, 80(4):1387–1432.

Enrich, J., Li, R., Mizrahi, A., and Reguant, M. (2024). Measuring the impact of time-of-use pricing on electricity consumption: Evidence from Spain. *Journal of Environmental Economics and Management*, 123(February 2023):102901.

Fabra, N., Rapson, D., Reguant, M., and Wang, J. (2021). Estimating the Elasticity to Real-Time Pricing: Evidence from the Spanish Electricity Market. *AEA Papers and Proceedings*, 111:425–429.

Fabra, N. and Reguant, M. (2020). A model of search with price discrimination. *European Economic Review*, 129(C).

Fowlie, M., Wolfram, C., Baylis, P., Spurlock, C. A., Todd-Blick, A., and Cappers, P. (2021). Default Effects and Follow-On Behaviour: Evidence from An Electricity Pricing Program. *Review of Economic Studies*, 88(6):2886–2934.

Fu, Z., Novan, K., and Smith, A. (2024). Do time-of-use prices deliver energy savings at the right time? *Journal of Environmental Economics and Management*, 128(November).

Gibbard, P. and Remmy, K. (2024). The impact of price comparison tools on electricity retailer choices. Technical report, University of Bonn and University of Mannheim, Germany.

Han, X., Liu, Z., and Wang, T. (2023). Nonlinear pricing in multidimensional context: An empirical analysis of energy consumption. *International Journal of Industrial Organization*, 91(December 2021):103034.

Hendren, N., Landais, C., and Spinnewijn, J. (2021). *Choice in Insurance Markets : A Pigouvian Approach to Social Insurance Design*.

Hinchberger, A. J., Jacobsen, M. R., Knittel, C. R., Sallee, J. M., and van Benthem, A. (2024). The Efficiency of Dynamic Electricity Prices.

Imelda, Fripp, M., and Roberts, M. J. (2024). Real-Time Pricing and the Cost of Clean Power. *American Economic Journal: Economic Policy*, 16(4):100–141.

Ito, K., Ida, T., and Tanaka, M. (2023). Selection on Welfare Gains: Experimental Evidence from Electricity Plan Choice. *American Economic Review*, 113(11):2937–2973.

Jessoe, K. and Rapson, D. (2014). Knowledge is (less) power: Experimental evidence from residential energy use. *American Economic Review*, 104(4):1417–1438.

Joskow, P. and Tirole, J. (2006). Retail electricity competition. *The RAND Journal of Economics*, 37(4):799–815.

Joskow, P. L. and Wolfram, C. D. (2012). Dynamic pricing of electricity. *American Economic Review*, 102(3):381–385.

Kang, Z. Y. (2023). The Public Option and Optimal Redistribution. A.

Kavulla, T. (2023). Why Is the Smart Grid So Dumb? Technical report, Energy Systems Integration Group.

Laffont, J.-J. and Tirole, J. (1993). *A theory of incentives in procurement and regulation*. MIT press.

Leautier, T.-O. (2014). Is Mandating "Smart Meters" Smart? *The Energy Journal*, 35(4):135–158.

Leslie, G., Pourkhanali, A., and Roger, G. (2021). Identifying consumption profiles and implicit cross-subsidies under fixed-rate electricity tariffs. *SSRN Electronic Journal*.

Levinson, A. and Silva, E. (2022). The Electric Gini: Income Redistribution through Energy Prices†. *American Economic Journal: Economic Policy*, 14(2):341–365.

Martimort, D., Pouyet, J., and Staropoli, C. (2020). Use and abuse of regulated prices in electricity markets: "How to regulate regulated prices?". *Journal of Economics and Management Strategy*, 29(3):605–634.

Poletti, S. and Wright, J. (2020). Real-Time Pricing and Imperfect Competition in Electricity Markets*. *Journal of Industrial Economics*, 68(1):93–135.

Rochet, J.-C. and Chone, P. (1998). Ironing, Sweeping, and Multidimensional Screening. *Econometrica*, 66(4):783.

Rothschild, M. and Stiglitz, J. (1976). Equilibrium in competitive insurance markets: An essay on the economics of imperfect information. *Quarterly Journal of Economics*, 90(4):629–649.

Schittekatte, T., Mallapragada, D., Joskow, P. L., and Schmalensee, R. (2024). Electricity Retail Rate Design in a Decarbonizing Economy: An Analysis of Time-of-use and Critical Peak Pricing. *The Energy Journal*, 45(3):25–56.

Stole, L. A. (2007). Chapter 34 Price Discrimination and Competition. *Handbook of Industrial Organization*, 3(06):2221–2299.

Veiga, A. (2023). Price Discrimination in Selection Markets. *Review of Economics and Statistics*, pages 1–45.

Veiga, A. and Glen Weyl, E. (2016). Product design in selection markets. *Quarterly Journal of Economics*, 131(2):1007–1056.