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Competitive Proximity and Opening Hours in Finland's Pharmacy Market*

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Abstract

We examine the relationship between opening hours and proximity to competition in the Finnish pharmacy market. In this market, competition is primarily based on non-price factors such as service hours due to regulated prices and pharmacy locations. We develop a theoretical model of duopolistic competition incorporating spatial and temporal dimensions in which pharmacies compete on opening hours, given their exogenous locations and fixed prices for pharmaceuticals. We test the predictions of the theoretical model across multiple empirical specifications and observe that pharmacies for which the nearest competitor is further away generally have shorter opening hours.

Keywords: *pharmacies*, *opening hours*, *spatial competition*

JEL Codes: *L43*, *L81*, *R12*

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1 Introduction

Generally, price and quality constitute the two main factors of competition. While price competition is relatively straightforward to characterize in most economic settings, the latter is a far more multidimensional concept. For instance, in markets with heterogeneous goods, the variation in product characteristics typically also represents the quality differences between the products. In the retail service industry with relatively homogeneous services, competitive factors often relate to the availability of the services offered. This is especially true in the Finnish pharmacy markets, which we focus on in this study.

In Finland, as in many other countries, the retail price of pharmaceutical products in pharmacies is regulated. Similarly, many aspects of service quality in pharmacies are also regulated; thus, they can be assumed to be (almost) constant across most pharmacies. For example, educational requirements for pharmacists and other personnel, as well as the facilities of pharmacies, are regulated. Thus, the main competitive factors available for pharmacies are related to service availability.

The two key aspects of pharmacy service availability are opening hours and distance to services.[1] By regulating the pharmacy network, the regulator aims to ensure that the distance to pharmacies is not too large for any potential customer. However, opening hours are not regulated as strictly in Finland, leaving some room for competition with opening hours. This, in addition to the observation from a recent survey that 26% of respondents were not able to access pharmacy services due to pharmacies being closed, motivates us to study the relationship between opening hours and proximity to competition.[2] As proximity to a service point is a significant factor for customers, the geographical distance between different service points is a meaningful measure of potential competition.[3]

To study the relationship, we first develop a theoretical model of duopolistic competition in which pharmacies compete on opening hours, given their exogenous location and fixed price for pharmaceuticals. The model yields testable predictions on the relationship between equilibrium opening hours and multiple parameters describing demand and consumer preferences. The empirical part builds a simple quadratic model in which

[1]We mainly use the term *opening hours*. Other alternatives would be *business hours*, *service hours*, or *operating hours*. The concept of service time, however, differs as it refers to the duration of the actual delivery of a service (see e.g. Png and Reitman (1994)). In pharmacies, this could mean, for example, the time it takes to deliver a prescription medicine to the customer. Service time is one aspect of quality that is closely related to opening hours, as average service time depends on the general capacity.

[2]Louhisalmi et al. (2026). The survey had 2158 respondents.

[3]See Leppälä et al. (2025) who develop a method to analyze the importance of individual pharmacies within the service network.

we explain weekly opening hours with the intensity of competition. Across multiple empirical specifications, we observe that pharmacies for which the nearest competitor is further away generally have shorter opening hours. The relationship also holds when we examine opening hours at the weekday level. We also describe the overlap of daily opening hours between the closest competitors. Only a small fraction of competitor pairs have exactly the same opening times on a given day. Lastly, we examine the total duration of pharmacy opening hours that the population in a given area faces. Again, we observe that more distant competitors seem to offer shorter opening hours in total.

2 Previous Literature

Our work relates to a number of earlier theoretical studies on opening hours.[4] The model by Inderst and Irmen (2005) examines the effects of deregulation on opening hours and price competition and how opening hour decisions might mitigate price competition. As in this analysis and in many other examinations of opening hour decisions, they utilize a model of spatial and temporal competition. Their main result shows that if consumers place a high value on time, at equilibrium we observe asymmetric opening hours such that stores are open at partially different times. Consequently, firms aim to relax price competition by separating opening times, which might again raise prices as markets are segmented between consumers with different time preferences. Yamada (2019) extends their model by incorporating additional store quality investments. Similarly to Inderst and Irmen (2005), shopping hours reach an asymmetric equilibrium with different levels of quality investments given opening hours.

Shy and Stenbacka (2006) exclude price competition and they do not consider spatial dimension, as they purely illustrate the provision of service hours in the cases of single service provider and duopolistic competition. For our analysis, the result relating to a single service provider is interesting, as in many cases pharmacies in Finland can be considered locally a monopolistic service provider. They show that when the exogenous fixed price is below the consumer's willingness to pay from the service, the level of service hour provision is socially inefficiently low with a single service provider. Furthermore, with high operating costs and more uniform consumer preferences, the service hour provision is reduced and the service provider concentrates its operations to peak demand times. Shy and Stenbacka (2008) then extend their previous analysis with a spatial dimension and price competition. Instead of uniform consumer preferences, they consider

[4]The theoretical considerations of opening hours presented here are far from complete. See, for example, Rouwendal and Rietveld (1999) and the references therein for some earlier works.

different types of consumers, which are willing to either postpone, move forward (or both *bi-directional shoppers*) their preferred shopping time. From multiple results that they derive, we highlight the finding that with bi-directional consumers, stores have incentives to coordinate shopping hours in order to reduce costs. Flores and Wenzel (2016) consider an additional consumer group, namely *loyal consumers*, who only make purchases if their preferred store is open at their preferred time. The presence of loyal consumers creates a market expansion effect when the opening hours are deregulated since now also the loyal consumers have more chances to shop at their preferred time. However, this increase in demand might also induce price increases, making some segments of consumers worse off. In total, deregulation, however, is welfare enhancing for the consumers in their model.

Wenzel (2011) examines the competition between a large chain and smaller independent retailers and their opening hour decisions with respect to operating costs. If the difference in cost efficiency is sufficiently large in favor of the chain, the chain chooses to operate longer opening hours than the independent retailer. The Finnish pharmacy market has no chains, with one important exception, which we will describe in detail later. Indeed, we observe significant differences in opening hours for this chain and other smaller pharmacies.

While our setting shares some characteristics with the above studies, there are also some significant differences. The most obvious difference is that we exclude any price competition, as pharmacies operate under regulated prices. In this respect, the work by Shy and Stenbacka (2006) is closest to ours as they consider a fixed price setting. We extend their model by allowing potential market expansion[5] and parametrize population size and the distance between the firms in order to study their theoretical effect on opening hours.

Although there is a significant amount of empirical studies examining pharmacy availability and accessibility[6], the empirical evidence on the relationship between opening hours and competition is somewhat scarce (see, e.g. Kügler and Weiss (2016) for some earlier studies). Kügler and Weiss (2016) examine strategic interactions of opening hours within Austrian gasoline stations. They find that the stations do not respond strategically by increasing their own opening hours in response to an increase of hours in neighboring stations. However, the distance to neighboring stations significantly explains opening hours, implying that stations for which neighboring stations are closer and that face more competition, tend to have longer opening hours. In a similar vein, Habte

[5]Rouwendal and Rietveld (1999) study a theoretical model that also incorporates market expansion.

[6]See e.g. Tharumia Jagadeesan and Wirtz (2021) for a survey of literature outside economics. For a recent examination in the Finnish context see Pönkänen et al. (2025).

(2017) examines the relationship between the closeness of competition and opening hours in the Swedish car inspection markets and finds that opening hours increase with more competition and the closeness of competition. Contrary to Kügler and Weiss (2016), findings by De Haas et al. (2020) reveal the strategic behavior in terms of opening hours in the German grocery retail markets. They find that stores adjust their opening times depending on how other nearby outlets (same or other chains) set their corresponding opening hours. These effects are either by learning the local market demand conditions or market expansion as in the theoretical setting of Flores and Wenzel (2016).

In addition to the literature on opening hours and competition, our work is more broadly related to studies on the definition of geographical catchment area or markets and spatial competition. Often studies use circular radius based market definitions (see e.g. Habte and Holm (2022) and references therein). Such definitions are arbitrary, as they depend on the proper choice of circle radius, which might significantly differ between regions. Alternatively, as is done in this study, catchment areas or markets can be defined based on some form of grid based measures, as in Rozenfeld et al. (2011) (see also Pennerstorfer and Yontcheva, 2021). However, unlike Rozenfeld et al. (2011), we do not base our definition of geographical catchment areas on the aggregation of connected populated grid cells. Instead, we define the areas based on the distance of a grid cell from a given service point. This also allows for disconnected catchment areas for a single service point.[7] Lastly, our work tangentially relates to the topic of consumer search and firm location choices in response to that (see early work e.g. by Dudey, 1990). In our setting, pharmacies sell homogeneous goods with uniform prices, search costs are almost negligible, and it is mostly transportation costs (i.e. distance) that drive demand towards certain locations.[8]

Our contributions to the literature are twofold. Theoretically, we include the possibility of partial market coverage (i.e. unmet demand) and explicitly incorporate distance between the competitors and catchment population size as parameters characterizing the equilibrium level of opening hours. Thus, we allow the competitor's proximity and potential demand to differ between pharmacies and affect the choice of opening hours. Empirically, we add additional evidence to the scarce literature on the relationship between opening hours and competition. We also improve on some earlier measures of

[7] A third, clearly inferior, alternative would be to define catchment areas and markets based on administrative borders. Since customers can visit pharmacies on any side of administrative borders, this definition is not desirable.

[8] We, however, do not cover literature on time allocation and timing constraints, which studies how people divide their time between different activities and respond to different constraints on their time use (see e.g. Jacobsen and Kooreman, 2005).

competition.

3 Institutions

In this section, we briefly describe the main features of the Finnish pharmacy market.

The pricing of pharmaceuticals: The retail prices of pharmaceutical products are regulated through a maximum mark-up that pharmacies can charge above the wholesale price.[9] Pharmacies also sell products other than medicines, such as cosmetics and hygiene products, which are freely priced. The sale of these products is highly profitable, and they constitute a relatively significant share of the overall profits of pharmacies (see Kokko et al., 2025). Consequently, they can be a relevant product category affecting business decisions, such as opening hours, of pharmacists. In order to simplify our analysis, we exclude these products from the analysis.

The regulation on the number and location of pharmacies: Operating a pharmacy requires a government issued license, which grants the right to operate a pharmacy only in a certain *placement area*. Thus, there is no free entry into the markets. The placement area is often bounded by municipality borders, but it can also be a smaller area within the municipality. Pharmacies can be located freely within this placement area. The number of pharmacies is not regulated in the strict sense that there would be a predefined maximum number of pharmacies in Finland. However, the national regulatory agency, the Finnish Medicines Agency (Fimea), establishes new pharmacy licenses rather infrequently, so that in the short run, the number of pharmacies can be assumed to be almost fixed.

The regulation on opening hours: The opening hours of pharmacies can be set relatively freely. The legislation only specifies that the opening hours of pharmacies should meet the local demand for pharmaceuticals and pharmacy services. This concerns both the main pharmacies and the so-called branch pharmacies, which are subsidiary outlets of a certain main pharmacy. Pharmacy license can include some conditions for opening hours set by Fimea, but this rarely occurs.[10]

Branch pharmacies: While our analysis does not make any distinction between the main and branch pharmacies, their differences in opening hours are significant in the

[9] Since the 1st of April 2022, pharmacies are allowed to give discounts on over-the-counter (OTC) pharmaceuticals and sell them below the maximum ceiling price dictated by the mark-up regulation.

[10] As of 26th March 2025, no such conditions had been included in any then active license (information obtained from Fimea).

real world data. Thus, we describe in more detail the branch pharmacy arrangements. Branch pharmacies operate under the supervision of a pharmacist who also manages a main pharmacy. One pharmacist can have a maximum of three branch pharmacies alongside his/her main pharmacy. This means that the main and branch pharmacies fall under the same financial umbrella. Thus, the opening hours of main and branch pharmacies might be correlated, as they share financial resources. However, since our focus is on the interplay of competition and opening hours, with the assumption of a uniform cost structure, we abstract ourselves from any cost analysis. Furthermore, from the perspective of the availability of pharmacy services, main and branch pharmacies can be considered equivalent outlets that serve the service demand of their respective areas. Branch pharmacies are typically established in areas where, due to local demand conditions, it is not economically viable to establish a main pharmacy.

There are two types of branch pharmacies, namely *conditional* and *entitled* branches. Conditional branches are included as a condition in the main pharmacy license, and they are compulsory for pharmacists to operate. Pharmacists cannot close the operations of conditional branches based on their own decision. Entitled branches are voluntary to operate and are not bound so strictly to operate in certain regions. Conditional branches are generally required to operate in areas defined in the main pharmacy license, since the regulator aims to ensure the availability of pharmacy services in these areas.[11]

The presence of significant outlier operator: Most of the pharmacies in Finland are privately owned firms in which the pharmacist acts as a sole proprietor.[12] Besides the maximum of three branch pharmacies, no actual pharmacy chains are allowed. All of this is true, with one exception. The pharmacy of the University of Helsinki (*Yliopiston Apteekki* (YA) in Finnish) is the only actual pharmacy chain in Finland, with one main pharmacy and 16 branch pharmacies. No single entrepreneurial pharmacist is responsible for the outlets within the YA chain, but all outlets are run by the employed staff. These differences mean that YA has significantly different possibilities to operate pharmacies with longer opening hours than the remaining privately owned pharmacies.

[11] We have received information concerning the branch status from Fimea and it corresponds to the situation on the 18th of March 2025. Since then, the status might have changed.

[12] Pharmacists often employ other pharmaceutical professionals, so the pharmacist is not necessarily running the daily operations alone.

4 A Model of Opening Hours, Travel Distances, and Endogenous Market Coverage

Here we formulate the theoretical model that specifies the relationships between opening hours, travel distances and market demand. Note that the proofs and some complementary results are given in Appendix E, which also includes Table E.1 that collects the notation used throughout the model for ease of reference.

4.1 Setup

Consider a duopolistic pharmacy market in which pharmacies A and B sell a representative, homogeneous pharmaceutical good at a regulated retail price p to a continuum of heterogeneous consumers with unit demands and total mass N. The locations of the pharmacies are exogenously fixed at $d_A = 0$ and $d_B = D$, but their opening hours are chosen endogenously.

The consumers are distributed over a two-dimensional space–time domain. The spatial dimension is the closed interval $[0, D]$ representing physical address. The temporal dimension is the unit circle $\mathbb{S}^1 = \mathbb{R}/\mathbb{Z}$ obtained by identifying the points $t = 0$ and $t = 1$. The circle representation captures spillovers between adjacent time periods: a consumer whose ideal shopping time lies just before midnight may equally well postpone slightly into the next period or advance slightly into the previous one. Consumer i is described by a coordinate $(d_i, t_i) \in [0, D] \times \mathbb{S}^1$, where d_i is her location and t_i is her most preferred shopping time.

Figure 1 depicts this domain. The spatial segment $[0, D]$ runs along the axis of the cylinder, with the two pharmacies at its ends, while the recurring daily cycle is the circular cross-section, on which the consumer density peaks at $t = 1/2$ and is uniform along the spatial axis.

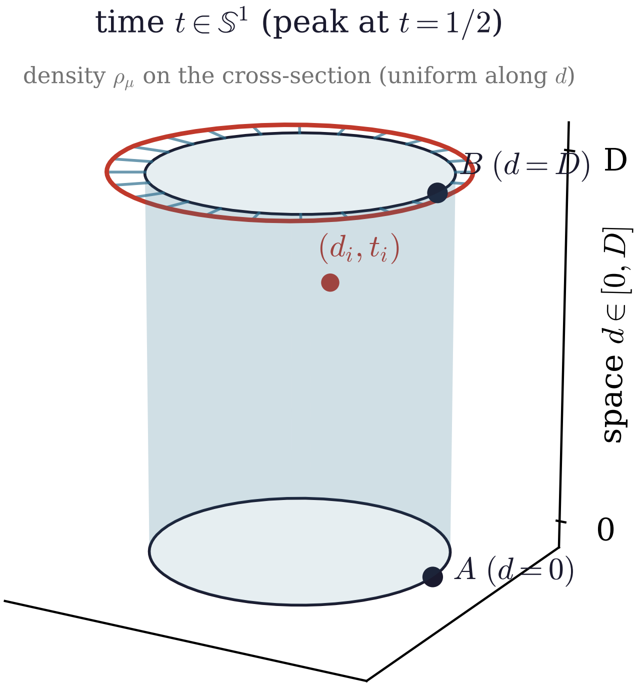


Figure 1: The space–time domain $[0, D] \times \mathbb{S}^1$

Notes: Space runs along the cylinder axis with pharmacies A and B at the ends; the time of day is the circle, on which the demand density peaks at the midday point $t = 1/2$.

Consumer density. Following Shy and Stenbacka (2006), the temporal density is single-peaked at $t = 1/2$, which represents the daily demand peak:

$$\rho_\mu(t) = \begin{cases} \mu + 4(1-\mu)\,t, & t \in [0, 1/2], \\ 4 - 3\mu - 4(1-\mu)\,t, & t \in [1/2, 1], \end{cases} \tag{1}$$

where $\mu \in [0, 1]$ is the uniformity parameter. The density is continuous, symmetric around $t = 1/2$, and integrates to one over $\mathbb{S}^1$. The parameter μ governs how concentrated demand is around the peak, as Figure 2 illustrates. When $\mu = 1$, the density is uniform: $\rho_1(t) \equiv 1$. As μ decreases toward 0, the density becomes more concentrated around the peak, with $\rho_\mu(0) = \rho_\mu(1) = \mu$ at the antipodal off-peak point and $\rho_\mu(1/2) = 2 - \mu$ at the peak. The spatial density is uniform on $[0, D]$, so the joint consumer density is $(N/D)\,\rho_\mu(t)$, with total mass N.

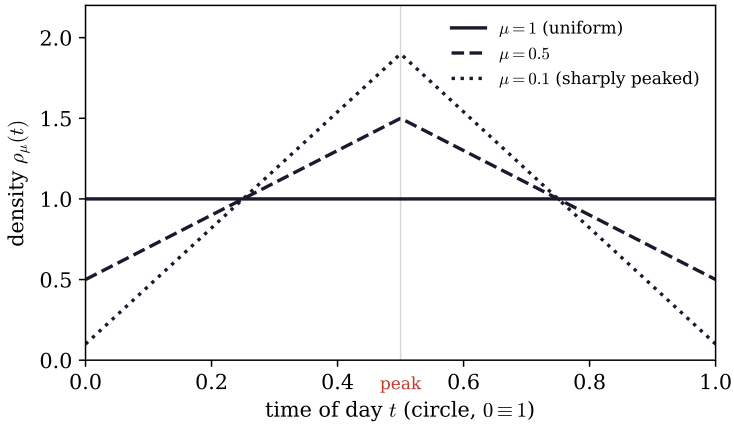


Figure 2: Consumer density over time for varying peakedness

Notes: The temporal density $\rho_\mu(t)$ for three values of the uniformity parameter μ. All three integrate to one; smaller μ concentrates demand around the midday peak.

Strategy space. Each pharmacy $j \in \{A, B\}$ chooses an opening arc $I_j \subset \mathbb{S}^1$, that is, a contiguous closed interval on the circle. The arc is parametrized by a duration $L_j \in [0, 1]$ and a midpoint $m_j \in \mathbb{S}^1$:

$$I_j = [m_j - L_j/2,\ m_j + L_j/2] \pmod 1. \tag{2}$$

Restricting attention to a single contiguous interval reflects the observation that pharmacies typically operate one continuous business window per day (e.g., from morning to evening) rather than multiple intermittent windows. The temporal mismatch between a consumer's ideal time t and pharmacy j's arc is the shortest-arc distance on $\mathbb{S}^1$:

$$g_j(t) \equiv \min_{s \in I_j} \text{dist}_{\mathbb{S}^1}(t, s), \tag{3}$$

so that $g_j(t) = 0$ if $t \in I_j$, and $0 < g_j(t) \leq (1 - L_j)/2$ otherwise, with the maximum attained at the antipode of the midpoint m_j.

Consumer utility and outside option. A consumer i purchasing at pharmacy j obtains additively separable[13] utility

$$u_i(j) = V - p - \delta\,|d_i - d_j| - \tau\, g_j(t_i), \tag{4}$$

[13]Thus, travel costs are assumed to be strictly invariant to the time of day.

and zero utility if she does not purchase. The parameter V is the basic consumption utility of the pharmaceutical good. The travel cost $\delta > 0$ scales the spatial distance to the pharmacy. The waiting cost $\tau > 0$ is the per-unit-of-time disutility of advancing or postponing shopping, incurred if and only if the pharmacy is closed at the consumer's ideal time. The consumer purchases from the pharmacy yielding the higher utility, provided that utility is non-negative; otherwise she does not purchase. This delivers an *endogenous market-coverage margin*: when opening hours are short, some consumers at intermediate locations and unfavorable times find both pharmacies' offerings too inconvenient and exit the market altogether.

Parameter restrictions.

Assumption 1. The parameters of the utility function (4) satisfy:

(i) $V - p \geq \tau/2$, so that a consumer located at a pharmacy's own address obtains non-negative utility from purchasing there at any arc length. This part is imposed only for economic plausibility (a non-degenerate always-served core at each location); it plays no role in any proof below, all of which turn on the marginal consumers at the spatial midpoint $d = D/2$ and the temporal antipode;

(ii) $V - p \in [\delta D/2,\ \delta D)$, so that consumers at the spatial midpoint $d = D/2$ obtain non-negative utility from either pharmacy at their own ideal time, while a consumer located at one pharmacy's address strictly prefers abstaining to travelling to the other;

(iii) $V - p < \delta D/2 + \tau/2$, so that, when opening hours are sufficiently short, a consumer at the spatial midpoint whose ideal time is maximally mismatched with both pharmacies strictly prefers the outside option ensuring that partial market coverage occurs for short enough arcs.

Parts (ii) and (iii) jointly imply $2(V - p) - \delta D \in [0, \tau)$, motivating the threshold parameter

$$H \equiv \frac{2(V - p) - \delta D}{\tau} \in [0, 1). \tag{5}$$

H is the maximum total temporal mismatch (across both pharmacies) that a consumer at the spatial midpoint can absorb before exiting the market. Correspondingly, $L^{\text{tr}} \equiv 1 - H$ is the *saturation threshold*: if both pharmacies' arcs have duration at least L^{tr}, every consumer is served by at least one pharmacy, although consumers whose ideal time falls outside both arcs are served with a positive but tolerable temporal mismatch. The binding case is coincident arcs at a common midpoint, where the joint mismatch reaches its maximum $\max_{t\in\mathbb{S}^1}[\,g_A(t)+g_B(t)\,]=1-L$; staggering can only reduce this maximum, so $L \geq L^{\text{tr}}$ is sufficient for full coverage regardless of how the two arcs are positioned.

Demand decomposition. Given the symmetric placement of the pharmacies and the linear-in-distance disutility, the consumer at time t who is just indifferent between A and B is located at

$$d^*(t) = \frac{D}{2} + \frac{\tau}{2\delta}\big[g_B(t) - g_A(t)\big]. \tag{6}$$

The *participation radius* of pharmacy j at time t — the maximum distance at which a consumer at time t obtains non-negative utility from j — is

$$r_j(t) = \frac{V - p - \tau\, g_j(t)}{\delta}. \tag{7}$$

At each t, the demand of A is determined by whichever of $d^*(t)$ and $r_A(t)$ is smaller, and similarly for B. The two participation radii fail to cover the segment — leaving a gap in which some consumers exit — exactly when $r_A(t) + r_B(t) < D$; substituting (7) gives $[2(V-p) - \tau(g_A + g_B)]/\delta < D$, equivalently $g_A(t) + g_B(t) > H$ with H as in (5). This motivates partitioning the time circle into two regimes:

$$E \equiv \big\{t \in \mathbb{S}^1 : g_A(t) + g_B(t) > H\big\} \qquad \text{(partial coverage at } t\text{)}, \tag{8}$$

$$C \equiv \big\{t \in \mathbb{S}^1 : g_A(t) + g_B(t) \leq H\big\} \qquad \text{(full coverage at } t\text{)}. \tag{9}$$

On C, the indifferent location $d^*(t)$ is interior to $[0, D]$ and the two pharmacies split the spatial market between them. On E, $r_A(t) + r_B(t) < D$ and a positive-measure spatial fringe in the middle of $[0, D]$ exits the market. The per-time spatial share of pharmacy j is

$$q_j(t) = \begin{cases} d^*(t)/D & \text{if } j = A \text{ and } t \in C, \\ (D - d^*(t))/D & \text{if } j = B \text{ and } t \in C, \\ r_j(t)/D & \text{if } t \in E. \end{cases} \tag{10}$$

The aggregate demand of j is

$$Q_j = N \int_{\mathbb{S}^1} q_j(t)\, \rho_\mu(t)\, dt. \tag{11}$$

The rival's opening hours enter Q_j through two distinct channels. First, on the full-coverage region C the indifferent location $d^*(t)$ in (6) depends on the rival's mismatch

$g_{-j}(t)$, so a longer rival arc shifts the indifference cut and reduces j's share at those times—the business-stealing margin. Second, the partition (E, C) itself depends on *both* arcs through the sum $g_A + g_B$: as shown above, a time slot is fully or partially covered according to whether $g_A(t) + g_B(t) \lessgtr H$, a criterion symmetric in the two pharmacies' mismatches. The only component of q_j that is independent of the rival is the per-time share *within* E, where $q_j(t) = r_j(t)/D$; this independence is economically correct, because on E the two participation radii do not overlap and each pharmacy serves an uncontested local-monopoly catchment separated by the dropout fringe.

Figure 3 illustrates this decomposition for a generic, asymmetric configuration in which the two pharmacies choose different midpoints and durations. The horizontal axis is the time circle cut at the peak, so the off-peak trough lies at the centre; the vertical axis is the spatial segment. Near the peak the two catchments meet at the indifferent location $d^*(t)$ and the firms compete head-to-head; at sufficiently off-peak times the participation radii fall short of one another and a dropout fringe E opens in the middle, where consumers abstain.

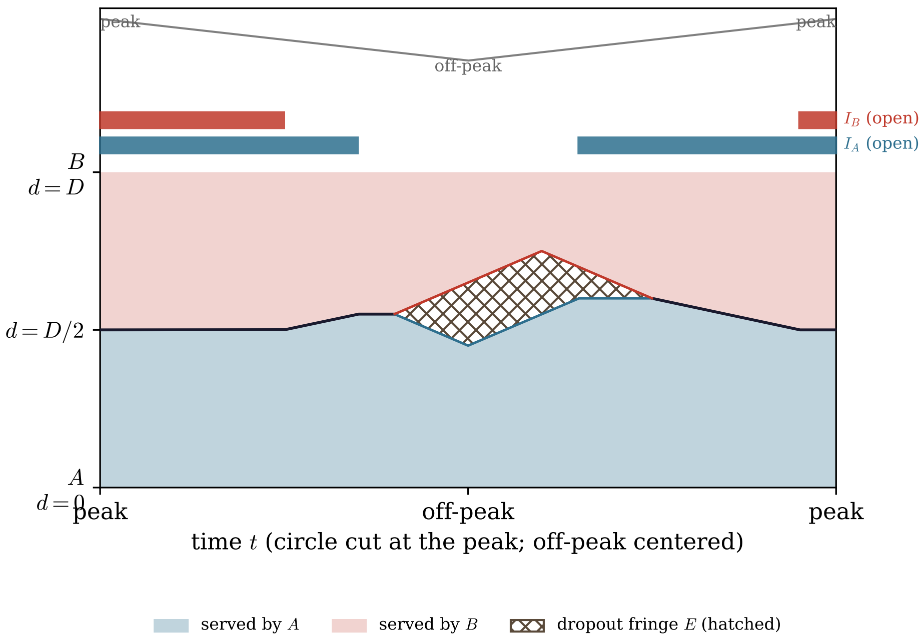


Figure 3: Demand in a general configuration with unequal midpoints and durations

Notes: Blue: consumers served by A; red: served by B; hatched: dropout fringe E. Horizontal axis is the time circle cut at the peak (off-peak centered). Illustrative parameters $V - p = 0.6$, $\delta = \tau = D = 1$ satisfy Assumption 1.

Cost and profit. The hourly operating costs include labor and other variable costs such as electricity. We assume the following convex cost function, in which parameter γ measures the slope of the marginal cost.

Assumption 2. Pharmacy $j \in \{A, B\}$ incurs an operating cost

$$C(L_j) = \tfrac{1}{2}\gamma\, L_j^2, \qquad \gamma > 0.$$

Since both retail price p and wholesale price w are regulated, each pharmacy earns a constant unit margin $m \equiv p - w > 0$ on every unit sold. The pharmacies simultaneously choose their arcs (L_j, m_j) to maximize profit:

$$\pi_j = m\, Q_j(I_A, I_B) - C(L_j), \qquad j \in \{A, B\}. \tag{12}$$

4.2 Equilibrium Analysis

This section establishes the existence of a symmetric Nash equilibrium and characterizes it, then rules out asymmetric durations among equilibria with a common midpoint at the demand peak; together, these pin down the symmetric profile as the unique equilibrium within the peak-centered class. We then show that this peak-centered profile is the unique equilibrium configuration in the full-coverage regime (for non-uniform demand; under uniform demand the duration is unique but the common midpoint is indeterminate), and that it remains an equilibrium under partial coverage as long as demand is not too flat; when demand is sufficiently flat the peak ceases to be an equilibrium and the firms gain by staggering their opening hours, as established in Appendix E.5. As prerequisite information, we decompose the marginal revenue and characterize how marginal changes in L_j and m_j affect each pharmacy's demand in Appendix E.2.

4.2.1 Symmetric Nash Equilibrium

We focus on the natural class of symmetric equilibria in which both pharmacies center their arcs at the demand peak.

Theorem 1 (Existence and characterization of the symmetric equilibrium)**.** Under Assumptions 1 and 2:

(a) *(Unconditional.)* The first-order condition

$$K\, \phi(L^*; \mu, H) = \gamma\, L^*, \tag{13}$$

with

$$K \equiv mN\tau/(4\delta D), \tag{14}$$

$$\phi(L;\mu,H) \equiv \big(1 - G(L;\mu)\big) + w_E(L;\mu,H), \tag{15}$$

$$G(L;\mu) = L\,(2-\mu) - (1-\mu)\,L^2, \tag{16}$$

$$w_E(L;\mu,H) = \begin{cases} \mu\,(L^{\text{tr}} - L) + (1-\mu)\,(L^{\text{tr}} - L)^2, & L < L^{\text{tr}}, \\ 0, & L \geq L^{\text{tr}}, \end{cases} \tag{17}$$

and $L^{\text{tr}} = 1 - H$, admits a unique solution $L^* \in (0,1)$; the solution is interior because the marginal benefit strictly exceeds the marginal cost at $L = 0$ and falls strictly short of it at $L = 1$, so corner arcs $L \in \{0,1\}$ are never best responses.

(b) *(Conditional.)* The symmetric peak-centered profile $(m_A^*, L_A^*) = (m_B^*, L_B^*) = (1/2, L^*)$ is a Nash equilibrium whenever either

  (i) $L^* \geq L^{\text{tr}}$ (the market is fully covered in equilibrium), or

  (ii) $\mu \leq \mu_{\text{NE}}(H, L^*)$ (demand is sufficiently peaked), where μ_{NE} is the exact equilibrium threshold defined in Appendix E.5.

Figure 4 shows the equilibrium configuration. In contrast to the asymmetric case of Figure 3, both arcs are centered on the peak with the common duration L^*, the picture is symmetric about both the peak and the spatial mid-line, the indifferent location is flat at $d^* = D/2$, and the dropout fringe is a symmetric lens confined to the off-peak centre.

The determination of L^* is shown in Figure 5. Marginal benefit $K\phi(L)$ is downward-sloping throughout and marginal cost γL is upward-sloping, so they cross exactly once, giving the unique interior L^* of Theorem 1. Marginal benefit is steeper below the saturation threshold L^{tr} and flatter above it: once the market is fully covered the market-expansion channel is exhausted and only business-stealing remains. Because ϕ is decreasing on both branches, the kink at L^{tr} does not threaten uniqueness.

Proposition 1 (No asymmetric durations at a common peak midpoint)**.** Under Assumptions 1 and 2, there is no Nash equilibrium with $m_A = m_B = 1/2$ and $L_A \neq L_B$.

The economic intuition is that a pharmacy with a shorter arc has a strictly larger set of times over which it can recapture demand by lengthening its arc — relative to the pharmacy with the longer arc. With identical, strictly convex costs, this asymmetric

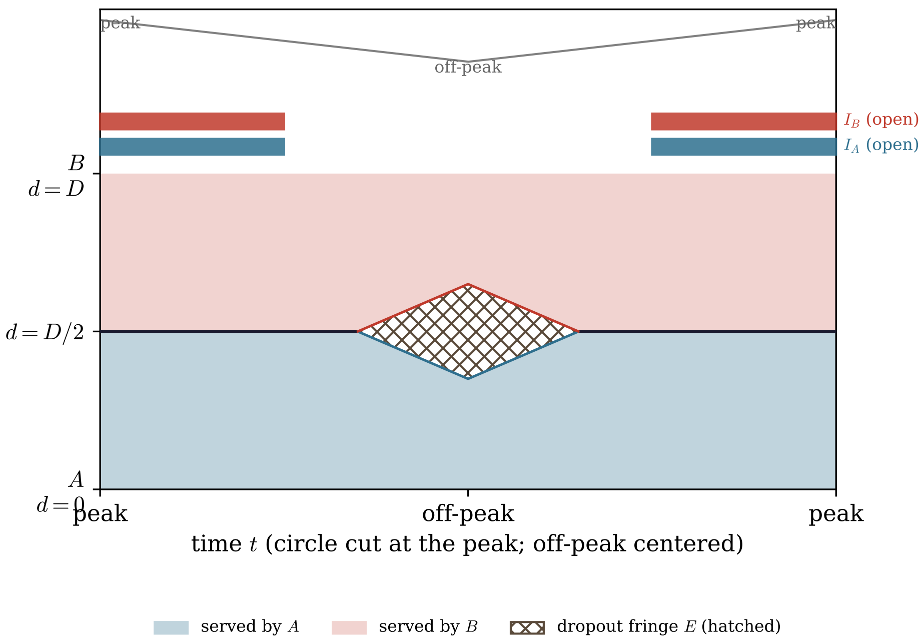


Figure 4: The symmetric equilibrium: both pharmacies centre their arcs at the peak with the common duration L^*

Notes: The contested boundary is flat at $d^* = D/2$ and the dropout fringe E is a symmetric off-peak lens. Same illustrative parameters as Figure 3.

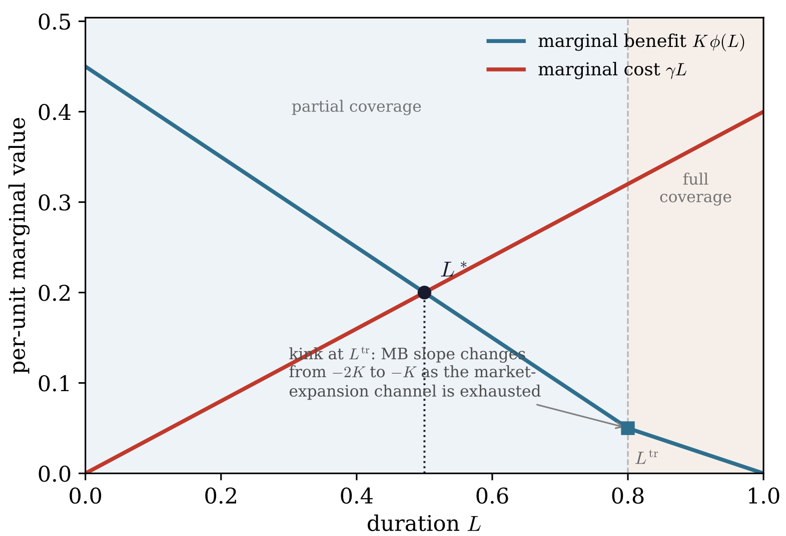


Figure 5: First-order condition: unique interior L^*

Notes: The downward-sloping marginal benefit $K\phi(L)$ crosses the rising marginal cost γL once, at the unique interior equilibrium L^*. The figure is drawn for the uniform case $\mu = 1$, in which ϕ is piecewise linear and the slope of $K\phi$ changes from $-2K$ to $-K$ at the saturation threshold L^{tr}, where the market-expansion channel is exhausted. For $\mu < 1$, ϕ is piecewise quadratic and these slopes are not constant, but ϕ remains strictly decreasing on both branches, so the single-crossing conclusion is unchanged.

marginal incentive cannot be reconciled with $L_A^* > L_B^*$. Together, Theorem 1 and Proposition 1 pin down the symmetric profile $(1/2,\, L^*)$ as the unique Nash equilibrium with peak-centered midpoints.

Remark 1 (Local structure of the peak under full coverage)**.** In the full-coverage regime the own-profit Hessian at the symmetric peak is diagonal and, for non-uniform demand ($\mu < 1$), negative definite, so the profile is a strict local optimum, and the midpoint and duration choices are locally orthogonal — a shift of the midpoint trades density symmetrically between the two ends of the arc, a first-order effect independent of arc length. This is what justifies the sequential, one-variable-at-a-time treatment of the two decisions. The midpoint curvature is proportional to the density slope $1-\mu$ and vanishes under uniform demand ($\mu = 1$), where the midpoint eigenvalue is zero — consistent with the continuum of midpoint-equivalent equilibria. The computation is in Appendix E.4.

4.2.2 Equilibrium Configurations Across Coverage Regimes

Remark 1 establishes that the peak is locally stable under full coverage; in that regime the conclusion is in fact global. Total served demand is fixed at N, so a midpoint shift cannot create surplus—it only relocates the contested boundary while moving an arc into thinner density. The same holds for a *coordinated* symmetric stagger in which both firms move to opposite sides of the peak: joint demand is unchanged, so staggering is a pure transfer between the firms. Pulling off the peak therefore sacrifices density with no offsetting gain, so for non-uniform demand ($\mu < 1$) the peak-centered profile is the unique equilibrium; under uniform demand its duration is still unique but the common midpoint is indeterminate.

Partial coverage is qualitatively different because total served demand is no longer fixed. By shifting their arcs apart the firms cover more distinct times and recapture part of the off-peak fringe that would otherwise abstain, so staggering can *expand* demand rather than merely redistribute it. The peak survives only when this expansion motive is weak—that is, when demand is not too flat. Appendix E.5 sharpens "not too flat" into an explicit threshold: the peak-centered profile is a Nash equilibrium for $\mu \leq \mu_{\mathrm{NE}}(H, L^*)$, the exact best-response threshold, which is bounded above by the closed-form pure-timing threshold $\mu_g(H, L^*)$ and coincides with it numerically. This equilibrium threshold lies strictly below the local second-derivative threshold μ^*, so local stability is necessary but not sufficient. For $\mu > \mu_g$ the firms gain by spreading their hours toward fuller temporal coverage, consistent with the asymmetric opening times documented in Section 6.3.2.

4.2.3 Closed-Form Special Case: Uniform Time Density

A useful and tractable special case obtains for $\mu = 1$, where the temporal density is uniform. The functions in (15)–(17) simplify to:

$$G(L;1) = L,$$
$$w_E(L;1,H) = \begin{cases} L^{\text{tr}} - L, & L < L^{\text{tr}}, \\ 0, & L \geq L^{\text{tr}}, \end{cases}$$
$$\phi(L;1,H) = \begin{cases} 1 + L^{\text{tr}} - 2L, & L < L^{\text{tr}}, \\ 1 - L, & L \geq L^{\text{tr}}. \end{cases}$$

The first-order condition (13) then admits closed-form solutions[14]:

$$L^*_{\text{full}} = \frac{mN\tau}{mN\tau + 4\gamma\delta D}, \qquad L^*_{\text{part}} = \frac{mN\tau\,(1 + L^{\text{tr}})}{2\,mN\tau + 4\gamma\delta D}. \tag{18}$$

The full-coverage formula L^*_{full} applies whenever $L^*_{\text{full}} \geq L^{\text{tr}}$, and the partial-coverage formula L^*_{part} otherwise; the two expressions agree at the boundary $L^* = L^{\text{tr}}$ by the continuity established in Step 3 of the proof of Theorem 1.

The full-coverage formula admits a particularly clean interpretation. Define the composite parameter

$$\theta \equiv \frac{mN\tau}{4\gamma\delta D}, \tag{19}$$

which measures the ratio of the demand-benefit scale K to the marginal-cost slope γ, so that $\theta = K/\gamma$. Then $L^*_{\text{full}} = \theta/(1+\theta)$.

Remark 2 (Status of L^*_{part} at $\mu = 1$)**.** The formulas in (18) characterize the *symmetric peak-centered candidate*—the solution to the duration FOC (13) under the maintained restriction $m_A = m_B = 1/2$. By the analysis of Section 4.2.2, this candidate fails to be a Nash equilibrium in the partial-coverage regime when $\mu > \mu_g$, and in particular at $\mu = 1$, where the absence of any density anchoring leaves staggering strictly profitable. We nevertheless retain $L^*_{\text{part}}(\mu = 1)$ below as a tractable analytical benchmark: its closed form transparently isolates the cost-scale and coverage-threshold dependencies of the symmetric FOC, and the qualitative comparative-statics patterns it generates carry over to the equilibrium peak-centered profile in the range $\mu \leq \mu_{\text{NE}}$ where that profile is

[14] See Remark 2: the closed forms (18) characterise the symmetric peak-centered candidate (solution of the duration FOC under $m_A = m_B = 1/2$), which by Appendix E.5 is not a Nash equilibrium in the partial-coverage regime when $\mu > \mu_g$; we retain $L^*_{\text{part}}(\mu = 1)$ only as an analytical benchmark.

realised. Statements in Section 4.3 about "the equilibrium duration" at $\mu = 1$ partial coverage should be read in this benchmark sense.

4.3 Comparative Statics

The comparative statics below concern the equilibrium duration L^* and apply throughout the peak-centered regime. Throughout this subsection, the exogenous primitives are N, m, τ, γ, δ, D, μ, and the consumer surplus level V (with p and the wholesale price held fixed). The coverage threshold $H = [2(V - p) - \delta D]/\tau$ is *not* a primitive but a composite of V, δ, D, and τ; consequently, each of these four parameters acts on L^* both directly and indirectly through H. This dual dependence makes the regime distinction essential.

Proposition 2 (First-order comparative statics of L^* by coverage regime)**.** Let L^* be the peak-centered duration characterized by (13). In parameter regions where the peak-centered profile is a Nash equilibrium, the following are the local comparative statics of the equilibrium duration.[15]

$\partial L^*/\partial(\cdot)$	N	m	τ	μ	γ	δ	D	V
Full coverage	+	+	+	+	−	−	−	0
Partial coverage	+	+	+	+	−	?	?	−

"?" denotes sign ambiguity: a negative direct effect through the cost scale and a positive indirect effect through the coverage threshold H. Although τ and V also enter H, their net signs remain positive and negative, respectively; only δ and D feature conflicting direct and threshold channels.

Figure 6 plots the full-coverage closed form against the two leading parameters. Equilibrium hours fall in the inter-pharmacy distance D and rise in the catchment population N, and the curvature differs by side: L^* is convex in the cost-side parameter D and concave in the benefit-side parameter N, the pattern established in Proposition 3. Each curve is drawn solid where the full-coverage expression is the realised equilibrium and dashed where the partial-coverage branch takes over.

The economic content is as follows. Larger catchment populations N, higher unit margins m, more impatient consumers (higher τ), and a flatter intraday demand profile

[15] One may examine the partial effect of the threshold itself: $\text{sign}(\partial L^*/\partial H) = \text{sign}(\phi_H)$, negative under partial coverage and zero under full coverage. This must *not* be added to the primitive comparative statics, since τ, δ, D, V already transmit their full effect on L^* partly through H; reporting $\partial L^*/\partial H$ alongside them would double-count that channel.

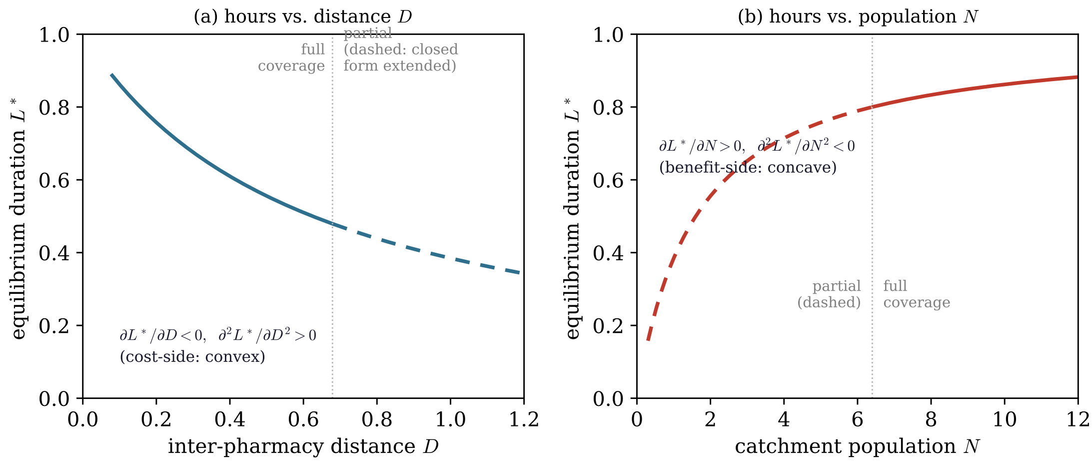


Figure 6: Comparative statics of the equilibrium duration (full-coverage closed form)

Notes: (a) L^* is decreasing and convex in distance D; (b) L^* is increasing and concave in population N. Solid: full-coverage region; dashed: the closed form extended past the regime boundary.

(higher μ) all raise the marginal benefit of being open and lengthen equilibrium hours in either regime; a steeper marginal-cost slope γ shortens them. The effect of inter-pharmacy distance D — the central object of the empirical analysis — is unambiguously negative whenever the market is fully covered: greater distance softens the business-stealing rivalry and shortens hours, and this remains the sign of the direct channel in every regime. Under partial coverage, however, a larger D also lowers the surplus available at the spatial periphery (it reduces H and raises the saturation threshold L^{tr}), enlarging the dropout fringe and strengthening the offsetting market-expansion incentive to stay open. The net effect can in principle reverse: the closed-form example in the proof of Proposition 2 exhibits $\partial L^*_{\text{part}}/\partial D > 0$ for the symmetric FOC candidate, and Figure 7 confirms that the reversal is realised at a genuine, sufficiently peaked equilibrium. The empirical prediction of a negative distance–hours relationship therefore holds cleanly in markets that are close to fully covered, while the model delivers the additional, testable implication that the relationship should weaken — and may even reverse — in markets with substantial unmet peripheral demand. The surplus level V has no effect under full coverage but shortens hours under partial coverage, through the same threshold channel: a more valuable good makes consumers more tolerant of inconvenience, thins the dropout fringe, and weakens the expansion motive.

Proposition 3 (Second-derivative comparative statics, closed form: full-coverage branch)**.** In the closed-form full-coverage case $\mu = 1$ with $L^* = L^*_{\text{full}}$ from (18), the equilibrium duration satisfies

$$\frac{\partial^2 L^*}{\partial N^2}, \frac{\partial^2 L^*}{\partial m^2}, \frac{\partial^2 L^*}{\partial \tau^2} < 0, \qquad \frac{\partial^2 L^*}{\partial \gamma^2}, \frac{\partial^2 L^*}{\partial \delta^2}, \frac{\partial^2 L^*}{\partial D^2} > 0.$$

The second-derivative signs are intuitive: the benefit-side parameters N, m, τ have diminishing marginal effects on the optimal duration (the function is concave), while the cost-side parameters γ, δ, D have effects that decay in magnitude as the parameter grows large (the function is convex). The empirical implication for the distance variable D is that the negative relationship between distance and opening hours should diminish as distance grows — motivating the quadratic specification used in the empirical analysis.

While Proposition 3 is established in closed form only for $\mu = 1$ and full coverage, the qualitative pattern — concavity in benefit-side parameters and convexity in cost-side parameters — persists for densities slightly below the uniform benchmark ($\mu \lesssim 1$) and for small changes in the primitives that keep the market fully covered. On the full-coverage branch ϕ is smooth in L, μ, and H, and $F_L < 0$ (Step 3 of the proof of Theorem 1) keeps the implicit-function mapping $L^*(\cdot)$ continuously differentiable, so each $\partial^2 L^*/\partial x^2$ is a continuous function of the parameters; since each is strictly signed at the benchmark, it retains that sign on a neighborhood. This argument does not extend across the saturation threshold $L^* = L^{\text{tr}}$, where w_E switches branches and ϕ has a kink in L, so the partial-coverage regime is treated separately in Proposition 4.

The benefit-side curvature (N, m, τ) and the operating-cost curvature (γ) carry over to the partial-coverage regime, whereas the convexity of L^* in the spatial cost parameters δ, D is specific to full coverage: once these parameters also move the coverage threshold H, their second-order effect becomes ambiguous (Proposition 4, proved in Appendix E.3).

Thus, the benefit-side curvature results (N, m, τ) and the operating-cost curvature (γ) are global across both coverage regimes, but the convexity of L^* in the spatial cost parameters δ and D is specific to full coverage. This mirrors the first-order pattern of Proposition 2: δ and D are precisely the parameters transmitting an effect through both the cost scale and the coverage threshold, and the two channels conflict at the level of curvature just as they do at the level of slope. For the empirical specification, the convex (weakening) distance effect that motivates the quadratic term is therefore a property of markets at or near full coverage; in markets with substantial unmet peripheral demand, the curvature in D need not retain that sign.

Figure 7 traces the equilibrium duration across both coverage regimes at a peaked demand profile ($\mu_0 = 0.15$), for which the peak-centered profile is the realized Nash equilibrium at every distance shown—verified directly by checking that no unilateral joint midpoint-duration deviation is profitable when the rival is held at $(1/2, L^*)$. Where the market is fully covered, greater distance softens competition and shortens hours ($\partial L^*/\partial D < 0$), an equilibrium property for every admissible μ. The relationship does not, however, reverse at the coverage boundary: it stays negative through a band of shallow partial coverage, where business-stealing still dominates despite a thin dropout fringe, and turns positive only deeper in the partial regime once the market-expansion channel dominates ($\partial L^*/\partial D > 0$). The minimum of L^* therefore lies strictly inside the partial-coverage region. The empirical implication is correspondingly graded: a negative distance–hours relationship is a property of well-served and mildly under-served markets alike, and weakens or reverses only where peripheral demand goes substantially unmet.

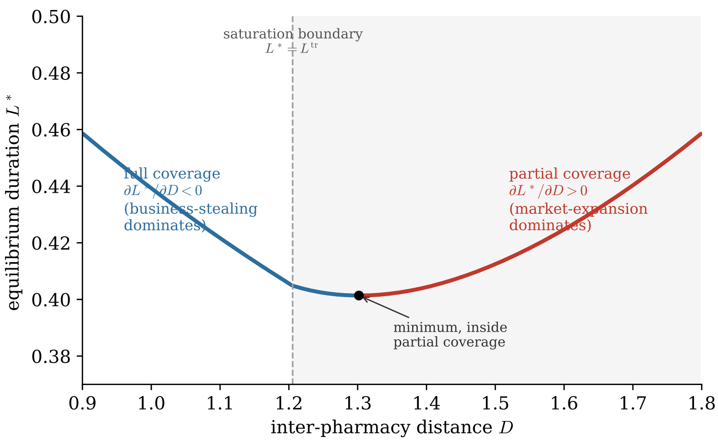


Figure 7: Distance and the numerically verified peak-centred equilibrium across coverage regimes

Notes: The equilibrium duration falls with distance through full coverage and a band of shallow partial coverage (blue) and rises once the market-expansion channel dominates deeper in the partial regime (red); the minimum lies *inside* the partial-coverage region (shaded), to the right of the saturation boundary $L^* = L^{\text{tr}}$ (dashed). Drawn at $\mu_0 = 0.15$, $V - p = 0.9$, $\gamma = 0.2$ (with $m = N = \tau = \delta = 1$); these differ from the other figures so the regime crossing is visible. At this μ_0 the peak-centered profile is the realised Nash equilibrium throughout the plotted range, confirmed by a direct best-response search (Appendix E.5).

5 Data

In this section, we describe in detail the main components of our data, namely the population grid data, the opening hours of pharmacies, and the data on distances between competitors. Data sources are listed in Appendix D which also includes some computational notes relating to road distances.

5.1 Population Grids

As the population data we use is the 1 x 1 kilometer (km) population grid of Finland, which includes each populated grid cell within the surface area of Finland, the total population in the grid cell, and the midpoints of the grid cells. We use the grid from the year 2024, describing the population at the end of that year.[16]

Table 1 has descriptive statistics for grid cell population and the distances from each grid cell to its nearest and second nearest pharmacy. Note that these are unweighted distances from cells to pharmacies, not accounting for the population in each grid. That is, the distances in Table 1 are averaged over the number of grid cells, not over the whole population. We use distances based on the road network as it is a more realistic distance measure between two points. Direct line (*crow fly*) distances neglect geographic barriers, which, in many parts of Finland, are relevant due to the high number of lakes. The details for the calculation of road distances are given in Appendix A and Appendix D.2. In total, there are 97,241 grid cells. The population distribution is heavily skewed to the left, as most of the cells have very small populations. As expected, the grid cells with more population have, on average, shorter distances as these cells are located in dense city areas.

[16]Instead of a 1x1 km grid, we could have alternatively utilized the grid with 250x250 meter grid cells. This would improve accuracy in characterizing competition and catchment population in dense urban areas, such as the capital area of Helsinki (see e.g. Jokelainen et al., 2025). However, in many parts of Finland, the smaller grid size would provide little additional informational value due to the relatively sparse population density of Finland. Furthermore, the main insights of this study are independent of the grid size.

Table 1: Grid level summary statistics: population and distances

Population group	Grid cells	Mean population	Median population	Mean Distance (1) (km)	Mean Distance (2) (km)
1-	42,554	2	2	18.56	31.03
5-	21,358	7	6	14.93	26.19
10-	27,346	26	19	10.85	20.51
100-	3,590	232	200	4.06	14.63
500-	1,163	709	690	2.40	9.08
1000-	1,129	1,981	1,677	1.69	3.58
5000-	93	6,574	6,301	0.72	1.34
10000-	8	13,020	11,473	0.40	0.63
Total	97,241	57	5	14.65	25.79

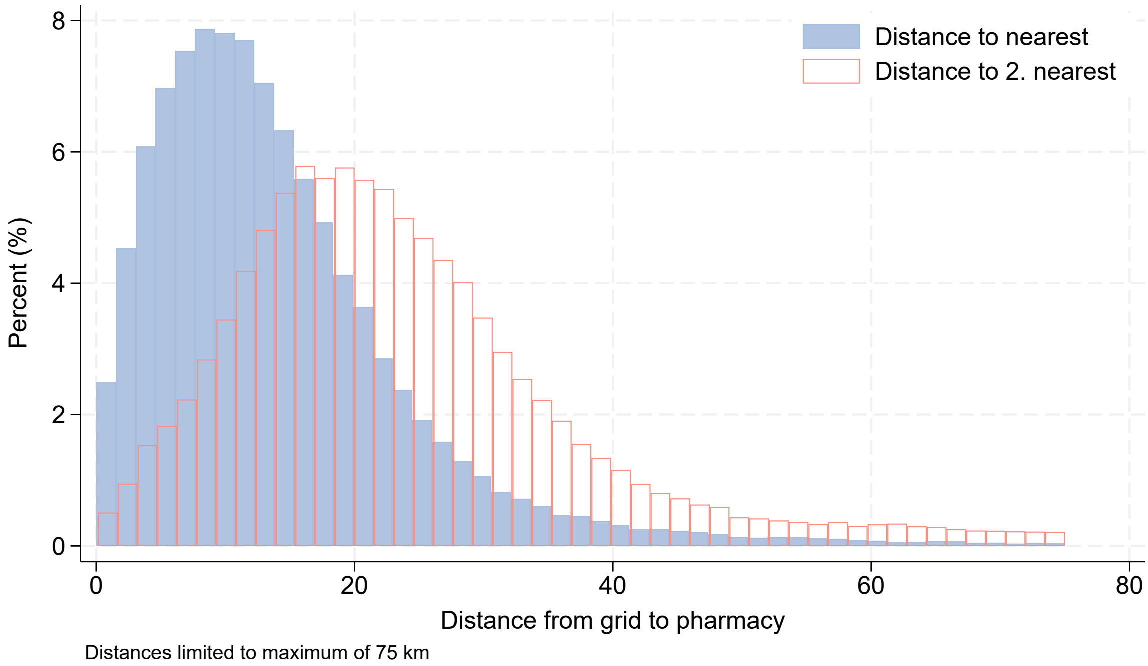
Total population 5,557,765

Distance (1): distance to closest

Distance (2): distance to second closest

The distribution of distances is more visible in Figure 8 where we have both the distance to the nearest pharmacy and the second nearest pharmacy from grid cells. We have excluded outlier distances and only plotted distances below 75 km to make the distribution more readable. Close to zero distances imply that the pharmacy is located close to the center of the grid cell. The distances to the second nearest pharmacy are also quite small in some cases, meaning that the two closest pharmacies for a given grid cell are located almost in the same location.

Figure 8: Distances from grid cells to pharmacies



5.2 Pharmacy Opening Hours, Locations and Distances

Next, we describe the pharmacy opening hours summarized at the weekly level, the catchment population for each pharmacy, and the distances to the competitors.

5.2.1 Weekly opening hours

Summary statistics for weekly opening hours are in Table 2. YA pharmacies are presented separately. In total, there are 833 pharmacy outlets, of which 17 are YA pharmacies. On average, main pharmacies are open much longer than branch pharmacies. Conditional branches are open less than entitled branches on average. The Helsinki University Pharmacy (*Helsinki YA*) has the longest opening hours, and YA also has one outlet that is always open (168 hours a week).

Table 2: Total weekly opening hours in pharmacies

	count	mean	sd	min	max
All pharmacies (excl. YA)	816	54.3	14.47	8.0	112.0
—Main pharmacies	647	58.6	12.52	35.0	112.0
—Branch pharmacies	169	38.0	8.60	8.0	68.0
By branch status:					
—*Conditional*	98	34.4	7.89	8.0	50.0
—*Entitled*	71	42.8	7.04	32.5	68.0
Helsinki YA	17	96.4	20.96	77.0	168.0

Besides the type of pharmacy outlet, several other factors might be related to opening hours. In Table 3 we have presented three such variables. First, we consider whether the pharmacy is the only one in the municipality. This might correspond to monopolistic market conditions in the area. Pharmacies that are the only one in their municipalities are open approximately 10 hours less on average. Mostly, this is likely explained by the local demand conditions. But it could also suggest that with less competitive pressure, pharmacies might find it profitable to stay open for a shorter period of time.

Second, the proximity to larger retail stores or shopping centers can also matter. Pharmacies might either voluntarily coordinate their opening hours to match the opening hours of other stores, or they might have contractual obligations to keep the pharmacy open as long as the shopping center itself is open. The difference is very clear, as pharmacies located near a large shopping outlet are open around 20 hours more on average in a week. Practically all pharmacies in Finland are located near some other services, such as smaller grocery stores. Thus, this variable only captures the effect of being located near a major retail concentration.

Third, there might be differences between main pharmacies in their opening hours depending on whether they have a branch or not. If the pharmacist has a branch or branches, pharmacist might need to divide her time between more than one outlet. In practice, pharmacist might have hired someone to take care of the daily operations of the branch, so it is also possible that having a branch has no effect on the opening hours of the main pharmacy. There is a small difference between the two groups, but on average, having a branch does not greatly affect the opening hours of main pharmacies.

Table 3: Additional opening hour statistics for pharmacies

Total weekly hours (h)*	count	mean	sd	min	max
Number of pharmacies in municipality					
—Multiple pharmacies in municipality	643	56.6	15.1	8	112
—One pharmacy in municipality	173	46.0	7.2	24	67
Distance to shop**					
—Distance to shop above 200m	629	49.8	12.3	8	102
—Distance to shop less than 200m	187	69.5	10.4	40	112
Main has a branch					
—No	501	59.0	12.3	36	112
—Yes	146	57.1	13.3	35	101

*YA excluded

**Shop refers here to a shopping center or a large hypermarket

Obviously, many other factors might be related to opening hours, such as public transport access, the availability of skilled workforce, the presence of nearby office or healthcare facilities, and whether the pharmacy has an online service. However, many of these other factors are explained by the concentration of population and the resulting higher demand. Thus, these other factors would ultimately capture the same underlying effect that the catchment population already captures.

5.2.2 Catchment population for pharmacies

The catchment population of pharmacies is summarized in Table 4. The detailed definition of catchment population is given in Appendix A. We report the distance weighted catchment populations as populations further away should account less for the total catchment population of a given pharmacy. Weighted population is also used in the estimations in Section 6. The weighting scheme allocates the grid cell population between the two competing pharmacies according to their distances from this cell. Allocating the whole population for both pharmacies would count the population twice. Allocating the entire population solely to the closest pharmacy would not be desirable given our theoretical set up where the population is divided between the competing pharmacies.

Main pharmacies serve more of the population on average than branch pharmacies. At a minimum, some main pharmacies serve no one. Obviously, this is not the reality; it is a result of our catchment definition and the consequent data imputation. See Appendix A.4 for details about data imputation. Conditional branches serve, on average, roughly three times less of the population than entitled branches, again validating the notion that conditional branches are located in areas of smaller demand.

Table 4: Distance weighted catchment population

	count	mean	sd	min	max
All pharmacies (excl. YA)	816	6,655.8	4,441.5	0.0	27,399
—Main pharmacies	647	7,377.5	4,444.7	0.0	27,399
—Branch pharmacies	169	3,893.0	3,169.8	665.6	19,738
By branch status:					
—Conditional	98	2,038.3	999.5	760.7	6,112
—Entitled	71	6,452.9	3,356.8	665.6	19,738
Helsinki YA	17	7,446.6	4,940.9	0.0	18,721

Distance weighted population for which pharmacy is either closest or 2. closest.

5.2.3 Distance to competitors

The distance to competition is summarized in Table 5. For each pharmacy, there is a set of other pharmacies that form the set of relevant competitors (see Appendix A). Based on this set, we calculate the average distance to competitors for each pharmacy. We weight the distance with the catchment population throughout our analysis, since competitors for which the shared catchment population is larger should be given more weight in calculating the average distance (see Appendix A.3). In other words, we do not want to give too much weight to competitors with whom the pharmacy shares very little catchment population. Again, since some pharmacies were neither the closest nor the second closest to any grid cell, it was not possible to determine the set of relevant competitors for these pharmacies following our definition. In these cases, we have set the distance equal to the distance to the closest other pharmacy (see Appendix A.4).

Table 5: Population weighted average distance to competitors

	count	mean	sd	min	max
All pharmacies (excl. YA)	816	13.4	15.95	0.1	180.1
—Main pharmacies	647	12.4	15.85	0.1	180.1
—Branch pharmacies	169	17.3	15.80	0.8	140.5
By branch status:					
—*Conditional*	98	25.1	16.30	5.0	140.5
—*Entitled*	71	6.5	5.32	0.8	24.9
Helsinki YA	17	1.1	0.72	0.0	2.3

Distances in kilometers (km)

There is one caveat in our measure of distance to competition. Since distances are calculated using all outlets regardless of their main/branch status, it is possible that the closest competitor for a given main pharmacy is its' own branch or the other way around. Obviously, this is not truly a competitive situation, as the same pharmacist decides the opening hours of both outlets.

Consequently, what follows is that we operate under the assumption that each outlet functions as an individual pharmacy outlet. This is also in line with our theoretical model, which does not differentiate between main and branch pharmacies. The assumption can be considered viable in the sense that if branches operated as individual main pharmacies, they would probably have shorter hours since branches are located in areas where the demand is smaller to begin with. In principle, this problem could be empirically tackled by calculating the average distance based only on true competitors, neglecting your own main or branch pharmacies. This, however, would not correspond to our grid based definition of catchment areas or relevant competitors. For customers in each grid cell, the relevant outlets are the two closest pharmacies, regardless of whether they belong to the same main-branch pair or not. The assumption of independent outlets keeps the interpretation of empirical estimations more simplistic, as we can neglect the possible dependencies between two or more outlets.[17]

Lastly, the average distance masks the fact that the closest competitor might be near, although, on average, the other relevant competitors might be further away. Thus, in our empirical setting, we will also use the minimum distance to the closest competitor

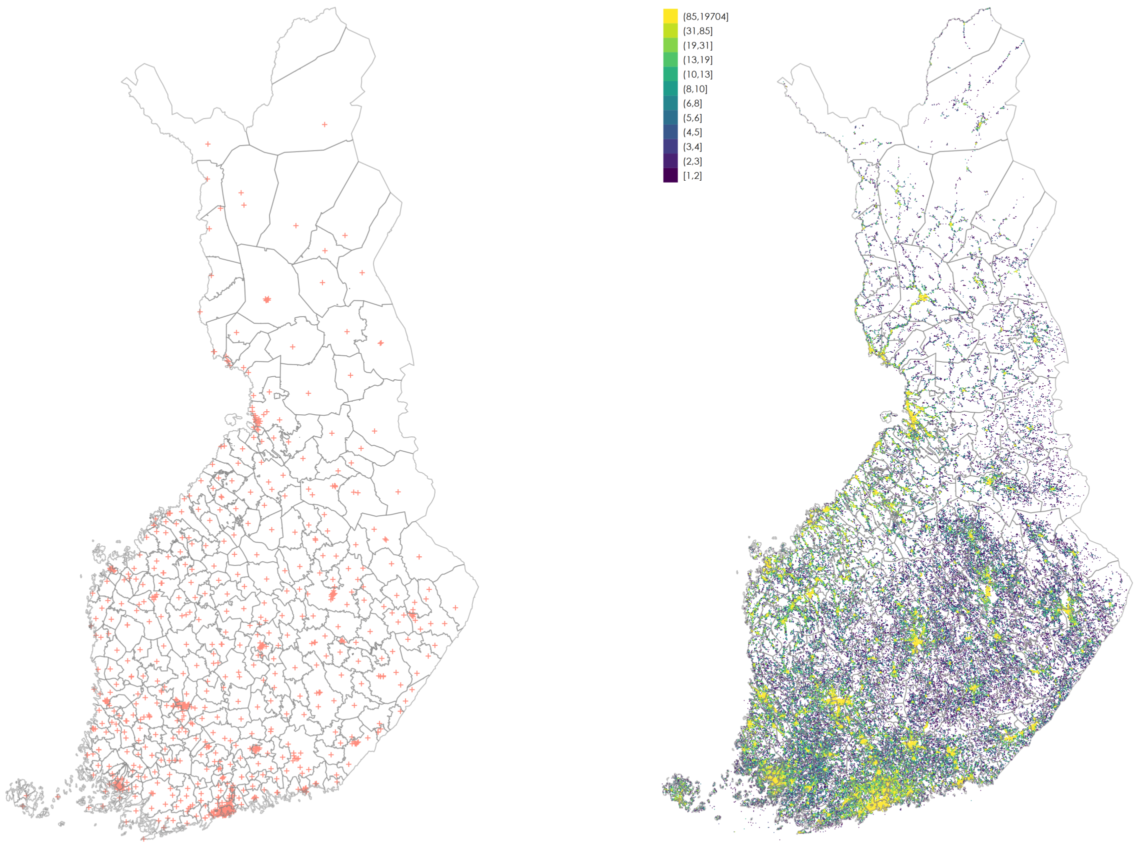
[17] Recall that one main pharmacy can have up to three branches, so it is even possible that two branches of the same main pharmacy are the closest competitors to each other.

as an alternative measure of distance as a robustness check. The summary statistics of the minimum distance are in Appendix C.

5.3 Spatial Illustration of Data

First, we illustrate the location of pharmacies and the population in grid cells in Figures 9a and 9b, along with the municipal borders. Most pharmacies are located in the southern part of Finland, while the northern part has relatively few pharmacies. The clusters of pharmacies depict larger cities. As expected, the distribution of pharmacies is strongly correlated with the location of the population. Finland is a sparsely populated country, as a large proportion of grid cells include only a few inhabitants, and large areas of Finland have no population at all.

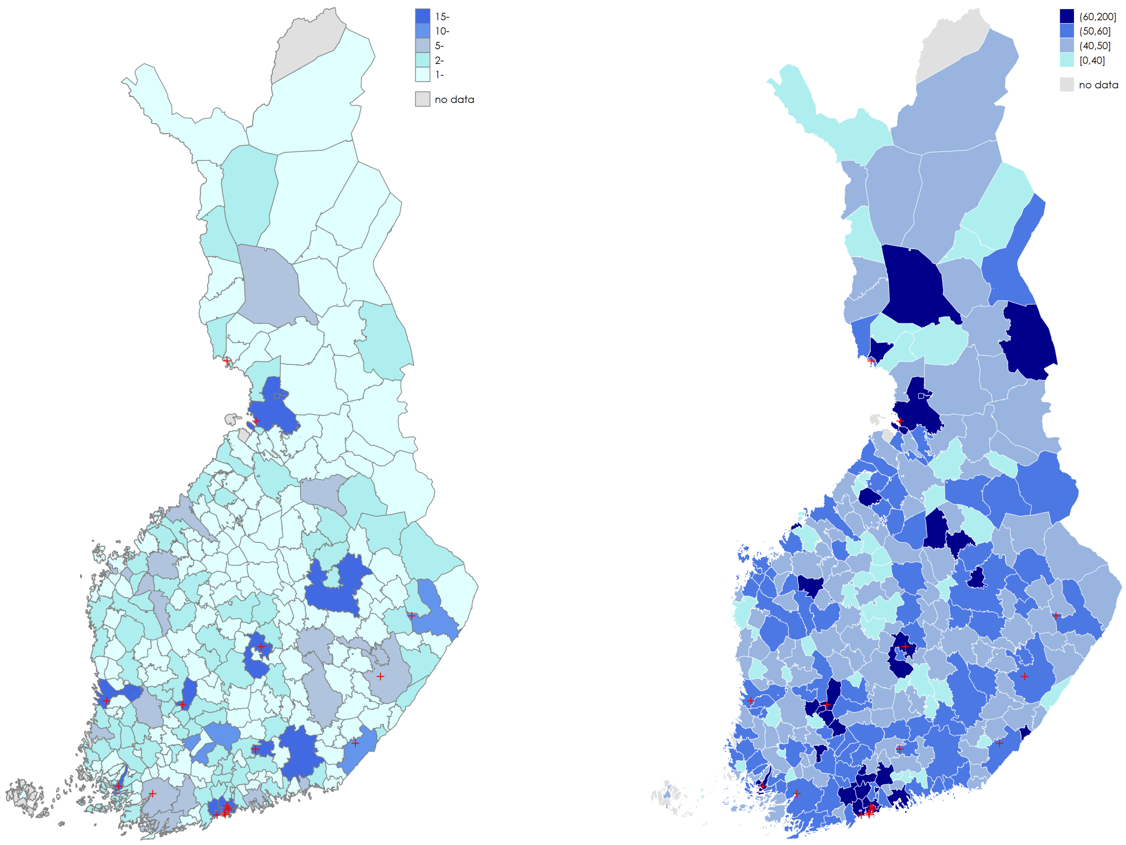
Figure 9: Pharmacies and population in Finland



(a) Pharmacy network **(b)** Population grid cells

Next, we illustrate the number of pharmacies and their average weekly opening hours at the municipal level.[18] Although we operate at the level of grid cells in our empirical analysis, using the municipal level simplifies the illustration of the spatial distribution of pharmacy opening hours. We also denote the location of YA pharmacies, as they might have a significant effect on the average weekly opening hours in the municipality. Many municipalities have only one pharmacy, and a large fraction of municipalities have fewer than five pharmacies. For most municipalities, average weekly opening hours are within the range of 40 to 60 hours. Interestingly, there are also some smaller municipalities in which the average hours are greater than 60 hours.

Figure 10: Pharmacies and opening hours in municipalities



(a) The number of pharmacies

(b) The average weekly opening hours

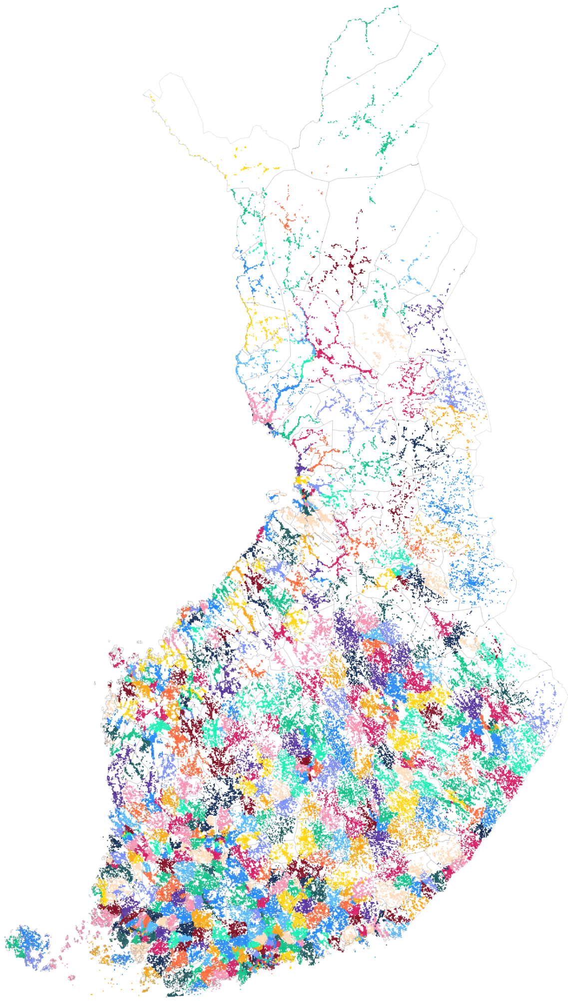
Notes: Red markers indicate the location of a Helsinki University pharmacy (YA).

The approximate catchment areas for the pharmacies that are the closest to some population grid cells are illustrated in Figure 11. We say approximate, because there are slight computational deviations from such catchment areas that would be geographically

[18]In Appendix C.2 the same information is illustrated for the capital region of Helsinki.

consistent. Appendix D.2 details these computational issues. Most catchment areas are geographically consistent, and the grid cells form clear, continuous areas. For example, in northern Finland, the shape of the area closely follows the road network, as the population is located near roads. In the largest cities and the capital region around Helsinki, the catchment areas can be quite small due to the large number of pharmacies. Catchment areas also generally do not follow municipal boundaries, a feature that follows from our definition of markets and competitors. Recall that there is a set of pharmacies that is not the closest pharmacy for any grid cell. Consequently, there are fewer catchment areas than there are pharmacies.

Figure 11: Catchment areas for the closest pharmacies



Notes: The map uses 18 different colors to indicate the separate catchment areas.

6 Empirical Results

To estimate the relationship between opening hours and competition, we use several alternative empirical specifications and data structures. First, we examine the relationship at the aggregate level of total weekly opening hours in a cross section of pharmacies. Second, we create a panel at the pharmacy-weekday level. This data structure enables us to examine more closely the variation in opening hours between weekdays. Lastly, we further expand the panel dimension to the grid cell level and construct a cell-weekday level panel to study changes in the total duration of pharmacy opening hours that each grid cell observes from its' two closest pharmacies. In addition to our main estimation results, we run several robustness checks, which are presented in Appendix B.

6.1 Weekly opening hours

In our baseline OLS-models, the total weekly opening hours are explained by the average (weighted) distance to the competitors. The specification is given in Equation 20, in which h_i refers to the weekly opening hours for pharmacy i, D_i refers to the distance measure (*proximity of competition*), and D_i^2 is the distance squared since we allow the effect of distance to change the further the competition is located.

$\boldsymbol{X_i}$ refers to a set of controls, including catchment population, dummy variables indicating whether the pharmacy is close to other large retail stores, and whether the pharmacy is the Helsinki University Pharmacy (YA). We exclude the main and branch status and the branch type as controls since they partly capture the same effects as distance and population, given that the outlet type is partly defined by local demand.

C_i are the county dummies that account for some regional health factors that might affect the demand for pharmacy services.

We cluster the standard errors at the municipal level, as the underlying treatment level, which being the regulator's decision to open new pharmacies, varies at the municipal level. The coefficient estimate for the distance variable can also be interpreted as the response of the opening hours to different geographical configurations of the pharmacy network decided by the regulator. The regression results for the OLS-models are in Table 6.

$$h_i = \alpha + \beta_1 D_i + \beta_2 D_i^2 + \theta \boldsymbol{X_i} + \gamma C_i + \epsilon_i, \tag{20}$$

Table 6: Total weekly hours (hrs/week): OLS-results

	OLS 1	OLS 2	OLS 3	OLS 4
Distance to competition				
Average distance (km)	-0.128**	-0.271**	-0.251**	
	(0.05)	(0.10)	(0.08)	
(Average distance)^2		0.00151*	0.00139*	
		(0.00)	(0.00)	
Minimum distance				-0.257**
				(0.09)
(Minimum distance)^2				0.00170*
				(0.00)
Population effects				
Population	2.683**	2.393**	2.360**	2.445**
	(0.50)	(0.57)	(0.56)	(0.54)
Population^2	-0.0843**	-0.0745**	-0.0796**	-0.0827**
	(0.02)	(0.02)	(0.02)	(0.02)
Other controls				
Shop near †	12.77**	12.11**	12.19**	12.33**
	(0.97)	(1.10)	(1.10)	(1.07)
University pharmacy (YA)	33.51**	32.79**	33.11**	33.43**
	(4.49)	(4.28)	(3.99)	(4.04)
Observations	833	833	833	833
R^2	0.568	0.574	0.597	0.596
SE cluster	Municipal	Municipal	Municipal	Municipal
County dummies			YES	YES

Standard errors in parentheses

Depvar: Weekly opening hours (hrs/week)

†Distance to shop less than 200 m

* $p < 0.05$, ** $p < 0.01$

All models show a statistically significant negative relationship between distance and opening hours. The further the competition is on average, the shorter the opening hours we observe. In the model with the quadratic term, the coefficient corresponds to approximately 1/4 of an hour reduction in opening hours for each kilometer of distance increased. The quadratic term has a positive coefficient, meaning a diminishing relationship between opening hours and distance. Using the minimum distance instead of average distance produces very similar coefficients. Population, on the other hand, has the opposite signs in its' coefficient estimates, implying that a larger catchment population is associated with longer opening hours, but the relationship is again diminishing. The coefficient estimates agree with our theoretical predictions for both variables in terms of the curvature of the effects. These opposite effects also indicate that while close competition might extend opening hours, the catchment population is divided among a higher number of pharmacies, thus shortening opening hours. This observation bears similarities with Jokelainen et al. (2025) who find that deregulation of entry barriers might lead to excess entry and an inefficient scale of operations.

6.2 Endogeneity of Distance Measure

Although the regulator exogenously decides whether to establish a pharmacy in some municipality, pharmacies still have the freedom to choose their location within the municipality (or smaller placement area). This decision might again be affected by the opening hours of other pharmacies within the municipality. Consequently, the distance to competition is not necessarily completely exogenously determined in this setting.

To account for this, we run an instrumental variable regression in which distance and its' squared term are instrumented.[19] Candidates for valid instruments should have only an indirect effect on opening hours through distance and be relatively highly correlated with the distance itself. As pharmacy locations are regulated at the municipal level, a variable such as the land area of the municipality first seems like a valid candidate for an instrument. In practice, pharmacies are still able to be densely located near each other, even in a municipality with a relatively large land area. Thus, administrative borders do not necessarily say much about how widely pharmacies are located. Instead, we construct our instruments based on the geographical unit used in this study, namely the 1x1 km population grid cell. Importantly, the instruments do not utilize population information, since population is entered as a separate control variable. The two candidate instruments Z_1 and Z_2 we construct are the following:

- **Grid cells per pharmacy (Z_1):** The number of grid cells that form the catchment area of a given pharmacy.

[19] One approach to establish a causal link between competition and opening hours would be to utilize new entries and estimate their effect on the opening hours of incumbent pharmacies. However, since entries are relatively infrequent due to the strict licensing policy, such an examination would, at best, be rather limited in scope.

- **Maximum distance from grid cell to pharmacy (Z_2):** Within the grid cells forming the catchment area of a given pharmacy, the maximum distance from any cell midpoint to the pharmacy.

Both candidate instruments describe one aspect of the size of the catchment area. The first instrument Z_1 characterizes the total size of the catchment area in terms of square kilometers. The latter Z_2 characterizes the extent to which the catchment area expands geographically. In both cases, the larger the catchment area, the more likely it is that the average distance to competition is higher. One may ask how this is different, for example, from the land area of the municipality as a possible instrument for which the same logic applies. The subtle difference is in our definition of the catchment area; for every grid cell in the catchment area, there are two pharmacies competing for the population of that cell. Thus, for both instruments, the likelihood of competitor being far away increases the more cells there are within the catchment area or the more distant the furthest cell is. In other words, our catchment area always includes relevant competition, whereas municipality based definitions do not necessarily do so, for example, in cases where there is only one pharmacy in the municipality.

The IV-regression results are presented in Table 7. Compared to the OLS, the results for the distance coefficient vary in models 1a and 1b in terms of the magnitude of the coefficient estimates. Models 2a and 2b produce coefficient estimates that are rather close to the OLS-estimates. Figure C4 in Appendix C.4, illustrates the implied relationship between opening hours with distance and population in a manner similar to what is theoretically presented in Figure 6.

The pattern in coefficient estimates is explained by our specifications and instruments. The difference between 1a and 1b shows the importance of including a quadratic term. The difference between 1a and models 2a and 2b is explained by the performance of our instruments. In model 1a, the squared instrument (Z_1^2) for the quadratic distance term does not perform well, even though the first stage for the main distance effect gives a rather strong relationship between the distance and the instrument. Our first candidate instrument, Z_1, likely suffers from the same problem as the land area of the municipality, since the instrument is basically the size of the catchment area in terms of grid cells. In Appendix C.3 we visually illustrate the difference between the workings of the two instruments. The difference between models 2a and 2b shows that adding an inferior extra instrument does not necessarily improve the performance of the estimated model.

Table 7: Total weekly hours (hrs/week): IV-results

	IV 1a	IV 1b	IV 2a	IV 2b
Distance to competition				
(1) Average distance (km)	-0.809**	-0.106	-0.245**	-0.200*
	(0.24)	(0.06)	(0.09)	(0.08)
(2) (Average distance)^2	0.0145**		0.00128*	0.000996*
	(0.01)		(0.00)	(0.00)
Population effects				
Population	2.059**	2.661**	2.370**	2.477**
	(0.71)	(0.54)	(0.54)	(0.54)
Population^2	-0.0687*	-0.0902**	-0.0799**	-0.0837**
	(0.03)	(0.02)	(0.02)	(0.02)
Observations	833	833	833	833
SE type	Municipal	Municipal	Municipal	Municipal
County dummies	YES	YES	YES	YES
Other controls	YES	YES	YES	YES
Instruments	Z1, sq(Z1)	Z1	Z2,sq(Z2)	both
First stage F (1)	55.36	63.77	81.49	134.3
First stage F (2)	8.064		70.28	63.55
Regressors to instruments	just	just	just	over
K-P F-statistic				51.70

Standard errors in parentheses

Depvar: Weekly opening hours (hrs/week)

* $p < 0.05$, ** $p < 0.01$

The second instrument, Z_2, works better because the maximum distance from the grid cells to pharmacies more closely captures the geographical scope (or extent) of the catchment area. If the most distant grid cell for a given pharmacy is 50 kilometers away, it is quite likely that the competitor for that cell must also be relatively far away.

Table 8 shows the correlations between our distance measure, the instruments, and their squares. Although the number of cells per pharmacy is correlated relatively strongly with the average distance, the correlation significantly diminishes with the squared distance. This is not the case with the maximum distance from grid cell to pharmacy, as the correlation between squared terms is even stronger. Although these correlations alone do not establish instrument validity, together with the obtained first stage F-values and

K-P statistics, they clearly illustrate the difference in the workings of our two candidate instruments.

Table 8: Correlations with instruments

	Average distance	(Average distance)^2
Grid cells per pharmacy	0.62	0.31
(Grid cells per pharmacy)^2	0.52	0.28
Max distance from g-to-p	0.76	0.67
(Max distance from g-to-p)^2	0.67	0.89

Lastly, we consider whether there are any potential threats to our IV design due to alternative path variables, as discussed in Danieli et al. (2026). First, we discuss whether there are any *alternative path outcome* (APO) variables that are associated with the outcome but also with the instrument, consequently creating an alternative path from instrument to outcome that is not through treatment (*distance to competition*). Obviously, a number of variables can easily be argued to be associated with opening hours. These can include, for example, variables such as the opening hours of any other services nearby, the availability of a competent workforce, or even the characteristics of pharmacists. However, many of such variables are unlikely to be associated with our main instrument Z_2, which being the maximum distance from a grid cell within the catchment area.

The only factor that can easily be thought of as such a variable is the composition of the customer base in terms of travel distance. That is, if the pharmacists keep their pharmacies open longer because they have many long distance customers, then there would be a possible path from instrument to outcome that does not go through our treatment. But given that the furthest distance comes from a single cell, it is unlikely that it would dictate the overall composition of travel distances within the catchment populations. Furthermore, for this alternative path to hold, we would need to assume that pharmacists make opening hour decisions based on the travel distances of some of their customers. Basically, this would require that pharmacists have such information available, a requirement that seems very unlikely. Thus, we argue that concerns related to APO variables seem quite small.

The second possible threat to our IV-design is *alternative path instrument* (API) variables that are related to the instrument and might also be related to the outcome. The most likely candidates for confounding variables in this case would be geography related, as distances within the catchment area are probably associated with such variables. However, geography can hardly be argued to be directly associated with opening hours. Thus, we consider that the threat to our IV design through API variables is also likely to be negligible.[20]

6.3 Weekday Panel of Opening Hours

In this section, we examine two alternative panel data versions of our dataset. First, we construct a pharmacy-weekday level panel that allows us to analyze weekday level variations in pharmacy opening hours in response to the distance to competition.

Second, we further expand our panel dimension and construct a weekday panel at the level of population grid cells. While the pharmacy level panel reveals how long a particular pharmacy is open on a given day, the grid cell panel characterizes the total duration of opening hours between the two closest pharmacies for every grid cell. For the regulator concerned about the availability of services, this is ultimately the relevant variable since the regulator is interested in whether these two pharmacies are jointly open sufficiently long for the population of a given grid cell.

6.3.1 Pharmacy level opening hours over weekdays

At the pharmacy level, the daily panel consists of a total of 5,831 observations ($7 \times$ [number of pharmacies = 833]). The daily variation in opening hours is presented in Table 9. Note that the summary statistics are conditional on being open and also exclude YA. Most pharmacies are open during the work week (Mon-Fri), but during the weekends, especially the opening hours of branch pharmacies, are reduced. It is striking that on Sundays only six branches are open according to our data.

[20] In Appendix B with specification no. 6, we test one candidate for a potential API variable.

Table 9: Pharmacy opening hours at the weekday level

	Main pharmacy			**Branch pharmacy**		
	N	share open (%)	mean hrs	N	share open (%)	mean hrs
Monday	646	99.8	10.05	165	97.6	7.70
Tuesday	647	100.0	10.04	162	95.9	7.73
Wednesday	646	99.8	10.04	157	92.9	7.73
Thursday	647	100.0	10.04	160	94.7	7.71
Friday	647	100.0	10.05	164	97.0	7.67
Saturday	614	94.9	6.69	27	16.0	5.63
Sunday	220	34.0	6.05	6	3.6	5.83

Daily average hours conditional of being open

The panel version of our estimation equation is rather similar to what we already had in the cross sectional case. Obviously, our dependent variable is now the opening hours h_{it} for the pharmacy i on a weekday t. The distance measure and any pharmacy specific controls remain fixed over weekdays. Consequently, direct weekday level fixed effects would absorb the effect of distance. Thus, we resort to dummy variable regression and include weekday specific dummy-variables W_i that account for unobserved weekday specific factors that might affect opening hours. Since there might be correlational patterns within pharmacies in opening hours over the weekdays, we use a two-way clustering of standard errors at the pharmacy-municipal level.

$$h_{it} = \alpha + \beta_1 D_i + \beta_2 D_i^2 + \theta \boldsymbol{X_i} + \gamma C_i + \lambda W_t + \epsilon_{it} \tag{21}$$

The results of our dummy variable panel regressions are presented in Table 10. Note that the regressions are conditional on being open, so observations for weekdays when the pharmacy is closed are dropped. The sign for the distance coefficient is expected, but at the daily level, the magnitude of the effect is smaller than what we observed at the weekly level, as weekly variation in opening hours is larger due to weekends. Alternative specifications of weekend dummies (daily or weekend dummy) both indicate significantly shorter opening hours during the weekends.

Table 10: Dummy variable panel regressions

	P1	P2 †	P3
Distance to competition			
Average distance (km)	-0.0454**	-0.0454**	-0.0446**
	(0.01)	(0.01)	(0.01)
(Average distance)^2	0.000247**	0.000245**	0.000242**
	(0.00)	(0.00)	(0.00)
Population effects			
Population	0.166**	0.228**	0.228**
	(0.05)	(0.06)	(0.06)
Population^2	-0.00532**	-0.00741**	-0.00746**
	(0.00)	(0.00)	(0.00)
Other controls†			
Shop near ‡	0.940**	1.274**	1.210**
	(0.13)	(0.14)	(0.14)
University pharmacy (YA)	3.817**	4.154**	4.093**
	(0.53)	(0.53)	(0.53)
Is weekend			-3.488**
			(0.06)
Saturday		-3.123**	
		(0.06)	
Sunday		-4.532**	
		(0.16)	
Observations	5027	5027	5027
R^2	0.321	0.667	0.654

Standard errors in parentheses

Pharmacy-municipality -level two-way clustering of standard errors.

County dummies and constant not reported.

†Only Sat and Sun dummies reported; Monday as a reference group.

‡Distance to shop less than 200 m

* $p < 0.05$, ** $p < 0.01$

6.3.2 Total Duration of Daily Opening Hours

Up to this point, we have examined the opening hours of individual pharmacies, weekly or daily. For consumers and the regulator, the more relevant issue is how pharmacy services are provided in total by any pharmacy. In comparison to the peak-centered symmetric equilibrium analyzed in Section 4, the actual cost and demand factors faced by the nearby pharmacies might differ and lead to different opening hour choices. Furthermore, under partial coverage and sufficiently dispersed shopping time preferences, pharmacies might spread their opening hours even under identical costs and demand as discussed in Appendix E.4. As such, the key interest from the policy perspective lies in the total service span, or duration of hours, available to the consumers in a specific location and not only in the opening hours of a single pharmacy.

Empirically we examine this with the degree of overlapping opening hours, which characterizes how the closest competitors are open at different times of the day. Overlap can mean multiple scenarios, as we illustrate in Appendix C.5. Since all scenarios are related to the concept of the total daily duration of opening hours, we focus on that here. More formally, we define the total duration $dur_{l,t}$ of opening hours in location l (population grid cell) and on weekday t as the difference between the later closing time (*close*) and the earlier opening time (*open*) between the two closest pharmacies A and B as follows.

$$dur_{l,t} = max(close_{A,t}, close_{B,t}) - min(open_{A,t}, open_{B,t}) \tag{22}$$

The total duration captures essentially a very different aspect of the decision regarding opening hours than the individual pharmacy level opening hours. The total duration that the service is provided by either of the pharmacies might not change even if another one changes its hours of operation. This is clear if we examine some of the overlap scenarios in Appendix C.5. For example, in the case of encompassing overlap, pharmacy B could extend its' opening hours without affecting the total duration of service provided.

The total duration data at the grid cell level is significantly larger than the pharmacy level data, as we now have 680,687 observations ($7 \times$ [number of population grid cells $= 97,241$]). Similarly to Table C3, we first count the presence of different overlap scenarios at the grid level. This is done in Table 11. We observe a high number of asymmetries in durations and midpoints of opening hours.[21] We exclude cases where both closest pharmacies are closed on a given day.

[21] Midpoint refers to the time of day that is in the middle of the duration. That is, if a pharmacy opens at 8 am (8:00) and closes at 4 pm (16:00), the midpoint is noon (12:00)

Table 11: Counts of overlap scenarios at the grid cell level

	Same midpoint		
	No	Yes	Total
Same duration			
No	459,344	27,040	486,384
Yes	20,605	101,204	121,809
Total	479,949	128,244	608,193

Conditional of either pharmacy being open.

Next, we summarize the total duration of pharmacy opening hours and the distances between the two closest pharmacies for each grid cell on all weekdays. The count of grid cell-weekday pairs is very high with smaller populations. This directly follows from the distribution of the population, as we have a large number of cells with very low populations. The mean total duration increases along with the population group, meaning that for grid cells with larger populations, the two closest pharmacies are, on average, open for longer. Finally, the distance between the two closest pharmacies is, on average, smaller with larger populations. Together, duration and distance indicate that, on average, more distant competitors are less open jointly.

Table 12: Total duration and distance by population groups

Population group	Grid cells (count)	Cell-day pairs (count)	Total duration* (mean)	Distance** (mean)
1-	42,554	297,878	7.63	31.34
5-	21,358	149,506	7.83	26.34
10-	27,346	191,422	8.30	19.71
100-	3,590	25,130	8.73	13.07
500-	1,163	8,141	9.51	8.04
1000-	1,129	7,903	10.37	3.07
5000-	93	651	11.06	1.22
10000-	8	56	10.07	0.44
Total	97,241	680,687	7.96	25.66

*Total duration between two closest pharmacies

**Distance between closest and 2. closest pharmacy

Lastly, we characterize the possible effect of distance on total duration. Since we now operate at the grid level, we can also take the age structure of each grid cell into account more conveniently in some specifications. More specifically, we estimate the following equation using cell-weekday pairs.

$$dur_{lt} = \alpha + \beta_1 D_l + \beta_2 D_l^2 + \theta \boldsymbol{X_l} + \gamma C_l + \lambda W_t + \epsilon_{lt} \tag{23}$$

where D_l is the distance between the two closest pharmacies for each location l, X_l is the set of location specific controls, C_l is the county dummy for a given location, and W_t is the weekday dummy. The location specific controls include alternative population variables in different specifications, whether the closest pharmacy is YA, and whether the closest pharmacy has a shopping center nearby. The results in Table 13 show similarities with the pharmacy level regressions in Table 10 in terms of coefficient signs. However, the interpretations differ because the explanatory variables are different. The distance variable is the distance between the two closest pharmacies for each cell, not the average distance between all the competitors. A negative coefficient implies that the greater the distance between the two closest pharmacies, the shorter the total duration of pharmacy opening hours observed for a given location. We have clustered the standard errors at the level of closest pharmacy pair as this is the level in which the grid level variation in total duration over weekdays occurs.

The shared catchment population is now the population shared by the closest pair of pharmacies, not the catchment population of an individual pharmacy. The larger shared catchment population increases opening hours, as does a larger grid cell population in alternative specifications. Only the population group with the youngest population is significant. If the cell has more children, it is more likely to also be an area of higher demand since young children live with their parents. Although insignificant, the oldest population group has a negative effect. Rather than depicting the likely higher demand for pharmaceuticals for this group, this variable probably captures more of the effect of being an area of lower demand, as areas with lower populations due to migration loss generally have an older age structure.

Table 13: Daily total duration regressions

	(1)	(2)	(3)	(4)
Distance between competitors				
Distance (km)*	-0.0226**	-0.0204**	-0.0382**	-0.0521**
	(0.005106)	(0.005235)	(0.004433)	(0.004356)
$(\text{Distance})^2$	0.0000971**	0.0000859**	0.000159**	0.000229**
	(0.000032)	(0.000032)	(0.000035)	(0.000035)
Population effects				
Shared catchment population	0.0000858**	0.000102**		
	(0.000028)	(0.000025)		
$(\text{Shared population})^2$	-2.99e-11	-1.24e-09		
	(0.000000)	(0.000000)		
Grid cell population			0.000327**	
			(0.000042)	
Population (0-14 y)				0.00141**
				(0.000453)
Population (15-64 y)				0.000117
				(0.000114)
Population (65+ y)				-0.000226
				(0.000211)
Other controls				
Closest is YA	3.161**	3.066**	2.688**	2.468**
	(0.632526)	(0.667117)	(0.590582)	(0.520403)
Shop near for closest†	1.310**	1.356**	1.503**	1.354**
	(0.268659)	(0.206789)	(0.201609)	(0.119447)
Observations	680687	680687	680687	233303
R^2	0.064	0.796	0.791	0.777
Weekday dummies	NO	YES	YES	YES
County dummies	NO	YES	YES	YES

Standard errors in parentheses

Clustering of standard errors at the level of closest pharmacy pair.

*Distance between the two closest pharmacies for the grid cell.

†Closest has shopping center near.

* $p < 0.05$, ** $p < 0.01$

7 Conclusions and Avenues for Future Work

In this study, we explore the relationship between the opening hours of Finnish pharmacies and the proximity of competition. The empirical results across various model specifications agree with the theoretical predictions about the likely effects of proximity. Competition further away implies shorter opening hours, although this effect diminishes with distance. The catchment population has a positive effect on opening hours, implying that higher potential demand encourages pharmacies to have longer opening hours. Similar patterns are observed regardless of whether we observe opening hours on a weekly or daily level. In addition, we examine the total duration of services offered to a given population in each location. We observe that the opening hours provided jointly by the two closest pharmacies decrease as the distance between the pharmacies increases.

There are some limitations and extensions in our study that warrant further consideration. First, unambiguous causal relationship between competition and opening hours might be difficult to claim in this context, as we cannot observe all possibly relevant factors, such as personal preferences for working hours, that affect the pharmacist's decision on opening hours.

The second caveat is related to the empirical main-branch pairing. We proceeded with the assumption of independent outlets, but in the Finnish setting, with a high prevalence of branch pharmacies, this is not necessarily the optimal assumption, and in the future, this dependence should be examined more closely. The anticipated effect of this would most likely relate to the magnitude of the business stealing effect, as in reality there is no business stealing between the main pharmacy and its' branch.

For policymakers and the regulator, these findings send a relatively clear message. Incentives to have longer opening hours can be increased by relaxing the entry barriers for new pharmacies. As new pharmacies are established, the distance from competition will decrease. However, the catchment population would now also be divided among a higher number of pharmacies, leading to smaller demand that would imply shorter opening hours. The regulator who optimizes the pharmacy network consequently must balance these two effects stemming from distance to competition and population when considering the sufficient provision of opening hours.

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Appendix

A Definition of the set of competitors

The catchment area, catchment population, and consequently, the set of relevant competitors are calculated and defined by the population grid cells for which each pharmacy is either the closest or the second closest pharmacy. The catchment area can be considered the relevant market for each pharmacy. Our approach is similar in spirit to what Pennerstorfer and Yontcheva (2021) suggests. But instead of matching grid cells based on their population and closeness, we match cells to the same catchment area based on their distance to different pharmacies.

To illustrate the calculation process, we use an example dataset of five population grid cells and five pharmacies (A,B,C,D,E) with hypothetical values for the distance to pharmacies from the cells. We focus on pharmacies A and B, but obviously the calculation would be the same for all pharmacies.

After the set of competitors is defined, the average distance to competitors is trivial to define. The average could be calculated as an arithmetic mean or with a weighting scheme in which each distance is weighted by the population that is related to that specific distance. We use the latter since it better captures the fact that large populations nearby should account more for the average distance than smaller populations further away. We first illustrate the calculation with an unweighted mean, however.

The process for determining the set of competitors and the average distance to the competitors involves the following steps.

1. Calculate the distance using the road network from each grid cell midpoint to each pharmacy location.

2. For each grid cell, find the two pharmacies that are the closest and the second closest for that cell, along with the associated distances to these pharmacies.

3. For each pharmacy, define the catchment area and catchment population based on all grid cells for which the pharmacy is either the closest or the second closest pharmacy.

4. For a given pharmacy, define the set of relevant competitors as all pharmacies that share a grid cell between them. That is, if two pharmacies compete from a given grid cell, they are considered relevant competitors to each other.

5. For each pharmacy, calculate the average distance to competition using the set of relevant competitors.

In the first step, we use the road network of Finland to calculate distances from the grid cell midpoints to the pharmacy coordinates.[22] Calculating road distances from every cell to each pharmacy would result in a very large number of unnecessary calculations and would be time consuming. Thus, we first filter the five closest pharmacies for each grid cell using direct line (*crow-fly*) distances, which can be calculated quickly. The road distances are then calculated to these five pharmacies. We calculate the road distances both by the car road network and walking routes, and choose the minimum of these, as especially in dense urban areas, car routes might result in overly long routes. In some cases, the route is not necessarily defined in the underlying map data. In these cases, we use the predicted distance from a simple linear regression in which the observed road distances are explained by the direct line distance. The second step is self-explanatory, but let us clarify steps 3 to 5 below.

A.1 The set of competitors

In Table A1, we have the five example cells, the pharmacies that are the closest and second closest for that grid cell, and the corresponding distances from the cell to the pharmacy.

Table A1: Example set of pharmacies, grids and distances

Grid cell	Closest pharmacy	Second closest pharmacy	Distance to closest	Distance to 2. closest
g1	A	B	1	2
g2	A	C	2	5
g3	B	A	1	4
g4	D	A	2	3
g5	E	A	3	7

[22]See Appendix D.2 for some computational notes on road distances.

The competitors for pharmacy A would be pharmacies B,C, D, and E. For pharmacy B, A would be the only competitor, as B does not share grid cells with any other pharmacy. Now assume that for pharmacies A and B we observe the following distances between them and their competitors.

Table A2: Distances to competitors

Pharmacy	Competitor	Distance to competitor
A	B	0.5
A	C	1.0
A	D	1.5
A	E	2.0
B	A	0.5

Given these distances, we can then calculate the unweighted average distance to competitors for each pharmacy as shown in Table A3. The average for pharmacy B is, of course, just the distance to A, as it has no other competitors.

Table A3: Unweighted average distances to competitors

Pharmacy	Average distance to competitors
A	(0.5+1.0+1.5+2.0)/4 = 1.25
B	0.5

A.2 Catchment population

Catchment population is defined as the population each pharmacy serves as the closest or the second closest pharmacy. Let us assume the following populations for each of the grid cells that are associated with pharmacies A and B.

Table A4: Population in grids cells

Pharmacy	Grid cell	Population
A	g1	1
A	g2	2
A	g3	3
A	g4	4
A	g5	5
B	g1	1
B	g3	3

Now, we could calculate the total population catchment of each pharmacy as follows. Note that this is an unweighted population, as the whole population in each associated grid is taken into account in the total catchment population of each pharmacy. Given the assumed populations in each of the five grids, we see that the total population that pharmacy A competes for is 15, and 4 for B. On average, A is servicing a grid with a population of 3.

Table A5: Population in grids for pharmacies A and B

Pharmacy	Total catchment population	Average catchment population
A	$1 + 2 + 3 + 4 + 5 = 15$	$(1 + 2 + 3 + 4 + 5)/5 = 3$
B	$1 + 3 = 4$	$(1 + 3)/2 = 2$

While the unweighted population describes the total potential customer base of a pharmacy, it may be more reasonable to weight the population using the distances. That is, the further a certain individual is from the pharmacy, the more unlikely it is that this individual would travel to that specific pharmacy. In order to weight the population of each grid, we define the distance weights for grid cells as in Table A6.

Table A6: Distance weighted populations for pharmacies A and B

Grid	Population	Closest pharmacy	2. closest pharmacy	Distance to closest	Distance to 2. closest	Distance weight*	Weighted population for closest pharmacy	Weighted population for 2. closest pharmacy
g1	1	A	B	1	2	0.67	0.67	0.33
g2	2	A	C	2	5	0.71	1.43	0.57
g3	3	B	A	1	4	0.80	2.40	0.60
g4	4	D	A	2	3	0.60	2.40	1.60
g5	5	E	A	3	7	0.70	3.50	1.50

*Weight = the share of population for the closest pharmacy.

The weight for the closest pharmacy describes the share of the population for that pharmacy from each grid. The weight w for grid g and the closest pharmacy is defined in relation to distances d of the closest (1) and second closest (2) pharmacies.[23] The weight is inversely related to the distance to the second closest pharmacy $d_{g,2}$.

$$w_{g,1} = \left(\frac{d_{g,2}}{d_{g,1} + d_{g,2}} \right)$$

The weight for the second closest pharmacy is defined as the residual of the above as $w_{g,2} = 1 - w_{g,1}$. The weights imply that the further the second closest pharmacy is from the grid, the smaller share of the population from the specific grid is allocated to that pharmacy. Now we can calculate the distance weighted catchment population for each pharmacy as in Table A7.

Table A7: Total and average distance weighted populations for pharmacies A and B

Pharmacy	Total weighted catchment population	Average weighted catchment population
A	sum of green cells = 5.80	5.80/5 = 1.160
B	sum of red cells = 2.77	2.77/2 = 1.385

We see that, for instance, in grid cell *g5*, the catchment population of pharmacy A is only 1.5 instead of the unweighted population of 5, since A is located very far away from that specific cell. On the other hand, pharmacy B receives most of the population from grid cell *g5*, as it is located much closer to that cell than pharmacy A.

[23] By definition $d_{g,1} < d_{g,2}$.

A.3 Weighted distance to competitors

When we have the set of relevant competitors defined, we can proceed to calculate the catchment population weighted distance to competition. Recall that in Table A3 we calculated the unweighted average distance to competitors. This, however, gave the same weight to a competitor with little shared catchment population as it did to a competitor with a significantly larger shared catchment population. Thus, we weight the average distance to competitors using the shared unweighted catchment population. This is illustrated in Table A8. The sum of population weighted distances for pharmacy A is now 1.33, since distances with more shared population receive larger weights, whereas the unweighted average distance was 1.25. Note that the fifth cell is not included as it would double count the distance between A and B.

Table A8: Weighted average distance to competitors for pharmacy A

Pharmacy	Competitor	Distance to competitor	Shared population	Population weight	Weighted distance
A	B	0.5	4	4/15 = 0.27	0.13
A	C	1.0	2	2/15 = 0.13	0.13
A	D	1.5	4	4/15 = 0.27	0.40
A	E	2.0	5	5/15 = 0.33	0.66
B	A	–	–	–	–
Unweighted average distance		1.25			
Sum of weighted distances					1.33

A.4 Cases with no catchment and competitors defined

Here we summarize the assumptions for manual imputation of values in cases in which our procedure of determining catchment area, population, and relevant competitors cannot by definition find values for these variables. This happens when a pharmacy is neither the closest or second closest pharmacy to any grid cell. These pharmacies are typically located between other pharmacies so that all the surrounding pharmacies capture all the catchment population. Recall that there were only 7 such cases, and thus the effect of these assumptions is minimal in our empirical setting. Of course, in some other settings or applications, these assumptions might have a larger effect, and there are also alternative assumptions that could be made. For example, in cases in which our measure cannot determine the catchment population or set of competitors, they could be determined using radius based circle measures instead.

The imputations are as follows:

- **Number of competitors** = 1
  - We assume that such pharmacies have only one relevant competitor (the closest).
- **Distance to competition** = **Minimum distance to the other outlet**
  - The distance measure is assumed to be the distance to the nearest other pharmacy, as the average over the set of competitors cannot be calculated.
- **Catchment population** = 0
  - Since these pharmacies were not the closest or second closest to any grid cell, we assume their catchment population is zero. That is, the number of grid cells allocated to these pharmacies is zero.

B Robustness checks

We conduct several robustness checks for our cross-sectional estimation results. As a base specification for these checks, we use model IV 2a from Table 7. We run several alterations of the model to account for some possible caveats in our results. The checks we run are the following:

1. **Drop YA:** As YA pharmacies significantly differ in terms of their organizational form, we estimate the model without them,

2. **Drop if no closest competitor:** As some pharmacies are not the closest or second closest to any grid cell, the closest competitor according to our definition cannot be found. We estimate the model without these.

3. **Explain Mon-Fri hours alone:** Workweek hours might systematically differ from weekend hours, so we define the total opening hours from Monday to Friday as an alternative dependent variable.

4. **Explain Sat-Sun hours alone:** Same as above, but now for total opening hours on Saturdays and Sundays.

    - We first run this using a standard linear model. However, since we observe a mass of zero opening hours during the weekends (see Table 9), we also utilize hurdle regression (see Cragg (1971)). Hurdle regression jointly models both the decision of being open and the opening hours conditional on being open.

5. **Account for main and branch dependencies:** Although accounting for this in a satisfactory way is difficult, we check whether having your own main or branch pharmacy as the closest competitor has any relationship with your own opening hours.

6. **Control for municipal grouping:** Statistics Finland provides a three way grouping of municipalities into rural, semi-urban and urban (cities) municipalities. We add this control because there might be some additional factors related to the level of urbanization that are not taken into account by our base controls. The grouping is indirectly based on population density.

Table B1: Robustness checks with IV

	R1	R2	R3	R4	R5	R6
Distance to competition						
(1) Average distance (km)	-0.198*	-0.198*	-0.202**	-0.0421	-0.209*	-0.315**
	(0.09)	(0.08)	(0.07)	(0.04)	(0.08)	(0.11)
(2) (Average distance)^2	0.00101*	0.00101*	0.00103**	0.000248	0.00124*	0.00164**
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Population effects						
Population	2.541**	2.715**	1.633**	0.737**	2.321**	2.322**
	(0.54)	(0.47)	(0.39)	(0.18)	(0.45)	(0.53)
Population^2	-0.0848**	-0.0926**	-0.0555**	-0.0244**	-0.0768**	-0.0768**
	(0.02)	(0.02)	(0.01)	(0.01)	(0.02)	(0.02)
Own branch closest					0.187	
					(0.96)	
Own main closest					-11.44**	
					(1.30)	
Observations	816	826	833	833	826	833

Standard errors in parentheses
Depvar: Weekly opening hours (hrs/week)
Model IV 2a as a base specification
* $p < 0.05$, ** $p < 0.01$

Apart from model 4, all models produce similar coefficient estimates, which we have already observed earlier. The distance coefficient in model 4 is expected to be smaller than for the rest of the week, as there are obviously fewer hours on the weekend. Having your own branch as the closest competitor does not seem to have a statistically significant effect, implying that the opening hours of main pharmacies are probably set independently of a branch. The sign is somewhat unexpected, though. If there were any effect, we would expect it to be negative since pharmacists have to divide their time between two outlets, for example, in administrative work. On the other hand, this variable might also be indicative of pharmacy size, as larger pharmacies generally have branches, and larger pharmacies might also be open longer. Having your own main pharmacy as your closest competitor has a very significant and large effect on opening hours. However, this variable mainly captures the effect of being a branch pharmacy and is thus not indicative of the competitive situation between the two outlets. Lastly, controlling for an additional municipal grouping slightly increases the effect of distance. This implies that accounting for factors related to urbanization level is possibly relevant and also reduces concerns related to alternative path instrument variables, as the specification controls for one possible source of such a path.

The coefficient estimates in model 4 might be biased as the mass of zeros in opening hours is not accounted for by the standard OLS. Thus, in Tables B2 and B3, we present the results for the hurdle regression. Interestingly, the selection model gives a positive coefficient for the distance variable. We interpret that rather than the effects of nearby competition, the selection model captures the likelihood of being the solitary provider of service in a relatively large area (e.g. municipal). In these cases, the distance to the nearest competitor might be quite large, but as the solitary service provider, there might also be more incentives to keep the pharmacy open during the weekends. The actual marginal effects of distance on weekend hours show a similar coefficient to model 4 from Table B1, but now the effect is significant.

Table B2: Hurdle regression: latent variable and selection models

	Latent model
Outcome model: weekend hours	
Average distance (km)	-0.149**
	(0.03)
(Average distance)^2	0.000714**
	(0.00)
Population	0.215
	(0.12)
Population^2	-0.00681
	(0.00)
Selection model	
Average distance (km)	0.0303*
	(0.01)
(Average distance)^2	-0.000145
	(0.00)
Population	0.421**
	(0.09)
Population^2	-0.0148**
	(0.00)
N	833
SE type	Municipal
FE	County
Other controls	YES

Other controls: *Shop near* and *Is YA*

* $p < 0.05$, ** $p < 0.01$

Table B3: Hurdle regression: marginal effects

	Coefficient	Std. error	p-value
Distance (km)	-0.051*	0.024	0.033
Population	0.454**	0.094	0.000

* p<0.05, ** p<0.01

As the last robustness check, we use an alternate measure of competition. We define the measure as the number of competitors for which road distances are less than or equal to a given threshold. Note that this is not exactly the same as radius based measures, which generally include the number of competitors within a fixed radius circle (see e.g. Habte and Holm, 2022). Our measure accounts for the fact that the road distances within a circle might be longer than the radius of the circle. We use thresholds of 1, 5, 10, and 20 kilometers.

As expected, the higher number of competitors increases the total weekly opening hours. Using a larger threshold diminishes the effect since competition further away matters less. Note that even with the 20 km threshold, many pharmacies do not face competition within that distance.

Table B4: OLS with alternate measure of competition

	1 km	5 km	10 km	20 km
Number of competitors	2.126**	0.361**	0.129**	0.0539**
	(0.19)	(0.05)	(0.03)	(0.02)
Observations	833	833	833	833
SE cluster	Municipal	Municipal	Municipal	Municipal
FE	County	County	County	County

Standard errors in parentheses

Depvar: Weekly opening hours (hrs/week)

OLS 3 as base specification

* $p < 0.05$, ** $p < 0.01$

C Additional material

C.1 Additional summary statistics

The average distances to competitors might hide the fact that the closest competitor can nevertheless be quite nearby. Table C1 summarizes descriptive statistics for the distance to the closest competitor. We see that the closest competitor can be located almost in the same location as the pharmacy itself. Interestingly, the minimums of the average distance in Table 5 and the minimum for the distance to the closest competitor are equal, which implies that the set of competitors in some cases can include only one pharmacy. With the given level of rounding, the closest competitor for some YA outlets seems to be located exactly in the same location.

Table C1: Minimum distance to competition (closest competitor)

	count	mean	sd	min	max
All pharmacies (excl. YA)	816	10.4	13.46	0.1	160.5
—Main pharmacies	647	9.7	13.90	0.1	160.5
—Branch pharmacies	169	12.9	11.28	0.3	76.7
By branch status:					
—*Conditional*	98	19.2	10.66	2.6	76.7
—*Entitled*	71	4.3	4.30	0.3	19.4
Helsinki YA	17	0.4	0.27	0.0	1.1

Distances in kilometers (km)

Next, we summarize the number of competitors for each pharmacy. The majority of pharmacies have 3 to 7 competitors. Around 10 % pharmacies have 8 or more competitors. On the other hand, 31 pharmacies have only one relevant competitor, according to our definition.

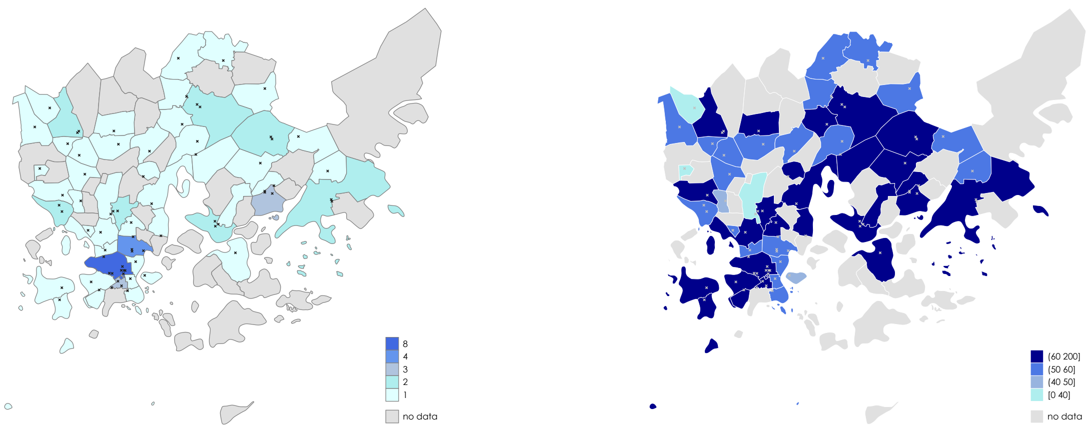
Table C2: The number of competitors

	Frequency	Percent	Cumulative
No. of competitors			
1	31	3.72	3.72
2	43	5.16	8.88
3	97	11.64	20.53
4	153	18.37	38.90
5	180	21.61	60.50
6	154	18.49	78.99
7	94	11.28	90.28
8	46	5.52	95.80
9	24	2.88	98.68
10	8	0.96	99.64
11	3	0.36	100.00
Total	833	100.00	

C.2 Pharmacies and opening hours in Helsinki region

Figure C1 has the same information as in Figure 10 for the postal code areas of the Helsinki region. Many areas have only one or two pharmacies. Most pharmacies have relatively long weekly opening hours. This is expected as Helsinki is the most populous city in Finland, and consequently most pharmacies have rather large catchment population. This is seen in Figure C2. Most pharmacies are located in cells with high population density, although in Helsinki even less populated grid cells can be relatively densely populated compared to the rest of the country.

Figure C1: Pharmacies and opening hours in Helsinki region



(a) Number of pharmacies **(b)** Average weekly opening hours

Notes: The cross symbol = pharmacy. The coastal lines and the island borders are smoothed. The smaller outer islands often belong to zip-code areas located on the continent.

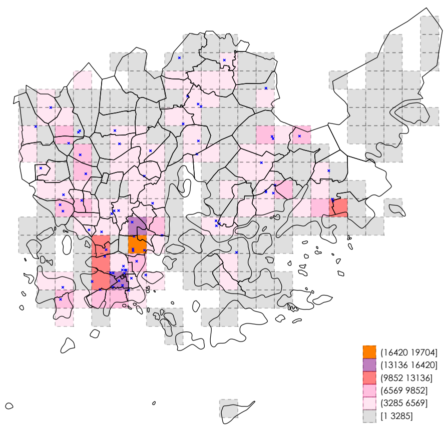


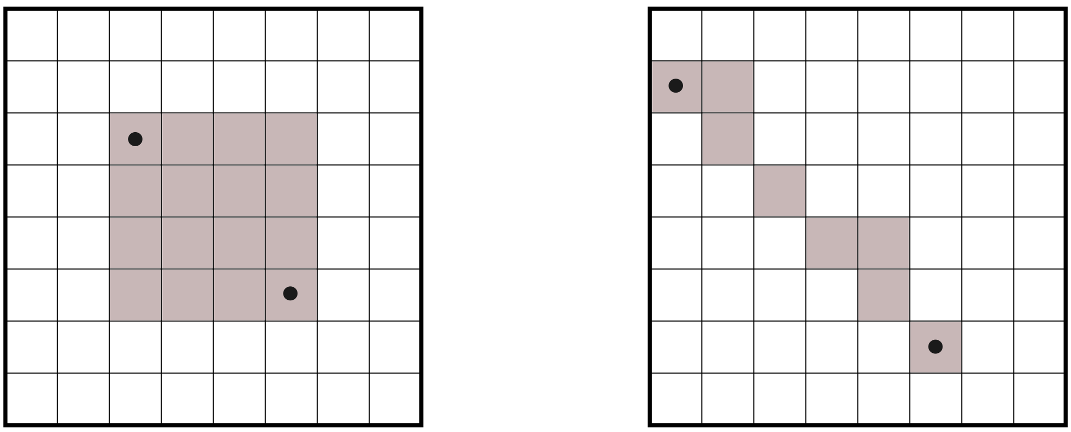
Figure C2: Population grids of Helsinki

C.3 Visual illustration of instruments

In Section 6.2, we noticed that out of the two candidate instruments, the first instrument Z_1 (grid cells per pharmacy) performed worse than the second instrument Z_2 (maximum distance from cell to pharmacy). Since the workings of these instruments might be somewhat complicated to describe, we further illustrate the difference in their mechanics in Figure C3.

Let us consider a universe of 8x8 grid cells and two pharmacies. For simplicity, we assume that pharmacies are located in the midpoints of the cells. Let us compare instruments in two cases. In Figure C3a, we have a catchment area of 16 cells for one of the pharmacies (black dots). The other black dot represents the competitor. Compare this to Figure C3b. Clearly, the size of the area in terms of cells might not have any clear relationship with the distance between the competitors, as the distance is longer in the second case despite being half the size of the first catchment area.

Figure C3: Visual illustration of instruments



(a) Catchment area of 16 cells

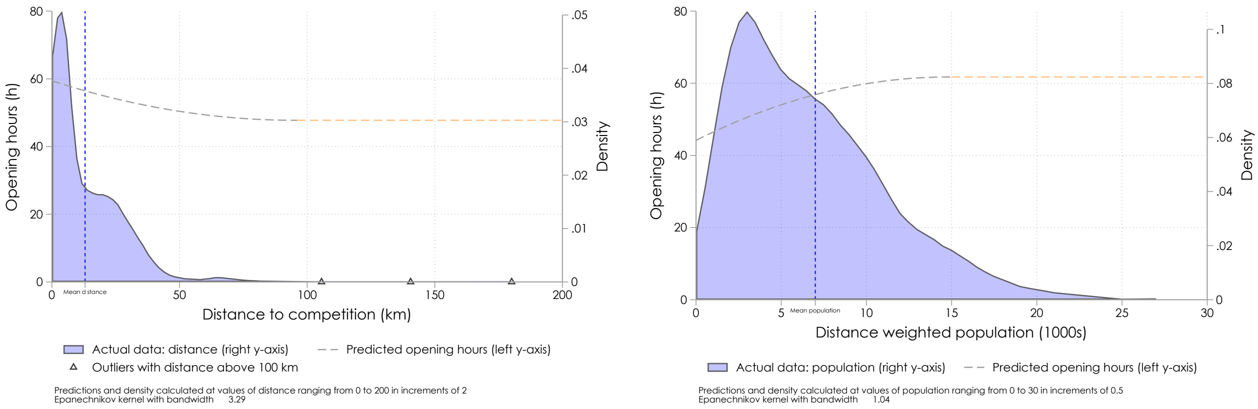
(b) Catchment area of 8 cells

C.4 Effects of distance and population illustrated

Here, we present the empirical counterpart to Figure 6. Using model IV 2a, we calculate the predicted weekly opening hours and plot these predictions together with the density of the underlying distance and population distributions. This allows us to visualize the relationship implied by the estimated model while also indicating where observations are concentrated. The predicted outcome is evaluated while the variable of interest is varying, and all other covariates are held at their sample mean. These results are given in Figure C4.

In both cases, the estimated relationship is quadratic. The predicted relationship for distance is convex (U-shaped), implying a minimum at the turning point. In contrast, the relationship with population is concave (inverted U-shaped), with the turning point being at the maximum. Note that we manually fixed the predicted values at the turning point level beyond the corresponding turning point (orange sections). This is done to emphasize the portion of the estimated relationship (gray section) preceding the turning point, where the sign of the slope corresponds to the sign of the first-order coefficient.

Figure C4: Visual illustration of relationship between opening hours with distance and population



(a) Relationship with distance

(b) Relationship with population

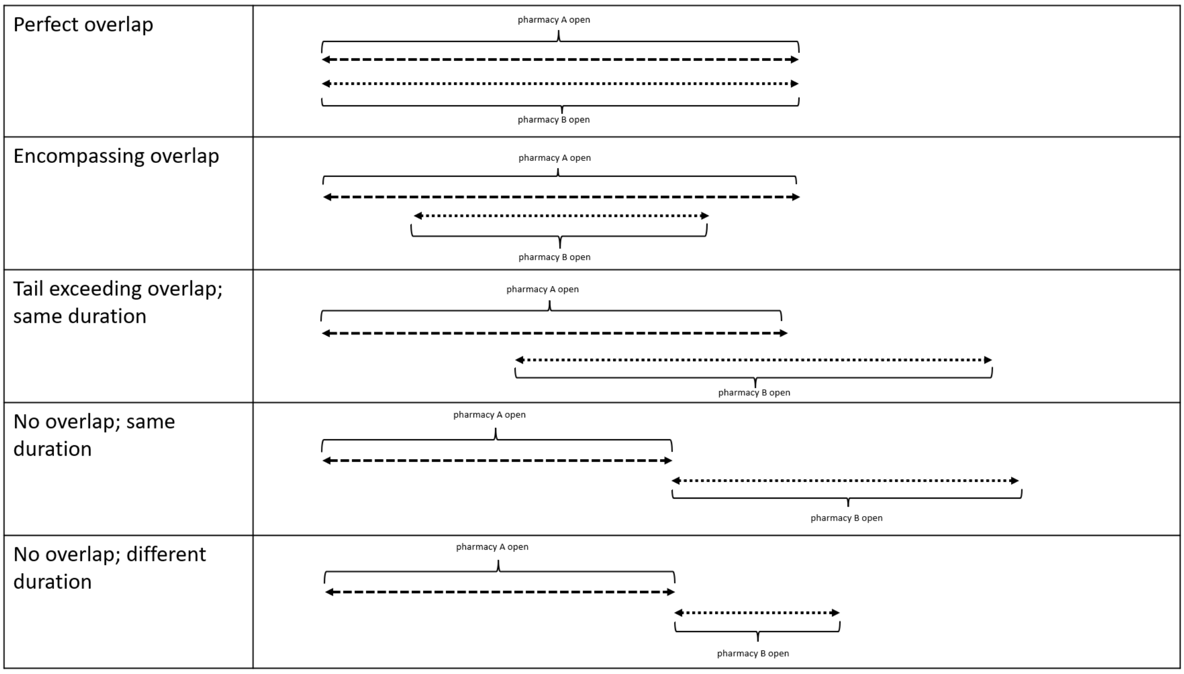
C.5 Different overlap scenarios

Different overlap scenarios in terms of opening hours are characterized by two variables, namely the duration of daily opening hours and the midpoint of this duration. We define the scenarios as follows:

1. **Same duration & same midpoint:** Perfect overlap; both are open the same duration at the same time of the day.
2. **Different duration & same midpoint:** Encompassing overlap OR tail exceeding overlap;
   - Encompassing overlap: the other is open longer in the morning AND evening.
   - Tail exceeding overlap: the other is open longer in the morning OR evening.
3. **Same duration & different midpoint:** Tail exceeding overlap OR no overlap.
4. **Different duration & different midpoint:** Can result in either encompassing overlap, tail exceeding overlap, or no overlap at all.

Some of these overlap scenarios are illustrated in Figure C5 for pharmacies A and B. For the last scenario (different duration & different midpoint), we illustrate the "no overlap" case to highlight that this situation can occur regardless of whether the duration differs or not.

Figure C5: Different overlap scenarios



Next, we characterize the extent of the overlap in our empirical data by tabulating the number of times we observe each main scenario (1 to 4) listed above. Note that only in scenario 1 does the same duration and midpoint uniquely identify the nature of the overlap (*perfect*). In all other scenarios (2 to 4) information on duration and midpoint alone does not characterize the exact type of overlap (or *no overlap*). We observe a fair amount of possible asymmetry in opening hours, as only 681 competitor pairs on a given weekday have exactly the same duration and midpoint for opening hours. Most of the overlap scenarios fall into category 4 with different durations and midpoints. Note also that overall we observe only 5368 overlap scenarios, not the full set of possible dates (7x833 = 5831) as we have excluded those cases when both pharmacies are closed on a given day.

Table C3: Counts of overlap scenarios at the pharmacy level

	Same midpoint		
	No	Yes	Total
Same duration			
No	4171	252	4423
Yes	264	681	945
Total	4435	933	5368

Conditional of either pharmacy being open.

We also summarize the differences in hours of duration and midpoints. This is done in Figures C6 and C7. The difference in durations when the other pharmacy of the competitor pair is closed is defined as the whole duration of the other pharmacy. Thus, we observe some quite large differences in durations. Especially if any of the YA pharmacies is the second counterpart of the pair. However, most of the duration differences are below 4 hours. The midpoint differences are mostly below 2 hours, which means that pharmacies tend to concentrate at least some part of their opening hours near each other.

Figure C6: Distribution of opening duration differences

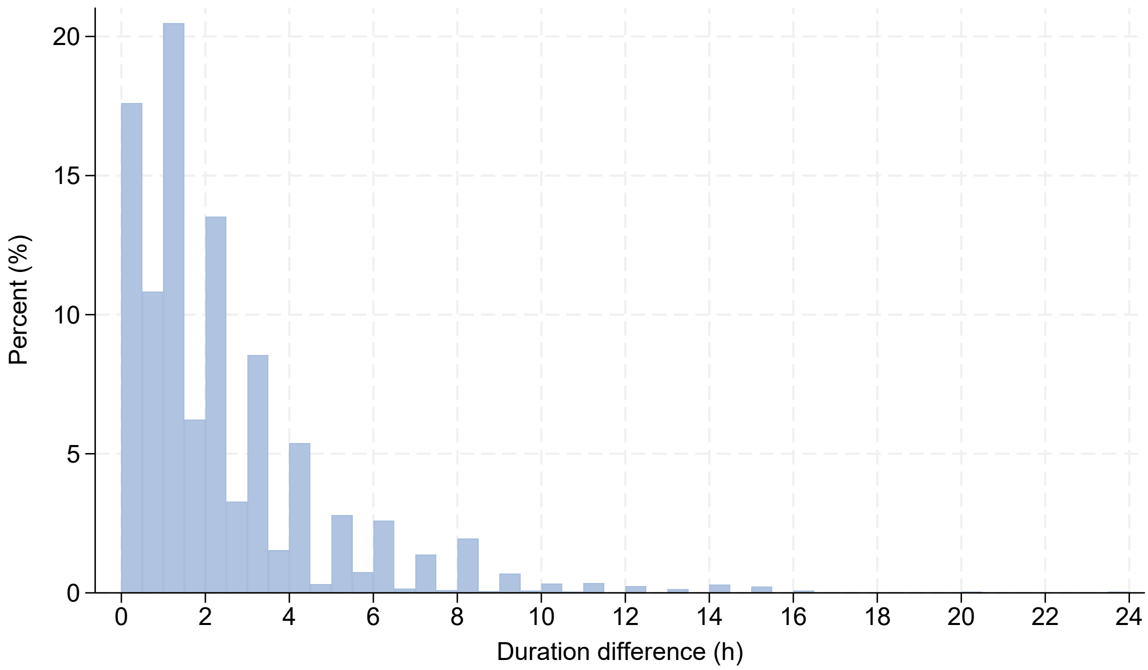
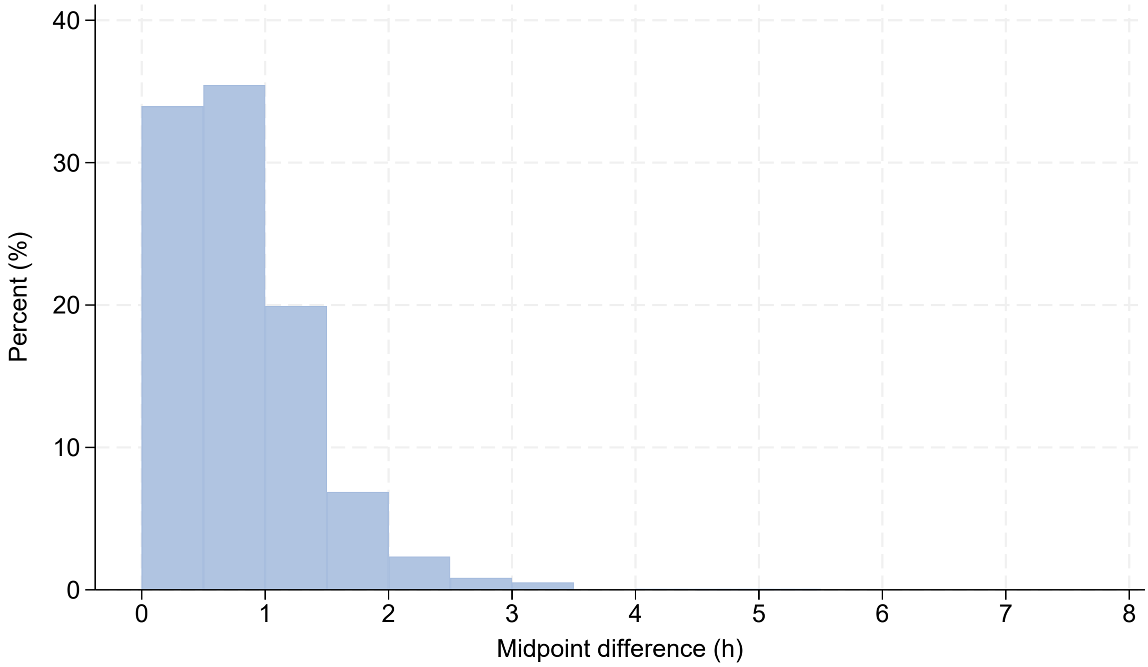


Figure C7: Distribution of opening midpoint differences



D Data Sources and Computational Notes

D.1 Data Sources

Here we list and describe the data sources used in this study. Since the original raw data on opening hours had to be completed with manual imputation for some pharmacies, the raw data sets below do not fully reproduce the results.

Pharmacy level data on their locations and opening hours: The location and opening hours of (most) pharmacies were obtained from the Association of Finnish Pharmacists through their pharmacy search service by using the legal mandate of the FCCA for making information requests. Thus, this dataset is not directly freely available. However, the corresponding data can, in principle, be scraped from the site of the service, although since the FCCA has obtained the data, the opening hours might have changed.

The data were created on the 18th of November 2024. The time of data creation should be such that no major national holidays or other holiday seasons obscure the opening hours to less than the usual opening hours. The data represent the coverage of the pharmacy network at a specific time, and the network of pharmacies and their opening hours most likely changed at least slightly since then.

Since the database is manually updated by the pharmacists, the data may contain opening hours that have not been updated recently. In these cases, we assume that opening hours have remained unchanged for these pharmacies for a longer time. This is not necessarily an unrealistic assumption, as pharmacies probably adjust their opening hours according to local demand, which is relatively stable over time. The data also had some gaps in opening hours and location coordinates. We have imputed this information manually from the websites of pharmacies and Google Maps search. Furthermore, the information concerning YA has been manually added as their information cannot be found in the Association's database. Besides standard opening hours, the data contains information, for example, on special opening hours, additional services offered in pharmacies such as low-level healthcare services, service languages, and possible delivery services. However, our focus is on the standard opening hours.

Other datasets are on the next page →

Population grid data: 1x1 km population grid data is provided by Statistics Finland and is downloadable from the website given below. We have used the 2024 population statistics as it was the latest available information at the time of the analysis. The version we use includes the midpoint coordinates as the location information (filename with *_kp* ending). Besides the location coordinates, the data includes the total population of the grid cell as well as the population in three broad age groups. Note that the population for these groups is not reported if the total cell population is too small.

Download URL for grid data:

https://www.paikkatietohakemisto.fi/geonetwork/srv/eng/catalog.search#/metadata/a901d40a-8a6b-4678-814c-79d2e2ab130c

Road network data: We use OpenStreetMap data for the entire road network of Finland. The data was downloaded from the URL below on 22nd of September, 2025, using the latest available version. This corresponds to a network covering all information until 21st of September, 2025.

Download URL for road network data:

https://download.geofabrik.de/europe/finland.html

Location of large retail stores and shopping centers: This data is partly created from an internal dataset available in the FCCA and it is thus not directly available. The data contains locations of most grocery retailers in Finland, but we focus on the largest hypermarkets of the two largest chains, namely the Prisma stores of the S-chain and Citymarket stores of the K-chain. Another component of the dataset is the locations of other shopping centers. This data was manually collected using Google Maps search based on the listing of shopping centers in the 2024 annual report of the Finnish Council of Shopping Centers.

Download URL for shopping center report:

https://www.kauppakeskusyhdistys.fi/media/kauppakeskusyhdistys_julkaisu2024_110424.pdf

Information on branch pharmacies: Information on branch status (conditional/entitled) and main-branch pairing was obtained from the Finnish Medicine Agency (Fimea) through an information request. The information was delivered to the FCCA on 18th of March, 2025 and it thus represents the situation at that point of time.

D.2 Computational Notes

Software for main analysis

All summary statistics and main regression results are computed using Stata/MP 19.5. The maps of Finland have been created using the user-written Stata command *geoplot* (Jann, 2023).

Road distance calculation

Calculating road distances has been done with the R-package *r5r* (Pereira et al., 2021).[24]. It is mainly designed for the calculation of travel times, and the route distance information is a side product of this optimization problem. Since travel time and distance optimization are somewhat different problems, this might lead to some inconsistencies in how some individual grid cells are allocated to each catchment area in terms of their distance from pharmacies. This could mean that some isolated grid cells belong to a different catchment area than their surrounding cells. Routing problems might also be affected by the underlying road network data. Depending on the version and source of the data, there might be some variations in the calculated travel times and route distances, as the accuracy of road network data might vary between different sources and versions of the data. For example, Pönkänen et al. (2025) refers to these data deficiencies in OpenStreetMap data, which might then lead to some inconsistencies in local routing, especially in areas with a sparse road network.

As we observed in Figure 11, catchment areas are mostly defined consistently. Some isolated cells inconsistent with the surrounding catchment areas are observed, but their occurrence does not seem to be systematic upon visual inspection. Also, the number of such cells seems to be relatively small. Thus, the effect of this phenomenon is likely to be quite small. There are a few solutions that future refinements of this analysis might consider. One is to identify problematic cells and then join them to the catchment areas to which they would naturally belong, possibly utilizing insights from Pennerstorfer and Yontcheva (2021) and Rozenfeld et al. (2011). Alternatively, we can seek ways to efficiently utilize routing tools in R that are better suited to optimizing distances. However, these alternative tools also have some downsides. Either they are computationally much heavier than *r5r* or they cannot be integrated into the R workflow as seamlessly. Indeed, the greatest advances of *r5r* are its' combined route calculation efficiency, even in larger networks, with a relatively straightforward implementation through R.

[24] See also `https://cran.r-project.org/web/packages/r5r/index.html`

E Theory Appendix

E.1 Notation

Table E1: Notation used throughout the model

Symbol	Description
Exogenous parameters	
N	Total mass of consumers (catchment population)
V	Gross consumption utility of the good
p	Regulated retail price
m	Unit margin earned on each sale, $m \equiv p - w$ (w: regulated wholesale price)
δ	Travel cost per unit of spatial distance
τ	Waiting cost per unit of temporal mismatch
γ	Slope of the operating-cost function $C(L) = \frac{1}{2}\gamma L^2$
D	Distance between the two pharmacies
μ	Uniformity of the temporal density ($\mu = 1$ uniform; $\mu \to 0$ peaked)
Derived constants (composites of the parameters above)	
H	Coverage threshold $\equiv [2(V-p)-\delta D]/\tau \in [0,1)$: maximum combined mismatch a midpoint consumer tolerates
L^{tr}	Saturation threshold $\equiv 1 - H$: duration above which the market is fully covered
Endogenous choice variables ($j \in \{A, B\}$)	
L_j	Duration of pharmacy j's opening hours (arc length), $L_j \in [0,1]$
m_j	Midpoint (timing) of pharmacy j's opening arc, $m_j \in \mathbb{S}^1$
I_j	Opening arc, $I_j = [m_j - L_j/2,\, m_j + L_j/2] \pmod 1$
Equilibrium and outcome objects	
L^*	Symmetric equilibrium duration
Q_j	Aggregate demand of pharmacy j
π_j	Profit of pharmacy j
Auxiliary functions and sets	
$\rho_\mu(t)$	Temporal density of ideal shopping times on $\mathbb{S}^1$
$g_j(t)$	Temporal mismatch: shortest-arc distance from t to I_j
$d^*(t)$	Indifferent location between A and B at time t (competitive margin)
$r_j(t)$	Participation radius of j at time t (extensive margin)
$q_j(t)$	Per-time spatial share of pharmacy j
E, C	Times of partial coverage ($g_A + g_B > H$) / full coverage ($g_A + g_B \le H$)

E.2 Marginal Revenue Decomposition

Here we characterize how marginal changes in L_j and m_j affect each pharmacy's demand. The analysis cleanly separates the two regimes E and C.

Lemma 1 (Per-time demand sensitivity to mismatch)**.** At any time t for which pharmacy j is closed:

$$\frac{\partial q_j(t)}{\partial g_j(t)} = \begin{cases} -\tau/(\delta D), & t \in E, \\ -\tau/(2\delta D), & t \in C. \end{cases}$$

Proof. On C, $q_A(t) = d^*(t)/D$ with $\partial d^*/\partial g_A = -\tau/(2\delta)$ from (6), so $\partial q_A/\partial g_A = -\tau/(2\delta D)$; the same magnitude holds for B. On E, $q_j(t) = r_j(t)/D$ with $\partial r_j/\partial g_j = -\tau/\delta$ from (7), so $\partial q_j/\partial g_j = -\tau/(\delta D)$. □

The factor-of-two difference between regimes reflects distinct economic margins. On C, extending hours steals consumers from the rival who would have purchased anyway: the pharmacy gains, the rival loses. On E, extending hours rescues consumers from the dropout fringe: the pharmacy gains and no one loses.

Lemma 2 (Marginal benefit of duration)**.** Holding m_j fixed, $\partial g_j/\partial L_j = -1/2$ on $\mathbb{S}^1 \setminus I_j$ and $\partial g_j/\partial L_j = 0$ on I_j. Therefore:

$$\frac{\partial Q_j}{\partial L_j} = \frac{N\tau}{2\delta D} \int_{E\cap(\mathbb{S}^1\setminus I_j)} \rho_\mu(t)\,dt \;+\; \frac{N\tau}{4\delta D} \int_{C\cap(\mathbb{S}^1\setminus I_j)} \rho_\mu(t)\,dt. \tag{24}$$

Proof. Extending L_j symmetrically around the midpoint m_j moves the arc's two endpoints outward at unit rate, so g_j falls at rate $1/2$ for every $t \in \mathbb{S}^1 \setminus I_j$ and is unchanged on I_j. The E/C partition shifts with L_j because $g_A + g_B$ shifts, but q_j is continuous across that boundary: at any t with $g_A(t) + g_B(t) = H$ one has $r_j(t) = d^*(t)$, so the two branches of (10) agree and the Leibniz boundary contributions cancel. Likewise q_j is continuous across the endpoints of I_j, where $g_j = 0$ on both sides. Combining with Lemma 1 and the joint density $(N/D)\rho_\mu$, then integrating over the spatial dimension (width D), yields (24). □

The two integrals in (24) are the two channels through which extending opening hours raises demand. On E, lengthening j's arc rescues consumers who would otherwise exit (the *market-expansion channel*); on C, it shifts the indifference location against the rival (the *business-stealing channel*). Both channels carry the same chain-rule factor $\partial g_j/\partial L_j = -1/2$, but the underlying per-time spatial sensitivities from Lemma 1 differ by a factor of two—$\tau/(\delta D)$ on E versus $\tau/(2\delta D)$ on C—yielding the final weights

$\tau/(2\delta D)$ and $\tau/(4\delta D)$ in (24). The factor-of-two advantage of E is the same point as in Lemma 1 (see the remark after Lemma 1).

Lemma 3 (Marginal benefit of midpoint)**.** Let L_j^{out} and R_j^{out} denote the time arcs immediately to the left and right of I_j on $\mathbb{S}^1$, each extending to the antipode of m_j. Then $\partial g_j/\partial m_j = +1$ on L_j^{out}, -1 on R_j^{out}, and zero on I_j, yielding

$$\begin{aligned}\frac{\partial Q_j}{\partial m_j} = \frac{N\tau}{\delta D}&\left[\int_{E\cap R_j^{\text{out}}} \rho_\mu - \int_{E\cap L_j^{\text{out}}} \rho_\mu\right] \\ &+ \frac{N\tau}{2\delta D}\left[\int_{C\cap R_j^{\text{out}}} \rho_\mu - \int_{C\cap L_j^{\text{out}}} \rho_\mu\right]. \end{aligned} \tag{25}$$

Moreover, if the rival's arc is centered at the peak, then $\partial Q_j/\partial m_j = 0$ at $m_j = 1/2$: both bracketed differences vanish, so a peak-centered midpoint satisfies pharmacy j's midpoint first-order condition.

Proof. Shifting the midpoint m_j rigidly translates the arc I_j around the circle without changing its length, so g_j is unaffected on I_j itself (where it remains zero). Off the arc, $g_j(t)$ equals the circular distance from t to the nearer endpoint of I_j. A marginal increase in m_j moves both endpoints by the same amount in the same direction: on the trailing side L_j^{out} the near endpoint recedes from t, so g_j rises at unit rate, $\partial g_j/\partial m_j = +1$; on the leading side R_j^{out} the near endpoint approaches t, so g_j falls at unit rate, $\partial g_j/\partial m_j = -1$. These two outer arcs meet at the antipode of m_j, where the assignment of t to the nearer endpoint switches.

By Lemma 1, the per-time spatial demand of j responds to a change in g_j at rate $\tau/(\delta D)$ on the partial-coverage region E and $\tau/(2\delta D)$ on the full-coverage region C. Multiplying these sensitivities by the density ρ_μ, by the spatial width D and population N embedded in the joint density $(N/D)\rho_\mu$, and by the local rates $\partial g_j/\partial m_j = \mp 1$ just established, then integrating over the two outer arcs, gives

$$\frac{\partial Q_j}{\partial m_j} = \frac{N\tau}{\delta D}\left[\int_{E\cap R_j^{\text{out}}} \rho_\mu - \int_{E\cap L_j^{\text{out}}} \rho_\mu\right] + \frac{N\tau}{2\delta D}\left[\int_{C\cap R_j^{\text{out}}} \rho_\mu - \int_{C\cap L_j^{\text{out}}} \rho_\mu\right],$$

which is (25); the leading (R_j^{out}) terms enter with a positive sign because reducing mismatch there raises demand, and the trailing (L_j^{out}) terms enter negatively.

It remains to show the right-hand side vanishes when both arcs are centered at the peak. Suppose $m_j = 1/2$ and the rival is also peak-centered, so the partition (E, C) is symmetric about $t = 1/2$ (it depends on t only through $g_A + g_B$, a function of circular distance from 1/2). The two outer arcs L_j^{out} and R_j^{out} are then mirror images under reflection through $t = 1/2$, and this reflection maps E to E and C to C. Because ρ_μ is itself symmetric about 1/2, the reflection is measure-preserving for the density, so $\int_{E\cap R_j^{\text{out}}} \rho_\mu = \int_{E\cap L_j^{\text{out}}} \rho_\mu$ and likewise for C. Both bracketed differences are therefore zero, and $\partial Q_j/\partial m_j = 0$ at $m_j = 1/2$. □

The midpoint first-order condition compares density-weighted mass on the leading side of j's arc to that on the trailing side, with E-mass weighted twice as heavily as C-mass. By symmetry of ρ_μ around $t = 1/2$, this difference vanishes whenever both pharmacies center their arcs at the peak.

E.3 Proofs

Theorem 1

Proof. Part (a) follows from Steps 2 and 3 below: Step 2 reduces the symmetric duration first-order condition to (13), and Step 3 shows that this equation admits a unique solution $L^* \in (0, 1)$. Part (b) follows from Steps 1 and 4: Step 1 shows that $m_A = m_B = 1/2$ is a mutual best response, with the cases distinguished by conditions (i) and (ii) of the theorem, and Step 4 verifies that, given the rival at $(1/2, L^*)$, the duration L^* is each firm's unique best response.

Step 1 (Midpoints). Suppose $m_B = 1/2$. By Lemma 3, the midpoint first-order condition $\partial Q_A/\partial m_A = 0$ is satisfied at $m_A = 1/2$, since both bracketed differences in (25) vanish when both arcs are peak-centered. To confirm this stationary point is a best response, consider a deviation $m_A \neq 1/2$. Its effect decomposes into a density effect — the arc moves into a region of strictly lower density, reducing Q_A — and, in partial coverage, a recapture effect, as the displaced arc covers off-peak times at which some consumers would otherwise abstain.

In the full-coverage regime the recapture effect is absent (no consumer abstains), so $Q_A = \frac{N}{2} + \frac{N\tau}{2\delta D}\big(\Psi_B - \Psi_A\big)$ and maximizing Q_A over m_A is equivalent to minimizing the density-weighted mismatch $\Psi_A(a) = \int_{S^1} g_A\, \rho_\mu\, dt$, where $m_A = \frac{1}{2} + a$. Since ρ_μ is symmetric about $t = 1/2$, Ψ_A is symmetric in a with $\Psi_A'(0) = 0$; and for a symmetric, single-peaked density the expected mismatch of an arc of fixed length is minimized when the arc is centred at the mode, so $a = 0$ is the global minimizer. The minimizer is unique and the optimum strict for $\mu < 1$ because $\Psi_A''(0) = 4(1-\mu)(1-L_A) > 0$ (Appendix E.4); hence $m_A = 1/2$ is the unique global best response. When $\mu = 1$ the midpoint is payoff-irrelevant and any midpoint profile constitutes a continuum of equivalent equilibria with the same duration.

In partial coverage, the two effects oppose one another; the density effect dominates and the peak remains the best response provided demand is sufficiently peaked, which we make precise in Appendix E.5. By symmetry, $m_B = 1/2$ is the best response to $m_A = 1/2$, so a peak-centered symmetric profile is a Nash equilibrium.

Step 2 (Symmetric duration first-order condition). At the symmetric profile $m_A = m_B = 1/2$ and $L_A = L_B = L$, $g_A(t) = g_B(t) \equiv g_L(t)$, the distance from t to the peak-centered arc $I^{\text{peak}}(L) = [(1-L)/2,\, (1+L)/2]$. The set E is then $\{t : g_L(t) > H/2\}$, which is nonempty if and only if $\max_t g_L(t) = (1-L)/2 > H/2$, equivalently $L < L^{\text{tr}}$. When nonempty, E is an arc of length $L^{\text{tr}} - L$ centered at the antipode $t = 0 \equiv 1$.

The density mass on $I^{\text{peak}}(L)$ is, by direct integration using ρ_μ:

$$G(L;\mu) = \int_{I^{\text{peak}}(L)} \rho_\mu(t)\, dt = L(2-\mu) - (1-\mu)L^2.$$

The density mass on E is, for $L < L^{\text{tr}}$, also by direct integration:

$$\int_E \rho_\mu(t)\, dt = 2\int_0^{(L^{\text{tr}}-L)/2} \big[\mu + 4(1-\mu)t\big]\, dt = \mu(L^{\text{tr}} - L) + (1-\mu)(L^{\text{tr}} - L)^2 = w_E(L;\mu,H).$$

Since $E \subset \mathbb{S}^1 \setminus I^{\text{peak}}$ (every point in I^{peak} has $g_L = 0 \le H/2$), the C-mass outside I^{peak} is $1 - G(L;\mu) - w_E(L;\mu,H)$. Applying Lemma 2 at the symmetric profile:

$$\begin{aligned} \left.\frac{\partial Q_A}{\partial L_A}\right|_{\text{sym}} &= \frac{N\tau}{2\delta D}\, w_E(L;\mu,H) + \frac{N\tau}{4\delta D}\big[1 - G(L;\mu) - w_E(L;\mu,H)\big] \\ &= \frac{N\tau}{4\delta D}\big[(1 - G(L;\mu)) + w_E(L;\mu,H)\big] = \frac{N\tau}{4\delta D}\,\phi(L;\mu,H). \end{aligned}$$

Setting $m \cdot \partial Q_A/\partial L_A = \gamma\, L$ yields (13).

Step 3 (Existence and uniqueness of L^*). Define

$$\Phi(L) \equiv \frac{mN\tau}{4\delta D}\,\phi(L;\mu,H) - \gamma\, L.$$

We show that Φ is continuous on $[0,1]$, strictly decreasing on $(0,1)$, $\Phi(0) > 0$, and $\Phi(1) < 0$. By the intermediate value theorem, Φ admits a unique zero $L^* \in (0,1)$.

Continuity: w_E is continuous at $L = L^{\text{tr}}$ (the partial-coverage branch evaluates to zero at $L = L^{\text{tr}}$, matching the full-coverage branch), so ϕ and hence Φ are continuous on $[0,1]$.

Strict monotonicity: In partial coverage ($L < L^{\text{tr}}$):

$$\begin{aligned}\phi'(L;\mu,H) &= -G'(L;\mu) + w_E'(L;\mu,H)\\ &= -\big[(2-\mu) - 2(1-\mu)L\big] + \big[-\mu - 2(1-\mu)(L^{\text{tr}} - L)\big]\\ &= -2 + 2(1-\mu)(2L - L^{\text{tr}}).\end{aligned}$$

Since $L \le L^{\text{tr}} < 1$ and $\mu \in [0,1]$, we have $2(1-\mu)(2L - L^{\text{tr}}) \le 2(1-\mu)L^{\text{tr}} < 2$, so $\phi'(L) < 0$. In full coverage ($L \ge L^{\text{tr}}$):

$$\phi'(L;\mu,H) = -G'(L;\mu) = -(2-\mu) + 2(1-\mu)L.$$

At $L = 1$ this evaluates to $-\mu \le 0$, with strict inequality whenever $\mu > 0$; for $L < 1$, the expression is strictly less than $-\mu$. (For $\mu = 0$, $\phi'(L) = -2 + 2L < 0$ on $L < 1$.) Hence $\phi'(L) < 0$ on $(0,1)$, and

$$\Phi'(L) = \frac{mN\tau}{4\delta D}\,\phi'(L) - \gamma < -\gamma < 0.$$

Boundary values: $\phi(0;\mu,H) = 1 + \mu L^{\text{tr}} + (1-\mu)(L^{\text{tr}})^2 > 0$, so $\Phi(0) > 0$. Because evaluating the boundary at $L = 1$ guarantees that $L \ge L^{\text{tr}}$ and $w_E = 0$, we have $\phi(1;\mu,H) = 1 - (2-\mu) + (1-\mu) + 0 = 0$, and so $\Phi(1) = -\gamma < 0$.

Step 4 (Mutual best response). Fix the rival at $(m_B, L_B) = (1/2,\ L^*)$, so that g_B is held fixed at the mismatch generated by the peak-centered arc $I^{\text{peak}}(L^*)$, and consider pharmacy A's problem in L_A (with $m_A = 1/2$). We show directly that A's marginal benefit is strictly decreasing in L_A; the argument is distinct from Step 3, which moved both arcs along the diagonal, because here only A's arc varies. From Lemma 2,

$$\frac{\partial Q_A}{\partial L_A} = \frac{N\tau}{2\delta D}\int_{E\cap(\mathbb{S}^1\setminus I_A)} \rho_\mu \;+\; \frac{N\tau}{4\delta D}\int_{C\cap(\mathbb{S}^1\setminus I_A)} \rho_\mu,$$

where, with g_B fixed, $E = \{t : g_A(t) + g_B(t) > H\}$ and C is its complement. As L_A increases: (i) the arc I_A expands, so the integration domain $\mathbb{S}^1 \setminus I_A$ contracts, removing strictly positive density mass from both integrals; and (ii) $g_A(t)$ falls pointwise on $\mathbb{S}^1 \setminus I_A$, so $g_A + g_B$ falls and the set E contracts (weakly) into C, transferring mass from the heavier weight $\frac{N\tau}{2\delta D}$ to the lighter weight $\frac{N\tau}{4\delta D}$. Both effects strictly reduce $\partial Q_A/\partial L_A$ wherever E or $\mathbb{S}^1 \setminus I_A$ has positive measure. Hence the marginal benefit $m\,\partial Q_A/\partial L_A$ is strictly decreasing in L_A while the marginal cost γL_A is strictly increasing, so A's profit is strictly concave in L_A and the best response is the unique L_A satisfying $m\,\partial Q_A/\partial L_A =$

γL_A. Evaluated at $g_B = g_{L^*}$, this best-response condition is exactly (13), whose unique solution is L^*; thus A's best response to $L_B = L^*$ is $L_A = L^*$. Combined with Step 1, the profile $(m_A, L_A) = (m_B, L_B) = (1/2,\, L^*)$ is a mutual best response and hence a Nash equilibrium.

Finally, in the full-coverage regime the joint optimum over (m_A, L_A) coincides with the coordinate-wise optimum identified in Steps 1 and 4. The duration argument above holds at $m_A = 1/2$, and the midpoint argument of Step 1 holds for any fixed L_A: under full coverage a deviation to $m_A \neq 1/2$ strictly lowers Q_A—hence profit, since costs depend only on L_A—at every L_A, while at $m_A = 1/2$ profit is strictly concave in L_A with maximizer L^*. Any joint deviation $(m_A, L_A) \neq (1/2, L^*)$ is therefore dominated by first resetting m_A to $1/2$ (weakly raising profit, strictly if $m_A \neq 1/2$ and $\mu < 1$) and then setting $L_A = L^*$ (weakly raising profit, strictly if $L_A \neq L^*$). Thus $(1/2, L^*)$ is a global best response over the full two-dimensional strategy space, not merely along each axis. In the partial-coverage regime the midpoint deviation carries an offsetting recapture effect, and the global best response is characterized in Appendix E.5. □

Proposition 1

Proof. Suppose, for contradiction, that (L_A^*, L_B^*) with $m_A = m_B = 1/2$ is a Nash and, without loss of generality, $L_A^* > L_B^*$. The common midpoint implies $I_B \subset I_A$. From Lemma 2, since $\mathbb{S}^1 \setminus I_B = (\mathbb{S}^1 \setminus I_A) \cup (I_A \setminus I_B)$,

$$\frac{\partial Q_B}{\partial L_B} - \frac{\partial Q_A}{\partial L_A} = \frac{N\tau}{2\delta D} \int_{E \cap (I_A \setminus I_B)} \rho_\mu + \frac{N\tau}{4\delta D} \int_{C \cap (I_A \setminus I_B)} \rho_\mu \;>\; 0,$$

where strict positivity uses that $I_A \setminus I_B$ has positive Lebesgue measure $L_A^* - L_B^* > 0$ and ρ_μ is positive everywhere. Both equilibrium arcs are interior, $L_j^* \in (0,1)$: a boundary arc cannot be a best response, since the marginal benefit at $L_j = 0$ is strictly positive (mirroring $\Phi(0) > 0$ in Step 3 of the proof of Theorem 1, evaluated at the rival's arc) while at $L_j = 1$ the marginal cost γ strictly exceeds the marginal benefit (mirroring $\Phi(1) < 0$), so each firm's profit-maximizing arc lies strictly inside $(0,1)$. The interior first-order conditions $m\,\partial Q_j/\partial L_j = \gamma\, L_j^*$ then give

$$m\left[\partial Q_B/\partial L_B - \partial Q_A/\partial L_A\right] = \gamma\,(L_B^* - L_A^*) < 0,$$

contradicting the strict positivity established above. □

Proposition 2

Proof. Write the first-order condition as $F(L^*; x) \equiv K\,\phi(L^*; \mu, H(x)) - \gamma L^* = 0$, where $K \equiv mN\tau/(4\delta D)$ and x denotes any primitive. By Step 3 of the proof of Theorem 1, $F_L = K\phi'(L^*) - \gamma < 0$, so by the implicit function theorem $\partial L^*/\partial x = -F_x/F_L$ and hence $\text{sign}(\partial L^*/\partial x) = \text{sign}(F_x)$, where F_x is the *total* partial derivative

$$F_x = K_x\,\phi(L^*) \;+\; K\,\phi_H(L^*)\,H_x \;+\; K\,\phi_\mu(L^*)\,\mu_x \;-\; L^*\,\gamma_x, \tag{26}$$

with the convention that $\mu_x = 1$ and $\gamma_x = 1$ only when x is μ or γ respectively, and zero otherwise. The relevant derivatives of the composites are

$$\frac{K_x}{K} = \frac{1}{N}, \frac{1}{m}, \frac{1}{\tau}, -\frac{1}{\delta}, -\frac{1}{D} \quad \text{for } x = N, m, \tau, \delta, D \text{ (and 0 for } V, \gamma, \mu),$$

$$H_\tau = -\frac{H}{\tau} \le 0, \quad H_\delta = -\frac{D}{\tau} < 0, \quad H_D = -\frac{\delta}{\tau} < 0, \quad H_V = \frac{2}{\tau} > 0,$$

and $H_x = 0$ for $x \in \{N, m, \gamma, \mu\}$. From the first-order condition (13), $\phi(L^*) = \gamma L^*/K > 0$ at the interior optimum. The sign of ϕ_H follows by direct differentiation: in full coverage $\phi = 1 - G(L; \mu)$ is independent of H, so $\phi_H = 0$; in partial coverage, using $L^{\text{tr}} = 1 - H$ so that $\partial/\partial H = -\partial/\partial L^{\text{tr}}$,

$$\phi_H = -\frac{\partial w_E}{\partial L^{\text{tr}}} = -\mu - 2(1-\mu)(L^{\text{tr}} - L) < 0 \qquad (L < L^{\text{tr}}),$$

since both terms are non-negative and μ and $(1-\mu)(L^{\text{tr}} - L)$ cannot vanish simultaneously on $L < L^{\text{tr}}$. Direct differentiation likewise gives

$$\phi_\mu = L(1-L) + (L^{\text{tr}} - L)\big[1 - (L^{\text{tr}} - L)\big] > 0 \text{ (partial)}, \qquad \phi_\mu = L(1-L) > 0 \text{ (full)}.$$

Full coverage ($\phi_H = 0$). Only the K-channel and the cost term in (26) survive: $F_N, F_m, F_\tau = (K/N, K/m, K/\tau)\phi > 0$; $F_\mu = K\phi_\mu > 0$; $F_\gamma = -L^* < 0$; $F_\delta = -(K/\delta)\phi < 0$; $F_D = -(K/D)\phi < 0$; and $F_V = 0$ since V enters only through H.

Partial coverage ($\phi_H < 0$). The parameters N, m, γ, μ do not enter H and inherit their full-coverage signs. For the four parameters entering H:

$$F_\tau = \frac{K}{\tau}\phi + K\phi_H\left(-\frac{H}{\tau}\right) = \frac{K}{\tau}\big(\phi - \phi_H H\big) > 0, \quad \text{since } \phi > 0 \text{ and } -\phi_H H \geq 0;$$

$$F_V = K\phi_H \cdot \frac{2}{\tau} < 0;$$

$$F_\delta = -\frac{K}{\delta}\phi + K\phi_H\left(-\frac{D}{\tau}\right) = \underbrace{-\frac{K}{\delta}\phi}_{<0} + \underbrace{K|\phi_H|\frac{D}{\tau}}_{>0};$$

$$F_D = -\frac{K}{D}\phi + K\phi_H\left(-\frac{\delta}{\tau}\right) = \underbrace{-\frac{K}{D}\phi}_{<0} + \underbrace{K|\phi_H|\frac{\delta}{\tau}}_{>0}.$$

The signs of F_δ and F_D are therefore indeterminate. That the ambiguity is genuine rather than an artifact of bounding is confirmed by the closed-form case $\mu = 1$: the numerator of $\partial L^*_{\text{part}}/\partial D$ is proportional to $mN\tau + 4\gamma\big[(V-p)-\tau\big]$, which changes sign over the admissible parameter region. For instance, at $m = N = \tau = \gamma = \delta = 1$, $D = 2$, $V - p = 1.4$ all three parts of Assumption 1 hold, $H = 0.8$, and the peak-centred FOC candidate $L^* = 0.12 < L^{\text{tr}} = 0.2$ lies strictly in partial coverage, yet $\partial L^*/\partial D = +0.052 > 0$; the same configuration yields $\partial L^*/\partial \delta > 0$. □

Proposition 3

Proof. Writing $L^* = \theta/(1+\theta)$ with $\theta = mN\tau/(4\gamma\delta D)$:

$$\frac{dL^*}{d\theta} = \frac{1}{(1+\theta)^2} > 0, \qquad \frac{d^2L^*}{d\theta^2} = -\frac{2}{(1+\theta)^3} < 0.$$

For any parameter x, the chain rule gives

$$\frac{\partial^2 L^*}{\partial x^2} = \frac{d^2L^*}{d\theta^2}\left(\frac{\partial\theta}{\partial x}\right)^2 + \frac{dL^*}{d\theta}\frac{\partial^2\theta}{\partial x^2}.$$

For $x \in \{N, m, \tau\}$, θ is linear in x, so $\partial^2\theta/\partial x^2 = 0$ and

$$\frac{\partial^2 L^*}{\partial x^2} = \frac{d^2L^*}{d\theta^2}\left(\frac{\partial\theta}{\partial x}\right)^2 < 0.$$

For $x \in \{\gamma, \delta, D\}$, $\theta = c/x$ for some $c > 0$, so $\partial\theta/\partial x = -\theta/x$ and $\partial^2\theta/\partial x^2 = 2\theta/x^2$.

Substituting:

$$\frac{\partial^2 L^*}{\partial x^2} = -\frac{2}{(1+\theta)^3} \cdot \frac{\theta^2}{x^2} + \frac{1}{(1+\theta)^2} \cdot \frac{2\theta}{x^2} = \frac{2\theta}{x^2(1+\theta)^3}\Big[(1+\theta) - \theta\Big] = \frac{2\theta}{x^2(1+\theta)^3} > 0.$$

□

Proposition 4 (Second-derivative comparative statics, closed form: partial-coverage branch)**.** In the closed-form case $\mu = 1$, let L^* denote the symmetric peak-centered FOC solution L^*_{part} from (18) (see the remark in Section 4.2.3 on its equilibrium status), and assume $0 < L^* < L^{\text{tr}}$. Four of the six second derivatives retain their full-coverage signs,

$$\frac{\partial^2 L^*}{\partial N^2}, \frac{\partial^2 L^*}{\partial m^2}, \frac{\partial^2 L^*}{\partial \tau^2} < 0, \qquad \frac{\partial^2 L^*}{\partial \gamma^2} > 0,$$

while the two spatial cost parameters that also enter the coverage threshold H are of ambiguous sign:

$$\frac{\partial^2 L^*}{\partial \delta^2} \quad \text{and} \quad \frac{\partial^2 L^*}{\partial D^2} \quad \text{may be positive, zero, or negative.}$$

Proof. Differentiating $L^*_{\text{part}} = mN\tau(1+L^{\text{tr}})/(2mN\tau+4\gamma\delta D)$ twice, with $L^{\text{tr}} = 1-H$ and $H = [2(V-p)-\delta D]/\tau$ treated as composites, every second derivative carries the positive denominator $(2mN\tau+4\gamma\delta D)^3$. For N, m, and γ the numerator factors as a sign-definite constant times $\delta D - 2(V-p) + 2\tau = \tau(1+L^{\text{tr}}) > 0$, giving $\partial^2 L^*/\partial N^2, \partial^2 L^*/\partial m^2 < 0$ and $\partial^2 L^*/\partial \gamma^2 > 0$. For τ the numerator bracket simplifies to $-mN\tau H - 4\gamma\delta D < 0$ (using $L^{\text{tr}} - 1 = -H$ and $H \geq 0$), so $\partial^2 L^*/\partial \tau^2 < 0$. For δ and D the bracket equals $2\gamma\tau(1+L^{\text{tr}}) - 2\gamma\delta D - mN\tau = -\big[mN\tau + 4\gamma\big((V-p)-\tau\big)\big]$, i.e. exactly the negative of the numerator of $\partial L^*/\partial D$ in Proposition 2. Equivalently, since at $\mu = 1$ the closed form L^*_{part} depends on δ and D only through the product δD and is a ratio of two functions affine in δD,

$$\frac{\partial^2 L^*}{\partial D^2} = -\frac{8\gamma\delta}{2mN\tau + 4\gamma\delta D}\frac{\partial L^*}{\partial D}, \qquad \frac{\partial^2 L^*}{\partial \delta^2} = -\frac{8\gamma D}{2mN\tau + 4\gamma\delta D}\frac{\partial L^*}{\partial \delta},$$

so each spatial-cost second derivative carries the sign opposite to the corresponding first derivative. All three signs are therefore attained on the admissible region. At $m = N = \tau = \gamma = \delta = 1$, $D = 2$, $V - p = 1.4$ (the configuration of Proposition 2, with $H = 0.8$ and $L^* = 0.12 < L^{\text{tr}} = 0.2$) one has $\partial L^*/\partial D > 0$ and hence $\partial^2 L^*/\partial D^2 < 0$; at $m = N = \tau = \gamma = \delta = 1$, $D = 1$, $V - p = 0.6$ ($H = 0.2$, $L^* = 0.3 < L^{\text{tr}} = 0.8$) one has $\partial L^*/\partial D < 0$ and $\partial^2 L^*/\partial D^2 > 0$; and at $V - p = 1 - \frac{1}{4\gamma}$ (e.g. $V - p = 0.75$ with $\gamma = 1$,

$D = 1$, $H = 0.5$, $L^* = 0.25 < L^{\mathrm{tr}} = 0.5$) the first derivative vanishes and so does the second. All three configurations satisfy Assumption 1 with $0 < L^* < L^{\mathrm{tr}} < 1$. □

E.4 Hessian at the Symmetric Peak (Full Coverage)

Fix B at $(1/2, L^*)$ and write $m_A = 1/2 + a$. Pharmacy A's profit depends on its controls only through $\Psi(m_A, L_A) \equiv \int_{S^1} g_A\, \rho_\mu\, dt$, via $\pi_A = \text{const} - \frac{mN\tau}{2\delta D}\Psi - \frac{1}{2}\gamma L_A^2$. Integrating the piecewise-linear g_A against the tent density gives $\partial^2\Psi/\partial a^2\big|_{a=0} = 4(1-\mu)(1-L_A)$ and $\partial^2\Psi/\partial a\,\partial L_A\big|_{a=0} = 0$, so the Hessian in (m_A, L_A) is diagonal,

$$\frac{\partial^2 \pi_A}{\partial m_A\,\partial L_A} = 0, \qquad \frac{\partial^2 \pi_A}{\partial m_A^2} = -\frac{2mN\tau}{\delta D}(1-\mu)(1-L^*) < 0, \qquad \frac{\partial^2 \pi_A}{\partial L_A^2} = K\phi'(L^*) - \gamma < 0,$$

and hence negative definite.

E.5 The Peak-Centred Profile in the Partial-Coverage Regime

This appendix studies when the peak-centred profile of Theorem 1 is a Nash equilibrium under partial coverage ($L^* < L^{\mathrm{tr}}$), and records what happens when it is not. It derives the closed-form threshold μ_g that delimits the peak-centred equilibrium up to a numerically negligible margin—the exact threshold μ_{NE} satisfies $\mu_{\mathrm{NE}} \le \mu_g$. Throughout, the rival is held at $(\frac{1}{2}, L^*)$ and pharmacy A contemplates a deviation; write $\ell^* \equiv L^{\mathrm{tr}} - L^*$ for the dropout width at the symmetric candidate and $\nu \equiv 4(1-\mu)$.

A unilateral midpoint deviation. Define the own-mismatch and joint-dropout integrals

$$\Psi(a) = \int_{S^1} g_A\, \rho_\mu\, dt, \qquad \mathcal{F}(a) = \int_{S^1} \big(g_A + g_B - H\big)^+ \rho_\mu\, dt. \tag{27}$$

By the per-time share (10), the aggregate demand of A when it plays $(\frac{1}{2} + a, L^*)$ against the peak-centered rival is

$$Q_A(a) = N\Big[\tfrac{1}{2} + \tfrac{\tau}{2\delta D}\big(\Psi_B - \Psi(a)\big) - \tfrac{\tau}{2\delta D}\,\mathcal{F}(a)\Big], \tag{28}$$

where Ψ_B is independent of a. For $0 \le a < \min\{\ell^*, H\}$ the sum $g_A + g_B$ has a plateau of width a over the off-peak trough and the partial-coverage set is the interval $E(a) = [\frac{a-\ell^*}{2}, \frac{a+\ell^*}{2}]$ of fixed length ℓ^*; differentiating (28) (the integrand vanishes on ∂E, so Leibniz' rule has no boundary terms) gives the demand change $\Delta Q(a) \equiv Q_A(a) - Q_A(0)$

with

$$\Delta Q'(a) = -\frac{N\tau}{2\delta D}\, a\big[(1-\mu)X - \mu - 2\nu a\big], \qquad X \equiv 6 - 2H - 6L^*. \tag{29}$$

Since $\Delta Q'(a) = -\frac{N\tau}{2\delta D}\, a\, B(a)$ with $B(a) \equiv (1-\mu)X - \mu - 2\nu a$ strictly decreasing, on $(0, \ell^*)$ the sign of $\Delta Q'$ equals that of $-B(a)$; any interior zero of B is thus a point where $\Delta Q'$ turns from negative to positive—a local minimum of ΔQ, not a maximum—so the maximum of ΔQ over $[0, \ell^*]$ is attained at an endpoint, $a = 0$ or $a = \ell^*$. The critical point $a_0 \equiv \frac{(1-\mu)X-\mu}{2\nu}$ is positive precisely when $(1-\mu)X - \mu > 0$—the local-stability condition $\mu < \mu^*$ of the second-derivative test below; when $a_0 \in (0, \ell^*)$, ΔQ dips to its minimum there before the saturating shift can pay off, while for $\mu \geq \mu^*$ one has $a_0 \leq 0$ and ΔQ increases monotonically on $(0, \ell^*)$—in either case the maximum lies at an endpoint. At the saturating shift $a = \ell^*$—the smallest displacement at which A's arc, together with the rival's, leaves no consumer uncovered—the dropout term vanishes ($\mathcal{F}(\ell^*) = 0$), and integrating (29) yields

$$\Delta Q(\ell^*) = -\frac{N\tau}{2\delta D}\,\frac{(\ell^*)^2}{2}\Big[\nu(1-L^*) - \tfrac{5}{6}\nu\ell^* - \mu\Big]. \tag{30}$$

For $a > \ell^*$ one has $\mathcal{F} \equiv 0$ and Ψ strictly increasing, so $Q_A(a) \leq Q_A(\ell^*)$: the saturating shift dominates every larger displacement.

When the peak is an equilibrium. The saturating shift is profitable exactly when (30) is positive, which—by the sign of its bracket—occurs when demand is flat enough; equivalently, the peak withstands this midpoint deviation precisely when demand is sufficiently peaked. Proposition 5 sharpens "sufficiently peaked" into the threshold μ_g and combines it with the duration deviation.

Proposition 5. Suppose the market is partially covered, $L^* < L^{\mathrm{tr}}$, and the plateau condition $\ell^* \leq \min\{L^*/2, H\}$ holds. Let

$$\mu_{\mathrm{NE}}(H, L^*) \equiv \sup\big\{\bar\mu \in [0,1] :\ (\tfrac{1}{2}, L^*) \text{ is a Nash equilibrium for every } \mu \leq \bar\mu\big\},$$

so the peak-centred profile is a Nash equilibrium whenever $\mu \leq \mu_{\mathrm{NE}}$. Then:

(a) the saturating midpoint shift (at fixed $L_A = L^*$) is strictly profitable iff $\mu > \mu_g(H, L^*)$, where

$$\mu_g = \frac{X_g}{X_g + 1}, X_g = 4(1-L^*) - \tfrac{10}{3}\ell^*; \tag{31}$$

(b) consequently the profile is not a Nash equilibrium for $\mu > \mu_g$, and for $\mu \leq \mu_g$

neither a pure-timing deviation (at $L_A = L^*$) nor a pure-duration deviation (at $m_A = 1/2$) is profitable;

(c) the exact threshold is bounded by the closed-form one: $\mu_{\text{NE}} \leq \mu_g$.

Proof. (a) The sign of (30) is the sign of $\mu - [\nu(1 - L^*) - \frac{5}{6}\nu\ell^*] = \mu - (1 - \mu)X_g$, using $\nu(1 - L^*) - \frac{5}{6}\nu\ell^* = (1 - \mu)[4(1 - L^*) - \frac{10}{3}\ell^*]$; this is positive iff $\mu > X_g/(X_g + 1)$, and by the domination of $a > \ell^*$ established below (30) the saturating shift is the most profitable timing deviation.

(b) For $\mu > \mu_g$ that shift is strictly profitable, so the profile is not a Nash equilibrium. For $\mu \leq \mu_g$, (29) with the domination of $a > \ell^*$ leaves $a = 0$ as the best timing deviation at $L_A = L^*$, and Step 4 of the proof of Theorem 1 gives strict concavity in L_A at $m_A = 1/2$ with maximiser L^*; hence no pure timing or pure duration deviation pays. Joint deviations are treated in Remark 3.

(c) Part (a) shows that for every $\mu > \mu_g$ the saturating midpoint shift is strictly profitable, so the peak-centred profile is not a Nash equilibrium at any such μ; hence no $\bar{\mu} > \mu_g$ satisfies the defining property of μ_{NE}, and $\mu_{\text{NE}} \leq \mu_g$. □

Remark 3 (Scope of the closed-form threshold)**.** Two qualifications. First, (31) is exact only under the plateau condition $\ell^* \leq \min\{L^*/2, H\}$ assumed above; where it fails—for instance over much of the partial-coverage range of Figure 7, where $\ell^* > L^*/2$ or H is near zero—(30) acquires additional kink terms and μ_g ceases to be the exact timing threshold. Second, even within the plateau regime μ_g bounds the equilibrium threshold from above, since simultaneous timing-and-duration deviations lower it to $\mu_{\text{NE}} \leq \mu_g$. Direct best-response computation gives $\mu_g - \mu_{\text{NE}} = O(\ell^*)$, below 3×10^{-3} in the plateau regime; and outside it—including at the parameters of Figure 7—it confirms the peak-centered profile is the *global* best response (maximum deviation gain below 10^{-5}). The comparative statics and figures all sit well inside the equilibrium region: at the parameters of Figure 7 ($\mu_0 = 0.15$) the plateau condition $\ell^* \leq \min\{L^*/2, H\}$ fails, so (31) is no longer the exact timing threshold there and the value $\mu_g \gtrsim 0.27$ it returns serves only as an indicative reference. The equilibrium guarantee at those parameters rests on the direct best-response search reported above (maximum deviation gain below 10^{-5}), not on the closed form. Within the plateau regime, where (31) is exact, the distinction between μ_g and μ_{NE} never affects any reported result.

The local second-derivative test gives a strictly weaker threshold. Letting $a \to 0$ in (29), the curvature at the peak is $\partial^2 Q_A/\partial m_A^2|_0 = -\frac{N\tau}{2\delta D}\left[(1-\mu)X - \mu\right]$, which is negative

—so the peak is a *local* best response—for $\mu < \mu^*$, where

$$\mu^*(H,L) = \frac{X}{X+1} = 1 - \frac{1}{7-2H-6L}, \qquad X = 6-2H-6L. \tag{32}$$

Since $X > X_g$ we have $\mu^* > \mu_g$: local stability is necessary but not sufficient for equilibrium. For $\mu \in (\mu_g, \mu^*)$ the peak is locally stable yet defeated by the non-marginal saturating deviation, so it is the global threshold μ_g (up to the negligible joint-deviation margin of Remark 3), not the local μ^*, that delimits the peak-centered equilibrium. Both thresholds decrease in L, but they move oppositely in the dropout width. Writing $X = 4(1-L)+2\ell^*$ and $X_g = 4(1-L)-\frac{10}{3}\ell^*$, the local threshold μ^* increases in ℓ^* (equivalently, decreases in H), whereas the global threshold μ_g decreases in ℓ^* (equivalently, increases in H): a wider dropout fringe makes the marginal stability test more permissive yet the binding non-marginal threshold stricter. The gap therefore widens,

$$\mu^* - \mu_g = \frac{(16/3)\,\ell^*}{(X+1)(X_g+1)},$$

so local stability becomes an increasingly misleading guide to equilibrium as unmet peripheral demand grows.

Beyond the threshold. For $\mu > \mu_g$ the profitable deviation is itself a stagger: A moves off the peak toward saturation, and by symmetry the same incentive applies to B. At a symmetric saturated profile $m_{A,B} = \frac{1}{2} \pm s$ with a common duration and $L+2s = L^{\mathrm{tr}}$, the joint mismatch satisfies $g_A(t)+g_B(t) \leq H$ for all t, so the market is fully covered and every consumer is served and each firm obtains demand $N/2$—strictly more than the peak demand $N\big(\frac{1}{2} - \frac{\tau}{2\delta D}\,\mathcal{F}_0\big)$, with $\mathcal{F}_0 \equiv \mathcal{F}(0) > 0$, at the same duration. When demand is sufficiently flat the firms thus have a mutual incentive to spread their opening hours, and the resulting fuller temporal coverage is consistent with the asymmetric opening-time patterns documented in Section 6.3.2. A full characterization of equilibrium in this regime—its existence, the equilibrium durations, and the welfare comparison with the peak—is beyond the scope of the present paper and is left to future work.