Retail Competition under the WIC Retail Delivery System: Insights from a Spatial Competition Model

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Abstract

The Special Supplemental Nutrition Program for Women, Infants, and Children (WIC) delivers food benefits through a retail delivery system. As this system ties WIC benefit redemption to WIC-authorized retailers while insulating WIC consumers from the retail prices of these foods, concerns have been raised about whether the system affects retailers' pricing incentives and generates price spillovers borne by non-WIC consumers. We therefore develop a spatial competition model to examine how this system shapes retail competition and analyze three market scenarios with different levels of e-commerce involvement. Our model shows that exclusive access to WIC demand leads WIC-authorized retailers to set higher equilibrium prices for WIC-approved product categories. These higher prices shift some non-WIC demand from WIC-authorized retailers to non-WIC-authorized retailers, raising the latter's equilibrium prices as well, though to a lesser extent. Moreover, the price distortions are more pronounced in markets with higher offline shopping costs, lower offline retail density, and a larger share of WIC consumers. Given that WIC accounts for a substantially larger share of total demand for infant formula than it does for other WIC-approved product categories, the price distortions are likely to be more pronounced for infant formula. Turning to e-commerce, we find that e-commerce entry intensifies retail competition, thereby mitigating offline price distortions, improving non-WIC consumer welfare, and reducing direct WIC spending. Further extending access to WIC consumers, an ongoing policy initiative, directly improves WIC consumer welfare, but its effects on non-WIC consumer welfare and direct WIC spending are ambiguous and depend on the share of WIC consumers and the relative costs of online and offline shopping.

Keywords: WIC retail delivery system · Retail competition · Spatial competition model · Infant formula

JEL Classification: L13 · L51 · L81 · I38 · D43

1 Introduction

The Special Supplemental Nutrition Program for Women, Infants, and Children (WIC) is a U.S. federal assistance program that provides supplemental foods, nutrition education, and health services to low-income pregnant and postpartum women, infants, and children under age 5. To facilitate food-benefit distribution, WIC authorizes a subset of offline retailers, known as WIC-authorized retailers, to serve as redemption sites. Each month, WIC participants receive allowances for specific categories of WIC-approved foods, such as infant formula, baby foods, grains, eggs, and canned fish, at WIC-authorized retailers.[1] WIC then reimburses these retailers based on the full retail prices of the redeemed products. This retailer-based redemption and reimbursement process forms the WIC retail delivery system.[2] As WIC participants are insulated from the retail prices of redeemed products, concerns have been raised that this delivery system may weaken WIC participants' price sensitivity and lead to higher retail prices for WIC-approved product categories.

[Insert *Table 1* here]

Table 1 presents the estimated WIC shares of total sales in 2005 across major WIC-approved product categories. Infant formula has attracted the greatest concern over potential WIC-induced price distortions, given WIC's substantial share of infant formula sales. Empirical evidence from retail scanner data suggests that WIC increases retail prices of infant formula (e.g., Oliveira, 2004; Rojas & Wei, 2019; U.S. Government Accountability Office, 2025). However, without richer market data, it remains challenging to determine whether these price increases originate at the wholesale level, the retail level, or both. Existing studies have largely examined the WIC rebate program and its implications for manufacturers' bidding and pricing strategies,[3] while paying less attention to how the WIC retail delivery system affects downstream retail competition. We therefore develop a spatial model of retail competition to study how the WIC retail delivery system shapes retailers' pricing incentives and market outcomes. We use infant formula as the motivating product category for the model,

[1] For the federal list of WIC-eligible foods, see https://www.fns.usda.gov/wic/food-packages/regulatory-requirements. WIC state agencies use this federal list as a baseline for developing and updating their own approved food lists. An exception is fruits and vegetables, which are issued as a cash-value benefit rather than as a fixed-quantity allowance.

[2] Two alternative delivery systems were used in the past. Vermont operated a home delivery system in which food benefits were delivered directly to WIC participants' homes. Mississippi and parts of Chicago, Illinois, employed a direct delivery system in which WIC participants obtained food benefits from state-operated storage facilities.

[3] The WIC rebate program is one of WIC's cost-containment policies. For certain WIC-approved product categories, WIC state agencies solicit competitive rebate bids from manufacturers and designate the winning manufacturer's product as the WIC contract brand. When a contract brand is specified, WIC participants are generally required to redeem their benefits for that brand. In the infant formula market, manufacturer rebates are often substantial, raising concerns that manufacturers may recoup part of these costs through higher retail prices ultimately paid by non-WIC consumers.

but the underlying economic mechanisms also apply to other WIC-approved product categories.

In this study, we adopt the circular retail market framework of Salop (1979) and Balasubramanian (1998). Salop's circular model has been widely used to study retail competition in a variety of settings, such as imperfect information (Balasubramanian, 1998), consumer heterogeneity (Shi, Zhou, & Jiang, 2019), and varying numbers of online retailers (Ford, Li, & Zheng, 2021). In the standard setup, offline retailers are evenly spaced along the circumference of a circle, while an online retailer, if present, is located at the center. Consumers are uniformly distributed along the circle and choose where to shop based on two main factors: convenience, captured by offline and online shopping costs, and product prices charged by each retailer. Building on this framework, we incorporate the WIC retail delivery system into the model by distinguishing between WIC-authorized and non-WIC-authorized retailers, as well as between WIC and non-WIC consumers. We distinguish WIC and non-WIC consumers by payment method: WIC consumers redeem WIC food benefits at WIC-authorized retailers, whereas non-WIC consumers pay out of pocket for products in WIC-approved categories at any retailer. The key mechanism is that WIC channels WIC consumers to WIC-authorized retailers through its benefit-redemption rules.

Considering that the effects of the WIC retail delivery system may vary with the extent of e-commerce involvement, we construct three scenarios to capture this heterogeneity: (1) markets without e-commerce, representing either the pre-e-commerce benchmark or markets where e-commerce entry remains limited; (2) markets in which the online channel serves only non-WIC consumers, reflecting the prevailing market structure in most U.S. regions; and (3) markets in which the online channel serves both WIC and non-WIC consumers, reflecting WIC's ongoing initiative to enable online benefit redemption. Note that, although online WIC benefit redemption is still in its early stages of implementation, comparing the equilibrium outcomes under Scenario 3 with those under Scenarios 1 and 2 provides useful insights into the potential implications of this ongoing policy initiative.

The model features two key types of equilibria: full-engagement equilibria and cap-exploitation equilibria. We formally define both types of equilibria in Section 4. Our main analysis focuses on full-engagement equilibria, in which all retailers fully engage in price competition. In these equilibria, WIC-authorized retailers charge higher retail prices owing to their exclusive access to WIC demand. In response, non-WIC-authorized retailers also raise their prices, albeit to a lesser extent, reflecting strategic complementarity in pricing. The comparative statics further show that the WIC-induced price distortions are more pronounced in markets with higher offline shopping costs, lower offline retail density, and a larger share of WIC consumers. We then compare the equilibrium outcomes under Scenarios 1 and 2 and show that non-WIC consumers' access to the online channel increases competitive pressure on offline retailers. This mitigates offline price distortions, improves non-WIC consumer welfare, and reduces direct WIC spending. Finally, comparing Scenarios 2 and 3, we find that enabling online WIC benefit redemption directly improves WIC consumer welfare, but its effects on non-WIC consumer welfare and direct WIC spending are ambiguous.

The direction and magnitude of these effects depend on the WIC consumer share and the relative costs of online and offline shopping.

Our work relates to three areas of research. First, we contribute to the industrial organization literature on spatial retail competition. Building on standard spatial models that derive local market power from transportation and shopping costs (Balasubramanian, 1998; Hotelling, 1929; Salop, 1979), our framework introduces program-induced captive demand as an additional source of market power. By modeling the WIC retail delivery system in a spatial competition framework, we show how WIC-induced captive demand changes retailers' pricing incentives and generates price spillovers between WIC-authorized and non-WIC-authorized retailers. The spatial modeling framework also allows us to trace how market structure and shopping-cost frictions shape the magnitude of these price distortions. More broadly, taking the WIC program as a motivating case, our work illustrates the value of spatial competition models as analytical tools for studying institutional sources of captive demand and their implications for retail competition.

Second, we contribute to the literature on WIC and the retail pricing of WIC-approved product categories. As noted earlier, most existing studies focus on the U.S. infant formula market and examine how the WIC rebate program affects manufacturers' bidding and pricing strategies (e.g., Abito, Hui, Salant, & Uetake, 2023; An, Davis, Liu, & Xiao, 2023; Davis, 2012; Reed & Levedahl, 2012; Wang, 2023). In this strand of research, changes in retail prices are typically analyzed as downstream outcomes of upstream manufacturers' decisions. More closely related to our work are two studies that examine how WIC-authorized retailers set infant formula retail prices under the WIC rebate program, taking wholesale prices as given. Oliveira (2004) provides empirical evidence of retail price increases for both WIC contract and noncontract brands, with larger increases for WIC contract brands. Prell (2004) models retail competition as a Cournot oligopoly and provides a theoretical explanation for the price pattern documented in Oliveira (2004). By contrast, we show that, even absent a rebate program, the WIC retail delivery system can exert upward pressure on retail prices in WIC-approved product categories. Taken together, our findings and those of Oliveira (2004) and Prell (2004) point to two complementary sources of retailers' WIC-related pricing incentives: the retail delivery system itself and, when present, the rebate program. Another strand of empirical research documents heterogeneity among WIC-authorized retailers, showing that retail prices for WIC-approved products are often higher at smaller independent retailers than at larger chain retailers (e.g., Neuberger & Greenstein, 2004; Saitone, Sexton, & Volpe, 2015; Volpe, 2014). Our model instead abstracts from heterogeneity among WIC-authorized retailers to focus on how WIC authorization status itself shapes retail competition.

Third, we contribute to the literature on the competitive effects of e-commerce in retail markets. Prior theoretical and empirical studies show that, under certain conditions, direct or online channels can reduce consumer search and shopping costs, intensify competition in local markets, and exert downward pressure on offline retailers' prices (e.g., Chiang, Chhajed, & Hess, 2003; Friberg, Ganslandt, & Sandström, 2000; Jo, Matsumura, & Weinstein, 2024). In our study, we examine these competitive effects under the WIC retail delivery system by comparing three scenarios that progressively

expand the role of the online channel. This comparison allows us to assess whether, and under what conditions, e-commerce can mitigate WIC-induced offline price distortions, improve consumer welfare, and reduce direct WIC spending.

The rest of the paper is organized as follows. Section 2 provides an overview of WIC and its retail delivery system. Section 3 presents the model setup. Section 4 analyzes equilibrium outcomes under the three scenarios and discusses their implications for consumer welfare and direct WIC spending. Section 5 concludes by summarizing our findings and discussing directions for future research. All proofs and extensions are provided in the appendices.

2 Background

2.1 WIC Program

The WIC program, initiated in 1972, is administered by the U.S. Department of Agriculture (USDA). It operates nationwide, with WIC state agencies responsible for implementation under federal guidelines. WIC serves pregnant, postpartum, and breastfeeding women, infants, and children up to age 5 who meet income, residency, and nutritional-risk eligibility requirements. In general, income eligibility is based on household income at or below 185% of the federal poverty guidelines. As WIC is funded through annual discretionary appropriations, meeting the eligibility criteria does not guarantee enrollment. In 2020, the average monthly WIC-eligible population was about 12.51 million, yet only 50.2% received WIC benefits (USDA, 2023). Among WIC benefits and services, food benefits account for the largest share of program expenditures. According to USDA's WIC Program Participation and Costs report (2026), spending on food benefits totaled approximately $2.88 billion in 2020, accounting for 57.4% of total program expenditures.

2.2 WIC Retail Delivery System

2.2.1 The Role of WIC-Authorized Retailers

In 2020, there were approximately 40,100 WIC-authorized retailers, and over two-thirds of them were superstores or supermarkets (Bardin, Vericker, Larson, Thrasher, & Chesterman, 2025). WIC-authorized retailers serve as redemption sites where WIC participants redeem their food benefits. These retailers are authorized and monitored by WIC state agencies. According to federal WIC regulations, WIC state agencies must maintain an appropriate number and distribution of WIC-authorized retailers to ensure participant access, competitive food prices, and effective administrative oversight. Therefore, WIC authorization is selective rather than automatic, with approval depending on state selection criteria and the need to maintain a manageable retailer network.[4] Moreover, WIC-authorized retailers are required to comply with WIC cost-containment policies and meet minimum variety and stocking requirements for WIC-approved products to maintain their authorization. Noncompliance may result in the loss of WIC authorization.

[4]See 7 C.F.R. § 246.12(g)(1)–(3), available at https://www.ecfr.gov/current/title-7/subtitle-B/chapter-II/subchapter-A/part-246/subpart-E/section-246.12.

2.2.2 Cost-containment Policies at the Retail Level

Cost-containment policies enable WIC to enroll more participants with limited funding. At the retail level, WIC implements two key cost-containment policies for WIC-authorized retailers: prohibiting price discrimination and limiting reimbursements through maximum allowable reimbursement levels (MARLs). First, to ensure fair pricing practices, WIC-authorized retailers are required to charge the same prices for WIC-approved products in WIC and non-WIC transactions. Second, federal WIC regulations require state agencies to establish MARLs for WIC-approved products sold by WIC-authorized retailers. These levels are generally determined by factors such as retailer type, size, and geographic location. For WIC-authorized retailers, reimbursement claims exceeding MARLs may not be fully paid and may be subject to additional review. Thus, MARLs can be viewed as effective price caps imposed on WIC-authorized retailers. Although the details of retail-level cost-containment policies vary by state, their primary purpose is to discipline WIC-authorized retailers' pricing incentives in WIC transactions and to help ensure that WIC pays competitive prices for WIC-approved products (USDA, 2015).

2.2.3 Online WIC Benefit Redemption

USDA has been working to modernize WIC by supporting online ordering and internet-based transactions. In 2023, USDA issued the WIC Online Ordering and Transactions Proposed Rule, which aims to remove regulatory barriers to online WIC benefit redemption.[5] As part of these efforts, WIC has completed its transition from paper vouchers, previously used by WIC participants to redeem their food benefits at WIC-authorized retailers, to electronic benefit transfer (EBT) cards.

Beginning in 2024, the WIC state agencies in Minnesota, Iowa, and Nebraska partnered with Hy-Vee, a regional supermarket chain in the U.S. Midwest, to pilot online benefit redemption. Under these pilots, WIC participants in eligible areas can use their WIC EBT cards to order WIC-approved products online, but home delivery fees are not covered by WIC benefits and must be paid out of pocket. These out-of-pocket costs impose a financial burden on WIC participants, limiting their ability to fully benefit from online redemption. Recognizing this barrier, some state WIC agencies have begun exploring ways to offset delivery costs associated with online redemption.[6]

The rollout of online WIC benefit redemption is expected to shift a portion of WIC transactions from the offline channel to the online channel, prompting retailers to adjust their pricing strategies for WIC-approved product categories. Scenario 3 is designed to capture this ongoing policy initiative and examine its implications for retail competition, consumer welfare, and direct WIC spending.

[5] For more details, see the proposed rule at https://www.federalregister.gov/documents/2023/02/23/2023-02484/special-supplemental-nutrition-program-for-women-infants-and-children-wic-online-ordering-and.

[6] For example, the WIC agency in New Jersey has proposed using state funding to offset food delivery costs as part of its online redemption planning project.

3 Model

As noted earlier, given WIC's substantial share of infant formula sales, we use infant formula to motivate a broader model of retail competition under the WIC retail delivery system. Our modeling framework focuses on retail competition at the product-category level rather than at the brand level. We consider a local market in which offline retailers differ by WIC authorization status. WIC-authorized retailers, referred to as W-retailers, and non-WIC-authorized retailers, referred to as NW-retailers, compete on price for infant formula. In Scenarios 2 and 3, we further introduce a single online retailer, referred to as the E-retailer.[7] The E-retailer serves only non-WIC consumers in Scenario 2 but is WIC-authorized and can serve WIC consumers in Scenario 3. *Table 1* summarizes the key notation used throughout the analysis.

[Insert *Table 2* here]

The model is set up as follows: offline retailers, either W- or NW-retailers, are equidistantly positioned along a circular market with a circumference of 1. W-retailers serve both WIC and non-WIC consumers, while NW-retailers serve only non-WIC consumers. Let p_{ij} and c_{ij} denote the unit retail price and the marginal cost, respectively, for offline retailer j of type i, where $i \in \{w, nw\}$ and j indexes the retailers of this type. When the E-retailer enters the market, it is positioned centrally in the circular market. p_e and c_e denote the unit retail price and marginal cost for the E-retailer, respectively. As fixed costs do not affect equilibrium pricing, we normalize them to zero without loss of generality. In addition, we impose WIC cost-containment policies under which each WIC-authorized retailer must set a single price for both WIC and non-WIC consumers, subject to the cap $\bar{p}$.

Consumers, normalized to a total of 1, are uniformly distributed along the circumference. Each consumer visits exactly one retailer and purchases one unit of infant formula. Consumers are divided into two groups: a fraction θ (where $\theta \in [0, 1]$) are WIC consumers, and the remaining fraction, $1-\theta$, are non-WIC consumers. The valuation of the infant formula, denoted by V, is assumed to be identical for all consumers and sufficiently large so that any consumer is better off obtaining it. Consumers incur additional shopping costs regardless of whether they obtain infant formula online or offline. For offline shopping, the primary shopping costs are travel expenses, measured at a linear rate t per unit distance. This specification captures the intuition that consumers located farther away from an offline retailer face higher offline shopping costs. Let $l_{a,ij}$ denote the travel distance between consumer a and offline retailer ij. A non-WIC consumer's net utility from shopping at an offline retailer (either a W- or an NW-retailer) is $V - tl_{a,ij} - p_{ij}$. As WIC consumers do not pay formula prices when redeeming infant formula at WIC-authorized retailers, a WIC consumer's net utility from shopping at a W-retailer is $V - tl_{a,wj}$. When shopping online, consumers incur a uniform shopping cost μ, independent of their location. This cost captures

[7] For tractability, we model the online channel as a single representative E-retailer. This specification allows us to focus on competition between the online and offline channels rather than competition among online retailers. Introducing multiple online retailers would require modeling horizontal differentiation among them. Without such differentiation, Bertrand price competition would drive prices down to marginal cost and eliminate economic profits.

the disutility associated with online shopping, such as delivery fees, membership fees, and waiting time. A non-WIC consumer's net utility from shopping at the E-retailer is $V - \mu - p_e$. When the E-retailer is WIC-authorized, a WIC consumer's net utility from shopping at the E-retailer is $V - \mu$.

To capture the key features of the WIC retail delivery system while keeping the model analytically tractable, we introduce several simplifying assumptions.

Assumption 1 Retailers are homogeneous except for WIC authorization status and sales channel. In particular, all retailers have the same marginal cost: $c_{ij} = c_e = c$, $\forall i, j$.

This assumption defines a clean benchmark in which retailers differ only along two dimensions: whether they are WIC-authorized and whether they operate offline or online. This allows us to focus on how WIC authorization status and sales channel shape retail competition for infant formula, while setting aside other sources of retailer heterogeneity such as cost differences, store size, product assortment, and service quality.

On the cost side, we assume a common marginal cost c across all retailers. The parameter c is intended to capture the unit procurement cost of infant formula, a major component of retailers' marginal costs. Following Prell (2004), we treat retailer-level differences in procurement costs as negligible. Appendix B.2 relaxes this assumption by allowing marginal costs to differ across retailer types and shows that our main findings are qualitatively unchanged.

Assumption 2 There are equal numbers of W-retailers and NW-retailers ($N_w = N_{nw} = N \geq 1$) located in an alternating pattern within the market. *Figure 1* provides an illustrative example.

[Insert *Figure 1* here]

This assumption involves two modeling choices. The first is to take the offline retail structure as given. Specifically, we take the total number of offline retailers as fixed because the WIC retail delivery system is unlikely to affect retailers' entry into or exit from the local market.[8] Moreover, given that WIC authorization is governed by an administrative approval process, we treat the set of W-retailers as exogenous in our model.

Second, this assumption imposes a symmetric market structure. The equal-number condition gives W-retailers and NW-retailers the same market presence, while the alternating spatial arrangement makes their local competitive environments comparable. Together, these restrictions allow us to isolate WIC's effects on equilibrium outcomes without confounding the analysis with asymmetries in retailer numbers or

[8] An exception may arise for above-50-percent (A50) retailers, which derive more than 50 % of their annual food sales revenue from WIC transactions. However, these retailers represent only a small share of WIC-authorized retailers. According to Bardin et al. (2025), A50 retailers account for approximately 2% of WIC-authorized retailers in 2022.

locations. As a robustness check, Appendix B.1 considers an alternative market structure with fewer W-retailers than NW-retailers and shows that the main results are qualitatively unchanged.

Assumption 3 The fraction of WIC consumers in the market θ is predetermined.

Following prior theoretical work on how WIC affects infant formula pricing (Prell, 2004; Reed & Levedahl, 2012), we treat the share of WIC consumers as predetermined in the short-run pricing game. This reflects the fact that WIC participation is governed by administrative certification and recertification processes, so enrollment is unlikely to adjust immediately in response to changes in local retail prices.

Assumption 4 WIC consumers are better off redeeming their WIC benefits at WIC-authorized retailers than purchasing infant formula out of pocket from non-WIC-authorized retailers.

As noted in the Introduction, this assumption makes explicit that WIC consumers obtain infant formula only from WIC-authorized retailers in the model. For simplicity, we exclude the outside option in which sufficiently high shopping costs at WIC-authorized retailers induce some WIC consumers to forgo their benefits and purchase infant formula out of pocket from non-WIC-authorized retailers.

Assumption 5 Price caps are sufficiently high that they do not constrain competitive pricing by WIC-authorized retailers.

We define competitive prices as the prices WIC-authorized retailers would choose when fully engaging in market competition. As MARLs are designed to prevent excessive reimbursements rather than restrict competitive pricing, we assume that price caps do not bind at competitive prices. This assumption is plausible given that MARLs are often set at relatively high levels to accommodate exceptional circumstances (Meckel, 2020; Neuberger & Greenstein, 2004). Accordingly, cap-binding equilibria in which price caps constrain competitive pricing fall outside the scope of our analysis. We nevertheless allow for cap-exploitation equilibria, in which WIC-authorized retailers strategically set their prices at the caps.

The sequence of the game is as follows:

> **Stage 1:** Stage 1: Each retailer, observing all retailers' locations and types, independently and simultaneously sets its infant formula price to maximize profit.
> **Stage 2:** Each consumer, observing all retailers' locations, types, and prices, chooses where to obtain infant formula to maximize utility.

We solve the game by backward induction.

4 Equilibrium Analysis

To capture different levels of e-commerce involvement, we consider three scenarios, denoted by subscripts 1, 2, and 3. Scenario 1 describes a market in which e-commerce is unavailable. Scenario 2 extends Scenario 1 by introducing an E-retailer that serves only non-WIC consumers. Scenario 3 further extends the model by allowing the E-retailer to serve WIC consumers as well. In this section, we characterize and analyze the equilibrium outcomes under these three scenarios.

We define two types of equilibria: full-engagement equilibria (FEE), in which all WIC-authorized retailers (W-retailers in Scenarios 1–3 and the E-retailer in Scenario 3) fully engage in market competition, and cap-exploitation equilibria (CEE), in which one or more WIC-authorized retailers strategically set their prices at the price caps. The main analysis centers on FEE outcomes because they provide a competitive-pricing benchmark that aligns with the observation that WIC-authorized retailers typically charge infant formula prices below state MARLs.[9] CEE may also arise in our model, but the corresponding outcomes depend on the administratively set cap level. We characterize the conditions under which CEE arise in the main text and briefly discuss these corresponding outcomes in Appendix A.2.

4.1 Analysis of Scenario 1 (No E-commerce)

[Insert *Figure 2* here]

For clarity, we divide the market into WIC and non-WIC segments and discuss each segment in turn. In the non-WIC segment, N W-retailers and N NW-retailers compete in prices to attract non-WIC consumers. Given our assumption of a symmetric circular market, it suffices to analyze the price-setting game between a W-retailer and a neighboring NW-retailer. As shown in *Figure 2(a)*, there exists a point between these two retailers at which a non-WIC consumer is indifferent between shopping at either retailer. Let x and y denote the distances from the W-retailer and the NW-retailer to this indifferent point, respectively. As the distance between the two retailers is $\frac{1}{2N}$, we have $y = \frac{1}{2N} - x$. The location of the indifferent point is obtained by equating the following utility functions:

$$V - tx - p_w = V - ty - p_{nw} = V - t\left(\frac{1}{2N} - x\right) - p_{nw}\,,$$

which is equivalent to

$$x = \frac{1}{4N} + \frac{p_{nw} - p_w}{2t}\,,$$

and

$$y = \frac{1}{4N} - \frac{p_{nw} - p_w}{2t}\,.$$

Given that each offline retailer serves symmetric non-WIC demand on both sides and that non-WIC consumers account for a fraction $1 - \theta$ of all consumers, the market

[9] Interviews with officials from several WIC state agencies suggest that WIC-authorized retailers generally set and report infant formula prices below the applicable MARLs.

shares captured by each W-retailer and each NW-retailer in the non-WIC segment are $S_w^{NW} = 2(1-\theta)x$ and $S_{nw}^{NW} = 2(1-\theta)y$, respectively.

Turning to the WIC segment, WIC consumers obtain infant formula exclusively from W-retailers. If there is a single W-retailer, it captures the entire WIC segment, as shown in *Figure 2(b)*. When $N \geq 2$, WIC consumers shop at the nearest W-retailer. Between any two neighboring W-retailers, there exists a point at which a WIC consumer is indifferent between shopping at either W-retailer. Let z denote the distance from a W-retailer to this indifferent point. The market share of WIC consumers captured by each W-retailer is $S_w^W = 2\theta z$. Given the symmetry imposed by Assumption 2, each W-retailer captures the same market share in the WIC segment, $S_w^W = \frac{\theta}{N}$. Hence, we obtain

$$z = \frac{1}{2N}\,.$$

Next, we solve the optimization problems for the two types of retailers. Each W-retailer and each NW-retailer maximizes its own profit as follows:

$$\max_{p_w \leq \bar{p}_w} \pi_w = (p_w - c)\left[(1-\theta)\left(\frac{1}{2N} + \frac{p_{nw} - p_w}{t}\right) + \frac{\theta}{N}\right], \tag{1}$$

$$\max_{p_{nw}} \pi_{nw} = (p_{nw} - c)(1-\theta)\left(\frac{1}{2N} - \frac{p_{nw} - p_w}{t}\right). \tag{2}$$

Proposition 1 ***(FEE)*** *Under the assumptions of the model and conditions illustrated below, a unique (pure strategy) Bertrand-Nash equilibrium exists, where W-retailers fully engage in market competition. Equilibrium prices, market shares (of non-WIC consumers, WIC consumers, and total), and profits are given by*

$$\begin{array}{ll}
p_{w,1}^* = c + \frac{t}{2N} + \frac{2t\theta}{3N(1-\theta)}\,, & p_{nw,1}^* = c + \frac{t}{2N} + \frac{t\theta}{3N(1-\theta)}\,; \\
S_{w,1}^{NW*} = \frac{3-5\theta}{6N}\,, & S_{nw,1}^{NW*} = \frac{3-\theta}{6N}\,; \\
S_{w,1}^{W*} = \frac{\theta}{N}\,, & S_{nw,1}^{W*} = 0\,; \\
S_{w,1}^{Total*} = \frac{3+\theta}{6N}\,, & S_{nw,1}^{Total*} = \frac{3-\theta}{6N}\,; \\
\pi_{w,1}^* = \frac{t(3+\theta)^2}{36N^2(1-\theta)}\,, & \pi_{nw,1}^* = \frac{t(3-\theta)^2}{36N^2(1-\theta)}\,.
\end{array}$$

This equilibrium exists when two conditions are met: 1(a): $\theta < \frac{3}{5}$; and 1(b): $\bar{p}_w < c + \frac{t(3+\theta)^2}{36N\theta(1-\theta)}$.

PROOF. See Appendix A.1.1.

In the absence of WIC ($\theta = 0$), W-retailers and NW-retailers set the same price and obtain identical market shares and profits. Proposition 1 shows that the presence of WIC ($\theta > 0$) leads to higher formula prices set by both W-retailers and NW-retailers. Moreover, captive WIC demand gives W-retailers an advantage over NW-retailers.

Specifically, W-retailers always charge $\frac{t\theta}{3N(1-\theta)}$ higher than NW-retailers. Each W-retailer captures $\frac{\theta}{3N}$ more total market share and earns $\frac{t\theta}{3N^2(1-\theta)}$ more profits than each NW-retailer. The gaps in prices, total market shares, and profits between these two retail types are increasing in θ.

Next, we examine whether and how each market parameter moderates the effect of the WIC retail delivery system on equilibrium prices. For simplicity, we refer to the resulting price changes as distortionary effects.

Property 1 Given that $t > 0$, $N \in \mathbb{Z}^+$, and $\theta \in (0,1)$, the following price-related comparative statics hold:

(i) $\frac{\partial p^*_{w,1}}{\partial \theta} = \frac{2t}{3N(1-\theta)^2} > 0$; $\frac{\partial p^*_{nw,1}}{\partial \theta} = \frac{t}{3N(1-\theta)^2} > 0$.

(ii) $\frac{\partial^2 p^*_{w,1}}{\partial \theta^2} = \frac{4t}{3N(1-\theta)^3} > 0$; $\frac{\partial^2 p^*_{nw,1}}{\partial \theta^2} = \frac{2t}{3N(1-\theta)^3} > 0$.

(iii) $\frac{\partial^2 p^*_{w,1}}{\partial \theta \partial t} > 0$; $\frac{\partial^2 p^*_{nw,1}}{\partial \theta \partial t} > 0$.

(iv) $\frac{\partial^2 p^*_{w,1}}{\partial \theta \partial N} < 0$; $\frac{\partial^2 p^*_{nw,1}}{\partial \theta \partial N} < 0$.

(v) $\frac{\partial^2 p^*_{w,1}}{\partial \theta \partial c} = 0$; $\frac{\partial^2 p^*_{nw,1}}{\partial \theta \partial c} = 0$.

As Property 1(i) shows, p^*_w and p^*_{nw} are increasing in θ. The increase in p^*_w follows directly from the larger WIC demand base served by W-retailers. The increase in p^*_{nw} reflects strategic complementarity in prices. As W-retailers raise prices, some non-WIC consumers are diverted toward NW-retailers, which reduces competitive pressure on NW-retailers and allows them to raise their own prices. Property 1(ii) further reveals that these distortionary effects are more pronounced in markets with a higher fraction of WIC consumers.

Moreover, a higher offline shopping cost t and a lower offline retail density N amplify the distortionary effects, as indicated by Property 1(iii) and 1(iv). Both changes weaken competitive pressure in the offline channel: a higher t increases spatial differentiation among offline retailers, while a lower N reduces the number of competitors. In contrast, the distortionary effects are independent of the common marginal cost c, as shown by Property 1(v).

The FEE exists only when two conditions are satisfied. Condition 1(a) ensures that W-retailers obtain a positive market share in the non-WIC segment, which requires $\theta < \frac{3}{5}$. Condition 1(b) ensures that the price cap is not sufficiently high to make cap exploitation more profitable than competing in the non-WIC segment. This condition requires $\bar{p}_w < c + \frac{t(3+\theta)^2}{36N\theta(1-\theta)}$. If either condition fails, W-retailers set prices at the cap, and the market transitions from the FEE to the CEE.

4.2 Analysis of Scenario 2 (E-Retailer Serving the Non-WIC Segment Only)

[Insert *Figure 3* here]

When the E-retailer is introduced in the non-WIC segment, W-retailers and NW-retailers no longer compete directly, as distant non-WIC consumers opt for the E-retailer (see *Figure 3(a)*). Following the same approach as in Scenario 1, we identify a point at which a non-WIC consumer is indifferent between shopping at the nearest W-retailer and the E-retailer. This gives

$$V - tx - p_w = V - \mu - p_e \,,$$

which is equivalent to

$$x = \frac{p_e - p_w + \mu}{t} \,.$$

A non-WIC consumer located at a distance y from an NW-retailer is indifferent between shopping at the nearest NW-retailer and the E-retailer when

$$V - ty - p_{nw} = V - \mu - p_e \,,$$

which is equivalent to

$$y = \frac{p_e - p_{nw} + \mu}{t} \,.$$

The market shares of non-WIC consumers for each W-retailer and NW-retailer can still be written as $2(1-\theta)x$ and $2(1-\theta)y$, respectively. The remaining market share of non-WIC consumers is captured by the E-retailer and is given by $S_e^{NW} = (1-\theta)(1-2Nx-2Ny)$.

The WIC segment is unchanged from Scenario 1, so the market share of WIC consumers captured by each W-retailer remains $\frac{\theta}{N}$.

Each W-retailer, each NW-retailer, and the E-retailer solve the following profit-maximization problems:

$$\max_{p_w < \bar{p}_w} \pi_w = (p_w - c)\left[\frac{2(1-\theta)(p_e - p_w + \mu)}{t} + \frac{\theta}{N}\right], \tag{3}$$

$$\max_{p_{nw}} \pi_{nw} = (p_{nw} - c)\frac{2(1-\theta)(p_e - p_{nw} + \mu)}{t}, \tag{4}$$

$$\max_{p_e} \pi_e = (p_e - c)(1-\theta)\left(1 - \frac{2N\,(p_e - p_w + \mu)}{t} - \frac{2N\,(p_e - p_{nw} + \mu)}{t}\right). \tag{5}$$

Proposition 2 ***(FEE)*** *Under the assumptions of the model and conditions illustrated below, a unique (pure strategy) Bertrand-Nash equilibrium exists, where W-retailers fully engage in market competition. Equilibrium prices, market shares, and profits are given by*

$$p^*_{w,2} = c + \frac{t}{12N} + \frac{\mu}{3} + \frac{7t\theta}{24N(1-\theta)}\,, \quad p^*_{nw,2} = c + \frac{t}{12N} + \frac{\mu}{3} + \frac{t\theta}{24N(1-\theta)}\,,$$
$$S^{NW*}_{w,2} = \frac{2-7\theta}{12N} + \frac{2\mu(1-\theta)}{3t}\,, \quad S^{NW*}_{nw,2} = \frac{2-\theta}{12N} + \frac{2\mu(1-\theta)}{3t}\,,$$
$$S^{W*}_{w,2} = \frac{\theta}{N}\,, \quad S^{W*}_{nw,2} = 0\,,$$
$$S^{Total*}_{w,2} = \frac{2+5\theta}{12N} + \frac{2\mu(1-\theta)}{3t}\,, \quad S^{Total*}_{nw,2} = \frac{2-\theta}{12N} + \frac{2\mu(1-\theta)}{3t}\,,$$
$$\pi^*_{w,2} = \frac{[t(2+5\theta)+8N\mu(1-\theta)]^2}{288N^2t(1-\theta)}\,, \quad \pi^*_{nw,2} = \frac{[t(2-\theta)+8N\mu(1-\theta)]^2}{288N^2t(1-\theta)}\,,$$

$$p^*_{e,2} = c + \frac{t}{6N} - \frac{\mu}{3} + \frac{t\theta}{12N(1-\theta)}\,;$$
$$S^{NW*}_{e,2} = \frac{2-\theta}{3} - \frac{4N\mu(1-\theta)}{3t}\,;$$
$$S^{W*}_{e,2} = 0\,;$$
$$S^{Total*}_{e,2} = \frac{2-\theta}{3} - \frac{4N\mu(1-\theta)}{3t}\,;$$
$$\pi^*_{e,2} = \frac{[t(2-\theta)-4N\mu(1-\theta)]^2}{36Nt(1-\theta)}\,.$$

This equilibrium exists when three conditions are met: 2(a): $\frac{N\mu}{t} < \frac{2-\theta}{4(1-\theta)}$ *; 2(b):* $\theta < \frac{2t+8N\mu}{7t+8N\mu}$ *; and 2(c):* $\bar{p}_w < c + \frac{[t(2+5\theta)+8N\mu(1-\theta)]^2}{288Nt\theta(1-\theta)}$ *.*

PROOF. See Appendix A.1.2.

Without WIC ($\theta = 0$), the market equilibrium coincides with the benchmark in Balasubramanian (1998). As shown in Proposition 2, the WIC retail delivery system leads to higher prices across all retail types. In this scenario, W-retailers always charge $\frac{t\theta}{4N(1-\theta)}$ higher than NW-retailers. Each W-retailer captures $\frac{\theta}{2N}$ more total market share and earns $\frac{t\theta(1+\theta)}{12N^2(1-\theta)} + \frac{\mu\theta}{3N}$ more profits than each NW-retailer. Although these gaps widen as θ increases, they are less pronounced than those in Scenario 1.

We define $\frac{N\mu}{t}$ as the online-to-offline shopping-cost ratio, referred to as the ON2OFF ratio. A larger ON2OFF ratio indicates that online shopping is more costly relative to offline shopping. Without WIC, W-retailers have a competitive advantage over the E-retailer only when $\frac{N\mu}{t} > \frac{1}{4}$, in the sense that they set higher prices and collectively capture a larger market share than the E-retailer. With WIC, however, the corresponding thresholds depend on θ. Specifically, W-retailers set a higher price than the E-retailer when $\frac{N\mu}{t} > \frac{2-7\theta}{16(1-\theta)}$. The total market share captured by all W-retailers, NS^{Total*}_w, exceeds that captured by the E-retailer, S^{Total*}_e, when $\frac{N\mu}{t} > \frac{2-3\theta}{8(1-\theta)}$. Given that both thresholds are decreasing in θ, W-retailers are more likely to have the competitive advantage over the E-retailer as θ increases. This pattern arises because captive WIC demand reduces W-retailers' dependence on the non-WIC segment and weakens the competitive pressure exerted by the E-retailer.

Property 2 Given that $t > 0$, $N \in \mathbb{Z}^+$, and $\theta \in (0,1)$, the following price-related comparative statics hold:

(i) $\frac{\partial p^*_{w,2}}{\partial \theta} = \frac{7t}{24N(1-\theta)^2} > 0\,;$ $\frac{\partial p^*_{nw,2}}{\partial \theta} = \frac{t}{24N(1-\theta)^2} > 0\,;$ $\frac{\partial p^*_{e,2}}{\partial \theta} = \frac{t}{12N(1-\theta)^2} > 0\,.$

(ii) $\frac{\partial^2 p^*_{w,2}}{\partial \theta^2} = \frac{7t}{12N(1-\theta)^3} > 0$; $\frac{\partial^2 p^*_{nw,2}}{\partial \theta^2} = \frac{t}{12N(1-\theta)^3} > 0$; $\frac{\partial^2 p^*_{e,2}}{\partial \theta^2} = \frac{t}{6N(1-\theta)^3} > 0$.

(iii) $\frac{\partial^2 p^*_{w,2}}{\partial \theta \partial t} > 0$; $\frac{\partial^2 p^*_{nw,2}}{\partial \theta \partial t} > 0$; $\frac{\partial^2 p^*_{e,2}}{\partial \theta \partial t} > 0$.

(iv) $\frac{\partial^2 p^*_{w,2}}{\partial \theta \partial N} < 0$; $\frac{\partial^2 p^*_{nw,2}}{\partial \theta \partial N} < 0$; $\frac{\partial^2 p^*_{e,2}}{\partial \theta \partial N} < 0$.

(v) $\frac{\partial^2 p^*_{w,2}}{\partial \theta \partial c} = 0$; $\frac{\partial^2 p^*_{nw,2}}{\partial \theta \partial c} = 0$; $\frac{\partial^2 p^*_{e,2}}{\partial \theta \partial c} = 0$.

(vi) $\frac{\partial^2 p^*_{w,2}}{\partial \theta \partial \mu} = 0$; $\frac{\partial^2 p^*_{nw,2}}{\partial \theta \partial \mu} = 0$; $\frac{\partial^2 p^*_{e,2}}{\partial \theta \partial \mu} = 0$.

Property 2 shows that some of the distortionary effects identified in Scenario 1 persist after the E-retailer enters the non-WIC segment. Specifically, p^*_w, p^*_{nw}, and p^*_e are all increasing in θ. The distortionary effects are more pronounced in markets with higher θ, higher t, and lower N, while remaining independent of c.

Beyond these common patterns, Property 2 highlights additional implications of the E-retailer's entry into the non-WIC segment. First, comparing Properties 1(i) and 2(i) shows that the E-retailer's entry mitigates the price distortions among offline retailers. This occurs because the online channel intensifies competition in the non-WIC segment and constrains offline retailers' pricing power. Next, Property 2(vi) shows that μ do not affect these distortionary effects. This is because μ affects the relative attractiveness of the E-retailer for non-WIC consumers but does not alter the captive WIC demand faced by W-retailers.

For the FEE to hold in Scenario 2, three conditions must be satisfied. Condition 2(a) ensures that the E-retailer obtains a positive market share in the non-WIC segment. This requires the ON2OFF ratio to be sufficiently low, specifically $\frac{N\mu}{t} < \frac{2-\theta}{4(1-\theta)}$. Otherwise, the E-retailer is inactive in equilibrium, and the equilibrium outcomes effectively revert to those in Scenario 1. Notably, this condition becomes less restrictive as θ increases. Analogous to Conditions 1(a) and 1(b), Conditions 2(b) and 2(c) ensure that W-retailers have sufficient incentives to compete in the non-WIC segment. If Condition 2(a) holds but either Condition 2(b) or 2(c) is violated, W-retailers optimally set prices at the cap, and the market transitions from the FEE to the CEE.

4.3 Analysis of Scenario 3 (E-retailer Serving Both Segments)

[Insert *Figure 4* here]

In Scenario 3, non-WIC consumers follow the same shopping strategy as in Scenario 2. The key difference from Scenario 2 is that WIC consumers can now redeem their benefits through the online channel (see *Figure 4(b)*). We therefore proceed directly to the WIC segment.

In the WIC segment, WIC consumers' choice between online and offline shopping is fully determined by μ and t. A WIC consumer is indifferent between shopping at the nearest W-retailer and the E-retailer when

$$V - tz = V - \mu,$$

which is equivalent to

$$z = \frac{\mu}{t}\,.$$

Hence, the market share of WIC consumers captured by each W-retailer is $2\theta z$. The remaining market share of WIC consumers is captured by the E-retailer and is given by $S_e^W = \theta(1-2Nz)$. Note that once the E-retailer becomes WIC-authorized, it is subject to WIC price regulations, as are W-retailers. We therefore specify a separate price cap $\bar{p}_e$ for the E-retailer.

Each W-retailer, each NW-retailer, and the E-retailer solve the following profit-maximization problems:

$$\max_{p_w \le \bar{p}_w} \pi_w = (p_w - c)\left[\frac{2(1-\theta)(p_e - p_w + \mu)}{t} + \frac{2\theta\mu}{t}\right], \tag{6}$$

$$\max_{p_{nw}} \pi_{nw} = (p_{nw} - c)\frac{2(1-\theta)(p_e - p_{nw} + \mu)}{t}, \tag{7}$$

$$\begin{aligned}\max_{p_e \le \bar{p}_e} \pi_e =& (p_e - c)\left\{(1-\theta)\left[1 - \frac{2N(p_e - p_w + \mu)}{t} - \frac{2N(p_e - p_{nw} + \mu)}{t}\right]\right. \\ &\left. + \theta\left(1 - \frac{2N\mu}{t}\right)\right\}.\end{aligned} \tag{8}$$

Proposition 3 ***(FEE)*** *Under the assumptions of the model and conditions illustrated below, a unique (pure strategy) Bertrand-Nash equilibrium exists, where W-retailers and the E-retailer fully engage in market competition. Equilibrium prices, market shares, and profits are given by*

$$\begin{aligned}
&p^*_{w,3} = c + \tfrac{t}{12N} + \tfrac{\mu}{3} + \tfrac{(t+5N\mu)\theta}{12N(1-\theta)}\,, && p^*_{nw,3} = c + \tfrac{t}{12N} + \tfrac{\mu}{3} + \tfrac{(t-N\mu)\theta}{12N(1-\theta)}\,,\\
&S^{NW*}_{w,3} = \tfrac{1}{6N} + \tfrac{\mu(4-11\theta)}{6t}\,, && S^{NW*}_{nw,3} = \tfrac{1}{6N} + \tfrac{\mu(4-5\theta)}{6t}\,,\\
&S^{W*}_{w,3} = \tfrac{2\mu\theta}{t}\,, && S^{W*}_{nw,3} = 0\,,\\
&S^{Total*}_{w,3} = \tfrac{1}{6N} + \tfrac{\mu(4+\theta)}{6t}\,, && S^{Total*}_{nw,3} = \tfrac{1}{6N} + \tfrac{\mu(4-5\theta)}{6t}\,,\\
&\pi^*_{w,3} = \tfrac{[t+N\mu(4+\theta)]^2}{72N^2t(1-\theta)}\,, && \pi^*_{nw,3} = \tfrac{[t+N\mu(4-5\theta)]^2}{72N^2t(1-\theta)}\,,
\end{aligned}$$

$$\begin{aligned}
&p^*_{e,3} = c + \tfrac{t}{6N} - \tfrac{\mu}{3} + \tfrac{(t-N\mu)\theta}{6N(1-\theta)}\,;\\
&S^{NW*}_{e,3} = \tfrac{2}{3} - \theta - \tfrac{4N\mu(1-2\theta)}{3t}\,;\\
&S^{W*}_{e,3} = \tfrac{(t-2N\mu)\theta}{t}\,;\\
&S^{Total*}_{e,3} = \tfrac{2}{3} - \tfrac{2N\mu(2-\theta)}{3t}\,;\\
&\pi^*_{e,3} = \tfrac{[t-N\mu(2-\theta)]^2}{9Nt(1-\theta)}\,.
\end{aligned}$$

This equilibrium exists when five conditions are met: 3(a): $\frac{N\mu}{t} < \frac{1}{2}$ *; 3(b):* $4N\mu(1-2\theta) < t(2-3\theta)$ *; 3(c):* $\theta < \frac{t+4N\mu}{11N\mu}$ *; 3(d):* $\bar{p}_w < c + \frac{[t+N\mu(4+\theta)]^2}{144N^2\mu\theta(1-\theta)}$ *; and 3(e):* $\bar{p}_e < c + \frac{[t-N\mu(2-\theta)]^2}{9N\theta(1-\theta)(t-2N\mu)}$ *.*

PROOF. See Appendix A.1.3.

Consistent with the propositions established in the previous two scenarios, Proposition 3 shows that WIC increases prices across all retail types. In this scenario, W-retailers always charge $\frac{\mu\theta}{2(1-\theta)}$ higher than NW-retailers. Each W-retailer captures $\frac{\mu\theta}{t}$ more total market share and earns $\frac{t\mu\theta+2N\mu^2\theta(2-\theta)}{6Nt(1-\theta)}$ more profits than each NW-retailer. Although these gaps widen with θ, they are less pronounced than those in Scenario 2.

We next compare the equilibrium outcomes of W-retailers and the E-retailer. W-retailers charge a higher price than the E-retailer when $\frac{N\mu}{t} > \frac{1}{8-\theta}$, and the total market share captured by all W-retailers exceeds that captured by the E-retailer when $\frac{N\mu}{t} > \frac{1}{4-\theta}$. Relative to Scenario 2, higher ON2OFF thresholds are required for W-retailers to have a competitive advantage over the E-retailer in Scenario 3.

Property 3 Given that $\mu > 0$, $N \in \mathbb{Z}^+$, $\theta \in (0,1)$, and $\frac{N\mu}{t} < \frac{1}{2}$, the following price-related comparative statics hold:

(i) $\frac{\partial p^*_{w,3}}{\partial\theta} = \frac{t+5N\mu}{12N(1-\theta)^2} > 0$; $\frac{\partial p^*_{nw,3}}{\partial\theta} = \frac{t-N\mu}{12N(1-\theta)^2} > 0$; $\frac{\partial p^*_{e,3}}{\partial\theta} = \frac{t-N\mu}{6N(1-\theta)^2} > 0$.

(ii) $\frac{\partial^2 p^*_{w,3}}{\partial\theta^2} = \frac{t+5N\mu}{6N(1-\theta)^3} > 0$; $\frac{\partial^2 p^*_{nw,3}}{\partial\theta^2} = \frac{t-N\mu}{6N(1-\theta)^3} > 0$; $\frac{\partial^2 p^*_{e,3}}{\partial\theta^2} = \frac{t-N\mu}{3N(1-\theta)^3} > 0$.

(iii) $\frac{\partial^2 p^*_{w,3}}{\partial\theta\partial t} > 0$; $\frac{\partial^2 p^*_{nw,3}}{\partial\theta\partial t} > 0$; $\frac{\partial^2 p^*_{e,3}}{\partial\theta\partial t} > 0$.

(iv) $\frac{\partial^2 p^*_{w,3}}{\partial\theta\partial N} = -\frac{t}{12N^2(1-\theta)^2} < 0$; $\frac{\partial^2 p^*_{nw,3}}{\partial\theta\partial N} = -\frac{t}{12N^2(1-\theta)^2} < 0$; $\frac{\partial^2 p^*_{e,3}}{\partial\theta\partial N} = -\frac{t}{6N^2(1-\theta)^2} < 0$.

(v) $\frac{\partial^2 p^*_{w,3}}{\partial\theta\partial c} = 0$; $\frac{\partial^2 p^*_{nw,3}}{\partial\theta\partial c} = 0$; $\frac{\partial^2 p^*_{e,3}}{\partial\theta\partial c} = 0$.

(vi) $\frac{\partial^2 p^*_{w,3}}{\partial\theta\partial\mu} > 0$; $\frac{\partial^2 p^*_{nw,3}}{\partial\theta\partial\mu} < 0$; $\frac{\partial^2 p^*_{e,3}}{\partial\theta\partial\mu} < 0$.

In line with Properties 1 and 2, Property 3 shows that the distortionary effects increase with θ and t but decreases with N for all retail types. Beyond these common patterns, Property 3 offers two additional insights. First, comparing Properties 2(i) and 3(i) reveals that the E-retailer's entry into the WIC segment attenuates the price distortions for W-retailers but amplifies those for NW-retailers and the E-retailer. Second, Property 3(vi) shows that μ begins to shape the distortionary effects. Specifically, a higher μ amplifies the distortionary effects on $p^*_{w,3}$ while reducing those on $p^*_{nw,3}$ and $p^*_{e,3}$.

For the FEE to hold in Scenario 3, five conditions must be satisfied. Conditions 3(a) and 3(b) ensure that the E-retailer obtains a positive market share in both the WIC and non-WIC segments. Condition 3(c) ensures that W-retailers obtain a positive market share in the non-WIC segment. Notably, the threshold for θ in Condition 3(c) is lower than that in Condition 2(b) of Scenario 2. This reflects that, once the E-retailer enters the WIC segment, W-retailers have stronger incentives to remain active in the non-WIC segment. Lastly, Conditions 3(d) and 3(e) ensure that both W-retailers and the E-retailer earn higher profits under the FEE than they would by setting prices at their respective caps.

Condition 3(a) differs from the other four conditions in that it governs whether the E-retailer is active in the WIC segment. It requires the ON2OFF ratio to be sufficiently low, i.e., $\frac{N\mu}{t} < \frac{1}{2}$, for the online channel to attract WIC consumers. If this condition is not satisfied, the E-retailer is inactive in the WIC segment, and the equilibrium outcomes effectively revert to those in Scenario 2. The remaining four conditions determine whether the FEE can be sustained. If any of these conditions is violated, either W-retailers or the E-retailer optimally set prices at the corresponding cap, and the market transitions from the FEE to the CEE.

[Insert *Figure 5* here]

Figure 5 summarizes the equilibrium structure that emerges when online WIC benefit redemption is introduced. It highlights the distinction between permitted entry and realized participation of the E-retailer in the WIC segment. Enabling online WIC benefit redemption does not guarantee that the E-retailer actually serves WIC consumers in equilibrium. The resulting local market equilibrium depends on the parameters θ, μ, N, t, $\bar{p}_e$, and $\bar{p}_w$.

4.4 Consumer Welfare and Direct WIC Spending

Having analyzed retailer-side equilibrium outcomes, we now turn to the implications for consumer welfare and direct WIC spending on infant formula. We derive the equilibrium levels of non-WIC consumer welfare, WIC consumer welfare, and direct WIC spending under the FEE for each scenario, with the derivations provided in Appendix A.1. Given that the within-scenario comparative statics for these outcomes largely follow from the price-related comparative statics established above, we do not repeat them here and instead focus on cross-scenario comparisons. To abstract from price-cap-induced changes in the equilibrium structure, we treat the price caps as parameter-dependent policy instruments that are adjusted to sustain the FEE for each parameter configuration.

We begin with aggregate non-WIC consumer welfare, denoted by CW^{NW}. It is obtained by summing, across all non-WIC consumers, each consumer's valuation of infant formula, net of the retail price and associated shopping costs. The resulting equilibrium levels of CW^{NW} are given below, where the subscripts 1, 2, and 3 correspond to Scenarios 1, 2, and 3, respectively:

$$CW_1^{NW*} = (V-c)(1-\theta) - \frac{t(45-54\theta+5\theta^2)}{72N(1-\theta)};$$

$$CW_2^{NW*} = (V-c)(1-\theta) - \frac{t(44-56\theta-\theta^2)}{288N(1-\theta)} - \frac{\mu(5-4\theta)}{9} + \frac{2N\mu^2(1-\theta)}{9t};$$

$$CW_3^{NW*} = (V-c)(1-\theta) - \frac{t(11-12\theta)}{72N(1-\theta)} - \frac{\mu(10-23\theta+15\theta^2)}{18(1-\theta)} + \frac{N\mu^2(16-64\theta+73\theta^2)}{72t(1-\theta)}.$$

Aggregate WIC consumer welfare, denoted by CW^W, is computed analogously, except that WIC consumers do not pay the formula price. The equilibrium levels of aggregate WIC consumer welfare are given by:

$$CW_1^{W*} = \left(V - \frac{t}{4N}\right)\theta\,;$$

$$CW_2^{W*} = \left(V - \frac{t}{4N}\right)\theta\,;$$

$$CW_3^{W*} = \left(V - \mu + \frac{N\mu^2}{t}\right)\theta\,.$$

Direct WIC spending on infant formula, denoted by WS, is measured as gross retail-level reimbursements for infant formula redeemed by WIC consumers.[10] The equilibrium levels of direct WIC spending are as follows:

$$WS_1^* = \left[c + \frac{t}{2N} + \frac{2t\theta}{3N(1-\theta)}\right]\theta\,;$$

$$WS_2^* = \left[c + \frac{t}{12N} + \frac{\mu}{3} + \frac{7t\theta}{24N(1-\theta)}\right]\theta\,;$$

$$WS_3^* = \left[c + \frac{t^2 - N\mu t(3-\theta) + N^2\mu^2(8-\theta)}{6Nt(1-\theta)}\right]\theta\,.$$

4.4.1 Analytical Comparisons

Property 4 When the FEE conditions are simultaneously satisfied in all three scenarios, the comparative patterns for consumer welfare and direct WIC spending are as follows:

1. $\begin{cases} CW_3^{NW*} > CW_2^{NW*} > CW_1^{NW*}, & \text{if } \frac{N\mu}{t} > \frac{8+\theta}{2(32-57\theta)}\,, \\ CW_2^{NW*} > CW_3^{NW*} > CW_1^{NW*}, & \text{if } \frac{N\mu}{t} < \frac{8+\theta}{2(32-57\theta)}\,, \\ CW_3^{NW*} = CW_2^{NW*} > CW_1^{NW*}, & \text{if } \frac{t}{N\mu} = \frac{2(32-57\theta)}{8+\theta}\,. \end{cases}$

2. $CW_3^{W*} > CW_2^{W*} = CW_1^{W*}$.

3. $\begin{cases} WS_3^* < WS_2^* < WS_1^*, & \text{if } \frac{N\mu}{t} > \frac{2-5\theta}{16-2\theta}\,, \\ WS_2^* < WS_3^* < WS_1^*, & \text{if } \frac{N\mu}{t} < \frac{2-5\theta}{16-2\theta}\,, \\ WS_3^* = WS_2^* < WS_1^*, & \text{if } \frac{N\mu}{t} = \frac{2-5\theta}{16-2\theta}\,. \end{cases}$

The results were computed using Wolfram Mathematica 14.0.

Property 4 shows that, relative to Scenario 1, Scenario 2 improves non-WIC consumer welfare and reduces direct WIC spending on infant formula. By contrast, the

[10] This measure does not account for manufacturer rebates. We assume manufacturer rebates remain constant across scenarios, so excluding them does not affect the cross-scenario comparisons.

effects of moving from Scenario 2 to Scenario 3 on non-WIC consumer welfare and direct WIC spending are ambiguous and depend on the ON2OFF ratio and θ. For direct WIC spending, however, the comparison between Scenarios 2 and 3 is unambiguous when $\theta \geq 0.4$, as Scenario 3 yields lower direct WIC spending than Scenario 2. Scenario 3 also improves WIC consumer welfare relative to Scenarios 1 and 2, as online WIC benefit redemption reduces WIC consumers' shopping costs.

4.4.2 Numerical Comparisons

For illustration, we set the fraction of WIC consumers in the market to 40% ($\theta = 0.4$) and examine how the ON2OFF ratio affects consumer welfare and direct WIC spending.[11] The choice of $\theta = 0.4$ is motivated by the fact that most states had WIC infant shares close to 40% in 2020 (see *Figure A2* in Appendix A.1). We set $N = 1$ and $t = 1$, and vary μ to trace changes in the ON2OFF ratio. The remaining parameters, $V = 5$ and $c = 2$, are set for illustrative purposes and do not affect the cross-scenario comparisons.

[Insert *Figure 6* here]

Figure 6(a)–(c) shows how changes in the ON2OFF ratio, captured by μ, affect consumer welfare and direct WIC spending. Since Scenario 1 does not involve e-commerce, consumer welfare and direct WIC spending in this scenario are invariant to μ. In Scenarios 2 and 3, we restrict μ to values that satisfy the corresponding FEE conditions, as shown in *Figure 6(a)–(c)*. When $\mu \in [0, \frac{1}{6})$, the FEE does not exist in Scenario 2 because the ON2OFF ratio is too low for W-retailers to capture a positive market share in the non-WIC segment (Condition 2(b) is not satisfied). When $\mu \in (\frac{1}{2}, \frac{2}{3})$, the ON2OFF ratio is too high for the E-retailer to remain active in the WIC segment in Scenario 3 (Condition 3(a) is not satisfied), leading Scenario 3 to revert to Scenario 2. When $\mu \geq \frac{2}{3}$, the ON2OFF ratio is too high for the E-retailer to remain active in the non-WIC segment in Scenario 2 (condition 2(a) is not satisfied), leading Scenario 2 to revert to Scenario 1. Therefore, the FEE exists in all three scenarios only when $\mu \in [\frac{1}{6}, \frac{1}{2}]$, which allows us to compare consumer welfare and direct WIC spending across scenarios.

Figure 6(a) shows that as the ON2OFF ratio increases, non-WIC consumer welfare in Scenarios 2 and 3 gradually declines and approaches the level in Scenario 1. This pattern is intuitive, as a higher ON2OFF ratio makes the online channel less attractive relative to the offline channel. Moreover, Scenario 3 yields lower non-WIC consumer welfare than Scenario 2 when $\mu < \frac{21}{46}$, but higher welfare when $\mu > \frac{21}{46}$, consistent with Property 4(i). This comparison implies that the E-retailer's entry into the WIC segment may reduce non-WIC consumer welfare when online shopping costs are sufficiently low relative to offline shopping costs.

Figure 6(b) shows shows how WIC consumer welfare varies with the ON2OFF ratio across the three scenarios. Scenario 3 improves WIC consumer welfare relative to Scenarios 1 and 2 by allowing online redemption. However, these welfare gains

[11] As a robustness check, we also report the results for $\theta = 0.2$ and $\theta = 0.55$ in Appendix B.4.

diminish as the ON2OFF ratio increases. This pattern reinforces the concern raised in Section 2.2.3 that high online shopping costs, such as delivery fees, may limit the benefits of online redemption.

Figure 6(c) shows how direct WIC spending varies with the ON2OFF ratio across the three scenarios. In Scenario 2, direct WIC spending increases with the ON2OFF ratio because a higher ON2OFF ratio weakens the competitive pressure exerted by the online channel in the non-WIC segment, thereby strengthening W-retailers' pricing power. In Scenario 3, direct WIC spending follows a U-shaped pattern with respect to the ON2OFF ratio. When the ON2OFF ratio is low, WIC demand is tilted toward the E-retailer, strengthening the E-retailer's pricing power and increasing direct WIC spending. Conversely, when the ON2OFF ratio is high, WIC demand is tilted toward offline W-retailers, shifting pricing power toward them and again increasing direct WIC spending. Direct WIC spending is therefore lower at moderate ON2OFF ratios, where WIC demand is more evenly distributed between the online and offline channels.

Consistent with Property 4(iii), the presence of the E-retailer in Scenarios 2 and 3 intensifies retail competition, leading to lower direct WIC spending than in Scenario 1. Moreover, Moreover, under our calibration of =0.4, Scenario 3 consistently yields lower direct WIC spending than Scenario 2.

when $\theta = 0.4$, Scenario 3 consistently yields lower direct WIC spending than Scenario 2.

In Scenario 3, direct WIC spending exhibits a U-shaped relationship with the ON2OFF ratio. Low ON2OFF ratios favor online redemption, strengthening the E-retailer's pricing . High ON2OFF ratios favor offline redemption, shifting pricing power toward W-retailers and again increasing direct WIC spending. Direct WIC spending is therefore lower at moderate ON2OFF ratios, where neither channel has a clear shopping-cost advantage.

5 Conclusions

In addition to WIC, there are many food assistance programs worldwide that rely on private retailers to deliver benefits to program participants. Examples include the Supplemental Nutrition Assistance Program (SNAP), the largest food assistance program in the United States, and Healthy Start in the United Kingdom. By using existing retail networks, this delivery approach can improve food access and reduce the administrative and logistical costs associated with direct food distribution. However, it also raises concerns about potential price spillovers to non-participants. The price-spillover concern is more pronounced under the WIC retail delivery system because WIC combines three distinctive features: (i) benefit redemption only at a subset of offline retailers, which restricts participants' shopping options; (ii) quantity-based, category-specific benefits that reduce participants' price sensitivity for WIC-approved foods; and (iii) a large WIC share of demand in some WIC-approved product categories, especially infant formula. Together, these features may weaken price discipline in WIC-approved product categories, thereby strengthening retailers' incentives to set

higher prices. Motivated by this concern, we develop a theoretical framework to analyze retail competition under the WIC retail delivery system and examine how this system shapes retailers' pricing incentives and market outcomes.

Our model yields two types of equilibria, FEE and CEE. The main analysis focuses on the FEE, in which all retailers fully engage in price competition. In this equilibrium, exclusive access to WIC demand gives WIC-authorized retailers a competitive advantage over non-WIC-authorized retailers, leading them to set higher prices. The higher prices charged by WIC-authorized retailers shift some non-WIC demand toward non-WIC-authorized retailers, allowing the latter to raise their prices as well, though to a lesser extent. These WIC-induced price distortions are more pronounced in markets with higher offline shopping costs, lower offline retailer density, and a larger share of WIC consumers. Moreover, these WIC-induced price distortions are more pronounced in markets with higher offline shopping costs, lower offline retailer density, and a larger share of WIC consumers. These findings suggest that the WIC retail delivery system can generate market-wide price effects whose magnitude depends on local market conditions. For non-WIC consumers, this system lowers welfare not only through higher retail prices, but also through higher realized shopping costs for those who switch to less convenient retailers.

Given the rise of e-commerce, we also examine two additional scenarios. In Scenario 2, non-WIC consumers have access to the online channel. We find that e-commerce access increases competitive pressure on offline retailers, thereby mitigating offline price distortions, improving non-WIC consumer welfare, and reducing direct WIC spending.

The model shows that WIC authorization gives authorized retailers a demand-side advantage by enabling them to serve WIC consumers, which allows them to charge higher prices than non-WIC-authorized retailers.

WHen E-retailer enter the non-WIC segment, its presence alleviates price distortions among offline retailers, benefits non-WIC consumers through lower prices and better access, and reduces direct WIC formula spending.

Scenario 3 explores the potential implications of integrating the E-retailer into the WIC distribution system. The findings show that while benefiting WIC consumers, such integration introduces uncertainty regarding its effects on non-WIC consumer welfare and WIC spending, contingent on the fraction of WIC consumers and the relative costs of online and offline shopping.

Notably, in markets where online shopping is significantly costlier than offline shopping, WIC consumers may be unable to access the benefits of online redemption. This raises important policy considerations regarding the necessity of targeted subsidies for online shipping costs to enhance WIC consumer welfare and promote multichannel competition. Alternatively, to attract WIC consumers, online retailers may offer them reduced shipping costs. As an example, Amazon and Walmart Plus have introduced a discounted membership for consumers participating in government assistance programs.

Finally, when deriving the FEE for each scenario, we also identify the conditions under which these equilibria hold. These conditions emphasize the importance of appropriately setting both the fraction of WIC consumers and the WIC price

caps. If either is set too high, WIC-authorized retailers may strategically price at the caps, leading to greater price distortions and inefficiencies in the retail infant formula market.

Our model, though designed for the U.S. retail infant formula market, offers broader insights into the distribution of other WIC-approved products. Given these products' lower dependence on WIC consumers, greater availability of substitutes, and higher price elasticity of demand, price distortions are expected to be significantly smaller than those observed for infant formula. Furthermore, our framework can be extended to study other public food assistance programs that adopt a similar distribution system. However, the framework must be precisely adjusted to reflect the distinct subsidy schemes and policy regulations of these programs.

Discuss another equlibrium. no doubt it may happen in practice. There is no doubt that market price will still raise and even higher than competitive prices.

To the best of our knowledge, this paper is the first to develop a theoretical framework for analyzing retail competition under the WIC retail delivery system. While the model provides valuable insights into retailers' pricing incentives and market outcomes, it necessarily abstracts from several institutional and market-structure features. These limitations suggest several directions for future research. First, we compare FEE outcomes across scenarios while holding the underlying market primitives fixed. This approach allows us to isolate the direct effects of e-commerce access on retail competition under the WIC retail delivery system. In practice, however, e-commerce entry or expansion may affect offline retailers' entry and exit decisions, thereby changing retailer density and the intensity of local competition (Chava, Oettl, Singh, & Zeng, 2024). Future research could incorporate these endogenous adjustments in offline market structure to better understand how e-commerce reshapes local retail competition.

Second, we represent the online channel with a single E-retailer to keep the model focused on the core mechanism. Future work could extend the framework to include multiple online retailers and omnichannel retailers that operate across both offline and online channels. Such an extension would allow researchers to examine how online competition and cross-channel integration further shape retailers' pricing incentives under the WIC retail delivery system.

Third, given our focus on retail competition under the WIC retail delivery system, we model retail prices at the product-category level and treat retailers' marginal costs as given. Accordingly, the model does not explicitly incorporate the WIC rebate program, vertical interactions between manufacturers and retailers, or brand-level pricing strategies for WIC contract and noncontract brands. A natural extension would be to develop a vertical model in which manufacturers' rebate bids and wholesale prices are endogenously determined. This would provide a more comprehensive understanding of how the WIC rebate program and the WIC retail delivery system jointly influence retail prices in WIC-approved product categories.

Finally, although our model captures key dimensions of retailer and consumer heterogeneity, real-world markets may involve additional forms of heterogeneity that affect retail competition under the WIC retail delivery system. Retailers may differ in store size, product assortment, service quality, and geographic accessibility, while

consumers may differ in their shopping costs across offline and online channels. Future research could further examine these forms of heterogeneity and their implications for retail competition in this setting.

Statements and Declarations

The authors have no financial relationships or conflicts of interest to disclose related to this research.

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Tables

Table 1: WIC-Approved Product Categories Ranked by WIC Sales Share, 2005

Product category	WIC sales share (%)
Infant formula	56.3
Beans	9.5
Peanut butter	4.8
Milk	4.4
Adult cereal	4.1
Vegetables and fruits	2.7
Eggs	2.3
Juice	2.0
Cheese	2.0
Bread	0.6
Canned fish	0.6

Notes: The table includes all WIC-approved product categories reported in National Academies of Sciences, Engineering, and Medicine (2017). For each product category, the WIC sales share is calculated as estimated WIC sales divided by estimated total market sales.

Table 2: Summary of key notation.

Parameter	Description
p_{ij}, p_e	Unit retail price charged by offline retailer j of type i, where $i \in \{w, nw\}$ and j indexes retailers of type i, and by the E-retailer, respectively.
$\bar{p}_w$, $\bar{p}_e$	Price caps for W-retailers and the E-retailer, respectively.
c_{ij}, c_e	Marginal costs of offline retailer j of type i and the E-retailer, respectively.
S_{ij}^k, S_e^k	Market shares of type-k consumers captured by offline retailer j of type i and by the E-retailer, respectively, where $k \in \{W, NW, Total\}$.
π_{ij}, π_e	Profits earned by offline retailer j of type i and by the E-retailer, respectively.
N_i	Number of type-i offline retailers.
t	Per-unit travel cost when shopping at an offline retailer.
μ	Online shopping cost.
V	Consumers' valuation of infant formula.
θ	Fraction of WIC consumers in the market, $\theta \in [0, 1]$.
CW^k	Aggregate welfare of type-k consumers.
WS	Direct WIC spending on infant formula before manufacturer rebates.

Figures

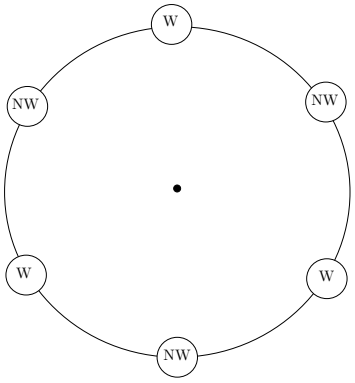


Fig. 1: Circular market with alternating W- and NW-retailers ($N = 3$).

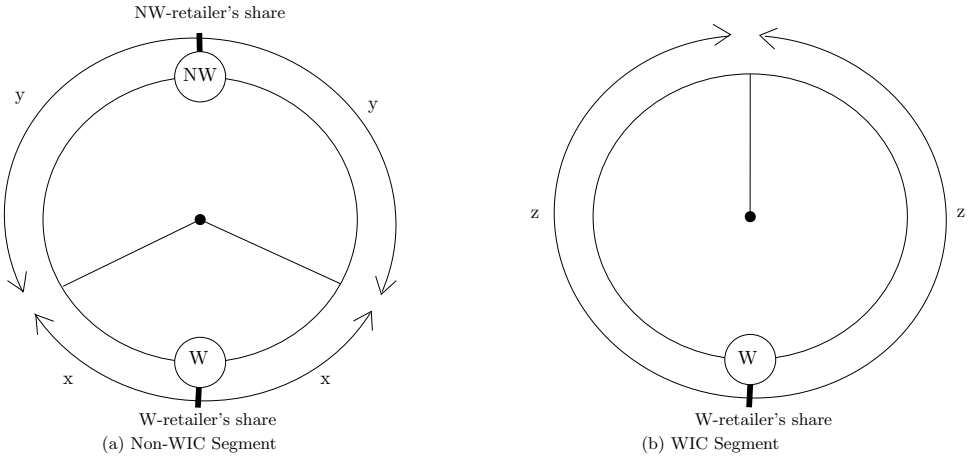


Fig. 2: Spatial setting of the circular market under Scenario 1 ($N = 1$).

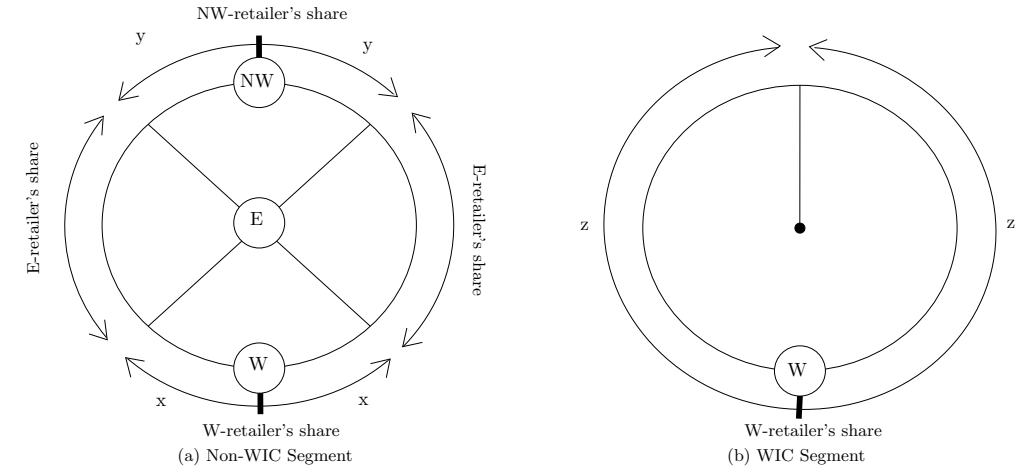


Fig. 3: Spatial setting of the circular market under Scenario 2 ($N = 1$).

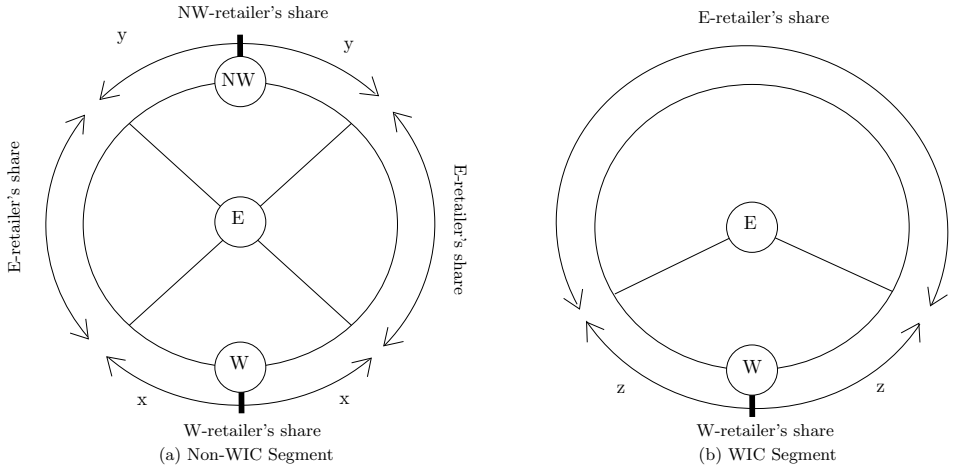


Fig. 4: Spatial setting of the circular market under Scenario 3 ($N = 1$).

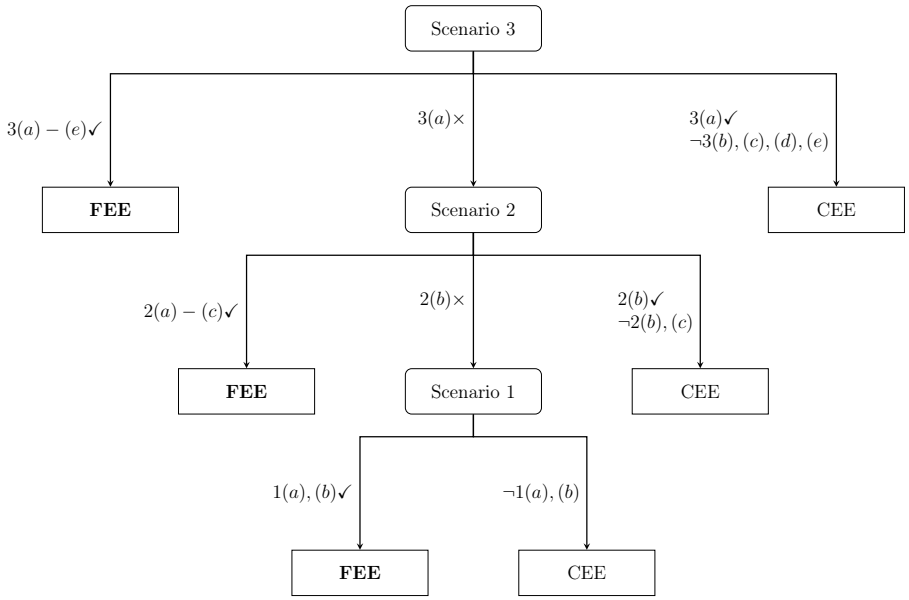
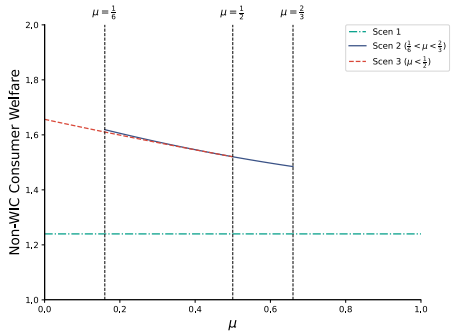
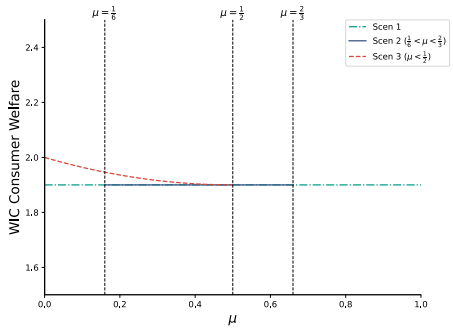


Fig. 5: Equilibrium structure when WIC online redemption is introduced.

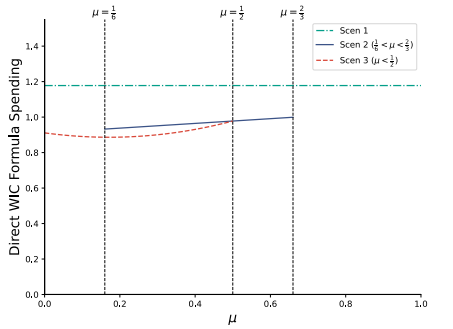
Note. FEE and CEE refer to full-engagement equilibria and cap-exploitation equilibria, respectively. "✓" indicates that the listed condition(s) hold, "×" indicates that the listed condition(s) do not hold, and "¬" indicates that at least one of the listed conditions does not hold.



6(a). Non-WIC Consumer Welfare



6(b). WIC Consumer Welfare



6(c). Direct WIC Spending

Fig. 6: Consumer welfare and direct WIC spending across scenarios ($\theta = 0.4$)

Note. The figures are generated using the parameter values $\theta = 0.4$, $V = 5$, $c = 2$, $N = 1$, and $t = 1$. Due to the FEE conditions in Scenarios 2 and 3, μ cannot take all possible values. Specifically, (1) when $\mu \in [0, \frac{1}{6})$, no FEE exists in Scenario 2; (2) when $\mu \in (\frac{1}{2}, \frac{2}{3})$, Scenario 3 reverts to Scenario 2; and (3) when $\mu \geq \frac{2}{3}$, Scenario 2 reverts to Scenario 1.

Appendix to

"How WIC Shapes the U.S. Retail Market: Insights from a Spatial Competition Model"

This appendix contains the following sections:

Appendix A. Equilibrium Derivations and Analysis

A.1. Derivation of Full-Engagement Equilibria (FEE)

A.1.1 Scenario 1 (No E-commerce)

A.1.2 Scenario 2 (E-Retailer Serving the Non-WIC Segment Only)

A.1.3 Scenario 3 (E-retailer Serving Both Segments)

A.1.4 Alternative Values of θ in Numerical Comparisons

A.2 Derivation of Cap-Exploitation Equilibria (CEE)

Appendix B. Model Extensions

B.1 Unequal Numbers of W- and NW-Retailers

B.2 Marginal-Cost Heterogeneity

B.3 Store-Traffic Margins

Appendix A Equilibrium Derivations and Analysis

A.1 Derivation of Full-Engagement Equilibria (FEE)

A.1.1 Scenario 1 (No E-commerce)

Proof of Proposition 1 (FEE)

In Scenario 1, each W-retailer and each NW-retailer solves the following profit-maximization problem:

$$\max_{p_w<\bar{p}} \pi_{w,1} = (p_w - c)\left[(1-\theta)\left(\frac{1}{2N} + \frac{p_{nw}-p_w}{t}\right) + \frac{\theta}{N}\right], \tag{A1}$$

$$\max_{p_{nw}} \pi_{nw,1} = (p_{nw} - c)(1-\theta)\left(\frac{1}{2N} - \frac{p_{nw}-p_w}{t}\right). \tag{A2}$$

Taking the first-order conditions w.r.t. p_w and p_{nw}, respectively, yields the following equilibrium prices, p_w^* and p_{nw}^*:

$$p_{w,1}^* = c + \frac{t}{2N} + \frac{2t\theta}{3N(1-\theta)},$$
$$p_{nw,1}^* = c + \frac{t}{2N} + \frac{t\theta}{3N(1-\theta)}.$$

Given the equilibrium prices, we solve for the equilibrium market shares and profits of W-retailers and NW-retailers:

$$\begin{aligned}
&S_{w,1}^{NW*} = \tfrac{3-5\theta}{6N}, && S_{nw,1}^{NW*} = \tfrac{3-\theta}{6N};\\
&S_{w,1}^{W*} = \tfrac{\theta}{N}, && S_{nw,1}^{W*} = 0;\\
&S_{w,1}^{Total*} = \tfrac{3+\theta}{6N}, && S_{nw,1}^{Total*} = \tfrac{3-\theta}{6N};\\
&\pi_{w,1}^* = \tfrac{t(3+\theta)^2}{36N^2(1-\theta)}, && \pi_{nw,1}^* = \tfrac{t(3-\theta)^2}{36N^2(1-\theta)}.
\end{aligned}$$

Recall that x denotes the distance from a W-retailer to its farthest non-WIC consumers, and y denotes the distance from an NW-retailer to its farthest non-WIC consumers. Given the equilibrium prices, the corresponding x_1^* and y_1^* are obtained as follows:

$$x_1^* = \frac{3-5\theta}{12N(1-\theta)},$$
$$y_1^* = \frac{-3+\theta}{12N(-1+\theta)}.$$

z denotes the distance from a W-retailer to its farthest WIC consumer. It depends only on the location of W-retailers. Under our model setup and assumptions, z is given by:

$$z_1^* = \frac{1}{2N}\,.$$

The equations and corresponding outcomes for non-WIC consumer welfare, WIC consumer welfare, and direct WIC spending are presented below:

$$\begin{aligned} CW_1^{NW*} &= 2N(1-\theta)\left[\int_0^{x_1^*}\left(V - p_{w,1}^* - tl\right)dl + \int_0^{y_1^*}\left(V - p_{nw,1}^* - tl\right)dl\right] \\ &= (V-c)(1-\theta) - \frac{t(45-54\theta+5\theta^2)}{72N(1-\theta)}\,, \\ CW_1^{W*} &= 2N\theta\left[\int_0^{z_1^*}(V-tl)\,dl\right] \\ &= (V - \frac{t}{4N})\theta\,, \\ WS_1^* &= p_{w,1}^*\theta \\ &= \left[c + \frac{t}{2N} + \frac{2t\theta}{3N(1-\theta)}\right]\theta\,. \end{aligned}$$

Required Conditions

For the equilibrium above to be sustained, the following conditions must hold:

1(a). Each W-retailer must obtain a positive market share in the non-WIC segment, i.e., $S_w^{NW*} > 0$. This condition can be rewritten as $\theta < \frac{3}{5}$.

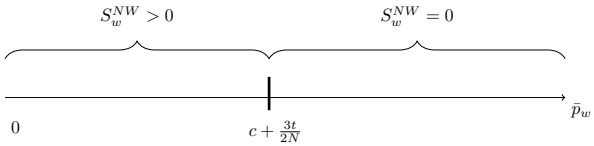


Fig. A1: Range of $\bar{p}_w$.

1(b). For each W-retailer, engaging in market competition must be more profitable than setting the price at the cap. *Figure A1* illustrates the range of $\bar{p}_w$, which is divided into two regions by the cutoff $c + \frac{3t}{2N}$. The cutoff is obtained by evaluating $p_{w,1}^*$ at $\theta = \frac{3}{5}$. First, consider the case in which the price cap lies above the FEE equilibrium price but below the cutoff, i.e., $p_{w,1}^* \leq \bar{p}_w < c + \frac{3t}{2N}$. In this interval, charging $\bar{p}_w$ allows W-retailers to attract non-WIC consumers, but such an upward deviation is less profitable than competitive pricing and is therefore irrelevant for sustaining the FEE. Next, when $\bar{p}_w \geq c + \frac{3t}{2N}$, charging $\bar{p}_w$ prevents W-retailers from attracting any non-WIC consumers. However, if the price cap is excessively high, W-retailers may find it more profitable to charge $\bar{p}_w$ than to set competitive prices. Therefore, sustaining the FEE requires each W-retailer to earn a higher profit under competitive pricing than

it would earn by setting its price at the cap and serving only WIC consumers, i.e., $(p^*_{w,1} - c)S^{Total*}_{w,1} > (\bar{p}_w - c)\frac{\theta}{N}$. This condition gives the following upper bound for the price cap:

$$\bar{p}_w < c + \frac{t(3+\theta)^2}{36N\theta(1-\theta)}\,.$$

Comparison of Equilibrium Outcomes

W-retailers vs. NW-retailers:

$$p^*_{w,1} - p^*_{nw,1} = \frac{t\theta}{3N - 3N\theta} > 0\,,$$

$$S^{Total*}_{w,1} - S^{Total*}_{nw,1} = \frac{\theta}{3N} > 0\,,$$

$$\pi^*_{w,1} - \pi^*_{nw,1} = \frac{t\theta}{3N^2(1-\theta)} > 0\,.$$

A.1.2 Scenario 2 (E-Retailer Serving the Non-WIC Segment Only)

Proof of Proposition 2 (FEE)

In Scenario 2, the E-retailer enters the market and serves non-WIC consumers only. Each W-retailer, each NW-retailer, and the E-retailer solve the following profit-maximization problems:

$$\max_{p_w \le \bar{p}_w} \pi_w = (p_w - c)\left[\frac{2(1-\theta)(p_e - p_w + \mu)}{t} + \frac{\theta}{N}\right], \tag{A3}$$

$$\max_{p_{nw}} \pi_{nw} = (p_{nw} - c)\frac{2(1-\theta)(p_e - p_{nw} + \mu)}{t}\,, \tag{A4}$$

$$\max_{p_e} \pi_e = (p_e - c)(1-\theta)\left[1 - \frac{2N\,(p_e - p_w + \mu)}{t} - \frac{2N\,(p_e - p_{nw} + \mu)}{t}\right]. \tag{A5}$$

Taking the first-order conditions w.r.t. p_w, p_{nw}, and p_e, respectively, yields the following equilibrium prices, p^*_w, p^*_{nw}, and p^*_e:

$$p^*_{w,2} = c + \frac{t}{12N} + \frac{\mu}{3} + \frac{7t\theta}{24N(1-\theta)}\,,$$

$$p^*_{nw,2} = c + \frac{t}{12N} + \frac{\mu}{3} + \frac{t\theta}{24N(1-\theta)}\,,$$

$$p^*_{e,2} = c + \frac{t}{6N} - \frac{\mu}{3} + \frac{t\theta}{12N(1-\theta)}\,.$$

The corresponding equilibrium market shares and profits are as follows:

$$\begin{array}{lll}
S^{NW*}_{w,2} = \frac{2-7\theta}{12N} + \frac{2\mu(1-\theta)}{3t}\,, & S^{NW*}_{nw,2} = \frac{2-\theta}{12N} + \frac{2\mu(1-\theta)}{3t}\,, & S^{NW*}_{e,2} = \frac{2-\theta}{3} - \frac{4N\mu(1-\theta)}{3t}\,; \\
S^{W*}_{w,2} = \frac{\theta}{N}\,, & S^{W*}_{nw,2} = 0\,, & S^{W*}_{e,2} = 0\,; \\
S^{Total*}_{w,2} = \frac{2+5\theta}{12N} + \frac{2\mu(1-\theta)}{3t}\,, & S^{Total*}_{nw,2} = \frac{2-\theta}{12N} + \frac{2\mu(1-\theta)}{3t}\,, & S^{Total*}_{e,2} = \frac{2-\theta}{3} - \frac{4N\mu(1-\theta)}{3t}\,; \\
\pi^*_{w,2} = \frac{[t(2+5\theta)+8N\mu(1-\theta)]^2}{288N^2t(1-\theta)}\,, & \pi^*_{nw,2} = \frac{[t(2-\theta)+8N\mu(1-\theta)]^2}{288N^2t(1-\theta)}\,, & \pi_{e,2} = \frac{[t(2-\theta)-4N\mu(1-\theta)]^2}{36Nt(1-\theta)}\,.
\end{array}$$

The corresponding x^*_2, y^*_2, and z^*_2 are derived as follows:

$$\begin{aligned}
x^*_2 &= \frac{2-7\theta}{24N(1-\theta)} + \frac{\mu}{3t}\,, \\
y^*_2 &= \frac{2-\theta}{24N(1-\theta)} + \frac{\mu}{3t}\,, \\
z^*_2 &= \frac{1}{2N}\,.
\end{aligned}$$

The equations and corresponding outcomes for non-WIC consumer welfare, WIC consumer welfare, and direct WIC spending are presented below:

$$\begin{aligned}
CW^{NW*}_2 &= 2N(1-\theta)\left[\int_0^{x^*_2}\left(V - p^*_{w,2} - tl\right)dl + \int_0^{y^*_2}\left(V - p^*_{nw,2} - tl\right)dl\right] + S^{NW*}_{e,2}\left(V - p^*_{e,2} - \mu\right) \\
&= (V-c)(1-\theta) - \frac{t(44-56\theta-\theta^2)}{288N(1-\theta)} - \frac{\mu(5-4\theta)}{9} + \frac{2N\mu^2(1-\theta)}{9t}\,, \\
CW^{W*}_2 &= 2N\theta\left[\int_0^{z^*_2}(V-tl)\,dl\right] \\
&= (V - \frac{t}{4N})\theta\,, \\
WS^*_2 &= p^*_{w,2}\theta \\
&= \left[c + \frac{t}{12N} + \frac{\mu}{3} + \frac{7t\theta}{24N(1-\theta)}\right]\theta\,.
\end{aligned}$$

Required Conditions

For the equilibrium above to be sustained, the following conditions must hold:

2(a). The E-retailer obtains a positive market share in the non-WIC segment, i.e., $S^{NW*}_e > 0$. This condition can be restated as $\frac{N\mu}{t} < \frac{2-\theta}{4(1-\theta)}$. If this condition is not met, the E-retailer is inactive in equilibrium, and the equilibrium outcomes effectively revert to those in Scenario 1. Taking the first derivative of $\frac{2-\theta}{4(1-\theta)}$ w.r.t θ, we obtain

$\frac{1}{4(1-\theta)^2} > 0$, indicating that an increase in θ relaxes the condition for the E-retailer to be active in the non-WIC segment.

2(b). Each W-retailer must obtain a positive market share in the non-WIC segment, i.e., $S_w^{NW*} > 0$. This condition can be rewritten as $\theta < \frac{2t+8N\mu}{7t+8N\mu}$.

2(c). For each W-retailer, competitive pricing must be more profitable than setting its price at the cap and serving only WIC consumers, i.e., $(p_{w,2}^* - c)S_{w,2}^{Total*} > (\bar{p}_w - c)\frac{\theta}{N}$. This condition gives the following upper bound for the price cap:

$$\bar{p}_w < c + \frac{[t(2+5\theta) + 8N\mu(1-\theta)]^2}{288Nt\theta(1-\theta)}\,.$$

Comparison of Equilibrium Outcomes

W-retailers vs. NW-retailers:

$$p_{w,2}^* - p_{nw,2}^* = \frac{t\theta}{4N - 4N\theta} > 0\,,$$
$$S_{w,2}^{Total*} - S_{nw,2}^{Total*} = \frac{\theta}{2N} > 0\,,$$
$$\pi_{w,2}^* - \pi_{nw,2}^* = \frac{t\theta(1+\theta)}{12N^2(1-\theta)} + \frac{\mu}{3N} > 0\,.$$

W-retailers vs. E-retailers:

$$p_{w,2}^* - p_{e,2}^* = \frac{t(-2+7\theta)}{24N(-1+\theta)} - \frac{2\mu}{3}\,,$$

so $p_{w,2}^* > p_{e,2}^*$ if $\frac{N\mu}{t} > \frac{2-7\theta}{16(1-\theta)}$.

$$NS_{w,2}^{Total*} - S_{e,2}^{Total*} = \frac{1}{4}\left(-2 + 3\theta - \frac{8N(-1+\theta)\mu}{t}\right)\,,$$

so $NS_{w,2}^{Total*} > S_{e,2}^{Total*}$ if $\frac{N\mu}{t} > \frac{2-3\theta}{8(1-\theta)}$.

A.1.3 Scenario 3 (E-retailer Serving Both Segments)

Proof of Proposition 3 (FEE)

In Scenario 3, each W-retailer, each NW-retailer, and the E-retailer solve the following profit-maximization problems:

$$\max_{p_w \le \bar{p_w}} \pi_w = (p_w - c)\left[\frac{2(1-\theta)(p_e - p_w + \mu)}{t} + \frac{2\theta\mu}{t}\right]\,, \tag{A6}$$

$$\max_{p_{nw}} \pi_{nw} = (p_{nw} - c)\frac{2(1-\theta)(p_e - p_{nw} + \mu)}{t}\,, \tag{A7}$$

$$\begin{aligned}\max_{p_e \le \bar{p}_e} \pi_e =& (p_e - c)\Bigg\{(1-\theta)\left[1 - \frac{2N(p_e - p_w + \mu)}{t} - \frac{2N(p_e - p_{nw} + \mu)}{t}\right] \\ &+ \theta\left(1 - \frac{2N\mu}{t}\right)\Bigg\}.\end{aligned} \tag{A8}$$

Taking the first-order conditions w.r.t. p_w, p_{nw}, and p_e, respectively, yields the following equilibrium prices, p_w^*, p_{nw}^*, and p_e^*:

$$\begin{aligned} p_{w,3}^* &= c + \frac{t}{12N} + \frac{\mu}{3} + \frac{(t+5N\mu)\theta}{12N(1-\theta)}, \\ p_{nw,3}^* &= c + \frac{t}{12N} + \frac{\mu}{3} + \frac{(t-N\mu)\theta}{12N(1-\theta)}, \\ p_{e,3}^* &= c + \frac{t}{6N} - \frac{\mu}{3} + \frac{(t-N\mu)\theta}{6N(1-\theta)}. \end{aligned}$$

The corresponding equilibrium market shares and profits are as follows:

$$\begin{array}{lll} S_{w,3}^{NW*} = \frac{1}{6N} + \frac{\mu(4-11\theta)}{6t}, & S_{nw,3}^{NW*} = \frac{1}{6N} + \frac{\mu(4-5\theta)}{6t}, & S_{e,3}^{NW*} = \frac{2}{3} - \theta - \frac{4N\mu(1-2\theta)}{3t}; \\ S_{w,3}^{W*} = \frac{2\mu\theta}{t}, & S_{nw,3}^{W*} = 0, & S_{e,3}^{W*} = \frac{(t-2N\mu)\theta}{t}; \\ S_{w,3}^{Total*} = \frac{1}{6N} + \frac{\mu(4+\theta)}{6t}, & S_{nw,3}^{Total*} = \frac{1}{6N} + \frac{\mu(4-5\theta)}{6t}, & S_{e,3}^{Total*} = \frac{2}{3} - \frac{2N\mu(2-\theta)}{3t}; \\ \pi_{w,3}^* = \frac{[t+N\mu(4+\theta)]^2}{72N^2t(1-\theta)}, & \pi_{nw,3}^* = \frac{[t+N\mu(4-5\theta)]^2}{72N^2t(1-\theta)}, & \pi_{e,3}^* = \frac{[t-N\mu(2-\theta)]^2}{9Nt(1-\theta)}. \end{array}$$

The corresponding x_3^*, y_3^*, and z_3^* are derived as follows:

$$\begin{aligned} x_3^* &= \frac{t + 4N\mu - 11N\mu\theta}{12Nt(1-\theta)}, \\ y_3^* &= \frac{t + 4N\mu - 5N\mu\theta}{12Nt(1-\theta)}, \\ z_3^* &= \frac{\mu}{t}. \end{aligned}$$

The equations and corresponding outcomes for non-WIC consumer welfare, WIC consumer welfare, and direct WIC spending are presented below:

$$\begin{aligned} CW_3^{NW*} &= 2N(1-\theta)\left[\int_0^{x_3^*}\left(V - p_{w,3}^* - tl\right)dl + \int_0^{y_3^*}\left(V - p_{nw,3}^* - tl\right)dl\right] + S_{e,3}^{NW*}\left(V - p_{e,3}^* - \mu\right) \\ &= (V-c)(1-\theta) - \frac{t(11-12\theta)}{72N(1-\theta)} - \frac{\mu(10-23\theta+15\theta^2)}{18(1-\theta)} + \frac{N\mu^2(16-64\theta+73\theta^2)}{72t(1-\theta)}, \end{aligned}$$

$$
\begin{aligned}
CW_3^{W*} &= 2N\theta \int_0^{z_3^*} (V - tl)\, dl + S_{e_3}^{W*}(V - \mu) \\
&= (V - \mu + \frac{N\mu^2}{t})\theta\,, \\
WS^* &= NS_{w,3}^{W*} p_{w,3}^* + S_{e,3}^{W*} p_{e,3}^* \\
&= \left[c + \frac{t^2 - N\mu t(3-\theta) + N^2\mu^2(8-\theta)}{6Nt(1-\theta)}\right]\theta\,.
\end{aligned}
$$

Required Conditions

For the equilibrium above to be sustained, the following conditions must hold:

3(a). The E-retailer must obtain a positive market share in the WIC segment; otherwise, it is inactive in the WIC segment, and the equilibrium outcomes effectively revert to those in Scenario 2. Thus, we have $S_{e,3}^{W*} > 0 \Rightarrow \frac{N\mu}{t} < \frac{1}{2}$.

3(b). The E-retailer must obtain a positive market share in the non-WIC segment, i.e., $S_{e,3}^{NW*} > 0 \Rightarrow 4N\mu(1-2\theta) < t(2-3\theta)$.

3(c). Each W-retailer must obtain a positive market share in the non-WIC segment, i.e., $S_{w,3}^{NW*} > 0 \Rightarrow \theta < \frac{t+4N\mu}{11N\mu}$.

3(d). For each W-retailer, competitive pricing must be more profitable than setting its price at the cap $\bar{p}_w$ and serving only WIC consumers, i.e., $(p_{w,3}^* - c)S_{w,3}^{Total*} > (\bar{p}_w - c)\frac{2\mu\theta}{t}$. This condition gives the following upper bound for $\bar{p}_w$:

$$
\bar{p}_w < c + \frac{[t + N\mu(4+\theta)]^2}{144N^2\mu\theta(1-\theta)}\,.
$$

3(e). For the E-retailer, competitive pricing must be more profitable than setting its price at the cap $\bar{p}_e$ and serving only WIC consumers, i.e., $(p_{e,3}^* - c)S_e^{Total*} > (\bar{p}_e - c)\frac{(t-2N\mu)\theta}{t}$. This condition gives the following upper bound for $\bar{p}_e$:

$$
\bar{p}_e < c + \frac{[t - N\mu(2-\theta)]^2}{9N\theta(1-\theta)(t-2N\mu)}\,.
$$

Comparison of Equilibrium Outcomes

W-retailers vs. NW-retailers:

$$
\begin{aligned}
p_{w,3}^* - p_{nw,3}^* &= \frac{\mu\theta}{2(1-\theta)} > 0\,, \\
S_{w,3}^{Total*} - S_{nw,3}^{Total*} &= \frac{\mu\theta}{t} > 0\,, \\
\pi_{w,3}^* - \pi_{nw,3}^* &= \frac{\mu t\theta + 2N\mu^2\theta(2-\theta)}{6Nt(1-\theta)} > 0\,.
\end{aligned}
$$

W-retailers vs. E-retailers:

$$
p_{w,3}^* - p_{e,3}^* = \frac{N\mu(8-\theta) - t}{12N(1-\theta)}\,,
$$

so $p^*_{w,3} > p^*_{e,3}$ if $\frac{N\mu}{t} > \frac{1}{8-\theta}$.

$$NS^{Total*}_{w,3} - S^{Total*}_{e,3} = \frac{N\mu(4-\theta) - t}{2t},$$

so $NS^{Total*}_{w,3} > S^{Total*}_{e,3}$ if $\frac{N\mu}{t} > \frac{1}{4-\theta}$.

A.1.4 Alternative Values of θ in Numerical Comparisons

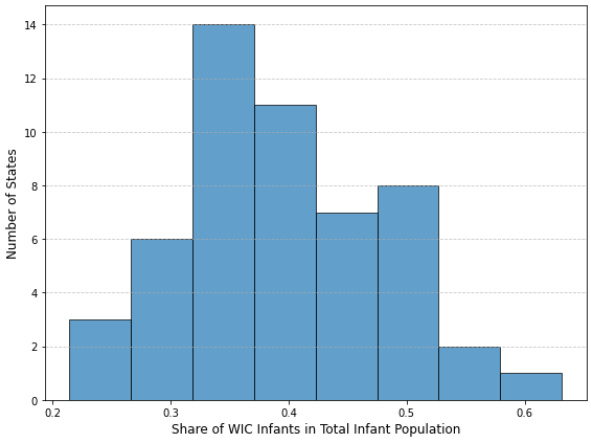


Fig. A2: Distribution of WIC Infant Share Across States in 2020

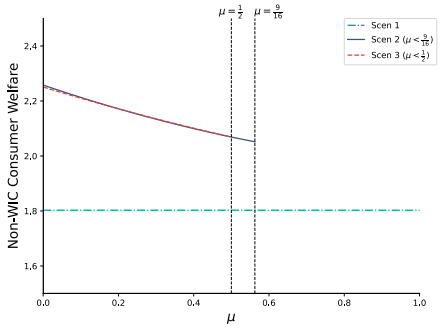
Figure A2 presents the distribution of WIC infant shares across states in 2020. The data are drawn from the WIC infant data released by the U.S. Department of Agriculture (2025) and the birth data released by the U.S. Centers for Disease Control and Prevention (Osterman et al., 2022). We use this measure as a state-level proxy for the fraction of WIC consumers. Ideally, this proxy would account for state-level formula-feeding rates separately for WIC and non-WIC households with infants, but such information is not publicly available to our knowledge.

Among all states, Utah has the lowest WIC infant share, at 24.14%, while Mississippi has the highest, at 63.13%. Since WIC infant shares in many states cluster around 40%, we set $\theta = 0.4$ for the illustrative analysis in Section 5 of the main text. As a sensitivity check, we consider two alternative values, $\theta = 0.2$ and $\theta = 0.55$, while holding all other parameters at the same values as in the main text.

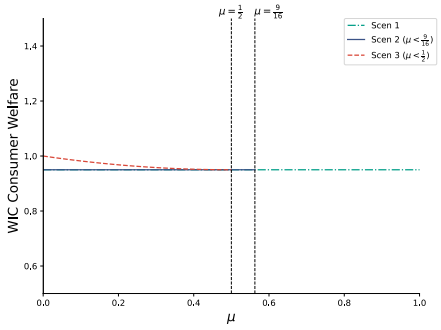
We begin by setting $\theta = 0.2$. *Figure A3(a)–(c)* show how the ON2OFF ratio affects consumer welfare and direct WIC spending. Similarly, the FEE conditions in Scenarios 2 and 3 place restrictions on μ. The FEE exists in all three scenarios only when $\mu \in [0, \frac{1}{2})$. *Figure A3* exhibits patterns similar to those in *Figure 6* in the main

text. The key distinction appears in *Figure A3(c)*, where direct WIC spending in Scenario 3 exceeds that in Scenario 2 when $\mu < \frac{5}{78}$. This pattern is consistent with Property 4(iii): when $\theta < 0.4$ and the ON2OFF ratio is sufficiently low, enabling online redemption increases direct WIC spending on infant formula.

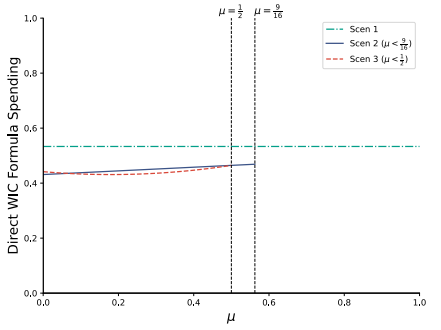
Next, we consider $\theta = 0.55$. *Figures A4(a)–(c)* show that, relative to Scenario 1, both Scenario 2 and Scenario 3 improve non-WIC consumer welfare while reducing direct WIC spending. When $\theta = 0.55$, the ranges of μ over which the FEE exist in Scenarios 2 and 3 do not overlap. As a result, a direct comparison of FEE outcomes between these two scenarios is not feasible. However, when $\mu \in [0, \frac{20}{41}]$, Scenario 2 falls into the CEE region, where W-retailers strategically set prices at the cap. Although the CEE outcomes depend on the imposed price caps and therefore cannot be derived explicitly without additional assumptions, we can still infer that, within this range, Scenario 3 yields higher non-WIC consumer welfare and lower direct WIC spending than Scenario 2.



A3(a). Non-WIC Consumer Welfare



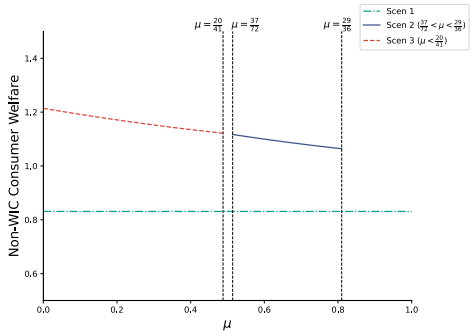
A3(b). WIC Consumer Welfare



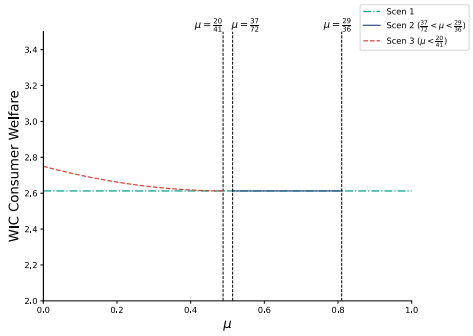
A3(c). Direct WIC Spending

Fig. A3: Consumer Welfare and Direct WIC Spending across Scenarios, $\theta = 0.2$

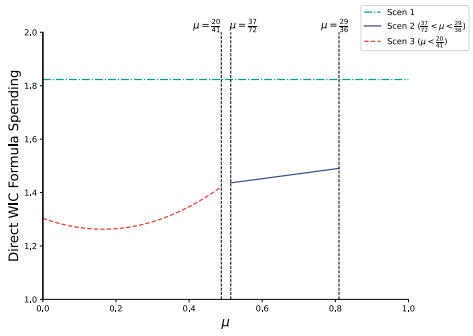
Note. The figures are generated using the parameter values $\theta = 0.2$, $V = 5$, $c = 2$, $N = 1$, and $t = 1$. Due to the FEE conditions in Scenarios 2 and 3, μ cannot take all possible values: (1) when $\mu \in (\frac{1}{2}, \frac{9}{16})$, Scenario 3 reverts to Scenario 2; (2) when $\mu \geq \frac{2}{3}$, Scenario 2 reverts to Scenario 1.



A5(a). Non-WIC Consumer Welfare



A5(b). WIC Consumer Welfare



A5(c). Direct WIC Spending

Fig. A4: Consumer Welfare and Direct WIC Spending across Scenarios, $\theta = 0.55$

Note. The figures are generated using the parameter values $\theta = 0.55$, $V = 5$, $c = 2$, $N = 1$, and $t = 1$. Due to the FEE conditions in Scenarios 2 and 3, μ cannot take all possible values: (1) when $\mu \in [0, \frac{37}{72})$, no FEE exists in Scenario 2; (2) when $\mu \geq \frac{29}{36}$, Scenario 2 reverts to Scenario 1; (3) when $\mu \geq \frac{20}{41}$, no FEE exists in Scenario 3.

A.2 Cap-Exploitation Equilibria (CEE)

Under certain conditions, WIC-authorized retailers (W-retailers in Scenarios 1–3 and the E-retailer in Scenario 3) may find it more profitable to set their prices at the price caps rather than fully engage in price competition. As defined in Section 3 of the main text, we refer to the resulting market equilibria as Cap-Exploitation Equilibria (CEE). We use Scenario 1 as an illustrative example to characterize the conditions under which the CEE arises and the corresponding equilibrium outcomes.

Recall that two conditions must hold for the Full-Engagement Equilibria (FEE) to be sustained in Scenario 1. A violation of either condition leads to a transition from the FEE to the CEE. The first condition pertains to the fraction of WIC consumers in the market. When the fraction of WIC consumers becomes sufficiently large, specifically $\theta \geq \frac{3}{5}$, W-retailers have no incentive to compete in the non-WIC segment. As a result, W-retailers charge the price cap to maximize their profits. The second condition imposes a restriction on the price cap, specifically $\bar{p}_w < c + \frac{t(3+\theta)^2}{36N\theta(1-\theta)}$, because excessively high caps can also discourage W-retailers from competing in the non-WIC segment even when $\theta < \frac{3}{5}$.

Under the CEE in Scenario 1, W-retailers serve only WIC consumers, while NW-retailers serve only non-WIC consumers. When $N = 1$, a single NW-retailer monopolizes the non-WIC segment and adjusts its pricing strategy in response to $\bar{p}_w$. When $N \geq 2$, NW-retailers compete with their neighboring NW-retailers. The corresponding equilibrium prices, market shares, and profits under the CEE are given by:

$$
\begin{aligned}
&\tilde{p}^*_{w,1} = \bar{p}_w\,, && \tilde{p}^*_{nw,1} = c + \tfrac{t}{N}\,;\\
&\tilde{S}^{NW*}_{w,1} = 0\,, && \tilde{S}^{NW*}_{nw,1} = \tfrac{1-\theta}{N}\,;\\
&\tilde{S}^{W*}_{w,1} = \tfrac{\theta}{N}\,, && \tilde{S}^{W*}_{nw,1} = 0\,;\\
&\tilde{S}^{Total*}_{w,1} = \tfrac{\theta}{N}\,, && \tilde{S}^{Total*}_{nw,1} = \tfrac{1-\theta}{N}\,;\\
&\tilde{\pi}^*_{w,1} = \tfrac{(\bar{p}_w - c)\theta}{N}\,, && \tilde{\pi}^*_{nw,1} = \tfrac{(cN+t)(1-\theta)}{N^2}\,.
\end{aligned}
$$

The corresponding $\tilde{x}^*_1$, $\tilde{y}^*_1$, and $\tilde{z}^*_1$ are as follows:

$$
\begin{aligned}
\tilde{x}^*_1 &= 0\,,\\
\tilde{y}^*_1 &= \tfrac{1}{2N}\,,\\
\tilde{z}^*_1 &= \tfrac{1}{2N}\,.
\end{aligned}
$$

The non-WIC consumer welfare, WIC consumer welfare, and direct WIC spending are outlined below:

$$
\begin{aligned}
\tilde{CW}^{NW*}_1 &= (V - C)(1-\theta) - \tfrac{5t(1-\theta)}{4N}\,,\\
\tilde{CW}^{W*}_1 &= \left(V - \tfrac{t}{4N}\right)\theta\,,\\
\tilde{WS}^*_1 &= \bar{p}_w\theta\,.
\end{aligned}
$$

Equilibrium Comparisons

In markets with $\theta < \frac{3}{5}$ and $N \geq 2$,

$$\tilde{CW}_1^{NW*} - CW_1^{NW*} = -\frac{t(3-5\theta)(15-17\theta)}{72N(1-\theta)} < 0\,,$$
$$\tilde{WS}_1^{*} - WS_1^{*} = (\bar{p}_w - p_{w,1}^{*})\theta > 0\,.$$

Comparing non-WIC consumer welfare and direct WIC spending under the CEE and FEE shows that excessively high price caps not only increase direct WIC spending but also reduce non-WIC consumer welfare. Note that, when $\theta \geq 3/5$, no FEE exists and thus comparisons between the CEE and FEE outcomes are not applicable.

Similar to Scenario 1, Scenarios 2 and 3 also feature a transition from FEE to CEE when the fraction of WIC consumers and the applicable price caps exceed their scenario-specific thresholds. As the CEE derivations for Scenarios 2 and 3 follow the logic described above, we do not elaborate further here.

Appendix B Model Extensions

In this appendix, we consider three extensions of the main model. The first extension considers an alternative offline market structure with unequal numbers of W-retailers and NW-retailers. The second extension allows marginal costs to vary across retailer types. The third extension introduces store-traffic margins to capture the additional profits that retailers may earn from consumers' other purchases during the same shopping trip. These extensions have two main purposes: (1) to examine whether the core pricing mechanisms identified in the main model continue to hold qualitatively under alternative specifications; and (2) to demonstrate the flexibility of our modeling framework by showing how it can be adapted to different retail settings and used to generate additional implications.

B.1 Unequal Numbers of W- and NW-Retailers

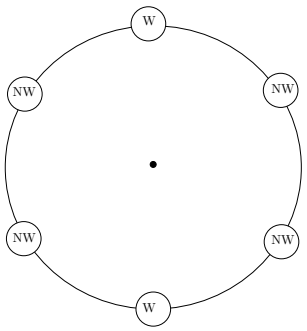


Fig. B.1: Circular market with a repeating NW-W-NW pattern ($N_w = 2$).

In the main text, we assume an equal number of W-retailers and NW-retailers. In Extension 1, we consider an alternative market structure in which the number of NW-retailers is twice the number of W-retailers, that is, $N_{nw} = 2N_w$. For tractability, we assume that offline retailers are evenly spaced along the circular market in a repeating NW-W-NW pattern (as illustrated in *Figure B.1*).

We analyze this market structure under Scenario 1 (see *Figure B.2*). A key feature of this structure is that, in the non-WIC segment, each NW-retailer competes with a W-retailer on one side and another NW-retailer on the other. As shown in *Figure B.2a*, we label the two NW-retailers located on either side of a representative W-retailer as NW-retailer A and NW-retailer B. Following the same procedure as in the main text, we solve the retailers' profit-maximization problems as follows:

$$\max_{p_w \leq \bar{p}_w} \pi_w = (p_w - c)\left[(1-\theta)\left(\frac{1}{3N_w} + \frac{p_{nwa} - p_w}{2t} + \frac{p_{nwb} - p_w}{2t}\right) + \frac{\theta}{N_w}\right], \quad \text{(B1)}$$

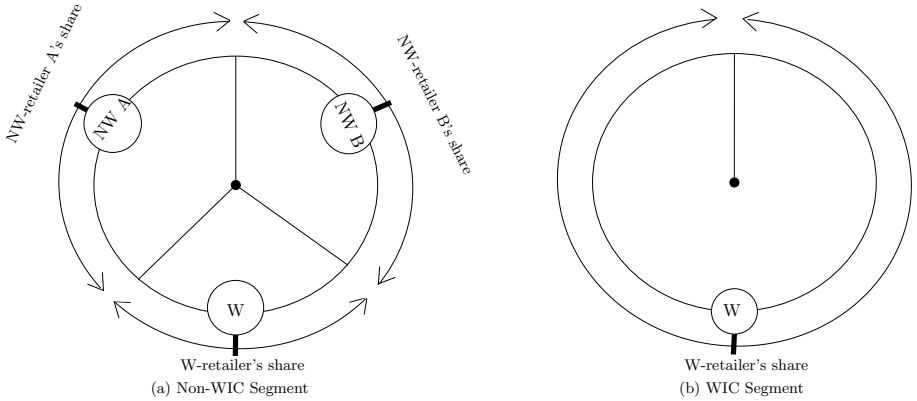


Fig. B.2: Spatial setting of the circular market under Scenario 1 with a repeating NW-W-NW pattern ($N_w = 1$, $N_{nw} = 2$).

$$\max_{p_{nwa}} \pi_{nwa} = (p_{nwa} - c)(1-\theta)\left(\frac{1}{3N_w} - \frac{p_{nwa} - p_w}{2t} - \frac{p_{nwa} - p_{nwb}}{2t}\right), \tag{B2}$$

$$\max_{p_{nwb}} \pi_{nwb} = (p_{nwb} - c)(1-\theta)\left(\frac{1}{3N_w} - \frac{p_{nwb} - p_w}{2t} - \frac{p_{nwb} - p_{nwa}}{2t}\right). \tag{B3}$$

Taking the first-order conditions w.r.t. p_w, p_{nwa}, and p_{nwb}, respectively, yields the following equilibrium prices, p_w^*, p_{nwa}^*, and p_{nwb}^*:

$$p_{w,1}^* = c + \frac{t}{3N_w} + \frac{3t\theta}{5N_w(1-\theta)},$$

$$p_{nwa,1}^* = p_{nwb,1}^* = p_{nw,1}^* = c + \frac{t}{3N_w} + \frac{t\theta}{5N_w(1-\theta)}.$$

Given the equilibrium prices, we solve for the equilibrium market shares and profits of W-retailers and NW-retailers:

$$\begin{aligned}
&S_{w,1}^{NW*} = \tfrac{5-11\theta}{15N_w}, && S_{nw,1}^{NW*} = \tfrac{5-2\theta}{15N_w};\\
&S_{w,1}^{W*} = \tfrac{\theta}{N_w}, && S_{nw,1}^{W*} = 0;\\
&S_{w,1}^{Total*} = \tfrac{5+4\theta}{15N_w}, && S_{nw,1}^{Total*} = \tfrac{5-2\theta}{15N_w};\\
&\pi_{w,1}^{*} = \tfrac{t(5+4\theta)^2}{225N_w^2(1-\theta)}, && \pi_{nw,1}^{*} = \tfrac{t(5-2\theta)^2}{225N_w^2(1-\theta)}.
\end{aligned}$$

The corresponding outcomes for non-WIC consumer welfare, WIC consumer welfare, and direct WIC spending are presented below:

$$
\begin{aligned}
CW_1^{NW*} &= 2N_w(1-\theta)\Bigg[\int_0^{\frac{5-11\theta}{30N_w(1-\theta)}}\left(V-c-\frac{t(5+4\theta)}{15N_w(1-\theta)}-t\ell\right)d\ell \\
&\quad+\int_0^{\frac{5+\theta}{30N_w(1-\theta)}}\left(V-c-\frac{t(5-2\theta)}{15N_w(1-\theta)}-t\ell\right)d\ell \\
&\quad+\int_0^{\frac{1}{6N_w}}\left(V-c-\frac{t(5-2\theta)}{15N_w(1-\theta)}-t\ell\right)d\ell\Bigg] \\
&= (V-c)(1-\theta)-\frac{t(125-150\theta+\theta^2)}{300N_w(1-\theta)}\,, \\
CW_1^{W*} &= 2N_w\theta\left[\int_0^{\frac{1}{2N_w}}(V-tl)\,dl\right] \\
&= (V-\frac{t}{4N_w})\theta\,, \\
WS_1^* &= p_{w,1}^*\theta \\
&= \left[c+\frac{t}{3N_w}+\frac{3t\theta}{5N_w(1-\theta)}\right]\theta\,.
\end{aligned}
$$

For the FEE above to be sustained, the following conditions must hold: 1(a). $S_w^{NW*} > 0 \Rightarrow \theta < \frac{5}{11}$; 1(b). $(p_{w,1}^* - c)S_{w,1}^{Total*} > (\bar{p}_w - c)\frac{\theta}{N} \Rightarrow \bar{p}_w < c + \frac{t(5+4\theta)^2}{225N_w\theta(1-\theta)}$.

Given that $t > 0$, $N \in \mathbb{Z}^+$, and $\theta \in (0,1)$, the following price-related comparative statics hold:

(i) $\dfrac{\partial p_{w,1}^*}{\partial\theta} = \dfrac{3t}{5N_w(1-\theta)^2} > 0\,;\ \dfrac{\partial p_{nw,1}^*}{\partial\theta} = \dfrac{t}{5N_w(1-\theta)^2} > 0\,.$

(ii) $\dfrac{\partial^2 p_{w,1}^*}{\partial\theta^2} = \dfrac{6t}{5N_w(1-\theta)^3} > 0\,;\ \dfrac{\partial^2 p_{nw,1}^*}{\partial\theta^2} = \dfrac{2t}{5N_w(1-\theta)^3} > 0\,.$

(iii) $\dfrac{\partial^2 p_{w,1}^*}{\partial\theta\partial t} > 0\,;\ \dfrac{\partial^2 p_{nw,1}^*}{\partial\theta\partial t} > 0\,.$

(iv) $\dfrac{\partial^2 p_{w,1}^*}{\partial\theta\partial N_w} < 0\,;\ \dfrac{\partial^2 p_{nw,1}^*}{\partial\theta\partial N_w} < 0\,.$

(v) $\dfrac{\partial^2 p_{w,1}^*}{\partial\theta\partial c} = 0\,;\ \dfrac{\partial^2 p_{nw,1}^*}{\partial\theta\partial c} = 0\,.$

It is evident that, under the FEE, the price-related comparative statics in Property 1 of the main text continue to hold in this alternative market structure. This suggests that the core pricing mechanism identified in the main model is not driven by the assumption that W-retailers and NW-retailers are present in equal numbers.

Next, we compare the FEE outcomes with those in the main model. This comparison allows us to examine the trade-offs arising from a lower share of W-retailers among offline retailers. For comparability, we hold the total number of offline retailers fixed at six. Under this setup, the number of W-retailers decreases from three

in the main model to two in Extension 1. The corresponding results are reported in *Table B1*. When fewer offline retailers are WIC-authorized, $p^*_{w,1}$ increases and $p^*_{nw,1}$ decreases, thereby widening the price gap between the two retailer types. This occurs because fewer W-retailers increase the market share of WIC consumers captured by each W-retailer, while more NW-retailers intensify competition in the non-WIC segment. Accordingly, non-WIC consumer welfare and direct WIC spending increase, and the conditions for sustaining the FEE become more restrictive. For WIC consumers, welfare decreases because a lower share of W-retailers raises the average travel cost of redeeming benefits.

Table B1: Comparison of FEE Outcomes: Main Model vs. Extension 1

Outcome	Main model	Extension 1	Direction of change
$p^*_{w,1}$	$c+\frac{t(3+\theta)}{18(1-\theta)}$	$c+\frac{t(5+4\theta)}{30(1-\theta)}$	Higher
$p^*_{nw,1}$	$c+\frac{t(3-\theta)}{18(1-\theta)}$	$c+\frac{t(5-2\theta)}{30(1-\theta)}$	Lower
$S^{NW*}_{w,1}$	$\frac{3-5\theta}{18}$	$\frac{5-11\theta}{30}$	Lower
$S^{NW*}_{nw,1}$	$\frac{3-\theta}{18}$	$\frac{5-2\theta}{30}$	Lower
$S^{W*}_{w,1}$	$\frac{\theta}{3}$	$\frac{\theta}{2}$	Higher
$\pi^*_{w,1}$	$\frac{t(3+\theta)^2}{324(1-\theta)}$	$\frac{t(5+4\theta)^2}{900(1-\theta)}$	Higher
$\pi^*_{nw,1}$	$\frac{t(3-\theta)^2}{324(1-\theta)}$	$\frac{t(5-2\theta)^2}{900(1-\theta)}$	Lower
CW_1^{NW*}	$(V-c)(1-\theta)-\frac{t(45-54\theta+5\theta^2)}{216(1-\theta)}$	$(V-c)(1-\theta)-\frac{t\left(125-150\theta+\theta^2\right)}{600(1-\theta)}$	Higher
CW_1^{W*}	$\left(V-\frac{t}{12}\right)\theta$	$\left(V-\frac{t}{8}\right)\theta$	Lower
WS_1^*	$\left[c+\frac{t(3+\theta)}{18(1-\theta)}\right]\theta$	$\left[c+\frac{t(5+4\theta)}{30(1-\theta)}\right]\theta$	Higher
Condition 1(a)	$\theta<\frac{3}{5}$	$\theta<\frac{5}{11}$	More restrictive
Condition 1(b)	$\bar{p}_w<c+\frac{t(3+\theta)^2}{108\theta(1-\theta)}$	$\bar{p}_w<c+\frac{t(5+4\theta)^2}{450\theta(1-\theta)}$	More restrictive

Notes: All outcomes are evaluated under the FEE in Scenario 1. The total number of offline retailers is fixed at six. The last column reports the direction of change in Extension 1 relative to the main model.

This extension focuses on the case in which W-retailers are fewer than NW-retailers. In markets with a high fraction of WIC consumers, however, WIC state agencies may authorize more offline retailers to serve WIC consumers, leading W-retailers to outnumber NW-retailers. The implications of this case would mirror those reported in *Table B1*, with the direction of the changes reversed. We therefore do not analyze this case separately.

B.2 Marginal-Cost Heterogeneity

In the main text, we assume that all retailers have identical marginal costs. In Extension 2, we relax this assumption by allowing marginal costs to differ across retailer types. We continue with Scenario 1 to show how relaxing this assumption affects the FEE. Let c_w and c_{nw} denote the marginal costs of W-retailers and NW-retailers, respectively. The retailers' profit-maximization problems are now given by

$$\max_{p_w<\bar{p}} \pi_{w,1} = (p_w - c_w)\left[(1-\theta)\left(\frac{1}{2N} + \frac{p_{nw}-p_w}{t}\right) + \frac{\theta}{N}\right], \tag{B4}$$

$$\max_{p_{nw}} \pi_{nw,1} = (p_{nw} - c_{nw})(1-\theta)\left(\frac{1}{2N} - \frac{p_{nw}-p_w}{t}\right). \tag{B5}$$

Solving the first-order conditions yields

$$p^*_{w,1} = \frac{2c_w + c_{nw}}{3} + \frac{t}{2N} + \frac{2\theta t}{3N(1-\theta)},$$
$$p^*_{nw,1} = \frac{c_w + 2c_{nw}}{3} + \frac{t}{2N} + \frac{\theta t}{3N(1-\theta)}.$$

The corresponding equilibrium market shares and profits are as follows:

$$S^{NW*}_{w,1} = \tfrac{3-5\theta}{6N} + \tfrac{(1-\theta)(c_{nw}-c_w)}{3t}, \qquad S^{NW*}_{nw,1} = \tfrac{3-\theta}{6N} + \tfrac{(1-\theta)(c_w-c_{nw})}{3t};$$
$$S^{W*}_{w,1} = \tfrac{\theta}{N}, \qquad S^{W*}_{nw,1} = 0;$$
$$S^{Total*}_{w,1} = \tfrac{3+\theta}{6N} + \tfrac{(1-\theta)(c_{nw}-c_w)}{3t}, \qquad S^{Total*}_{nw,1} = \tfrac{3-\theta}{6N} + \tfrac{(1-\theta)(c_w-c_{nw})}{3t};$$
$$\pi^*_{w,1} = \tfrac{[t(3+\theta)+2N(1-\theta)(c_{nw}-c_w)]^2}{36N^2t(1-\theta)}, \qquad \pi^*_{nw,1} = \tfrac{[t(3-\theta)+2N(1-\theta)(c_w-c_{nw})]^2}{36N^2t(1-\theta)}.$$

The corresponding outcomes for non-WIC consumer welfare, WIC consumer welfare, and direct WIC spending are presented below:

$$CW_1^{NW*} = \left(V - \frac{c_w + c_{nw}}{2}\right)(1-\theta) - \frac{t(45 - 54\theta + 5\theta^2)}{72N(1-\theta)} + \frac{(c_w - c_{nw})\left[N(1-\theta)(c_w - c_{nw}) + 2t\theta\right]}{18t},$$
$$CW_1^{W*} = \left(V - \frac{t}{4N}\right)\theta,$$
$$WS_1^* = \left[\frac{2c_w + c_{nw}}{3} + \frac{t}{2N} + \frac{2t\theta}{3N(1-\theta)}\right]\theta.$$

For the FEE above to be sustained, the following conditions must hold: 1(a). $S^{NW*}_w > 0$ and $S^{NW*}_w > 0 \Rightarrow -\frac{t(3-\theta)}{2N(1-\theta)} < c_w - c_{nw} < \frac{t(3-5\theta)}{2N(1-\theta)}$; 1(b). $(p^*_{w,1} - c)S^{Total*}_{w,1} > (\bar{p}_w - c)\frac{\theta}{N} \Rightarrow \bar{p}_w < c_w + \frac{[t(3+\theta)+2N(1-\theta)(c_{nw}-c_w)]^2}{36Nt\theta(1-\theta)}$.

Given that $t > 0$, $N \in \mathbb{Z}^+$, and $\theta \in (0, 1)$, the following price-related comparative statics hold:

(i) $\dfrac{\partial p^*_{w,1}}{\partial \theta} = \dfrac{2t}{3N(1-\theta)^2} > 0\,;\ \dfrac{\partial p^*_{nw,1}}{\partial \theta} = \dfrac{t}{3N(1-\theta)^2} > 0\,.$

(ii) $\dfrac{\partial^2 p^*_{w,1}}{\partial \theta^2} = \dfrac{4t}{3N(1-\theta)^3} > 0\,;\ \dfrac{\partial^2 p^*_{nw,1}}{\partial \theta^2} = \dfrac{2t}{3N(1-\theta)^3} > 0\,.$

(iii) $\dfrac{\partial^2 p^*_{w,1}}{\partial \theta \partial t} > 0\,;\ \dfrac{\partial^2 p^*_{nw,1}}{\partial \theta \partial t} > 0\,.$

(iv) $\dfrac{\partial^2 p^*_{w,1}}{\partial \theta \partial N} < 0\,;\ \dfrac{\partial^2 p^*_{nw,1}}{\partial \theta \partial N} < 0\,.$

(v) $\dfrac{\partial^2 p^*_{w,1}}{\partial \theta \partial c_w} = \dfrac{\partial^2 p^*_{w,1}}{\partial \theta \partial c_{nw}} = 0\,;\ \dfrac{\partial^2 p^*_{nw,1}}{\partial \theta \partial c_w} = \dfrac{\partial^2 p^*_{nw,1}}{\partial \theta \partial c_{nw}} = 0\,.$

The comparative-static results show that, under the FEE, the price-related results in Property 1 of the main text continue to hold when marginal costs differ across retailer types. This suggests that the core pricing mechanism identified in the main model is not driven by the assumption of identical marginal costs across retailer types. A key difference from the main model is that each retailer type's equilibrium price now depends not only on its own marginal cost but also on the marginal cost of the other retailer type. It is also worth noting that, under marginal-cost heterogeneity, Condition 1(a) is no longer a simple restriction on θ. Instead, it requires the cost difference between W-retailers and NW-retailers to be sufficiently small in either direction, so that both retailer types retain positive market shares in the non-WIC segment.

Next, we consider the possibility that marginal-cost heterogeneity across retailer types arises from the WIC retail delivery system. Suppose that, absent WIC authorization, all offline retailers have the same marginal cost c. If WIC authorization changes the marginal cost of W-retailers, then $c_{nw} = c$ and $c_w = c + \Delta$, where Δ captures the effect of WIC authorization on W-retailers' marginal cost. We further compare the FEE outcomes with those in the main model. The results are reported in *Table B2*. A key insight from this comparison is that the direction of change depends on the sign of Δ. If WIC authorization increases W-retailers' marginal cost, that is, $\Delta > 0$, the cost increase is only partially passed through to $p^*_{w,1}$. Specifically, a unit increase in Δ raises $p^*_{w,1}$ by $\frac{2}{3}$ and $p^*_{nw,1}$ by $\frac{1}{3}$. As a result, relative to the main model, each W-retailer has a lower markup and a lower market share in the non-WIC segment, whereas each NW-retailer has a higher markup and a higher market share in the non-WIC segment. These changes imply that, if $\Delta > 0$, assuming identical marginal costs may lead to overestimation of W-retailers' profits and underestimation of NW-retailers' profits. If $\Delta < 0$, the direction of this bias is reversed.

Table B2: Comparison of FEE Outcomes: Main Model vs. Extension 2

Outcome	Main model	Extension 2	Direction of change	
			$\Delta > 0$	$\Delta < 0$
$p^*_{w,1}$	$c + \frac{t}{2N} + \frac{2t\theta}{3N(1-\theta)}$	$c + \frac{t}{2N} + \frac{2t\theta}{3N(1-\theta)} + \frac{2\Delta}{3}$	Higher	Lower
$p^*_{nw,1}$	$c + \frac{t}{2N} + \frac{t\theta}{3N(1-\theta)}$	$c + \frac{t}{2N} + \frac{t\theta}{3N(1-\theta)} + \frac{\Delta}{3}$	Higher	Lower
$S^{NW*}_{w,1}$	$\frac{3-5\theta}{6N}$	$\frac{3-5\theta}{6N} - \frac{(1-\theta)\Delta}{3t}$	Lower	Higher
$S^{NW*}_{nw,1}$	$\frac{3-\theta}{6N}$	$\frac{3-\theta}{6N} + \frac{(1-\theta)\Delta}{3t}$	Higher	Lower
$S^{W*}_{w,1}$	$\frac{\theta}{N}$	$\frac{\theta}{N}$	Unchanged	Unchanged
$\pi^*_{w,1}$	$\frac{t(3+\theta)^2}{36N^2(1-\theta)}$	$\frac{[t(3+\theta)-2N(1-\theta)\Delta]^2}{36N^2t(1-\theta)}$	Lower	Higher
$\pi^*_{nw,1}$	$\frac{t(3-\theta)^2}{36N^2(1-\theta)}$	$\frac{[t(3-\theta)+2N(1-\theta)\Delta]^2}{36N^2t(1-\theta)}$	Higher	Lower
CW_1^{NW*}	$(V-c)(1-\theta) - \frac{t(45-54\theta+5\theta^2)}{72N(1-\theta)}$	$(V-c)(1-\theta) - \frac{t(45-54\theta+5\theta^2)}{72N(1-\theta)} + \frac{\Delta[N(1-\theta)\Delta+t(11\theta-9)]}{18t}$	Lower	Higher
CW_1^{W*}	$\left(V - \frac{t}{4N}\right)\theta$	$\left(V - \frac{t}{4N}\right)\theta$	Unchanged	Unchanged
WS_1^*	$\left[c + \frac{t}{2N} + \frac{2t\theta}{3N(1-\theta)}\right]\theta$	$\left[c + \frac{t}{2N} + \frac{2t\theta}{3N(1-\theta)} + \frac{2\Delta}{3}\right]\theta$	Higher	Lower
Condition 1(a)	$\theta < \frac{3}{5}$	$-\frac{t(3-\theta)}{2N(1-\theta)} < \Delta < \frac{t(3-5\theta)}{2N(1-\theta)}$	-	-
Condition 1(b)	$\bar{p}_w < c + \frac{t(3+\theta)^2}{36N\theta(1-\theta)}$	$\bar{p}_w < c + \Delta + \frac{[t(3+\theta)-2N(1-\theta)\Delta]^2}{36Nt\theta(1-\theta)}$	-	-

Notes: All outcomes are evaluated under the FEE in Scenario 1. The last two columns report the direction of change in Extension 2 relative to the main model where applicable. A positive Δ means that WIC authorization raises W-retailers' marginal cost, while a negative Δ means that WIC authorization lowers W-retailers' marginal cost.

B.3 Store-Traffic Margins

In this extension, we consider the possibility that retailers treat infant formula (or other WIC-approved products) as traffic-generating products. That is, retailers may accept lower direct markups on infant formula to attract non-WIC consumers and earn additional margins from their broader shopping baskets. Again, we use Scenario 1 to illustrate the implications of store-traffic margins for the FEE outcomes. Let ρ_w and ρ_{nw} denote the additional expected margins that W-retailers and NW-retailers earn from non-WIC consumers, respectively. The retailers' profit-maximization problems are now given by

$$\max_{p_w<\bar{p}} \pi_{w,1} = (p_w - c + \rho_w)(1-\theta)\left(\frac{1}{2N} + \frac{p_{nw}-p_w}{t}\right) + (p_w - c)\frac{\theta}{N}\,, \tag{B6}$$

$$\max_{p_{nw}} \pi_{nw,1} = (p_{nw} - c + \rho_{nw})(1-\theta)\left(\frac{1}{2N} - \frac{p_{nw}-p_w}{t}\right). \tag{B7}$$

Solving the first-order conditions yields

$$p^*_{w,1} = c - \frac{2\rho_w + \rho_{nw}}{3} + \frac{t}{2N} + \frac{2\theta t}{3N(1-\theta)}\,,$$
$$p^*_{nw,1} = c - \frac{\rho_w + 2\rho_{nw}}{3} + \frac{t}{2N} + \frac{\theta t}{3N(1-\theta)}\,.$$

The corresponding equilibrium market shares and profits are as follows:

$$S^{NW*}_{w,1} = \tfrac{3-5\theta}{6N} + \tfrac{(1-\theta)(\rho_w-\rho_{nw})}{3t}\,, \qquad S^{NW*}_{nw,1} = \tfrac{3-\theta}{6N} + \tfrac{(1-\theta)(\rho_{nw}-\rho_w)}{3t}\,;$$
$$S^{W*}_{w,1} = \tfrac{\theta}{N}\,, \qquad S^{W*}_{nw,1} = 0\,;$$
$$S^{Total*}_{w,1} = \tfrac{3+\theta}{6N} + \tfrac{(1-\theta)(\rho_w-\rho_{nw})}{3t}\,, \qquad S^{Total*}_{nw,1} = \tfrac{3-\theta}{6N} + \tfrac{(1-\theta)(\rho_{nw}-\rho_w)}{3t}\,;$$
$$\pi_{w,1} = \tfrac{[t(3+\theta)+2N(1-\theta)(\rho_w-\rho_{nw})]^2}{36N^2t(1-\theta)} - \tfrac{\rho_w\theta}{N}\,, \qquad \pi_{nw,1} = \tfrac{[t(3-\theta)+2N(1-\theta)(\rho_{nw}-\rho_w)]^2}{36N^2t(1-\theta)}\,.$$

The corresponding outcomes for non-WIC consumer welfare, WIC consumer welfare, and direct WIC spending are presented below:

$$CW_1^{NW*} = (V-c)(1-\theta) - \frac{t(45-54\theta+5\theta^2)}{72N(1-\theta)} + \\ + \frac{N(1-\theta)(\rho_w-\rho_{nw})^2 + t\left[(9-11\theta)\rho_w + (9-7\theta)\rho_{nw}\right]}{18t}\,,$$
$$CW_1^{W*} = \left(V - \frac{t}{4N}\right)\theta\,,$$
$$WS_1^* = \left[c - \frac{2\rho_w+\rho_{nw}}{3} + \frac{t}{2N} + \frac{2t\theta}{3N(1-\theta)}\right]\theta\,.$$

For the FEE above to be sustained, the following conditions must hold: 1(a). $S_w^{NW*} > 0$ and $S_w^{NW*} > 0 \Rightarrow -\frac{t(3-\theta)}{2N(1-\theta)} < \rho_{nw} - \rho_w < \frac{t(3-5\theta)}{2N(1-\theta)}$; 1(b). $(p_{w,1}^* - c + \rho_w)S_{w,1}^{NW*} + (p_{w,1}^* - c)\frac{\theta}{N} > (\bar{p}_w - c)\frac{\theta}{N} \Rightarrow \bar{p}_w < c - \rho_w + \frac{[t(3+\theta)+2N(1-\theta)(\rho_w-\rho_{nw})]^2}{36Nt\theta(1-\theta)}$.

Given that $t > 0$, $N \in \mathbb{Z}^+$, and $\theta \in (0,1)$, the following price-related comparative statics hold:

(i) $\frac{\partial p_{w,1}^*}{\partial \theta} = \frac{2t}{3N(1-\theta)^2} > 0$; $\frac{\partial p_{nw,1}^*}{\partial \theta} = \frac{t}{3N(1-\theta)^2} > 0$.

(ii) $\frac{\partial^2 p_{w,1}^*}{\partial \theta^2} = \frac{4t}{3N(1-\theta)^3} > 0$; $\frac{\partial^2 p_{nw,1}^*}{\partial \theta^2} = \frac{2t}{3N(1-\theta)^3} > 0$.

(iii) $\frac{\partial^2 p_{w,1}^*}{\partial \theta \partial t} > 0$; $\frac{\partial^2 p_{nw,1}^*}{\partial \theta \partial t} > 0$.

(iv) $\frac{\partial^2 p_{w,1}^*}{\partial \theta \partial N} < 0$; $\frac{\partial^2 p_{nw,1}^*}{\partial \theta \partial N} < 0$.

(v) $\frac{\partial^2 p_{w,1}^*}{\partial \theta \partial c} = 0$; $\frac{\partial^2 p_{nw,1}^*}{\partial \theta \partial c} = 0$.

Note that the equilibrium profits for both retailer types include direct infant-formula markups and additional margins earned from non-WIC consumers. Again, under the FEE, incorporating store-traffic margins does not change the price-related comparative-static results in Property 1 of the main text. This suggests that the core pricing mechanism identified in the main model is not driven by a single-product profit-maximization setting. Although the store-traffic motive is not specific to the WIC retail delivery system, it has important implications when the traffic-generating product is WIC-approved. We show that this motive can lower the equilibrium prices of infant formula, thereby increasing non-WIC consumer welfare and reducing direct WIC spending on infant formula relative to the main model.

Next, we consider a simple case in which store-traffic margins are identical across retailer types, that is, $\rho_w = \rho_{nw} = \rho$. We then compare the resulting FEE outcomes with those in the main model. The results are reported in *Table B3*. With a common store-traffic margin, the FEE prices of both retailer types are lower by the same amount, ρ, relative to the main model. Therefore, the price gap between W-retailers and NW-retailers remains unchanged, and so do their market shares in the non-WIC segment. For the conditions required for the FEE to hold, Condition 1(a) remains unchanged because each W-retailer's market share in the non-WIC segment is unaffected by the common store-traffic margin. Condition 1(b), however, becomes more restrictive than in the main model. This is because the common store-traffic margin is passed through to lower formula prices, reducing the W-retailers' total profits and thus making the FEE harder to sustain.

Table B3: Comparison of FEE Outcomes: Main Model vs. Extension 3

Outcome	Main model	Extension 3	Direction of change
$p^*_{w,1}$	$c + \frac{t}{2N} + \frac{2t\theta}{3N(1-\theta)}$	$c - \rho + \frac{t}{2N} + \frac{2t\theta}{3N(1-\theta)}$	Lower
$p^*_{nw,1}$	$c + \frac{t}{2N} + \frac{t\theta}{3N(1-\theta)}$	$c - \rho + \frac{t}{2N} + \frac{t\theta}{3N(1-\theta)}$	Lower
$S^{NW*}_{w,1}$	$\frac{3-5\theta}{6N}$	$\frac{3-5\theta}{6N}$	Unchanged
$S^{NW*}_{nw,1}$	$\frac{3-\theta}{6N}$	$\frac{3-\theta}{6N}$	Unchanged
$S^{W*}_{w,1}$	$\frac{\theta}{N}$	$\frac{\theta}{N}$	Unchanged
$\pi^*_{w,1}$	$\frac{t(3+\theta)^2}{36N^2(1-\theta)}$	$\frac{t(3+\theta)^2}{36N^2(1-\theta)} - \frac{\rho\theta}{N}$	Lower
$\pi^*_{nw,1}$	$\frac{t(3-\theta)^2}{36N^2(1-\theta)}$	$\frac{t(3-\theta)^2}{36N^2(1-\theta)}$	Unchanged
CW^{NW*}_1	$(V-c)(1-\theta) - \frac{t(45-54\theta+5\theta^2)}{72N(1-\theta)}$	$(V-c)(1-\theta) - \frac{t(45-54\theta+5\theta^2)}{72N(1-\theta)} + (1-\theta)\rho$	Higher
CW^{W*}_1	$\left(V - \frac{t}{4N}\right)\theta$	$\left(V - \frac{t}{4N}\right)\theta$	Unchanged
WS^*_1	$\left[c + \frac{t}{2N} + \frac{2t\theta}{3N(1-\theta)}\right]\theta$	$\left[c - \rho + \frac{t}{2N} + \frac{2t\theta}{3N(1-\theta)}\right]\theta$	Lower
Condition 1(a)	$\theta < \frac{3}{5}$	$\theta < \frac{3}{5}$	Unchanged
Condition 1(b)	$\bar{p}_w < c + \frac{t(3+\theta)^2}{36N\theta(1-\theta)}$	$\bar{p}_w < c - \rho + \frac{t(3+\theta)^2}{36N\theta(1-\theta)}$	More restrictive

Notes: All outcomes are evaluated under the FEE in Scenario 1. The last column report the direction of change in Extension 3 relative to the main model. ρ denotes the common additional expected margin that both W-retailers and NW-retailers earn from non-WIC consumers.