# The Role of WIC in the U.S. Retail Infant Formula Market

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**Abstract**

The Special Supplemental Nutrition Program for Women, Infants, and Children (WIC) procures approximately half of the infant formula sold in the U.S. and distributes it to participants through WIC-authorized stores. Existing research has primarily focused on the impact of WIC on manufacturers' strategies, whereas far less is known about how WIC may reshape pricing behavior at the retail level. In this study, we develop a spatial competition model to explore the implications of WIC's distribution system on retail competition. Our model first shows that WIC grants WIC-authorized retailers a disproportionate competitive advantage while driving up prices for both WIC-authorized and non-authorized retailers. Moreover, higher offline shopping costs, lower offline retail density, and a greater fraction of WIC consumers in the market may exacerbate the price distortions induced by WIC. Next, given the rise of e-commerce, this study analyzes market equilibrium outcomes under different levels of e-commerce involvement. The results show that e-commerce entry heightens retail competition, thus alleviating price distortions among offline retailers, enhancing non-WIC consumer welfare, and reducing direct WIC formula spending. However, further integrating e-commerce into WIC's distribution system—an initiative WIC is actively promoting—may introduce uncertainty regarding its impact on non-WIC consumer welfare and WIC spending. Nevertheless, our estimates indicate that this initiative holds

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significant potential to improve the efficiency of WIC spending in enhancing overall consumer welfare.

**Keywords:** WIC, U.S. infant formula market, retail competition, e-commerce, spatial competition model

# 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 the age of five. To efficiently distribute food benefits while facilitating participant access, WIC partners with a select group of local private stores, referred to as WIC-authorized stores.[1] Each month, WIC participants can obtain WIC-approved products—such as infant formula, grains, fruits, and vegetables—in predetermined quantities for free from these stores, with WIC subsequently reimbursing these stores at full retail prices. As WIC participants are completely price insensitive, public concerns arise that this distribution system may distort retailers' pricing strategies, potentially driving up retail prices for WIC-approved products.

Among all WIC-approved products, infant formula is subject to the greatest concerns regarding potential WIC-induced price increases. By accounting for nearly half of all infant formula sales in the United States, WIC is likely to reshape pricing strategies at both the wholesale and retail levels. Empirical evidence from supermarket scanner data suggests that WIC significantly contributes to higher retail prices for infant formula (e.g., Oliveira, 2004; Rojas and Wei, 2019; U.S. Government Accountability Office, 2025). However, without access to firm-level data, such as procurement and operational costs, it remains unclear

[1] Two alternative systems for distributing WIC food benefits have been implemented in the past but are no longer in operation. Vermont previously employed a home delivery system, delivering food directly to participants' homes. In Mississippi and parts of Chicago, Illinois, a direct distribution system was utilized, wherein participants collected food from state-managed store facilities.

whether these price effects stem from wholesale pricing, retail pricing, or both. While prior studies have primarily investigated WIC's impact on manufacturers' strategies under the assumption of perfect competition in the downstream market (Abito et al., 2022; An et al., 2023; Wang, 2023), studies on how WIC influences retail competition are strikingly sparse. To address this gap, we develop a spatial competition model to explore the potential impact of WIC's distribution system on retailers' pricing strategies and welfare outcomes.

In this study, we adopt a circular retail market framework following Salop (1979) and Balasubramanian (1998). Salop's circular model has been widely used to analyze retail competition under various settings, such as incomplete market information (Balasubramanian, 1998), consumer heterogeneity (Shi, Zhou and Jiang, 2019), and varying numbers of online retailers (Ford, Li and Zheng, 2021). In the classic settings, offline stores are evenly distributed along the circumference of a circle, while e-commerce, if present, is situated at the center. Consumers, uniformly distributed along the circumference, make shopping decisions based on two key factors: convenience, influenced by both offline and online shopping costs, and product prices set by each store. Building upon the classic settings, our model further incorporates WIC's role by classifying stores into WIC-authorized and non-authorized stores and consumers into WIC and non-WIC consumers. All incumbent retailers are assumed to engage in price competition for WIC-approved infant formula, which is empirically shown to dominate the market and appeals to both WIC and non-WIC consumers (e.g., Oliveira, Frazao and Smallwood, 2011; Huang and Perloff, 2014; Wang, 2023).[2]

Furthermore, considering that the extent of WIC's impact could be contingent on the level of e-commerce involvement, we construct three scenarios to capture these variations: (1) markets without e-commerce involvement, typically observed in regions where online shopping costs far exceed offline shopping costs or where other structural barriers restrict e-commerce entry; (2) markets where online shopping is limited to non-WIC consumers,

[2]Although our analysis focuses on the price competition of WIC-approved infant formula, the findings shed light on the broader pricing strategies that retailers adopt for their overall infant formula offerings. The key driving force is that WIC exogenously shifts the store selection preferences of a group of consumers.

reflecting the prevailing market structure of most U.S regions; and (3) markets where online shopping is accessible to both WIC and non-WIC consumers. These three scenarios are formally defined and constructed in Section 4. Notably, while Scenario 3 is hypothetical, it is particularly relevant given ongoing WIC modernization initiatives, which aim to introduce online redemption for participants. Comparing welfare outcomes between the status quo and Scenario 3 will provide valuable insight into the feasibility of integrating online retailers into WIC's distribution system.

Our analysis shows that WIC-authorized retailers set higher prices for infant formula as a result of their exclusive access to WIC consumers. In response, non-authorized retailers also increase prices slightly, driven by strategic complementarity. Moreover, the WIC-induced price distortions are more pronounced in markets characterized by higher offline shopping costs, lower retail density, and a greater fraction of WIC consumers. Next, the entry of e-commerce—despite currently being limited to serving non-WIC consumers—might help alleviate price distortions among offline retailers, benefit non-WIC consumers through lower prices and better access, and reduce direct WIC formula spending. Last, while benefiting WIC consumers, integrating e-commerce into WIC may introduce uncertainty regarding its effect on non-WIC consumer welfare and WIC spending. The extent and direction of the effect hinge on the fraction of WIC consumers and the relative costs of online and offline shopping. However, subsequent estimation of the return on direct WIC formula spending provides a clearer picture, suggesting that this initiative would enhance the efficiency of WIC spending by improving overall consumer welfare.

This study contributes to two key areas of research. First, it advances the theoretical literature on spatial market competition. The seminal work of Hotbllino (1929) introduced the linear spatial competition model, but its applicability is constrained by edge effects and the principle of minimum differentiation. To address these limitations, Salop (1979) developed the circular spatial competition model, providing a more realistic framework for analyzing retail competition. Subsequently, Balasubramanian (1998) extended Salop's circular model by incorporating e-commerce, illustrating how the entry of online retailers reshapes competitive dynamics and influences consumer purchasing decisions. The theoretical insights from Balasubramanian (1998) have been empirically validated in several studies, including Cui, Zhu and Chen (2024) and Forman, Ghose and Goldfarb (2009). Our study further extends Salop's circular model to examine how offline retailers compete against their neighboring rivals and online retailers under WIC's distribution system. Our findings highlight the potential of the spatial competition framework as an analytical tool for designing and evaluating such distribution systems, which are increasingly adopted by public food assistance programs. This framework offers critical insights into the trade-offs between market efficiency, consumer welfare, and program costs.

Our study also contributes to the literature on WIC's impact on infant formula prices. The hypothesis that WIC drives price increases is typically tested by comparing the prices of WIC-approved infant formula brands with those of non-WIC brands or by examining price changes before and after a brand gains WIC approval. While empirical evidence indicates that WIC is associated with higher formula prices, identifying the precise mechanisms remains challenging. Our study is closely related to Prell (2004), which also focuses on WIC's impact at the retail level. The author employed a Cournot model to analyze how WIC-authorized stores set prices for both WIC-approved and non-WIC brands, demonstrating that the prices of WIC-approved brands increase with the fraction of WIC consumers in the market. While some of our findings align with those of Prell (2004), our study differs in two key aspects. First, we focus on competition among multiple retail types, particularly between WIC-authorized and non-authorized stores. Second, our model emphasizes market segmentation induced by WIC's distribution system rather than the presence of WIC-approved brands. By incorporating these factors, our study offers a new perspective on how WIC shapes retailers' pricing strategies, thereby influencing infant formula prices.

The rest of the paper is organized as follows: Section 2 provides an overview of the U.S. infant formula market and the WIC regulations relevant to this study. Section 3 introduces the model. Section 4 characterizes the equilibrium and presents a comparative statics analysis for each scenario. Section 5 compares the three scenarios in terms of consumer welfare and direct WIC formula spending. Section 6 concludes with a summary of our findings and directions for future research. All proofs are relegated to the Appendices.

# 2 Background

## 2.1 The U.S. Infant Formula Market

Infant formula provides essential nutrients for children's healthy growth and development, especially in families where breastfeeding is not feasible due to medical reasons or practical constraints. According to the U.S. CDC Breastfeeding Report Card (Centers for Disease Control and Prevention, 2022), 75% of children born in 2019 were partially or fully fed with formula. The U.S. infant formula market was valued at $4.5 billion in 2023 and is projected to reach $7.2 billion by 2032 (Custom Market Insights, 2024). Infant formula is categorized primarily into milk- and soy-based types and is available in three forms: liquid concentrate, powder, and ready-to-feed. Among these combinations, milk-based powder formula dominates the market, accounting for over 72% of the market share (Oliveira, 2011).

The U.S. wholesale infant formula market is highly concentrated. Three major manufacturers account for almost 98% of all U.S. formula sales: Abbott (the maker of Similac), Mead Johnson (the maker of Enfamil), and Nestlé (now Gerber, the maker of Good Start). Both strict U.S. Food and Drug Administration (FDA) regulations and high tariffs (up to 17.5%) hinder new entrants into the wholesale market (Yenerall et al., 2024).[3] Such concentration, even in the absence of WIC, could lead to significantly higher procurement costs, which are ultimately borne by consumers.

The distribution of infant formula has evolved over time. In 2002, supermarkets accounted

[3]The Infant Formula Act of 1980 established strict standards for the nutritional content, manufacturing, and testing of infant formula.

for 69% of infant formula sales, mass merchandisers for about 28%, and drugstores for about 4% (Prell, 2004). Over the past decade, many consumers have shifted to online shopping following the rise of e-commerce, reshaping the retail landscape. Amazon has emerged as the dominant retailer in the online infant formula market. Notably, Amazon employs a first-party operations model to sell infant formula, which is similar to the wholesale model adopted by offline retailers. This approach ensures stricter quality control and enhances consumer trust in the safety and authenticity of the formula.

Consumer demand for infant formula generally exhibits low price elasticity due to its essential role in infant nutrition and the limited availability of close substitutes (Oliveira, 2004). Moreover, consumer brand loyalty is high, even though manufacturers offer products with comparable ingredients. This is mainly because parents tend to stick to a brand once their infants get used to its formula (Le Huërou-Luron, Blat and Boudry, 2010). As noted earlier, many non-WIC consumers opt for WIC-approved infant formula, potentially driven by doctor endorsements (GAO, 1998; Oliveira, Frazao and Smallwood, 2011) and its widespread availability (GAO, 2006).

## 2.2 WIC Cost-Containment Policies

The WIC program, initiated in 1972, is administered by the U.S. Department of Agriculture (USDA). The program operates across all 50 states and the District of Columbia, and each WIC state agency has discretion in determining specific implementation details and eligibility criteria. WIC is a discretionary grant program funded annually by appropriation law, so it does not guarantee enrollment for all households that meet WIC eligibility criteria. In 2021, the average monthly WIC-eligible population was about 12.13 million, only 51.2% of whom received WIC benefits (Kessler et al., 2023). To extend its benefits to a larger number of eligible households, WIC has prioritized cost containment as a key policy objective.

Infant formula has historically been the largest expenditure in WIC food benefits, accounting for nearly 40% of total WIC food costs in the mid-1980s. To mitigate spending on infant formula, WIC has implemented a series of cost-containment policies at both the wholesale and the retail level. At the wholesale level, each WIC state agency periodically conducts competitive bidding to contract a single manufacturer to exclusively supply infant formula for WIC participants for the state in exchange for rebates, referred to as the WIC rebate program.[4] According to An et al. (2023), rebates offered by the WIC-contract manufacturers amount to approximately 85% of wholesale prices, enabling WIC to save an estimated $1.7 billion annually. As our focus is on retail competition, we do not explicitly model manufacturers' contract bidding and wholesale pricing strategies.[5] Instead, we assume that the WIC-approved infant formula is predetermined and that retailers' procurement costs are exogenous to retail competition in our model.

At the retail level, WIC implements two policies that are primarily aimed at cost containment for WIC-authorized stores: banning price discrimination and regulating prices through maximum allowable reimbursement levels (MARLs).[6] To ensure fair practices, WIC mandates that WIC-authorized stores cannot price discriminate but must maintain consistent pricing for all WIC-approved products across both WIC and non-WIC consumers. Moreover, local WIC agencies are required to establish MARLs for WIC-approved products at each WIC-authorized store. These levels are determined based on factors such as store type, size, and geographic location. WIC-authorized stores are required to keep their prices below the MARLs. However, MARLs are often set at relatively high levels to accommodate exceptional circumstances (Neuberger and Greenstein, 2004). While the specific details of cost-containment policies at the retail level vary by state, the primary goal is to ensure that WIC-authorized stores engage in market competition rather than exploit their exclusive access to WIC consumers (USDA, 2015). To better reflect the regulatory retail environment, our model incorporates price discrimination prohibitions and pricing caps.

[4]Some WIC state agencies collaborate in selecting contract manufacturers to enhance their negotiating power.

[5]For theoretical insights into manufacturers' strategies, refer to Betson (2009) and Davis (2012).

[6]The regulations governing the authorization and selection criteria for WIC-authorized retailers are delineated in the Code of Federal Regulations (CFR), Title 7, Subtitle B, Chapter II, Subchapter A, Part 246.

In addition to cost-containment policies, WIC-authorized retailers must also adhere to additional regulations, including offering a variety of WIC-approved products and maintaining minimum stocking levels. Noncompliance with these regulations or cost-containment policies may lead to the revocation of a store's WIC authorization.

While WIC authorization is open to all eligible offline retailers, the application process may be temporarily paused if local WIC agencies determine that either community needs are adequately met or their administrative capacity is fully utilized. Expanding the number of WIC-authorized stores can intensify competition but also escalate administrative costs. This trade-off is beyond the scope of this study. Instead, we assume a fixed ratio of offline WIC-authorized retailers (50%) in our model, which will be further detailed in Section 3.

## 2.3 WIC's Efforts to Enable Online Shopping

The USDA Food and Nutrition Service (FNS) has been working to modernize WIC by integrating online shopping into the program. In 2023, FNS introduced the WIC Online Ordering and Transactions Proposed Rule, which aims to remove regulatory barriers preventing WIC participants from using their benefits for online purchases.[7] As part of these efforts, WIC has completed the transition from paper vouchers to electronic benefit transfer (EBT) cards, laying the foundation for online payment systems. In mid-2024, WIC agencies in Nebraska, Minnesota, and Iowa launched online shopping pilots. While WIC participants in certain areas now have the option to redeem their food benefits online, WIC does not cover the associated delivery fees, which must be paid out of pocket. These additional costs could impose new financial challenges for WIC participants, limiting their access to the full benefit of this initiative.

The rollout of this initiative is expected to shift a portion of WIC consumers toward online shopping, prompting retailers to adjust their pricing strategies for infant formula accordingly. The framework of Scenario 3 is designed to evaluate the potential implications

[7] For more details, refer to the official publication in the Federal Register (2023).

of this shift for retail competition and welfare outcomes.

# 3 Model

We consider three types of retailers—offline WIC-authorized retailers, offline non-authorized retailers, and a single online retailer—competing on price for a single brand of infant formula under the WIC contract in the local market.[8] *Table 1* summarizes the key notations in this study.

Table 1: Notation for parameters.

| Parameter | Description |
|---|---|
| $p_{ij}$, $p_e$ | The unit retail price set by offline retailer $j$ of type $i$, where $i \in \{w, nw\}$ and $j$ indexes the retailers of this type, and by the E-retailer. |
| $\bar{p}$ | The price cap set by the WIC agency for WIC-authorized retailers. |
| $c_{ij}$, $c_e$ | The marginal costs for offline retailer $j$ of type $i$ and for the E-retailer. |
| $S_{ij}^k$, $S_e^k$ | The market share of type $k$ consumers captured by offline retailer $j$ of type $i$ and by the E-retailer, where $k \in \{W, NW, Total\}$. |
| $\pi_{ij}$, $\pi_e$ | The profit earned by offline retailer $j$ of type $i$ and by the E-retailer. |
| $N_i$ | The numbers of offline retailers of type i. |
| $t$ | The travel costs per unit distance when visiting an offline store. |
| $\mu$ | The online shopping costs. |
| $V$ | Consumers' valuation of the infant formula. |
| $\theta$ | The fraction of WIC consumers in the market, $\theta \in [0, 1]$. |
| $CW^k$ | The welfare of type $k$ consumers. |
| $GS$ | The WIC spending on infant formula without manufacturer's rebates. |

The model is set up as follows: Offline retailers are designated as either W- or NW-retailers and are equidistantly positioned along a circular market with a circumference of 1. W-retailers are WIC-authorized and 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 a single online retailer, designated as the E-retailer, enters

[8] We consider a market with a single online retailer because (1) it reflects the realistic structure of the U.S. infant formula market, where Amazon, a dominant retailer, leads online sales, and (2) it captures the key dynamics of online versus offline competition. Introducing two or more online retailers would require additional parameters to account for retail differentiation; otherwise, profits for any online retailer would fall to zero, which is beyond the scope of the study.

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. Following WIC price regulations, WIC-authorized retailers are required to maintain the same price for both WIC and non-WIC consumers and price within the caps, $\bar{p}$. As fixed costs do not influence retailers' pricing strategies in equilibrium, they are set to zero across all retailers.

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 $\theta$ (where $\theta \in [0,1]$) represents WIC consumers, and the remaining, $1-\theta$, are non-WIC consumers. The valuation of the formula, denoted by $V$, is assumed to be identical for all consumers and sufficiently large so that any consumer is better off purchasing it. This assumption is likely valid given consumers' low price elasticity and strong brand loyalty.

Consumers incur positive shopping costs regardless of whether the formula is purchased online or offline. For offline shopping, the primary cost is travel expenses, charged at a linear rate of $t$ per unit distance, then multiplied by the distance traveled. The travel distance, $l_{aij}$, depends on the relative locations of the consumer, $a$, and the offline retailer, $ij$. Thus, a non-WIC consumer's net utility from shopping at an offline retailer (either a W- or an NW-retailer) is $V - tl_{aij} - p_{ij}$, and a WIC consumer's net utility from shopping at a W-retailer is $V - tl_{awj}$. When shopping online at the E-retailer, consumers incur a uniform cost of $\mu$, which captures the disutility associated with online purchases, such as delivery costs, membership fees, and waiting times. A non-WIC consumer's net utility from shopping at the E-retailer is $V - \mu - p_e$, while a WIC consumer obtains a net utility of $V - \mu$ only when the E-retailer is WIC-authorized.

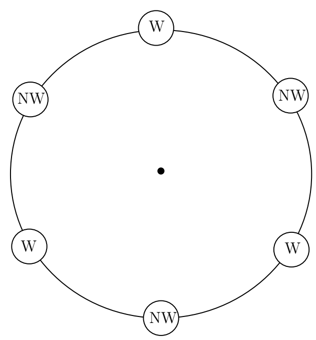
Given the increased complexity of the model after incorporating the role of WIC, we propose several additional assumptions and simplifications.

**Assumption 1** *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. (See an example in Figure 1).*

We assume symmetric competition along the circular market, enabling us to derive an equilibrium using the methodology suggested by Balasubramanian (1998). This assumption posits that a local WIC agency partners with half of the offline retailers for food benefit distribution. Although this proportion may not precisely correspond to the actual share of WIC-authorized retailers, it aligns with our primary objective of conducting a directional analysis rather than quantifying WIC's impact on retail competition.

In the standard Salop circular model, the number of offline retailers is determined endogenously by fixed costs and market size. In contrast, our model takes $N$ as exogenous. This is justified by the fact that infant formula sales constitute only a small share of retailers' total revenue and thus do not drive their entry or exit decisions.

Figure 1: The Circular Market, $N = 3$




**Assumption 2** *All retailers have the same marginal cost:* $c_{ij} = c_e, \forall\ i, j$.

The main marginal cost for retailers comes from procurement expenses. To simplify the algebra, we assume that differences in procurement expenses across local markets are negligible. There may be concerns about variation in marginal costs across different retail types, but our robustness checks show that these variations do not quantitatively affect our findings.

**Assumption 3** *The fraction of WIC consumers in the market,* $\theta$*, is pre-determined.*

Following Oliveira (2004) and Prell (2004), we assume that local WIC enrollment size is pre-determined and unaffected by price fluctuations in the short run.

**Assumption 4** *WIC consumers are always better off obtaining free infant formula at WIC-authorized retailers.*

This assumption guarantees that WIC consumers consistently choose WIC-authorized retailers over non-authorized ones to avoid purchasing out of pocket. Occasionally, high travel costs may lead them not to use WIC benefits, but we omit these cases from our model for simplicity.

**Assumption 5** *The price caps, $\bar{p}$, are consistently higher than the competitive equilibrium prices among WIC-authorized retailers.*

We define the competitive equilibrium prices of WIC-authorized retailers as those charged when they fully engage in market competition. As the Maximum Allowable Reimbursement Levels (MARLs) are set to encourage WIC-authorized retailers to engage in market competition rather than restrict their competitive pricing, we assume that the imposed price caps are sufficiently high to remain non-binding on the competitive equilibrium prices. Note that we do not rule out the possibility that WIC-authorized retailers strategically set their prices at the price caps to maximize their profits. The conditions under which this strategic behavior arises are thoroughly discussed in Section 4.

The sequence of the game is as follows:

> **Stage 1:** Each retailer, fully aware of all retailers' locations and types, independently and simultaneously determines the retail price of infant formula to maximize profit.
>
> **Stage 2:** Each consumer, with complete information on retailer types and prices, selects their purchase locations to maximize their utility.

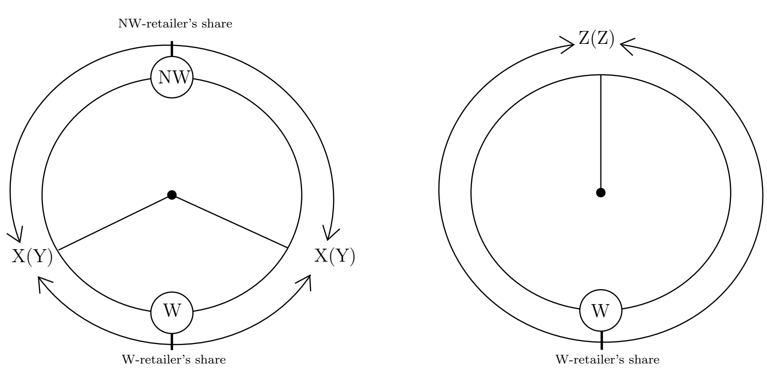
We solve this game using backward induction.

# 4 Equilibrium Analysis

**Scenarios** As mentioned previously, we construct three scenarios—described by subscripts 1, 2, and 3—to reflect varying levels of e-commerce involvement: Scenario 1 describes a market where e-commerce is unavailable; Scenario 2 extends Scenario 1 by introducing an online retailer that serves non-WIC consumers only; and Scenario 3 further expands the scope by allowing the online retailer to serve both WIC and non-WIC consumers. In this section, we characterize and analyze the equilibrium outcomes for each scenario. We then extend our analysis in Section 5 to compare the welfare outcomes across the three scenarios.

**Equilibrium Concept** We identify two equilibrium types: Full-engagement Equilibria (FEE), where 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), where at least one WIC-authorized retailer strategically prices at the price cap (i.e., MARLs). Given that infant formula prices set by WIC-authorized stores typically fall below the price caps,[9] our analysis primarily focuses on FEE, with a brief discussion of CEE provided in Appendix B.

## 4.1 Analysis of Scenario 1 (No E-commerce Involvement)




(a) Non-WIC Segment

(b) WIC Segment

Figure 2: Spatial Setting of the Circular Market in Scenario 1, $N = 1$

[9]This observation is drawn from interviews with several WIC agency representatives.

As mentioned previously, WIC's distribution system divides the retail market into WIC and non-WIC segments, which we discuss separately. First, in the non-WIC segment, $N$ W-retailers and $N$ NW-retailers compete against each other. Due to the symmetry inherent in the circular market, it suffices to analyze the price-setting game between a W-retailer and one of its neighboring NW-retailers. As shown in *Figure 2(a)*, there exists a point between these two retailers where a non-WIC consumer is indifferent to shopping at either retailer. The distance from the W-retailer to this point is denoted as $x$, while the distance from the NW-retailer is $y$. Given that the distance between the two retailers is $\frac{1}{2N}$, we can get $y = \frac{1}{2N} - x$. We can solve for the indifferent consumer location by equating the following utility functions:

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

which is equivalent to

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

and

$$y = \frac{1}{4N} - \frac{p_{nw} - p_w}{2t}\,. \tag{3}$$

Given that each offline retailers draws an equal number of consumers from both its left and right sides, and that the fraction of non-WIC consumers is $1 - \theta$, the market share of non-WIC consumers for each W-retailer, denoted by $S_w^{NW}$, is equal to $2(1 - \theta)x$, and the market share for each NW-retailer, denoted by $S_{nw}^{NW}$, is equal to $2(1 - \theta)y$.

In the WIC segment, WIC consumers obtain formula exclusively from W-retailers. In a market with a single W-retailer, that W-retailer would capture the entire market share of WIC consumers, as shown in *Figure 2(b)*. When $N \geq 2$, WIC consumers shop at the nearest W-retailer. Similarly, there exists a point at which a WIC consumer is indifferent between purchasing from a W-retailer and one of its nearest W-retailers. We denote the distance from the W-retailer to this point as $z$. Accordingly, the market share of WIC consumers obtained by each W-retailer, denoted by $S_w^W$, is $2\theta z$. Moreover, since Assumption 1 ensures that W-retailers are evenly spaced, each obtains an equal market share of WIC consumers, calculated as $\frac{\theta}{N}$. The corresponding $z$ is

$$z = \frac{1}{2N}. \tag{4}$$

Next, we solve the optimization problems for these two types of retailers. W-retailers and NW-retailers, respectively, maximize their profits by

$$\max_{p_w \le \bar{p}_w} \pi_w = (p_w - c)\left[(1-\theta)\left(\frac{1}{2N} + \frac{p_{nw} - p_w}{t}\right) + \frac{\theta}{N}\right] \tag{5}$$

and

$$\max_{p_{nw}} \pi_{nw} = (p_{nw} - c)(1-\theta)\left(\frac{1}{2N} - \frac{p_{nw} - p_w}{t}\right). \tag{6}$$

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

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

$$S_{w,1}^{NW*} = \tfrac{3-5\theta}{6N}; \quad S_{nw,1}^{NW*} = \tfrac{3-\theta}{6N};$$

$$S_{w,1}^{W*} = \tfrac{\theta}{N}; \quad S_{nw,1}^{W*} = 0;$$

$$S_{w,1}^{Total*} = \tfrac{3+\theta}{6N}; \quad S_{nw,1}^{Total*} = \tfrac{3-\theta}{6N};$$

$$\pi_{w,1}^* = \tfrac{t(3+\theta)^2}{36N^2(1-\theta)}; \quad \pi_{nw,1}^* = \tfrac{t(3-\theta)^2}{36N^2(1-\theta)};$$

*This equilibrium exists when two conditions are met: 1(a): $S_{w,1}^{NW*} > 0 \Rightarrow \theta < \frac{3}{5}$ and 1(b): $(p_{w,1}^* - c)S_{w,1}^{Total*} > (\bar{p}_w - c)\frac{\theta}{N}$. PROOF. See Appendix A1.*

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, W-retailers gain a competitive advantage over NW-retailers due to their exclusive access to WIC consumers. Specifically, W-retailers always charge $\frac{t\theta}{3N(1-\theta)}$ higher than NW-retailers, and each W-retailer gains $\frac{\theta}{3N}$ more total market share and $\frac{t\theta}{3N^2(1-\theta)}$ more profits than each NW-retailer. The gaps in prices, total market shares, and profits between these two retail types are increasing in $\theta$.

Next, we further investigate whether and how each market parameter moderates the effect of WIC on equilibrium prices. For simplicity, we refer to the changes in equilibrium prices induced by WIC as distortionary effects.

**Property 1** *Given that $t > 0$, $N \in \mathbb{Z}^+$, and $\theta \in (0, 1)$,*

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

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

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

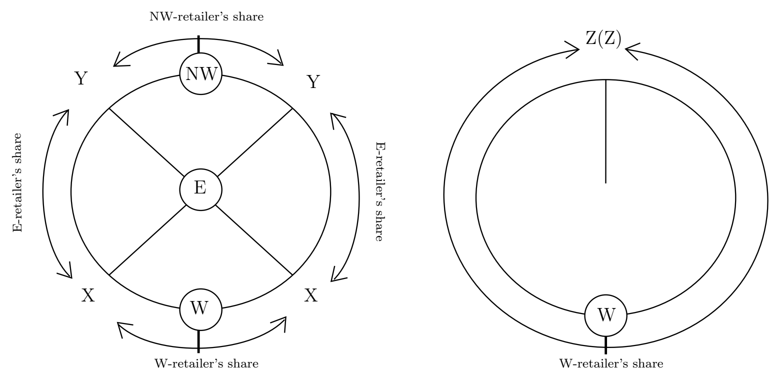
*v.* $\frac{\partial^2 p^*_{w,1}}{\partial \theta \partial c} = 0$; $\frac{\partial^2 p^*_{nw,1}}{\partial \theta \partial c} = 0$.

As Property 1(i) shows, $p^*_w$ and $p^*_{nw}$ are increasing in $\theta$. The increase in $p^*_w$ is quite straightforward as the fraction of WIC consumers grows. The increase in $p_{nw}$ is attributed to strategic complementarity: Higher prices charged by W-retailers induce more non-WIC consumers to shop at NW-retailers, prompting NW-retailers to adjust their prices strategically. Property 1(ii) further reveals that the distortionary effects are more pronounced in markets with a higher fraction of WIC consumers.

Moreover, higher offline shopping costs, $t$, and lower offline retail density, $N$, amplify the distortionary effects, as indicated by Property 1(iii) and 1(iv). A higher $t$ makes non-WIC consumers less sensitive to price changes, giving retailers more room to raise prices. A lower $N$ signifies less intense competition among retailers, weakening price pressures in the market. However, the distortionary effects are not affected by marginal costs, $c$, as confirmed by Property 1(iv).

The existence of the FEE above is contingent upon two conditions. Condition 1(a) ensures that W-retailers obtain a positive market share in the non-WIC market segment, which holds when $\theta < \frac{3}{5}$. Condition 1(b) ensures that price caps are not set at excessively high levels, such that competing in the non-WIC segment is more profitable for W-retailers than pricing at the caps. A violation of either condition will prompt W-retailers to price at the caps, leading to the market transition from the FEE to the CEE.

## 4.2 Analysis of Scenario 2 (E-commerce in the Non-WIC Segment)




(a) Non-WIC Segment (b) WIC Segment

Figure 3: Spatial Setting of the Circular Market in Scenario 2, $N = 1$

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)*). Using a similar approach as in Scenario 1, we identify a point where a non-WIC consumer is indifferent between purchasing from the nearest W-retailer and the E-retailer. The distance from the W-retailer to this point is $x$. Hence, we have

$$V - tx - p_w = V - \mu - p_e \,, \tag{7}$$

which is equivalent to

$$x = \frac{p_e - p_w + \mu}{t} \,. \tag{8}$$

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

$$V - ty - p_{nw} = V - \mu - p_e \,, \tag{9}$$

which is equivalent to

$$y = \frac{p_e - p_{nw} + \mu}{t} \,. \tag{10}$$

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

The WIC segment is the same as that in Scenario 1. Hence, the market share of WIC consumers for each W-retailer remains at $\frac{\theta}{N}$.

W-retailers, NW-retailers, and the E-retailer, respectively, maximize their profits by

$$\max_{p_w < \bar{p}_w} \pi_w = (p_w - c)\left[\frac{2(1-\theta)(p_e - p_w + \mu)}{t} + \frac{\theta}{N}\right], \tag{11}$$

$$\max_{p_{nw}} \pi_{nw} = (p_{nw} - c)\frac{2(1-\theta)(p_e - p_{nw} + \mu)}{t}\,, \tag{12}$$

$$\max_{p_e} \pi_e = (p_e - c)(1-\theta)\left(1 - \frac{2N\,(p_e - p_w + \mu)}{t} - \frac{2N\,(p_e - p_{nw} + \mu)}{t}\right). \tag{13}$$

**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 participate in market competition. Equilibrium prices, market shares, and profits are given by*

$p^*_{w,2} = c + \frac{t}{12N} + \frac{\mu}{3} + \frac{7t\theta}{24N(1-\theta)}$; $p^*_{nw,2} = c + \frac{t}{12N} + \frac{\mu}{3} + \frac{t\theta}{24N(1-\theta)}$; $p^*_{e,2} = c + \frac{t}{6N} - \frac{\mu}{3} + \frac{t\theta}{12N(1-\theta)}$;

$S^{NW*}_{w,2} = \frac{2-7\theta}{12N} + \frac{2\mu(1-\theta)}{3t}$; $S^{NW*}_{nw,2} = \frac{2-\theta}{12N} + \frac{2\mu(1-\theta)}{3t}$; $S^{NW*}_{e,2} = \frac{2-\theta}{3} - \frac{4N\mu(1-\theta)}{3t}$;

$S^{W*}_{w,2} = \frac{\theta}{N}$; $S^{W*}_{nw,2} = 0$; $S^{W*}_{e,2} = 0$;

$S^{Total*}_{w,2} = \frac{2+5\theta}{12N} + \frac{2\mu(1-\theta)}{3t}$; $S^{Total*}_{nw,2} = \frac{2-\theta}{12N} + \frac{2\mu(1-\theta)}{3t}$; $S^{Total*}_{e,2} = \frac{2-\theta}{3} - \frac{4N\mu(1-\theta)}{3t}$;

$\pi^*_{w,2} = \frac{[t(2+5\theta)+8N\mu(1-\theta)]^2}{288N^2t(1-\theta)}$; $\pi^*_{nw,2} = \frac{[t(2-\theta)+8N\mu(1-\theta)]^2}{288N^2t(1-\theta)}$; $\pi_{e,2} = \frac{[t(2-\theta)-4N\mu(1-\theta)]^2}{36Nt(1-\theta)}$;

*This equilibrium exists when three conditions are met: 2(a):* $S^{NW*}_{e,2} > 0 \Rightarrow \frac{N\mu}{t} < \frac{2-\theta}{4(1-\theta)}$*; 2(b):* $S^{NW*}_{w,2} > 0 \Rightarrow \theta < \frac{2t+8N\mu}{7t+8N\mu}$*; and 2(c):* $p^*_{w,2}S^{Total*}_{w,2} > (\bar{p}_w - c)\frac{\theta}{N}$.

*PROOF. See Appendix A2.*

Without WIC, the market equilibrium aligns with that of Balasubramanian (1998).[10] According to Proposition 2, the presence of WIC contributes to increased formula prices across all retail types. Again, the presence of WIC grants W-retailers a competitive advantage over NW-retailers. W-retailers always charge $\frac{t\theta}{4N(1-\theta)}$ higher than NW-retailers, and each W-retailer gains $\frac{\theta}{2N}$ more total market share and $\frac{t\theta(1+\theta)}{12N^2(1-\theta)} + \frac{\mu}{3N}$ more profits than each NW-retailer. While the gaps widen as $\theta$ increases, they are less pronounced compared to those observed in Scenario 1.

The ratio $\frac{N\mu}{t}$, which reflects the relative attractiveness of offline versus online shopping, determines the competitive advantage between W-retailers and the E-retailer. For ease of reference, we define this ratio as the offline-to-online cost (OFF2ON) ratio. Without WIC, W-retailers obtain a competitive advantage over the E-retailer when the OFF2ON ratio exceeds $\frac{1}{4}$. However, in the presence of WIC, the thresholds for competitive advantage become dependent on $\theta$. W-retailers set higher prices than the E-retailers when $\frac{N\mu}{t} > \frac{2-7\theta}{16(1-\theta)}$,

[10]Notice that in Balasubramanian (1998)'s settings, N=1 represents a single offline retailer, while in our settings, it corresponds to two offline retailers: a W-retailer and an NW-retailer.

and the total market share obtained by all W-retailers ($NS_w^{Total*}$) is more than that obtained by the E-retailer ($S_e^{Total*}$) when $\frac{N\mu}{t} > \frac{2-3\theta}{8(1-\theta)}$. It is evident that W-retailers are more likely to gain a competitive advantage over E-retailers as $\theta$ increases.

**Property 2** *Given that $t > 0$, $N \in \mathbb{Z}^+$, and $\theta \in (0,1)$,*

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

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

From Property 2, we identify several patterns similar to those outlined in Property 1 regarding the distortionary effects. First, $p^*_w$, $p^*_{nw}$, and $p^*_e$ are increasing in $\theta$. Second, the distortionary effects are more pronounced in markets with a higher $\theta$. Third, higher $t$ and lower $N$ amplify the distortionary effects. Lastly, the distortionary effects remain independent of $c$.

In addition, Property 2 introduces new insights following the E-retailer's entry into the non-WIC segment. First, a comparison of the distortionary effects in Properties 1(i) and 2(i) reveals that the E-retailer's entry mitigates the distortionary effects on the equilibrium prices of offline retailers. This is because heightened market competition limits offline retailers' ability to raise prices. Next, Property 2(vi) shows that online shopping costs, $\mu$, do not contribute to the distortionary effects as the E-retailer is not involved in the WIC segment.

For the FEE to hold in Scenario 2, three conditions must be met. The first, as stated in Condition 2(a), requires that the E-retailer secures a positive market share in the non-WIC segment. This occurs only if the OFF2ON ratio is sufficiently low, specifically $\frac{N\mu}{t} < \frac{2-\theta}{4(1-\theta)}$;

otherwise, the E-retailer has no incentive to remain in the non-WIC segment, and the game reverts to Scenario 1. Notably, the entry condition becomes less restrictive as $\theta$ increases. The rationale behind this is that a higher fraction of WIC consumers incentivizes offline retailers to raise their prices (as demonstrated in Scenario 1), thereby reducing consumers' sensitivity to online shopping costs relative to offline shopping costs.

Similar to Conditions 1(a) and 1(b), Conditions 2(b) and 2(c) are set to ensure that W-retailers have sufficient incentives to compete in the non-WIC segment. Unlike the fixed restriction on $\theta$ in Condition 1(a), the restriction on $\theta$ in this Scenario is contingent upon the values of $N$, $t$, and $\mu$. If 2(a) is satisfied but either Condition 2(b) or 2(c) is violated, the optimal strategy for W-retailers is to price at the caps, which causes the market to transition from the FEE to the CEE.

## 4.3 Analysis of Scenario 3 (E-commerce in Both Segments)

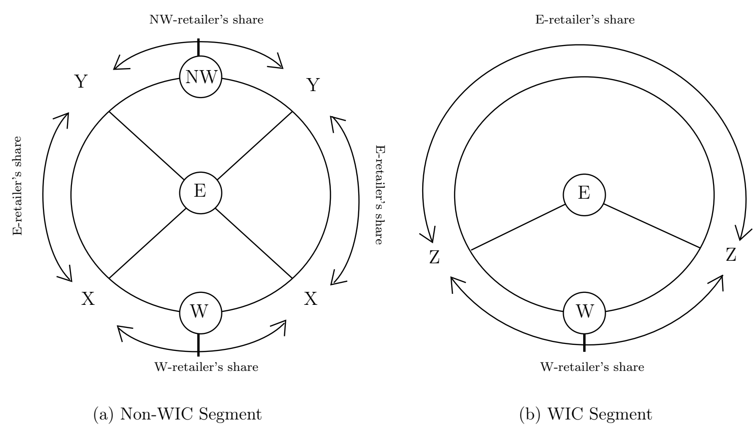



Figure 4: Spatial Setting of the Circular Market in Scenario 3, $N = 1$

Following the E-retailer's entry into the WIC segment, the shopping strategy of non-WIC consumers remains consistent with that in Scenario 2, but WIC consumers now have access to online shopping (see *Figure 4*). We skip the exploration of the non-WIC segment and proceed directly to that of the WIC segment. The choice between online and offline shopping for WIC consumers depends entirely on $\mu$ and $t$. As shown in *Figure 4b*, a WIC consumer located at a distance $z$ from a W-retailer is indifferent between purchasing from the W-retailer and the E-retailer when

$$V - tz = V - \mu\,, \tag{14}$$

which is equivalent to

$$z = \frac{\mu}{t}\,. \tag{15}$$

Thus, the market share of WIC consumers for each W-retailer, $S_w^W$, is equal to $2\theta z$, and the remaining market share of WIC consumers, captured by the E-retailer and denoted by $S_e^W$, is equal to $\theta(1 - 2Nz)$.

Note that once authorized by WIC, the E-retailer must comply with WIC price regulations, just like W-retailers. Here, we assume that WIC imposes different price caps on W-retailers and the E-retailer.

W-retailers, NW-retailers, and the E-retailer, respectively, maximize their profits by

$$\max_{p_w \leq \bar{p}_w} \pi_w = (p_w - c)\left[\frac{2(1-\theta)(p_e - p_w + \mu)}{t} + \frac{2\theta\mu}{t}\right], \tag{16}$$

$$\max_{p_{nw}} \pi_{nw} = (p_{nw} - c)\frac{2(1-\theta)(p_e - p_{nw} + \mu)}{t}\,, \tag{17}$$

$$\max_{p_e \leq \bar{p}_e} \pi_e = (p_e - c)\left[(1-\theta)\left(1 - \frac{2N\,(p_e - p_w + \mu)}{t} - \frac{2N\,(p_e - p_{nw} + \mu)}{t}\right) + \theta\left(1 - \frac{2N\mu}{t}\right)\right]. \tag{18}$$

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

$$p^*_{w,3} = c + \frac{t}{12N} + \frac{\mu}{3} + \frac{(t+5N\mu)\theta}{12N(1-\theta)}; \quad p^*_{nw,3} = c + \frac{t}{12N} + \frac{\mu}{3} + \frac{(t-N\mu)\theta}{12N(1-\theta)}; \quad p^*_{e,3} = c + \frac{t}{6N} - \frac{\mu}{3} + \frac{(t-N\mu)\theta}{6N(1-\theta)};$$

$$S^{NW*}_{w,3} = \frac{1}{6N} + \frac{\mu(4-11\theta)}{6t}; \quad S^{NW*}_{nw,3} = \frac{1}{6N} + \frac{\mu(4-5\theta)}{6t}; \quad S^{NW*}_{e,3} = \frac{2}{3} - \theta - \frac{4N\mu(1-2\theta)}{3t};$$

$$S^{W*}_{w,3} = \frac{2\mu\theta}{t}; \quad S^{W*}_{nw,3} = 0; \quad S^{W*}_{e,3} = \frac{(t-2N\mu)\theta}{t};$$

$$S^{Total*}_{w,3} = \frac{1}{6N} + \frac{\mu(4+\theta)}{6t}; \quad S^{Total*}_{nw,3} = \frac{1}{6N} + \frac{\mu(4-5\theta)}{6t}; \quad S^{Total*}_{e,3} = \frac{2}{3} - \frac{2N\mu(2-\theta)}{3t};$$

$$\pi^*_{w,3} = \frac{[t+N\mu(4+\theta)]^2}{72N^2t(1-\theta)}; \quad \pi^*_{nw,3} = \frac{[t+N\mu(4-5\theta)]^2}{72N^2t(1-\theta)}; \quad \pi^*_{e,3} = \frac{[t-N\mu(2-\theta)]^2}{9Nt(1-\theta)};$$

*This equilibrium exists when five conditions are met: 3(a):* $S^{W*}_{e,3} > 0 \Rightarrow \frac{N\mu}{t} < \frac{1}{2}$*; 3(b):* $S^{NW*}_{e,3} > 0 \Rightarrow 4N\mu(1-2\theta) < t(2-3\theta)$*; 3(c):* $S^{NW*}_{w,3} > 0 \Rightarrow \theta < \frac{t+4N\mu}{11N\mu}$*; 3(d):* $(p^*_{w,3}-c)S^{Total*}_{w,3} > (\bar{p}_w - c)\frac{2\mu\theta}{t}$*; and 3(e):* $(p^*_{e,3} - c)S^{Total*}_{e} > (\bar{p}_e - c)\frac{(t-2N\mu)\theta}{t}$*.*

*PROOF. See Appendix A3.*

Consistent with the previous two propositions, Proposition 3 shows that WIC increases formula prices across all retail types. Moreover, W-retailers continue to maintain a competitive advantage over NW-retailers. W-retailers always charge $\frac{\mu\theta}{2(1-\theta)}$ higher than NW-retailers, and each W-retailer gains $\frac{\mu\theta}{t}$ more total market share and $\frac{t\mu\theta+2N\mu^2\theta(2-\theta)}{6Nt(1-\theta)}$ more profits than each NW-retailer. As $\theta$ grows, the gaps widen but remain less pronounced than in Scenario 2 as a portion of the WIC consumer market share shifts to the E-retailer.

When comparing the market equilibrium between W-retailers and the E-retailer, W-retailers set higher prices than the E-retailer when $\frac{N\mu}{t} > \frac{1}{8-\theta}$, and vice versa. The total market share obtained by all W-retailers is greater than the total market share obtained by the E-retailer when $\frac{N\mu}{t} > \frac{1}{4-\theta}$, and vice versa. Compared to the thresholds of the OFF2ON ratio in Scenario 2, those in Scenario 3 are higher, reflecting stricter conditions for W-retailers to gain a competitive advantage over the E-retailer.

**Property 3** *Given that* $\mu > 0$*,* $N \in \mathbb{Z}^+$*,* $\theta \in (0,1)$*, and* $\frac{N\mu}{t} < \frac{1}{2}$*,* *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.* $\frac{\partial^2 p^*_{w,3}}{\partial^2\theta} = \frac{t+5N\mu}{6N(1-\theta)^3} > 0;\ \frac{\partial^2 p^*_{nw,3}}{\partial^2\theta} = \frac{t-N\mu}{6N(1-\theta)^3} > 0;\frac{\partial^2 p^*_{e,3}}{\partial^2\theta} = \frac{t-N\mu}{3N(1-\theta)^3} > 0$ ,

*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, for all retail types, the distortionary effects are increasing in $\theta$ and $t$ but decreasing in $N$. Beyond these commonalities, Property 3 reveals two key insights. First, a comparison between Property 2(i) and Property 3(i) reveals that the E-retailer's entry into the WIC market segment alleviates the distortionary effects on W-retailers' pricing but exacerbates the distortionary effects on the pricing of NW-retailers and the E-retailer. Next, as indicated by Property 3(vi), $\mu$ begins to shape the distortionary effects. Specifically, a higher $\mu$ amplifies the distortionary effects on $p^*_{w,3}$ while reducing those on $p^*_{nw,3}$ and $p^*_{e,3}$.

In equilibrium, five conditions must be satisfied. Conditions 3(a) and 3(b) ensure that the E-retailer secures a positive market share in each segment. Condition 3(c) ensures that W-retailers secure a positive market in the non-WIC segment. Notably, the fraction of WIC consumers required in Condition 3(c) is less restrictive compared to that in Condition 2(b) of Scenario 2, suggesting that the E-retailer's entry into the WIC segment enhances W-retailers' willingness to compete in the non-WIC segment. Furthermore, Conditions 3(d) and 3(e) establish that engaging in competition yields higher profits for both W-retailers and the E-retailer compared to pricing at the caps.

Among these conditions, Condition 3(a) is the most critical. The OFF2ON ratio must be sufficiently low, specifically $\frac{N\mu}{t} < \frac{1}{2}$, to incentivize WIC consumers to shift to online shopping. If this condition is not met, the E-retailer has no incentive to remain in the WIC segment, and the game reverts to Scenario 2. If Condition 3(a) is satisfied but any of the other four conditions are violated, either W-retailers or the E-retailer will price at the price caps, leading to a market transition from the FEE to the CEE.

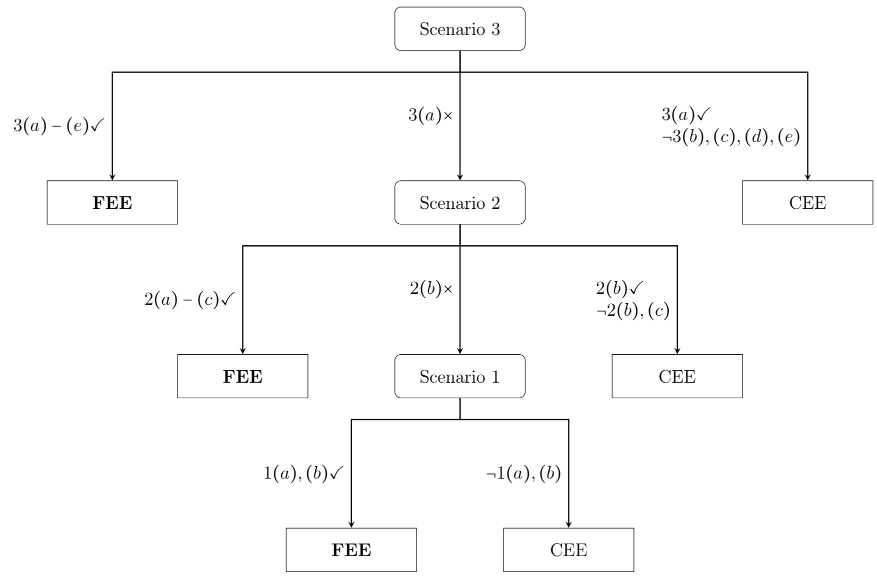



Figure 5: Market Structures after the Introduction of WIC Online Redemption
*Note.* FEE: Full-Engagement Equilibria (elaborated in the main text); CEE: Cap-Exploitation Equilibria (explained in Appendix C). "✓" denotes that the conditions are satisfied, "×" denotes that the conditions are violated, and "¬" denotes that at least one condition is violated.

*Figure 5* summarizes all possible market equilibria and their corresponding conditions when the E-retailer is permitted to enter the WIC segment. As demonstrated, the resulting market equilibrium is determined by the parameters $\theta$, $\mu$, $N$, $t$, $\bar{p}_e$, and $\bar{p}_w$.

# 5 Welfare Comparisons

In this section, we compare consumer welfare and direct WIC formula spending across the three scenarios under the Full-engagement Equilibria (FEE). The derivation process is detailed in Appendices A1–A3. In the following analysis, we assume that price caps are set to ensure that WIC-authorized retailers (W-retailers in Scenarios 1–3 and the E-retailer in Scenario 3) will not deviate from FEE due to excessively high price caps.

## 5.1 Analytical Comparisons

Non-WIC consumer welfare, denoted by $CW^{NW}$, is calculated as the sum of the differences between each non-WIC consumer's valuation of infant formula and their total expenses, which include the formula price and associated shopping costs. The outcomes are as follows:

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

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

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

WIC consumer welfare, denoted by $CW^W$, is computed similarly, except that WIC consumers do not bear the formula price:

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

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

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

To estimate direct WIC formula spending, denoted by $WS$, we focus solely on the retail prices paid by WIC for all WIC consumers. We do not consider manufacturer rebates; we assume that they remain constant across all scenarios. The outcomes are as follows:

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

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

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

**Property 4** *Given that all FEE conditions across the three scenarios are satisfied, the wel-*

*fare outcomes exhibit the following comparative patterns:*

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

$$ii.\ CW_3^{W*} > CW_2^{W*} = CW_1^{W*}\ \ ,$$

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

We begin by conducting analytical comparisons of the welfare outcomes, assuming that the FEE conditions hold simultaneously across all scenarios. Property 4 shows that, compared to Scenario 1, Scenario 2 enhances non-WIC consumer welfare and reduces direct WIC formula spending. However, moving from Scenario 2 to Scenario 3 introduces uncertainty regarding its effects on non-WIC consumer welfare and direct WIC formula spending, contingent upon the OFF2ON ratio and $\theta$. Meanwhile, compared to Scenarios 1 and 2, Scenario 3 enhances WIC consumer surplus by increasing accessibility and convenience for those located farther from W-retailers.

### 5.2 Numerical Comparisons

As an example, we fix the fraction of WIC consumers in the market at 40% ($\theta = 0.4$) to demonstrate the impact of the OFF2ON ratio on welfare outcomes.[11] This value is chosen as WIC infant shares centered around this level in most states in 2020 (see *Figure A2* in Appendix A). We continue to set $N = 1$ and $t = 1$, while varying $\mu$ to reflect changes in the OFF2ON ratio. The parameters $V = 5$ and $c = 2$ are assigned for illustration but do not

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

influence the comparative insights. *Figures 6(a–c)* depict how the OFF2ON ratio, adjusted by $\mu$, influences welfare outcomes in markets with 40% WIC consumers.

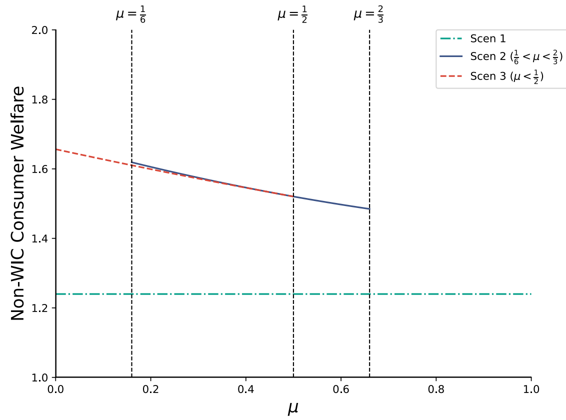
As Scenario 1 does not involve e-commerce, its welfare outcomes remain constant with respect to $\mu$. In Scenarios 2 and 3, $\mu$ cannot take all possible values due to the required conditions under the FEE, as partially illustrated in *Figures 6(a–c)*. First, when $\mu \in [0, \frac{1}{6})$, the FEE fails to exist in Scenario 2 due to low OFF2ON ratios (Condition 2(b) unsatisfied). Second, when $\mu \in (\frac{1}{2}, \frac{2}{3})$, the OFF2ON ratio is too high for the E-retailer to enter the WIC segment in Scenario 3 (Condition 3(a) unsatisfied), leading Scenario 3 to revert to Scenario 2. Third, when $\mu \geq \frac{2}{3}$, the OFF2ON ratio is too high for the E-retailer to enter the non-WIC segment in Scenario 2 (condition 2(b) unsatisfied), causing Scenario 2 to revert to Scenario 1. Therefore, only when $\mu \in [\frac{1}{6}, \frac{1}{2}]$ do the FEE welfare outcomes simultaneously exist across all three scenarios.

From *Figure 6(a)*, we observe that as the OFF2ON ratio increases, non-WIC consumer welfare in Scenarios 2 and 3 gradually declines, approaching the level in Scenario 1. This trend is intuitive, as a higher OFF2ON ratio weakens the competitive pressure and convenience provided by the online channel. Moreover, Scenario 3 delivers lower non-WIC consumer welfare than Scenario 2 at low OFF2ON ratios but achieves higher non-WIC consumer welfare when $\mu > \frac{21}{46}$, aligning with Property 4(i). This suggests that the E-retailer's entry into the WIC segment may disadvantage non-WIC consumers in markets where the online channel is significantly more attractive than the offline channel.

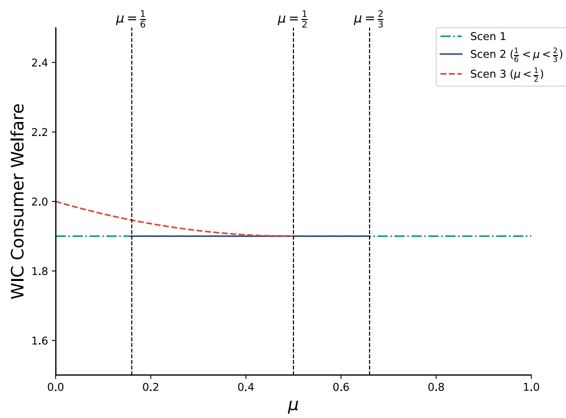
*Figure 6(b)* shows the relationship between the OFF2ON ratio and WIC consumer welfare. Since WIC consumers do not bear the formula price, the E-retailer's entry into the WIC segment significantly enhances their welfare, particularly in markets with low OFF2ON ratios. However, the gains from online access gradually diminish as the OFF2ON ratio increases. This trend echoes the concern that high online shopping costs, such as costly delivery fees, may limit the benefits of WIC modernization initiatives.

*Figure 6(c)* demonstrates how the OFF2ON ratio impacts direct WIC formula spending.

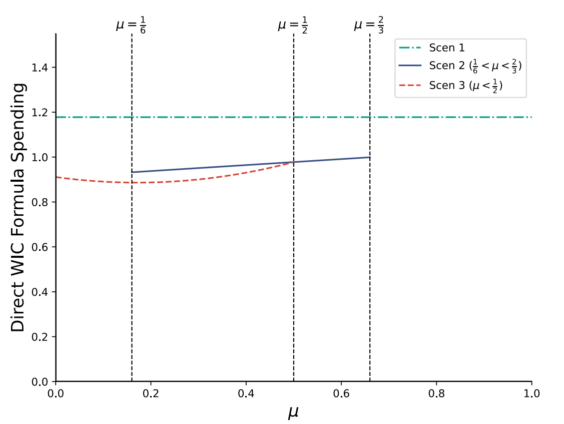
Figure 6: Welfare Comparisons




6(a). Non-WIC Consumer Welfare, $\theta = 0.4$




6(b). WIC Consumer Welfare




6(c). Direct WIC Formula Spending

*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, $\mu$ 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; (3) when $\mu \geq \frac{2}{3}$, Scenario 2 reverts to Scenario 1.

In line with Property 4(iii), the e-commerce involvement in Scenarios 2 and 3 heightens retail competition, leading to significantly lower WIC spending compared to Scenario 1. In Scenario 2, WIC spending is increasing in the OFF2ON ratio, as the growing competitive advantage of W-retailers allows them to raise prices. In Scenario 3, WIC spending exhibits a U-shaped trend. When the OFF2ON ratio approaches 0, the E-retailer holds a significant competitive advantage, enabling it to set excessively high prices. At high OFF2ON ratios, W-retailers adopt a similar pricing strategy. As a result, WIC spending reaches lower levels at moderate OFF2ON ratios, where competition between W-retailers and the E-retailer is relatively intense. Given that $\theta$ is set at 0.4, WIC spending in Scenario 3 is consistently lower than in Scenario 2. Referring back to the threshold in Property 4(iii), we conclude that WIC spending in Scenario 3 is consistently lower than in the other two scenarios when $\theta \geq 0.4$.

### 5.3 Return on WIC Formula Spending

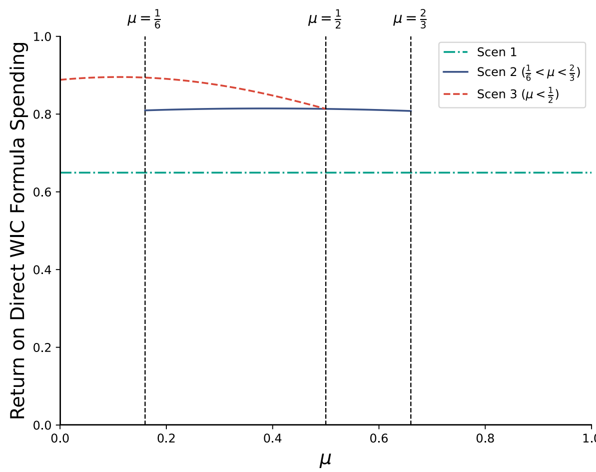
Finally, we assess how direct WIC formula spending contributes to overall consumer welfare improvements. For each scenario, we calculate the return on WIC spending (RWS) using the following formula:

$$\text{RWS} = \frac{CW^{NW*} + CW^{W*} - CW^{NW*}(\theta = 0)}{WS^{*}} \tag{19}$$

The RWS ratio evaluates WIC spending efficiency by capturing overall consumer welfare returns per dollar WIC spent on infant formula. The corresponding outcomes, presented in Appendix A, should be interpreted as lower-bound estimates, as manufacturer rebates are not incorporated.

Due to the complexity of the outcomes, analytical comparisons are challenging. Instead, we apply the same parameter values from the previous analysis to assess the RWS ratios. *Figure 7* depicts the relationship between the OFF2ON ratios and the RWS ratios across the three scenarios, offering clear insights. As the market shifts from Scenario 1 to Scenario 2,

Figure 7: Return on Direct WIC Formula Spending Excluding Rebates, $\theta = 0.4$




*Note.* The figure is 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, $\mu$ 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; (3) when $\mu \geq \frac{2}{3}$, Scenario 2 reverts to Scenario 1.

the E-retailer's entry into the non-WIC segment significantly improves the return on WIC spending. Recall that the transition from Scenario 2 to Scenario 3 may disadvantage non-WIC consumers in markets with low OFF2ON ratios (as observed in *Figure 6(a)*). However, the concurrent increase in WIC consumer welfare and the reduction in direct WIC formula spending ultimately improve the efficiency of WIC spending.

# 6 Conclusions

As concerns mount over WIC's potential impact on infant formula retail prices, this study investigates how WIC's distribution system shapes retail competition. By incorporating WIC's role into a spatial competition model, our theoretical framework offers structured insights into pricing and welfare outcomes while circumventing the need for market- and firm-level data. Our findings suggest that WIC-authorized retailers benefit from a competitive edge that allows them to charge higher prices than non-authorized retailers. Due to strategic complementarity, non-authorized retailers also respond with slight price increases. Moreover, price distortions induced by WIC may become more pronounced in markets characterized by high offline shopping costs, lower offline retail density, and a greater fraction of WIC participants.

Another key contribution of this study is the analysis of three distinct scenarios, each varying in the level of e-commerce involvement. In the presence of WIC, the participation of e-commerce is not solely determined by online shopping costs relative to offline shopping costs but also depends on the fraction of WIC consumers in the market. When an E-retailer chooses to enter, despite being limited to serving non-WIC consumers, 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. However, our subsequent estimation suggests that this initiative ultimately enhances the efficiency of WIC spending by improving overall consumer welfare. 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.

While our model provides valuable insights, it has certain limitations that open avenues for future research. First, consistent with the existing literature, we assume that the fraction of WIC consumers remains exogenous to short-run price fluctuations. However, since WIC is funded through a block grant, rising infant formula prices could potentially limit program enrollment. Expanding the framework to account for this endogenous response would offer deeper insights into the long-term interaction between WIC fund allocation and retail competition. Second, our model does not explicitly incorporate vertical interactions between manufacturers and retailers. Although our robustness checks indicate that variations in procurement costs across retail types do not qualitatively alter our conclusions, a vertical analysis could provide a more comprehensive understanding of WIC's broader impact on the U.S. infant formula market. Lastly, our model classifies retailers by WIC-authorization status and distribution channel and consumers by their participation in WIC but does not capture further heterogeneity. A deeper heterogeneous analysis would be a promising direction for future research.

**Declaration of Interest Statement**

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

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# Appendix A: Full-Engagement Equilibria (FEE)

## A1. Scenario 1

**Proof of Proposition 1 (FEE)** In Scenario 1, W-retailers and NW-retailers maximize their profits by:

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

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

Differentiating the profit functions above w.r.t. $p_w$ and $p_{nw}$, respectively, and setting each differential to zero yields the equilibrium prices, $p_w^*$ and $p_{nw}^*$.

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

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

Given the equilibrium prices, we can easily solve for the equilibrium market shares and profits for W-retailers and NW-retailers. The outcomes are presented in Proposition 1 in the main text.

Recall that $x$ represents the distance from a W-retailer to its farthest non-WIC consumers, and $y$ the distance from an NW-retailer to its farthest non-WIC consumers. Given $p_{w,1}^*$ and $p_{nw,1}^*$, the corresponding $x_1^*$ and $y_1^*$ are derived as follows:

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

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

$z$ represents 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 fixed at the following value:

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

The equations and corresponding outcomes for non-WIC and WIC consumer welfare, as well as direct WIC formula spending, are presented below.

$$CW_1^{NW*} = 2N(1-\theta)\left[\int_0^{x_1^*}\left(V - p_{w,1}^* - tl\right)dl + \int_0^{y_1^*}\left(V - p_{nw,1}^* - tl\right)dl\right]$$
$$= (V-c)(1-\theta) + \frac{t(45 - 54\theta + 5\theta^2)}{72N(1-\theta)}$$

$$CW_1^{W*} = 2N\theta\left[\int_0^{z_1^*}(V - tl)\,dl\right]$$
$$= (V - \frac{t}{4N})\theta$$

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

**Required Conditions**

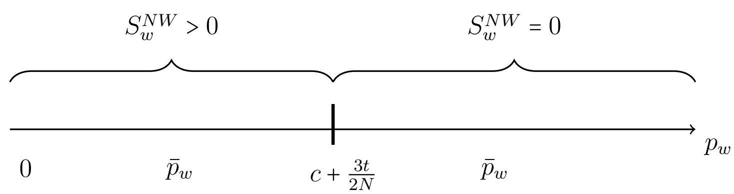



Figure A1.The Set of $\bar{p}_w$

The required conditions for the equilibrium above to be sustained are as follows:

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

1(b). For W-retailers, engaging in market competition must be more profitable than pricing at the price caps. The explicit mathematical condition is derived as follows.

*Figure A1* illustrates the possible positions of $\bar{p}_w$, segmented into two regions by the cutoff point, $c + \frac{3t}{2N}$. This cutoff is derived from $p_{w,1}^*(\theta = \frac{2}{3})$. First, for $\bar{p}_w < c + \frac{3t}{2N}$, W-retailers can attract non-WIC consumers by pricing at $\bar{p}_w$. However, this strategy is strictly dominated by competitive pricing and is thus irrelevant for sustaining the Full-Engagement Equilibrium (FEE).

Next, when $\bar{p}_w \geq c + \frac{3t}{2N}$, setting the price at $\bar{p}_w$ prevents W-retailers from attracting any non-WIC consumers. However, if price caps are extremely high, W-retailers may find it more profitable to price at $\bar{p}_w$ rather than adopting competitive pricing. Therefore, to ensure the existence of the FEE, we impose the following constraint:

$$(p_{w,1}^* - c)S_{w,1}^{Total*} > (\bar{p}_w - c)S_{w,1}^{W*} \Rightarrow (p_{w,1}^* - c)S_{w,1}^{Total*} > (\bar{p}_w - c)\frac{\theta}{N}$$

In Scenarios 2 and 3, we follow the same logic to impose constraints on the price caps.

**Equilibrium Analysis**

W-retailers vs. NW-retailers:

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

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

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

## A2. Scenario 2

**Proof of Proposition 2 (FEE)**

In Scenario 2, the E-retailer enters the market and serves non-WIC consumers only. W-retailers, NW-retailers, and the E-retailer maximize their profits by:

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

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

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

Differentiating the profit functions above w.r.t. $p_w$, $p_{nw}$, and $p_e$, respectively, and setting each differential to zero yields $p^*_w$, $p^*_{nw}$, 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 presented in Proposition 2 in the main text. The corresponding $x^*_2$, $y^*_2$, and $z^*_2$ are derived as follows:

$$x^*_2 = \frac{2 - 7\theta}{24N(1-\theta)} + \frac{\mu}{3t}$$

$$y_2^* = \frac{2-\theta}{24N(1-\theta)} + \frac{\mu}{3t}$$

$$z_2^* = \frac{1}{2N}$$

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

$$\begin{aligned} CW_2^{NW*} &= 2N(1-\theta)\left[\int_0^{x_2^*}\left(V - p_{w,2}^* - tl\right)dl + \int_0^{y_2^*}\left(V - p_{nw,2}^* - tl\right)dl\right] + S_{e,2}^{NW*}\left(V - p_{e,2}^* - \mu\right) \\ &= (V-c)(1-\theta) - \frac{t(44-56\theta-\theta^2)}{288N(1-\theta)} - \frac{\mu(5-4\theta)}{9} + \frac{2N\mu^2(1-\theta)}{9t} \end{aligned}$$

$$\begin{aligned} CW_2^{W*} &= 2N\theta\left[\int_0^{z_2^*}(V-tl)\,dl\right] \\ &= (V - \frac{t}{4N})\theta \end{aligned}$$

$$\begin{aligned} WS_2^* &= \theta p_{w,2}^* \\ &= \left[c + \frac{t}{12N} + \frac{\mu}{3} + \frac{7t\theta}{24N(1-\theta)}\right]\theta \end{aligned}$$

**Required Conditions**

Three conditions need to be satisfied in equilibrium.

2(a). The E-retailer enters the market and obtains a positive market share of non-WIC consumers, i.e., $S_e^{NW*} > 0$. This condition can be restated as $\mu < \frac{t(2-\theta)}{4N(1-\theta)}$. If this condition is not met, the game reverts to Scenario 1.

Take the first derivative of $\frac{t(2-\theta)}{4N(1-\theta)}$ with respect to $\theta$, we obtain $\frac{t}{4N(1-\theta)^2} > 0$, indicating that an increase in $\theta$ relaxes the entry barrier for the E-retailer.

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

2(c). For W-retailers, engaging in market competition must be more profitable than pricing at the price caps. The logic is consistent with that of Scenario 1, so we have $(p_{w,2}^* - c)S_{w,2}^{Total*} > (\bar{p}_w - c)\frac{\theta}{N}$.

**Equilibrium Analysis**

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:

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

$p^*_{w,2} > p^*_{e,2}$ when $\frac{N\mu}{t} > \frac{2-7\theta}{16(1-\theta)}$.

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

$NS^{Total*}_{w,2} > S^{Total*}_{e,2}$ when $\frac{N\mu}{t} > \frac{2-3\theta}{8(1-\theta)}$.

## A3. Scenario 3

**Proof of Proposition 3 (FEE)**

In Scenario 3, three types of retailers maximize their profits by:

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

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

$$\max_{p_e \le \bar{p_e}} \pi_e = (p_e - c)\left[(1-\theta)\left(1 - \frac{2N(p_e - p_w + \mu)}{t} - \frac{2N(p_e - p_{nw} + \mu)}{t}\right) + \theta\left(1 - \frac{2N\mu}{t}\right)\right] \tag{A8}$$

Differentiating the profit functions above w.r.t. $p_w$, $p_{nw}$, and $p_e$, respectively, and setting each differential to zero yields $p^*_w$, $p^*_{nw}$, and $p^*_e$.

$$p^*_{w,3} = c + \frac{t}{12N} + \frac{\mu}{3} + \frac{(t+5N\mu)\theta}{12N(1-\theta)}$$

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

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

The corresponding equilibrium market shares and profits are presented in Proposition 3 in the main text.

The corresponding $x^*_3$, $y^*_3$, and $z^*_3$ are derived as follows:

$$x_3^* = \frac{t + 4N\mu - 11N\mu\theta}{12Nt(1-\theta)}$$

$$y_3^* = \frac{t + 4N\mu - 5N\mu\theta}{12Nt(1-\theta)}$$

$$z_3^* = \frac{\mu}{t}$$

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

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

$$\begin{aligned} CW_3^{W*} &= 2N\theta\int_0^{z_3^*}(V - tl)\,dl + S_{e_3}^{W*}(V-\mu) \\ &= (V - \mu + \frac{N\mu^2}{t})\theta \end{aligned}$$

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

**Required Conditions**

Four conditions need to be satisfied in equilibrium.

3(a). The E-retailer must obtain a positive market share in the WIC segment; otherwise, the game reverts to 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., $S_{e,3}^{NW*} > 0$, which is equivalent to $4N\mu(1-2\theta) < t(2-3\theta)$.

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

3(d). For W-retailers, engaging in market competition must be more profitable than pricing at the price caps, i.e., $(p_{w,3}^* - c)S_{w,3}^{Total*} > (\bar{p}_w - c)\frac{2\mu\theta}{t}$.

3(e). For the E-retailer, engaging in market competition must be more profitable than pricing at the price caps, i.e., $(p_{e,3}^* - c)S_e^{Total*} > (\bar{p}_e - c)\frac{(t-2N\mu)\theta}{t}$.

**Equilibrium Analysis**

W-retailers vs. NW-retailers

$$p^*_{w,3} - p^*_{nw,3} = \frac{\mu\theta}{2(1-\theta)} > 0$$

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

$$\pi^*_{w,3} - \pi^*_{nw,3} = \frac{\mu t\theta + 2N\mu^2\theta(2-\theta)}{6Nt(1-\theta)}$$

W-retailers vs. E-retailers:

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

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

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

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

## A4. Welfare Comparison

**Analytical Comparisons**

Given that all the required conditions in the three scenarios are simultaneously satisfied, we obtain the following patterns:

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

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

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

The results were computed using Wolfram Mathematica 14.0.

**WIC Infant Share**

Figure A2. Distribution of WIC Infant Share Across States in 2020

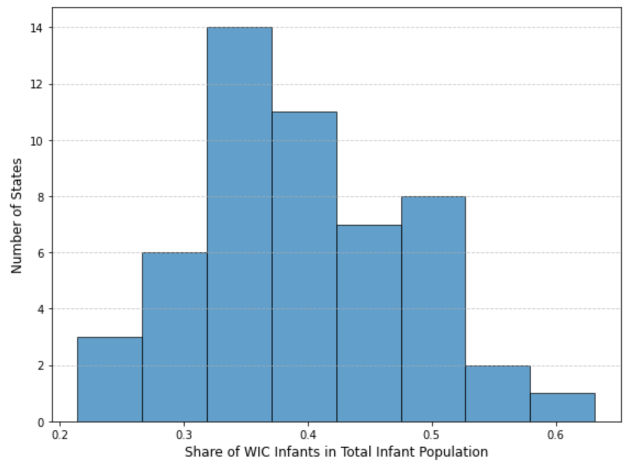



*Figure A2* presents the distribution of WIC infant shares across states in 2020. The information is sourced from the WIC Infant data released by the U.S. Department of Agriculture (2025) and the birth data released by the U.S. Centers for Disease Control and Prevention (Osterman et al., 2022). Among all states, Utah has the lowest WIC infant share at 24.14%, while Mississippi has the highest at 63.13%. The majority of states have WIC infant shares concentrated around 40%. Therefore, we set $\theta = 0.4$ in the main text in Section 5 for illustration.

**Return on Direct WIC Formula Spending**

For each scenario, we compute the Return on Direct WIC Formula Spending (RWS) using the following equation.

$$\text{RWS} = \frac{CW^{NW*} + CW^{W*} - CW^{NW*}(\theta = 0)}{WS^{*}} \tag{A9}$$

The outcomes are as follows:

$$\text{RWS}_1 = \frac{72cN(-1+\theta)\theta + t(90 - \theta(81 + 13\theta))}{12\theta(6cN(-1+\theta) - t(3+\theta))}$$

$$\text{RWS}_2 = \frac{t^2(-88 + \theta(28 + 73\theta)) + 64N^2(-1+\theta)\theta\mu^2 - 32Nt(-1+\theta)\theta(9c + 4\mu)}{12t\theta(-24cN(-1+\theta) + t(2+5\theta) - 8N(-1+\theta)\mu)}$$

$$\text{RWS}_3 = \frac{t^2 - 72cNt(-1+\theta) + 4Nt(-5+3\theta)\mu + N^2(24+\theta)\mu^2}{12\left(t^2 - 6cNt(-1+\theta) + Nt(-3+\theta)\mu - N^2(-8+\theta)\mu^2\right)}$$

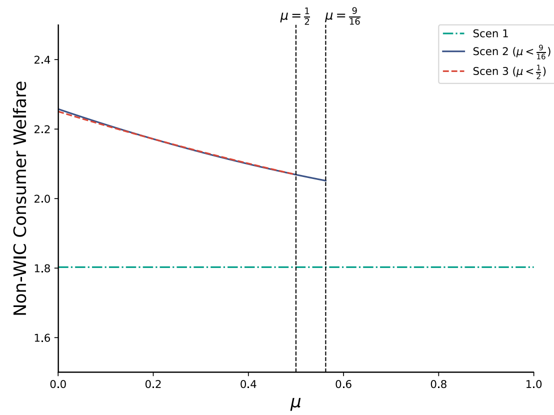
Given the complexity of the outcomes, we employ numerical comparisons. Section 5.3 provides the corresponding analysis.

**Numerical Comparisons,** $\theta = 0.2$ **and** $0.55$

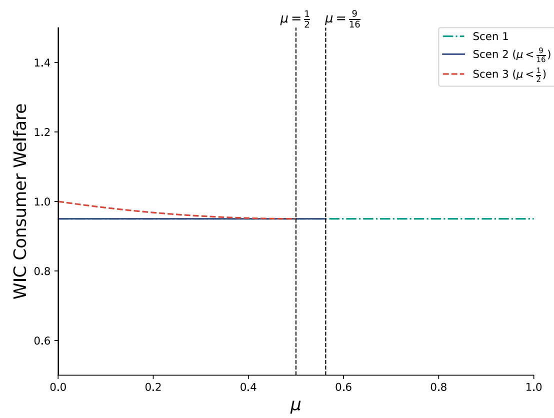
As a robustness check, we compare welfare outcomes in markets with 20% and 55% WIC consumers across the three scenarios.

We begin by analyzing markets with 20% WIC consumers. *Figures A3(a–c)* illustrate how the OFF2ON ratio influences welfare outcomes. Similarly, due to the FEE conditions in Scenarios 2 and 3, $\mu$ cannot take all possible values. The FEE exist in all three scenarios only when $\mu \in [0, \frac{1}{2})$. *Figures A3(a-c)* share many similarities with *Figures 6(a-c)* presented in the main text. The key distinction appears in *Figure A3(c)*, where direct WIC formula spending in Scenario 3 exceeds that in Scenario 2 when OFF2ON ratios are low, e.g., $\mu < \frac{5}{78}$, consistent with Property 4(iii). This finding suggests that the E-retailer's entry into the WIC segment may increase direct WIC formula spending when $\theta < 0.4$ and OFF2ON ratios are relatively low. However, as shown in *Figure A4*, the return on WIC spending is consistently higher in Scenario 3 compared to Scenarios 2 and 1, in line with the findings from *Figure 7* in the main text.

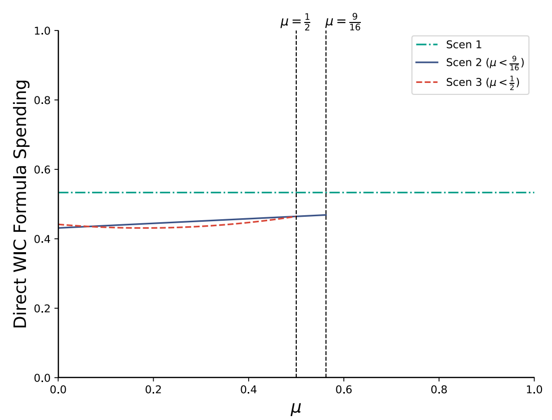
Figure A3. Welfare Comparisons, $\theta = 0.2$




A3(a). Non-WIC Consumer Welfare



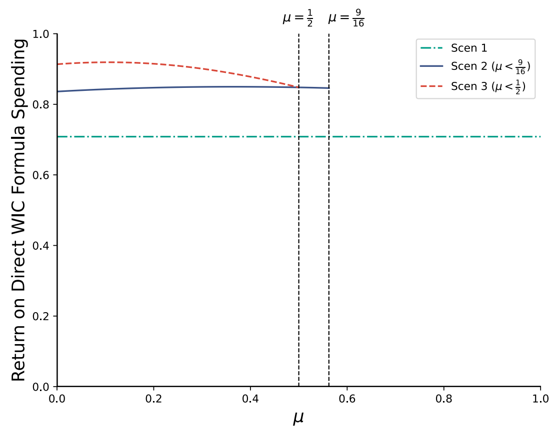

A3(b). WIC Consumer Welfare




A3(c). Direct WIC Formula Spending

*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, $\mu$ 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.

Figure A4. Return on Direct WIC Formula Spending Excluding Rebates, $\theta$ = 0.2

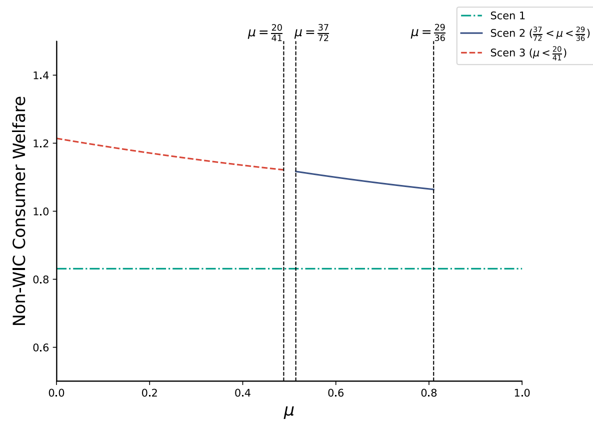



*Note.* The figures are generated using the parameter values $\theta = 0.2$, $V = 5$, $c = 2$, $N = 1$, and $t = 1$. Due to the FEE conditions in Scenarios 2 and 3, $\mu$ cannot take all possible values: (1) when $\mu \in (\frac{1}{2}, \frac{9}{16})$, Scenario 3 reverts to Scenario 2; (2) when $\mu \geq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

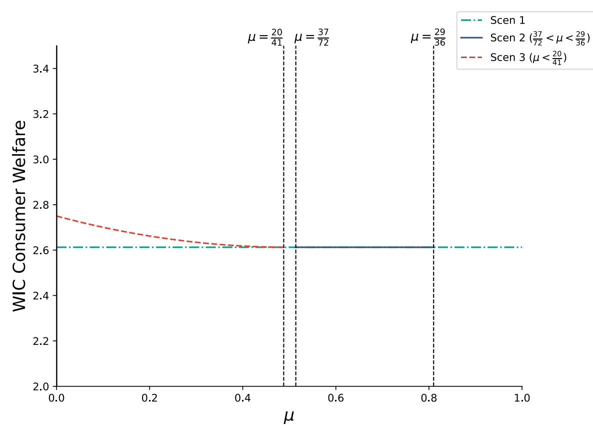
Next, we compare welfare outcomes in markets with 55% WIC consumers. Due to the FEE conditions in Scenarios 2 and 3, the welfare outcomes in these two scenarios never coexist, as illustrated in *Figures A5(a–c)* and *Figure A6*, making direct comparisons infeasible. When comparing Scenario 2 to Scenario 1 and Scenario 3 to Scenario 1, we find that e-commerce involvement could enhance consumer welfare and lower WIC spending, thereby improving the efficiency of WIC spending.

In *Figures A5* and *Figure A6*, when $\mu \in [0, \frac{20}{41}]$, Scenario 2 reaches the CEE, where W-retailers strategically set prices at the caps. Although the CEE welfare outcomes are contingent on price caps and cannot be explicitly derived, we can infer that, within this range, Scenario 3 yields greater non-WIC consumer welfare, lower WIC spending, and a higher return rate than Scenario 2.

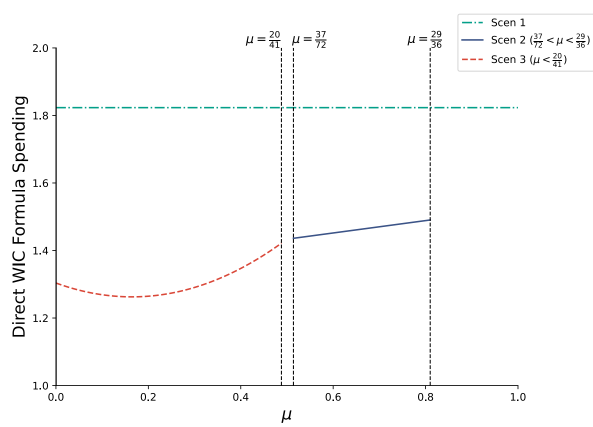
Figure A5. Welfare Comparisons, $\theta = 0.55$




A5(a). Non-WIC Consumer Welfare



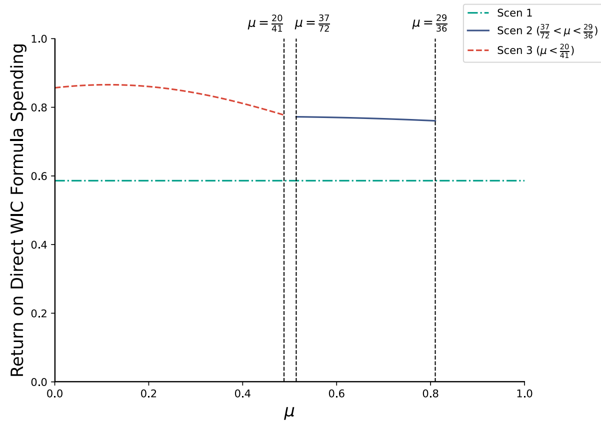

A5(b). WIC Consumer Welfare




A5(c). Direct WIC Formula Spending

*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, $\mu$ 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.

Figure A6. Return on Government Spending Excluding Rebates, $\theta = 0.55$




*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, $\mu$ 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.

# Appendix B: Cap-Exploitation Equilibria (CEE)

Under specific cases, W-authorized retailers (W-retailers in Scenarios 1-3 and the E-retailer in Scenario 3) may find it more profitable to price at the WIC price caps rather than engaging in market competition. We define the resulting market equilibria as Cap-Exploitation Equilibria (CEE) in Section 3. In this appendix, we adopt the framework of Scenario 1 as an illustrative example to delineate the conditions that trigger CEE and the corresponding equilibrium outcomes.

Recall that two conditions must be satisfied for the Full-Engagement Equilibrium (FEE) to be sustained in Scenario 1. A violation of either condition will result in a market transition from FEE to CEE.[12] 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 incentives to set competitive prices to attract non-WIC consumers. As a result, W-retailers will align their prices with the caps to maximize their profits. The second condition necessitates restrictions on price caps, specifically $(p^*_{w,1} - c)S^{Total*}_{w,1} > (\bar{p}_w - c)\frac{\theta}{N}$, as excessively high caps could also disincentivize W-retailers from competing in the non-WIC segment even when $\theta < \frac{3}{5}$.

Under our model setup and assumptions, when W-retailers strategically set prices at the WIC price caps, they forgo the market share of non-WIC consumers, which is subsequently captured by NW-retailers. In the case of $N = 1$, a single NW-retailer monopolizes the non-WIC market segment and adjusts its pricing strategy in response to $\bar{p}_w$. When $N \geq 2$, multiple NW-retailers compete with their nearest NW-retailers. The corresponding equilibrium prices, market shares, and profits (CEE) are given by:

$$\tilde{p}^*_{w,1} = \bar{p}_w \qquad \tilde{p}^*_{nw,1} = c + \frac{t}{N};$$

$$\tilde{S}^{NW*}_{w,1} = 0; \qquad \tilde{S}^{NW*}_{nw,1} = \frac{1-\theta}{N};$$

$$\tilde{S}^{W*}_{w,1} = \frac{\theta}{N}; \qquad \tilde{S}^{W*}_{nw,1} = 0;$$

$$\tilde{S}^{Total*}_{w,1} = \frac{\theta}{N}; \qquad \tilde{S}^{Total*}_{nw,1} = \frac{1-\theta}{N};$$

$$\tilde{\pi}^*_{w,1} = \frac{(\bar{p}_w - c)\theta}{N}; \qquad \tilde{\pi}^*_{nw,1} = \frac{(cN+t)(1-\theta)}{N^2}$$

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

$$\tilde{x}^*_1 = 0$$

[12] For a detailed discussion, see Appendix A1.

$$\tilde{y}_1^* = \frac{1}{2N}$$

$$\tilde{z}_1^* = \frac{1}{2N}$$

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

$$\tilde{CW}_1^{NW*} = (V - C)(1 - \theta) - \frac{5t(1 - \theta)}{4N}$$

$$\tilde{CW}_1^{W*} = (V - \frac{t}{4N})\theta$$

$$\tilde{WS}_1^* = \bar{p}_w \theta$$

**Equilibrium Analysis**

In markets with $\theta < \frac{3}{5}$,

$$\tilde{CW}_1^{NW*} - CW_1^{NW*} = -\frac{t(3 - 5\theta)(15 - 17\theta)}{72N(1 - \theta)} < 0$$

$$\tilde{WS}_1^* - WS_1^* = (\bar{p}_w - p_{w,1}^*)\theta > 0$$

The comparison of the obtained welfare outcomes with the FEE welfare outcomes in Scenario 1 reveals that excessively high price caps could reduce non-WIC consumer welfare while increasing WIC spending.

In markets where $\theta \geq \frac{3}{5}$, the FEE does not exist, so a comparison is not applicable.

Similar to Scenario 1, Scenarios 2 and 3 also undergo a transition from FEE to CEE when the fractions of WIC consumers and WIC price caps reach certain thresholds. While these thresholds differ across scenarios, the derivation process and corresponding outcomes remain analogous to those described above. Since this study does not focus on CEE, their derivation and analysis in Scenarios 2 and 3 are not further pursued.