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

Ming Ge[*] Di Fang[*†]

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Abstract

The Special Supplemental Nutrition Program for Women, Infants, and Children (WIC) plays an important role in the U.S. infant formula market, as roughly half of the infant formula sold is procured by WIC and distributed to its participants via WIC-authorized stores. Although prior research has primarily explored the impact of WIC on manufacturers' strategies, limited attention has been devoted to understanding how WIC reshapes retailer pricing. This study investigates the implications of WIC's distribution mechanism on retail competition. Our model suggests that WIC encourages all types of retailers to increase prices, with WIC-authorized stores gaining a disproportionate advantage due to their exclusive access to WIC consumers. Additionally, higher offline shopping costs, lower offline retail density, and a greater proportion of WIC consumers in the market may worsen the price distortions. The introduction of e-commerce, however, intensifies competition, mitigates price distortions, and reduces government spending. Furthermore, integrating e-commerce into WIC's distribution system demonstrates the potential to further decrease government spending while achieving greater efficiency in enhancing overall consumer welfare.

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

JEL: D43, I38, L11, L13

[*]Food and Resource Economics Department, University of Florida, Gainesville, FL, USA.
[†]Corresponding author. E-mail: difang@ufl.edu

1 Introduction

The Special Supplemental Nutrition Program for Women, Infants, and Children (WIC) provides supplemental foods, nutrition education, and health services to pregnant and postpartum women, infants, and children under five who are at nutritional risk. The U.S. infant formula market is divided into WIC and non-WIC segments: WIC consumers receive reimbursement from the program, whereas non-WIC consumers pay the full price. A key benefit of the program is free infant formula. WIC holds a significant share, as approximately half of the infant formula sold in the United States is from WIC-authorized stores.

During the procurement stage, each WIC state agency solicits competitive bids to contract with a single manufacturer that provides products exclusively for WIC participants in the state, known as the WIC rebate program.[1] During the distribution stage, WIC state agencies collaborate with chosen local stores, referred to as WIC-authorized stores, to distribute WIC infant formula to participants. The stores then request full retail price reimbursements from the state WIC agency.[2] The winning manufacturer collects wholesale payments from retailers but rebates WIC for the quantity obtained by WIC consumers. WIC-authorized stores profit from the price margin between wholesale and retail prices on both WIC and non-WIC sales. The WIC agency's spending on infant formula represents the difference between the retail prices of the redeemed formula and the rebates provided by the manufacturer.

Empirical evidence suggests that WIC substantially contributes to retail price increases for infant formula(Oliveira, 2004). While prior research has primarily investigated the impact of WIC's procurement mechanism on manufacturers' strategies, little attention has been paid to the retail level. We address this gap by exploring how WIC impacts retailers' pricing and market shares, consumer surplus for both WIC and non-WIC consumers, and direct

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

[2]The amount of infant formula allocated to each WIC household is determined by the infant's age and primary feeding method and is designed to sufficiently meet the infant's nutritional needs.

government spending. Since our focus is retail competition, we do not explicitly model the procurement stage.[3] Rather, we assume the WIC-contract formula is predetermined and that wholesale prices are exogenous to retail competition in the model (Davis, 2012).

We employ a circular retail market framework following Salop (1979) and Balasubramanian (1998). The Salop model has been adopted to study retail competition under different 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 Salop model, brick-and-mortar stores are evenly distributed along the circumference of a circle, while e-commerce, if present, is situated at the center. Consumers evenly distributed around 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 setting, we further incorporate WIC's distribution mechanism by classifying stores into WIC-authorized and non-authorized stores, and consumers into WIC and non-WIC consumers. In our model, all incumbent retailers engage in price competition for a single product, the WIC-contract 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) and Huang and Perloff (2014)).[4]

Furthermore, we construct three scenarios to account for these variations: (1) markets without e-commerce involvement, typically observed in regions where online shopping costs far exceed offline shopping costs or where other factors constrain the entry of online retailers;[5] (2) markets where online shopping is limited to non-WIC consumers, reflecting the current market structure; (3) markets where online shopping is available to both WIC and non-WIC consumers. While Scenario 3 is hypothetical, it is particularly relevant to the recent WIC

[3]For theoretical insights into manufacturers' contract bidding and wholesale pricing strategies, refer to Betson (2009) and Davis (2012).

[4]Although our analysis focuses on the price competition of WIC-contract infant formula, the findings also shed light on the broader pricing strategies that retailers adopt for their infant formula products. This is because WIC exogenously shifts the store selection preferences of a subset of consumers.

[5]The factors influencing online retailer entry include insufficient internet infrastructure, higher operating costs, limited market size, or significant entry barriers.

Modernization Act, which aims to introduce online redemption partners. Comparing welfare outcomes between the current situation and Scenario 3 offers insight into the feasibility of incorporating online retailers into WIC's distribution system.

Results suggest that price increases are most pronounced among WIC-authorized stores, with distortions being more noticeable in markets with higher offline shopping costs, lower retail density, and a larger share of WIC participants. E-commerce entry into the non-WIC segment appears to intensify competition, potentially reducing price distortions for offline retailers and lowering WIC agency expenditures. If e-commerce were to enter the WIC segment, competition could be strongest when shopping costs are moderate, leading to possible welfare gains for WIC consumers and improved government spending efficiency, which may inform policy discussions on integrating online retailers into WIC.

This paper contributes to the literature on spatial market competition and WIC's impact on infant formula prices. The foundational linear model by Hotbllino (1929) and the circular model by Salop (1979) shaped how we understand retail competition, with Balasubramanian (1998) later incorporating e-commerce. Building on this, we introduce WIC into a spatial competition framework and develop a circular model to examine how WIC's distribution mechanism and the presence of online retailers affect competition in the infant formula market.

Our study also relates to research on how WIC contracts influence formula prices. Prior work compares WIC and non-WIC brands or examines price changes post-contract, with studies like Oliveira (2004) finding WIC contracts raise prices and others (Huang and Perloff, 2014; Rojas and Wei, 2019; Wang, 2023; An et al., 2023) showing they boost sales. A key challenge has been disentangling price effects due to limited data on procurement costs and WIC redemptions. Closest to our approach, Prell (2004) used a Cournot model to examine retailer pricing strategies. Unlike their work, we focus on price competition across online and offline channels and show that WIC's distribution system pushes all retail types, including non-WIC-authorized stores, to raise 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 policies and regulations relevant to this paper. Section 3 sets up the model. Section 4 offers a detailed analysis of equilibrium outcomes within and across scenarios. Section 6 provides concluding remarks. All the proofs are relegated to the Appendices.

2 Background

2.1 US infant formula market

Infant formula is crucial for providing 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 US CDC Breastfeeding Report Card (Centers for Disease Control and Prevention, 2022), among children born in 2019, 75% were partially or fully fed with formula. The U.S. infant formula market size 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-based and soy-based types and is available in three physical 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 characterized by high concentration. Three major manufacturers account for almost 98 percent 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 the strict US Food and Drug Administration (FDA) regulations[6] and the high tariffs (up to 17.5%) hinder new entrants into the wholesale market (Yenerall et al., 2024). Such concentration, even in the absence of WIC, could lead to significantly higher

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

procurement costs, which are ultimately borne by consumers. An anecdote suggests that WIC's use of competitive sole-source contracts further exacerbates barriers to market entry and limits competition at the wholesale level.

Turning to the retail markets, the distribution of infant formula has evolved over time. According to Prell (2004), in 2002, supermarkets accounted for 69% of infant formula sales, mass merchandisers for about 28%, and drugstores for about 4%. Over the past two decades, with the rise of e-commerce, many consumers have shifted to online shopping, 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. 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). It is one of the motivating factors for manufacturers to secure WIC contracts, as WIC-contract brands gain significant advantages, including endorsements by doctors (GAO, 1998; Oliveira, Frazao and Smallwood, 2011) and preferential shelf placement in WIC-authorized stores (GAO, 2006).

2.2 WIC Cost Containment Policies

The WIC program, initiated in 1972, is administered by the United States Department of Agriculture. The program operates across all 50 states and the District of Columbia, with each WIC State agency having 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, yet only 51.2% received WIC benefits (Kessler et al., 2023). Thus, reducing program costs has become a key objective for WIC, as it enables WIC to extend its benefits to more households in need.

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 these costs, WIC has implemented a series of cost-containment policies at both the procurement and distribution stages. The rebate program mentioned earlier is one such cost-containment policy, which applies to manufacturers. According to An et al. (2023), rebates offered by the WIC-contract manufacturers amount to approximately 85% of the wholesale prices, enabling WIC to save an estimated $1.7 billion annually.

In retail markets, the two most important cost-containment policies WIC enforces on WIC-authorized stores are prohibiting price discrimination and regulating pricing through Maximum Allowable Reimbursement Levels (MARLs). To ensure fair practices, WIC mandates that WIC-authorized stores maintain consistent pricing for WIC-approved items across both WIC and non-WIC consumers. Moreover, each WIC state agency establishes MARLs for WIC-approved items at each WIC-authorized store, based on factors such as store type, size, and location. WIC-authorized stores are required to keep their prices below the MARLs. However, these MARLs are often set at relatively high levels to accommodate exceptional circumstances (Neuberger and Greenstein, 2004). Although the specific details of cost-containment policies at the retail level vary across states, the primary goal is to ensure that WIC-authorized stores engage in market competition rather than exploiting their exclusive access to WIC consumers, who are completely price insensitive. To better reflect the regulatory retail environment, our model incorporates price discrimination prohibitions and pricing caps.

Only WIC-authorized stores are eligible to serve WIC consumers and receive reimbursements from the program. While WIC authorization is open to all offline retailers, the application process would be temporarily paused if local WIC agencies believe that either community

needs are sufficiently met or their management capacity is fully utilized. In addition to the cost-containment policies, WIC-authorized retailers must adhere to other selection criteria, such as providing a variety of WIC-approved foods and meeting minimum stocking levels.[7] WIC-authorized stores must comply with WIC regulations and cost-containment policies to maintain their eligibility and authorization.

2.3 WIC Modernization Act

The WIC Modernization Act is a legislative initiative aimed at enhancing the accessibility and efficiency of the program.[8] A key component of the act is the introduction of online shopping options for WIC participants. The act aligns WIC with modern consumer practices while addressing logistical challenges faced by low-income families, particularly those in rural or underserved areas. 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 took the lead in launching online shopping pilots through a partnership with a retailer. While WIC participants in certain areas now have the option to redeem their food benefits online, the associated delivery fees are not covered by WIC and must be paid out of pocket. These additional costs undoubtedly impose a new financial challenge for WIC participants, limiting their access to the full benefit of this initiative.

The rollout of this initiative is anticipated to shift a portion of WIC consumers toward online shopping, prompting retailers to adjust their pricing strategies for infant formula accordingly. Scenario 3's framework is designed to evaluate the potential implications of this shift for retail competition and welfare outcomes.

[7]For more details on WIC-authorized stores, visit https://www.fns.usda.gov/wic/retail-store-factsheet.

[8]For more details on the WIC Modernization Act, visit https://www.fns.usda.gov/news-item/fns-005.23.

3 Model

Table 1: Notation for parameters.

Parameter	Description
p_{ij}, p_e	The unit retail price set by offline retailer j of type i, where $i \in \{w, nw, e\}$ and $j \in \{1, 2, 3, \ldots\}$, 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 $k \in \{W, NW, Total\}$.
π_{ij}, π_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.
μ	The online shopping costs.
V	Consumers' valuation of the infant formula.
θ	The fraction of WIC consumers in the market, $\theta \in [0, 1]$.
CS^k	The surplus for type k of consumers.
GS	The WIC spending on infant formula without manufacturer's rebates.

We consider three types of retailers competing on price for a single brand of infant formula that is under the WIC contract in the local market. *Table 1* summarizes the key notations in this study.

The model setup is as follows: offline retail stores, designated as either W- or NW-retailers, are equidistantly positioned along the circumference of the circular market. 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 marginal cost, respectively, for offline retailer j of type i, where $i \in \{w, nw\}$ and $j \in \{1, 2, \ldots, N\}$. When a single e-commerce retailer, designated as the E-retailer, enters the market, it is positioned centrally in the circular market.[9] p_e and c_e denote the unit retail price and marginal cost for the E-retailer, respectively. According to WIC regulations, retailers holding WIC authorization are required to maintain uniform pricing for both WIC

[9]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 the online sales and (2) it captures the key dynamics of online versus offline competition without sacrificing analytical clarity. 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.

and non-WIC consumers and set their prices within the WIC price limits, $\bar{p}$. Since fixed costs are not relevant to the pricing game, assume for the moment that $F_{ij} = F_e = 0$, $\forall i, j$.

A unit of consumers is uniformly distributed along the circumference. Each consumer visits exactly one retailer and purchases one unit of infant formula per period. Consumers are divided into two groups: a fraction θ (where $\theta \in [0,1]$) represents WIC consumers, and the remaining fraction, $1-\theta$, 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 valid given consumers' low price elasticity and strong brand loyalty.

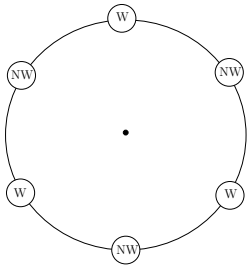
Consumers incur positive costs regardless of whether the formula is purchased online or offline. For offline shopping, the primary cost is travel expenses, charged at a linear rate t per unit distance multiplied by the distance traveled. The travel distance l_{aij} depends on the relative locations of the consumer a and the offline store ij. Thus, a non-WIC consumer's net utility from purchasing the formula at an offline store is $V - tl_{aij} - p_{ij}$, and a WIC consumer's net utility from purchasing at a W-retailer is $V - tl_{awj}$. When shopping online at the E-retailer, consumers incur a uniform cost μ. μ captures the disutility associated with online purchases, such as delivery costs, membership fees, and waiting times. A non-WIC consumer's net utility from purchasing 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 need to propose several additional assumptions to ensure its tractability.

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*).

This assumption is a technical simplification to ensure symmetric competition along the circle. With this assumption, we can derive a symmetric equilibrium by applying the methodology of Balasubramanian (1998). In practical terms, this assumption implies that a WIC local agency partners with half of the local offline stores to distribute WIC benefits.

Figure 1: The Circular Market, N=3



While it may not perfectly reflect the proportion of WIC-authorized offline stores across all retail markets, this assumption is appropriate for our main purpose of directional analysis rather than precise quantification of WIC's impact on retail competition.

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

The primary marginal cost for retailers arises from procurement costs. For algebraic simplicity, we assume that the differences in procurement costs within local markets are negligible.[10]

Assumption 3. *The fraction of WIC consumers in the market,* θ*, is an exogenous parameter.*

Following Oliveira (2004) and Prell (2004), we assume that the 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 ensures that WIC consumers always prefer shopping at WIC-authorized stores rather than non-authorized ones, where they need to purchase infant formula out-of-pocket. In practice, there are rare instances where WIC consumers may forgo redeeming WIC benefits due to high travel costs. For simplicity, these cases are excluded from our model.

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

[10]There may be concerns about variations in marginal costs across retailer types. However, our robust checks confirm that such differences do not qualitatively affect our results.

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 designed to encourage WIC-authorized stores to participate in market competition rather than restrict their competitive pricing, we assume that the imposed price caps are set sufficiently high to remain non-binding on the competitive equilibrium prices. Note that we do not rule out the possibility that WIC-authorized retailers may strategically set their prices at the price caps to maximize their profits. The conditions under which this strategic behavior arises be thoroughly discussed in the following section.

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.

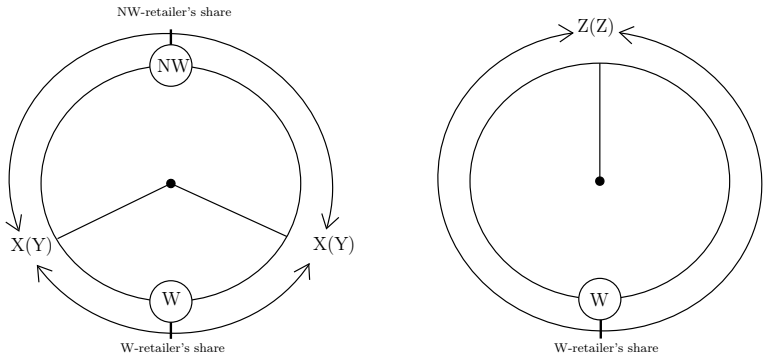
4 Analysis

Scenarios As mentioned earlier, we develop three scenarios to reflect varying levels of e-commerce involvement in the retail sector: Scenario 1 describes a market where online shopping is unavailable; Scenario 2 extends Scenario 1 by introducing an online retailer that serves non-WIC consumers; and Scenario 3 further expands the scope by allowing the online retailer to serve both WIC and non-WIC consumers. We first characterize and analyze the equilibrium outcomes for each scenario, and subsequently compare the welfare outcomes across the three scenarios.

Equilibrium Concept We restrict our attention to the Full-Engagement Equilibria (FEE), defined as the equilibria where W-authorized retailers (W-retailers in Scenarios 1-3 and the

E-retailer in Scenario 3) fully participate in market competition. This is because, to the best of our knowledge, retail prices set by WIC-authorized retailers are typically not constrained by the price caps.[11] In rare cases, W-authorized retailers may forgo market competition and strategically price at the price caps. We refer to such equilibria as Cap-Exploitation Equilibria (CEE), which are outlined in Appendix C.

4.1 Analysis of Scenario 1



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

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

Consider a simple scenario where e-commerce is absent from the market. For clarity, we divide the market into two segments, the non-WIC market segment and the WIC market segment. and discuss them separately.

In the non-WIC market segment, N W-retailers and N NW-retailers are competing against each other. Because of the symmetry of the circular market, it is sufficient to analyze the price-setting game in a W-retailer and one of its neighboring NW-retailers. As shown in *Figure 2(a)*, there exists a point between these two stores where a non-WIC consumer is indifferent to purchasing from either store. 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 stores is $\frac{1}{2N}$, we can get $y = \frac{1}{2N} - x$. Thus, we have

[11] The relevant information is obtained through interviews with several WIC agency representatives.

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

which is equivalent to

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

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

Each store serves consumers symmetrically located on both sides of its location. Therefore, the market share of non-WIC consumers for each W-retailer, denoted by S_w^{NW}, is equal to $2(1-\theta)x$; that for each NW-retailer, denoted by S_{nw}^{NW}, is equal to $2(1-\theta)y$.

Turning to the WIC market segment, WIC consumers obtain the formula exclusively from W-retailers. In a market with a single W-retailer, this W-retailer captures 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 where a WIC consumer is indifferent between purchasing from a W-retailer and one of its neighboring W-retailers. The distance from the W-retailer to this point is denoted as z. Therefore, the market share of WIC consumers for each W-retailer, denoted by S_w^W, is $2\theta z$. Under Assumption 1 that W-retailers are evenly distributed along the market, each W-retailer captures an equal 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 maximize their profits by

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

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

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

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

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

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

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

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

This equilibrium is sustainable when: 1(a). $S^{NW*}_{w,1} > 0 \Rightarrow \theta < \frac{3}{5}$*; and 1(b).* $(p^*_{w,1} - c)S^{Total*}_{w,1} > (\bar{p}_w - c)\frac{\theta}{N}$.

PROOF. See Appendix A1.

The required conditions are that 1(a). W-retailers obtain a positive market share in the non-WIC market segment and 1(b) For W-retailers, engaging in market competition must be more profitable than setting prices at the price caps.

At $\theta = 0$, reflecting no WIC, W-retailers and NW-retailers set the same price of $\frac{t}{2N}$ and obtain identical market shares and profits. Next, we discuss how the presence of WIC ($\theta > 0$) may distort retail competition. In the following analysis, we will refer to the changes brought by WIC to retail competition as the 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) $\frac{\partial^2 p^*_{w,1}}{\partial \theta \partial c} = 0$; $\frac{\partial^2 p^*_{nw,1}}{\partial \theta \partial c} = 0$.

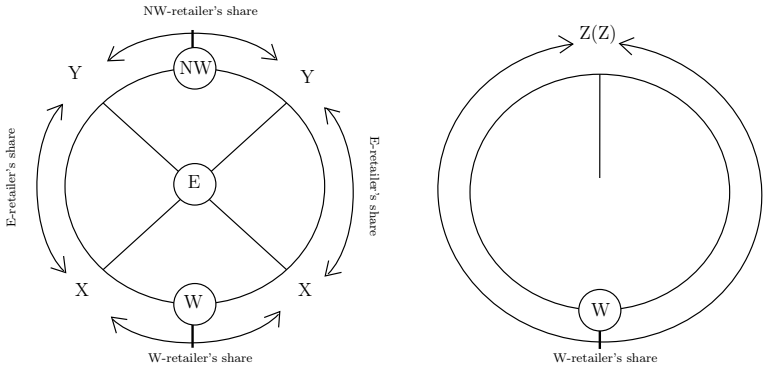
According to Property 1, p^*_w and p^*_{nw} are increasing in θ. The increase in p^*_w is quite straightforward as the fraction of WIC consumers grows. The increase in p_{nw} is attributed to strategic complementarity: higher prices charged by W-retailers induce more non-WIC consumers to shop at NW-retailers, prompting NW-retailers to adjust their prices strategically.

Property 1 further reveals the distortionary effects on retail pricing and the moderation roles played by other factors. We find that higher offline shopping costs t and lower offline retail density N amplify the distortionary effects on retail pricing of both retailer types. 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, further weakening price pressures in the market. Moreover, the distortionary effects are more pronounced in markets with a higher fraction of WIC consumers. Finally, the distortionary effects are independent of marginal costs, c.

In the presence of WIC, W-retailers gain a competitive advantage over NW-retailers. Specifically, W-retailers always charge $\frac{t\theta}{3N(1-\theta)}$ more 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. Notably, the gaps in prices, total market shares, and profits are increasing monotonically in θ.

Lastly, we briefly revisit and reaffirm the conditions under which the FEE holds in Scenario 1. W-retailers will actively compete in the non-WIC market segment when θ remains within a moderate range (as per Condition 1(a)) and price caps are not set at excessively high levels (as per Condition 1(b)). A violation of either condition will prompt W-retailers to price at the price caps, leading to the market transition from the FEE to the CEE.

4.2 Analysis of Scenario 2



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

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

Next, we consider a scenario where an E-retailer enters the market, competing with offline retailers in the non-WIC market segment. With the E-retailer's presence, 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 a 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

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

Note that 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 market share of non-WIC consumers captured by the E-retailer, denoted by S_e^{NW}, is equal to $(1-\theta)(1-2Nx-2Ny)$.

In the WIC market segment, WIC consumers still need to shop at W-retailers, the same as 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 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 certain conditions, 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:

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

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

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

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

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

This equilibrium is sustainable when: 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.

For the equilibrium to be sustained, both the E-retailer and W-retailers must obtain a positive market share in the non-WIC market segment, as ensured by conditions 2(a) and 2(b). Condition 2(c) ensures that W-retailers achieve greater profitability from competing than from pricing at the price caps.

When $\theta = 0$, the market equilibrium is consistent with that of Balasubramanian (1998).[12] The model predicts that the presence of WIC ($\theta > 0$) leads to higher formula prices set by all retail types.

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

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

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

(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 similar patterns to those outlined in Property 1 regarding the distortionary effects on retail pricing. First, p^*_w, p^*_{nw}, and p^*_e increase as θ grows. Second, the distortionary effects become more pronounced in markets with a higher θ. Third, higher t and lower N amplify the distortionary effects on retail pricing of all retail types. Lastly, the distortionary effects remain independent of c.

In addition to these similarities, Property 2 introduces new insights following the E-retailer's entry into the non-WIC market 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 offline retailers' pricing. This is because heightened market competition limits offline retailers' ability to raise prices. Next, Property 2(vi) shows that the size of online shopping costs, μ, does not affect how WIC influences retail pricing. This is likely because the E-retailer is not directly involved in WIC's distribution mechanism in this Scenario.

Next, we compare the market equilibrium between W-retailers and NW-retailers. Again, the presence of WIC grants W-retailers a competitive advantage over NW-retailers. W-retailers always charge $\frac{t\theta}{4N(1-\theta)}$ more 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. Similar to Scenario 1, the gaps between W-retailers and NW-retailers also increase monotonically in θ.

When comparing the market equilibrium between W-retailers and the E-retailer, the ratio $\frac{N\mu}{t}$, which reflects the relative attractiveness of the offline shopping channel compared to the online shopping channel, plays a pivotal role in determining which retail type secures a competitive advantage. For ease of reference, we define this ratio as We define this ratio as the offline-to-online cost (OFF2ON) ratio. In the classic Salop circular model, as $N\mu$ increases relative to t, the offline shopping channel becomes more favorable, and offline retailers can leverage their cost advantage to set higher prices. Without WIC, the threshold for competitive advantage between the online and offline channels is fixed at $\frac{1}{4}$. However, when $\theta > 0$, the threshold becomes dependent on θ. W-retailers set higher prices than the E-

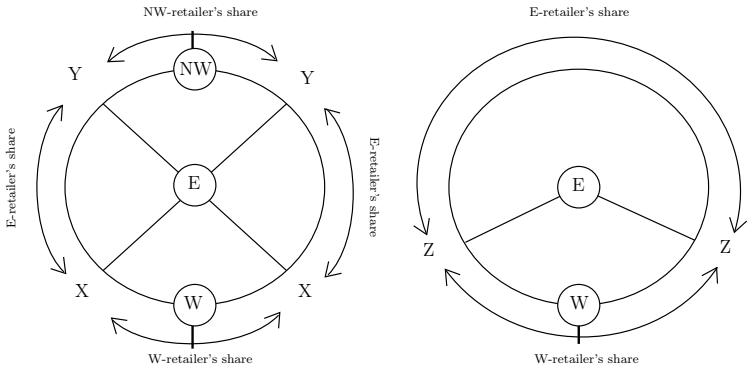
retailers when $\frac{N\mu}{t} > \frac{2-7\theta}{16(1-\theta)}$, and vice versa. Comparing equilibrium market shares, the total market share obtained by all W-retailers (NS_w^{Total*}) is greater than the total market share obtained by the E-retailer, S_e^{Total*} when $\frac{N\mu}{t} > \frac{2-3\theta}{8(1-\theta)}$, and vice versa. As θ grows, W-retailers are more likely to hold a competitive advantage over E-retailers.

Lastly, turning back to the required conditions for this equilibrium, we first note that the OFF2ON ratio must be sufficiently low, i.e., $\frac{N\mu}{t} < \frac{2-\theta}{4(1-\theta)}$ (as per Condition 2(a)); otherwise, the E-retailer has no incentive to enter the non-WIC market segment, and the game reverts to Scenario 1. Without WIC, the E-retailer's entry threshold is fixed at $\frac{1}{2}$. However, with the presence of WIC, the entry threshold gradually decreases as θ 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.

Conditions 2(b) and 2(c) are set to ensure that W-retailers have sufficient incentives to actively compete in the non-WIC market segment. Unlike the restriction on θ in Condition 1(a), which is fixed, that in Condition 2(b) is contingent upon the values of N, t, and μ. If Condition 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 price caps, which causes the market to transition from the FEE to the CEE.

4.3 Analysis of Scenario 3

In this scenario, we assume that the E-retailer is eligible to serve WIC consumers. The shopping strategy for non-WIC consumers remains consistent with that in Scenario 2, whereas WIC consumers now have access to the online channel (See *Figure 4*). We skip the exploration of non-WIC consumers' shopping strategy and proceed directly to that of WIC consumers. The choice between online and offline shopping for WIC consumers depends entirely on μ 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



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

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

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

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 market share of WIC consumers for the E-retailer, S_e^W, is equal to $\theta(1 - 2Nz)$.

To reduce the complexity of the model, we assume that WIC sets different price caps for the W-retailers and E-retailer in this scenario.

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

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

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

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

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:*

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

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

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

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

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

This equilibrium is sustainable when: 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.

In equilibrium, five conditions must be satisfied. 3(a) and 3(b) confirm that the E-retailer obtain a positive market share in each market segment, while 3(c) ensures that W-retailers remain active in the non-WIC market segment. Furthermore, conditions 3(d) and 3(e) establish that engaging in market competition yields higher profits for both W-retailers and the E-retailer than pricing at the price caps.

Property 3. *Given that* $\mu > 0$, $N \in \mathbb{Z}^+$, $\theta \in (0,1)$, *and* $\frac{N\mu}{t} < 2$,

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

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

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

According to Property 3, the presence of WIC leads to higher formula prices across all retail types, consistent with the findings in the previous two scenarios. As with Properties 1 and 2, it shows that, Property 3 suggests that, for all retail types, the distortionary effects on retail pricing are increasing in θ and t, but decreasing in N.

From Property 3, we derive two new insights. First, a comparison of price distortions between Property 2 and 3 reveal that the E-retailer's entry into the WIC market segment mitigates the distortionary effects on W-retailers' pricing but intensifies the distortionary effects on the pricing of NW-retailers and the E-retailer. Next, μ begins to affect how WIC influences retail pricing in this scenario. Specifically, a higher μ amplifies the distortionary effects on $p^*_{w,3}$ while reducing the effects on $p^*_{nw,3}$ and $p^*_{e,3}$.

Although a portion of the market share of WIC consumers is taken away by the E-retailer in this scenario, W-retailers maintain a competitive advantage over NW-retailers. W-retailers always charge $\frac{\mu\theta}{2(1-\theta)}$. 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. While the gaps widen as θ grows, but they are less pronounced compared to those observed in Scenario 2.

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 requirements for W-retailers to gain a competitive advantage over the E-retailer.

Among all the required conditions in Scenario 3, Condition 3(a) is the most important. The OFF2ON ratio must be sufficiently low to encourage WIC consumers to shift to online shopping. This shift is essential for the E-retailer to enter the WIC market segment. If this condition is violated, the game reverts to Scenario 2. The remaining conditions ensure that both W-retailers and E-retailers have adequate incentives to compete in the non-WIC market

segment. If Condition 3(a) is satisfied while any of the other four conditions are violated, either W-retailers or the E-retailer will price at the price caps, resulting in a market transition from the FEE to the CEE.

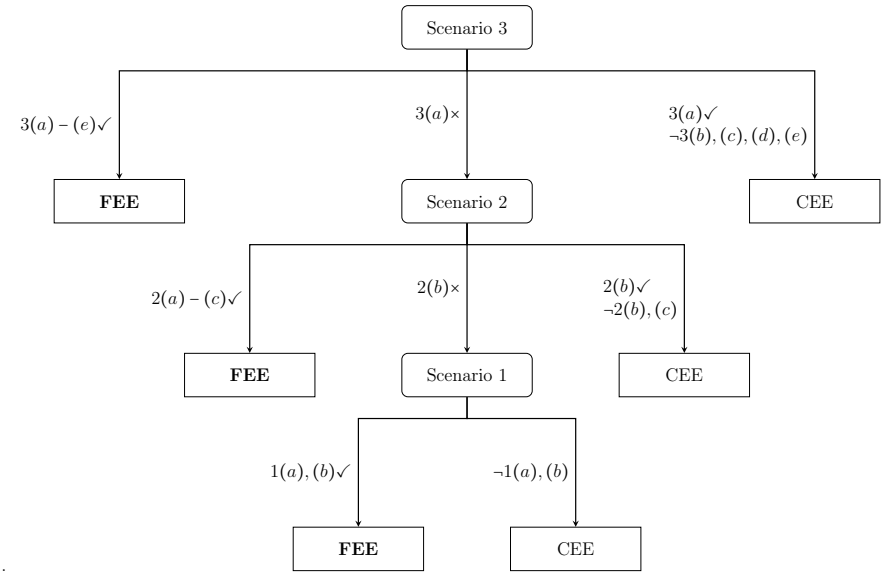


Figure 5: Market Structures after the Introduction of WIC Online Redemption

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 equilibria the market can reach and their corresponding conditions once the E-retailer is permitted to enter the WIC market segment. As shown above, the market equilibrium that emerges depends on the parameters θ, μ, N, t, $\bar{p}_e$, and $\bar{p}_w$.

4.4 Welfare Comparisons

We conduct a welfare comparison across the three scenarios outlined above, with a focus on consumer surplus and direct government spending. The comparisons are still confined to the welfare outcomes under the Full-Engagement Equilibria (FEE). The derivation process is detailed in Appendices A1 through A3. In the following analysis, we assume that the price caps are carefully calibrated to ensure that WIC-authorized stores do not strategically forgo market competition due to excessively high price caps.

For each scenario, the non-WIC consumer surplus is calculated by summing the difference, for each non-WIC customer, between their valuation of infant formula and the total costs incurred, including the formula price and the associated shopping costs. The outcomes are obtained as below:

$$\begin{aligned}
CS_1^{NW*} &= (V-c)(1-\theta) + \tfrac{t(45-54\theta+5\theta^2)}{72N(1-\theta)} \\
CS_2^{NW*} &= (V-c)(1-\theta) - \tfrac{t(44-56\theta-\theta^2)}{288N(1-\theta)} - \tfrac{\mu(5-4\theta)}{9} + \tfrac{2N\mu^2(1-\theta)}{9t} \\
CS_3^{NW*} &= (V-c)(1-\theta) - \tfrac{t(11-12\theta)}{72N(1-\theta)} - \tfrac{\mu(10-23\theta+15\theta^2)}{18(1-\theta)} + \tfrac{N\mu^2(16-64\theta+73\theta^2)}{72t(1-\theta)}
\end{aligned}$$

The calculation of the WIC consumer surplus is similar to that of the non-WIC consumer surplus, with the only difference being that WIC consumers do not bear the formula price. Thus, we have

$$\begin{aligned}
CS_1^{W*} &= (V - \tfrac{t}{4N})\theta \\
CS_2^{W*} &= (V - \tfrac{t}{4N})\theta \\
CS_3^{W*} &= (V - \mu + \tfrac{N\mu^2}{t})\theta
\end{aligned}$$

For estimating direct government spending, we focus solely on the retail prices, assuming that the rebates remain constant across all scenarios. Therefore, the government spending is simply the sum of the retail prices paid by WIC for each WIC consumer. The outcomes are as follows:

$$\begin{aligned}
GS_1^* &= \left[c + \frac{t}{2N} + \frac{2t\theta}{3N(1-\theta)}\right]\theta \\
GS_2^* &= \left[c + \frac{t}{12N} + \frac{\mu}{3} + \frac{7t\theta}{24N(1-\theta)}\right]\theta \\
GS_3^* &= \left[c + \frac{t^2 - N\mu t(3-\theta) + N^2\mu^2(8-\theta)}{6Nt(1-\theta)}\right]\theta
\end{aligned}$$

Property 4. *Given that all the required conditions across the three scenarios are satisfied, the welfare outcomes across the three scenarios follow the comparative patterns outlined below.*

$$\text{(i)} \begin{cases} CS_2^{NW*} > CS_3^{NW*} > CS_1^{NW*}, & \text{if } \frac{t}{N\mu} > \frac{2(32-57\theta)}{8+\theta}, \\ CS_3^{NW*} > CS_2^{NW*} > CS_1^{NW*}, & \text{if } \frac{t}{N\mu} < \frac{2(32-57\theta)}{8+\theta}, \\ CS_2^{NW*} = CS_3^{NW*} > CS_1^{NW*}, & \text{if } \frac{t}{N\mu} = \frac{2(32-57\theta)}{8+\theta}, \end{cases}$$

$$\text{(ii) } CS_3^{W*} > CS_2^{W*} = CS_1^{W*},$$

$$\text{(iii)} \begin{cases} GS_1^* > GS_2^* > GS_3^*, & \text{if } \frac{N\mu}{t} > \frac{2-5\theta}{8-\theta}, \\ GS_1^* > GS_3^* > GS_2^*, & \text{if } \frac{N\mu}{t} < \frac{2-5\theta}{8-\theta}, \\ GS_1^* > GS_2^* = GS_3^*, & \text{if } \frac{N\mu}{t} = \frac{2-5\theta}{8-\theta}. \end{cases}$$

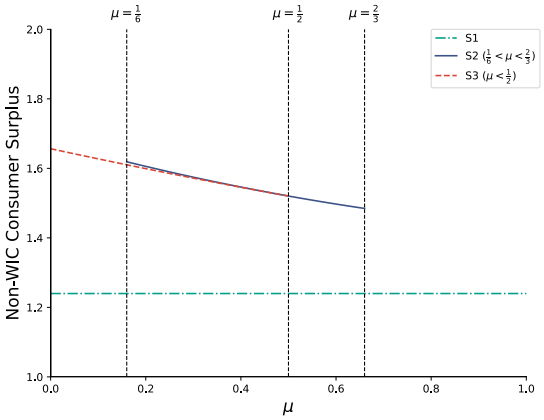
Property 4 shows that, compared to Scenario 1, Scenarios 2, characterized by the E-retailer's entry into the non-WIC segment, enhance non-WIC consumer surplus and reduce direct government spending. However, moving from Scenario 2 to Scenario 3 introduces ambiguity regarding the changes in non-WIC consumer surplus and direct government spending, contingent upon the the OFF2ON ratio and θ. Compared to Scenarios 1 and 2, the E-retailer's entry into the WIC market segment undoubtedly increases WIC consumer surplus by providing greater convenience to those living far from W-retailers.

To facilitate a clearer comparison, we set the fraction of WIC consumers in the market at 40% ($\theta = 0.4$). This value is chosen for analysis because most states in 2022 have WIC infant shares concentrated around this value (as illustrated in Figure A1, Appendix A).[13] Next, we assign $V = 5$, $c = 2$, $N = 1$, and $t = 1$, and vary μ to reflect the variations in the OFF2ON ratio. *Figures 6(a-c)* depict how the OFF2ON ratio, adjusted by μ, influences welfare outcomes in markets where 40% of consumers are enrolled in WIC.

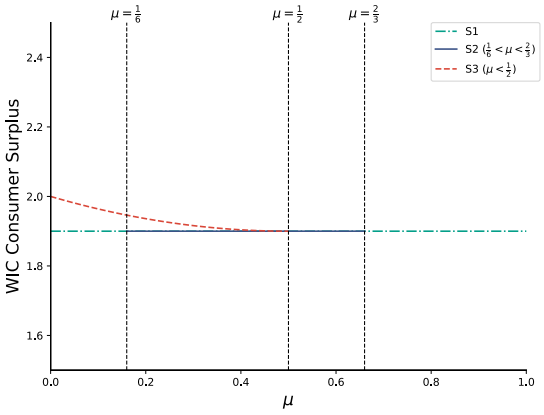
Due to constraints in the Full-Engagement Equilibria (FEE) of Scenarios 2 and 3, μ cannot take all possible values, as partially illustrated in *Figures 6(a-c)*. First, when $\mu \in [0, \frac{1}{6})$, the relatively low OFF2ON ratio compared to θ results in the non-existence of the

[13] We also report the results for $\theta = 0.2$ in Appendix A.

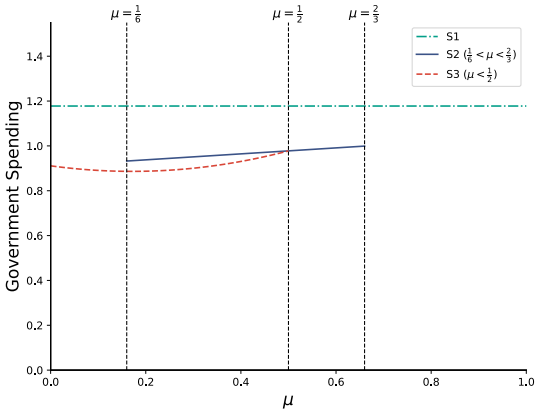
Figure 6: Welfare Comparison



6(a). Non-WIC Consumer Surplus



6(b). WIC Consumer Surplus



6(c). Government Spending

Note. The figures are generated using the parameter values $\theta = 0.4$, $V = 5$, $c = 2$, $N = 1$, and $t = 1$. Due to constraints in the FEE of Scenarios 2 and 3, μ cannot take all possible values (1) When $\mu \in [0, \frac{1}{6})$, no FEE exists in S2; (2) When $\mu \in (\frac{1}{2}, \frac{2}{3})$, S3 reverts to S2; (3) When $\mu \geq \frac{2}{3}$, S2 reverts to S1.

FEE in Scenario 2 (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 market 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 market 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 welfare outcomes of the FEE simultaneously exist across all three scenarios.

From *Figure 6a*, we observe that non-WIC consumer surplus in Scenario 2 and Scenario 3 declines continuously as the OFF2ON ratio increases. This trend is intuitive, as a higher OFF2ON ratio drives more non-WIC consumers to revert to offline shopping channels. Next, comparing Scenario 2 and Scenario 3, we find that the E-retailer's entry into the WIC market segment slightly reduces non-WIC consumer surplus when the OFF2ON ratio is relatively low. However, as the OFF2ON ratio increases, the non-WIC consumer surplus in Scenario 3 declines more slowly than in Scenario 2, eventually surpassing that in Scenario 2 at $\mu = \frac{21}{46}$. This observation aligns with the findings from Property 4(i).

Figure 6b show the relationship between the OFF2ON ratio and WIC consumer surplus. Since WIC consumers do not bear the formula prices, introducing the online shopping channel significantly improves their welfare, particularly when the OFF2ON ratio is low. However, as the OFF2ON ratio increases, the WIC consumers' gains from online access gradually decrease. This trend echoes the concern that the relative benefits of introducing the online redemption channel diminish as online shopping costs increase.

Figure 6c demonstrates how the OFF2ON ratio impacts government spending. In Scenario 2, government spending rises continuously with the OFF2ON ratio, as the increasing competitive advantage of W-retailers drives up their prices. Unlike Scenario 2, government spending in Scenario 3 exhibits a U-shaped trend. As the OFF2ON ratio approaches 0, the E-retailer secures a significant market share from both market segments, allowing it to set excessively high prices. At the other extreme, W-retailer adopt a similar pricing strategy when the OFF2ON ratio is relatively high. Government spending reaches its lowest point when

the OFF2ON ratio is at a moderate level, where the competition between W-retailers and the E-retailer is most intense. Given that θ is set at 0.4, government spending in Scenario 3 consistently remains lower than in Scenario 2. Referring back to the threshold established in Property 4(iii), we conclude that government spending in Scenario 3 is consistently smaller than in the other two scenarios when $\theta \geq 0.4$.

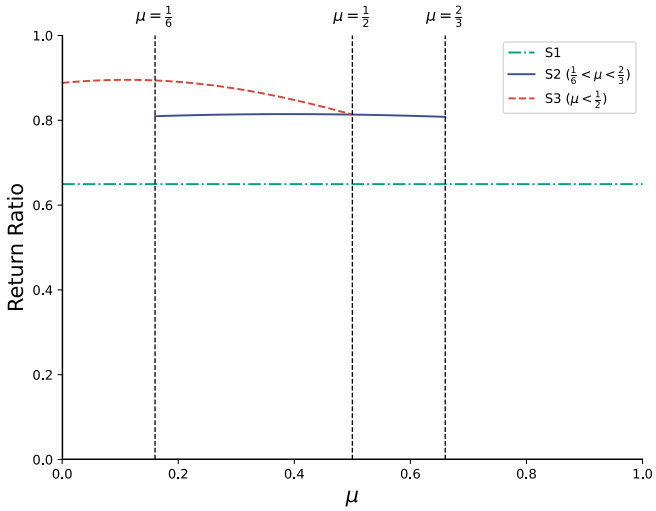
Given that the welfare comparisons do not offer a conclusive result regarding the implications of the E-retailer's entry into the WIC market segment, we extend our analysis to evaluate the improvement in overall consumer welfare relative to direct government spending across the three scenarios. This approach offers a more direct measure of the efficiency of government spending in promoting consumer welfare. Specifically, we calculate the return on government spending (RGS) using the following formula:

$$\text{RGS} = \frac{CS^{NW*} + CS^{W*} - CS^{NW*}(\theta = 0)}{GS^*}$$

The RGS ratio measures the return in overall consumer welfare for every dollar spent by WIC on infant formula. The results are provided in Appendix A. Note that this ratio does not reflect the actual return, as it excludes the rebates provided by manufacturers.

Finally, we apply the same parameter values as in the previous analysis to the RGS equations. *Figure 7* illustrates the relationship between the OFF2ON ratio and the return on government spending (RGS) across the three scenarios. The results indicate that the entry of the E-retailer into the non-WIC market segment leads to a significant increase in the RGS in Scenario 2 compared to Scenario 1, primarily due to heightened market competition. Compared to Scenario 2, Scenario 3 further improves the RGS by enhancing WIC consumers' welfare and intensifying competition between the E-retailer and W-retailers. However, the return on government spending in Scenario 3 exhibits a downward trend as the OFF2ON ratio increases. This pattern results from the combined effects of reduced welfare for WIC consumers and an increased competitive advantage for W-retailers.

Figure 7: Return on Government Spending Excluding Rebates



Note. The figure is generated using the parameter values $\theta = 0.4$, $V = 5$, $c = 2$, $N = 1$, and $t = 1$. Due to constraints in the FEE of Scenarios 2 and 3, μ cannot take all possible values (1) When $\mu \in [0, \frac{1}{6})$, no FEE exists in S2; (2) When $\mu \in (\frac{1}{2}, \frac{2}{3})$, S3 reverts to S2; (3) When $\mu \geq \frac{2}{3}$, S2 reverts to S1.

5 Conclusions

As concerns mount over the possibility that WIC raises the retail prices of infant formula, we examine the potential impact of WIC's distribution mechanism on retail competition. Our model indicates that WIC may lead retail outlets to raise prices, with this effect being most significant among WIC-authorized stores because of their exclusive access to WIC consumers. Price distortions become more pronounced in markets featuring higher offline shopping costs, lower offline retail density, and a greater proportion of WIC participants.

We examine e-commerce involvement with WIC and find that entry into the non-WIC market segment intensifies competition, mitigates price distortions among offline retailers, enhances consumer welfare in the non-WIC segment, and reduces WIC agency's direct expenditures related to formula. We further explore the potential of e-commerce entering the WIC market segment and suggest that market competition is most intense when offline and online shopping costs are at a moderate level. While non-WIC consumers may face welfare losses from the price increase of the online retailer, the considerable gains in WIC consumer

welfare and the notable reduction in WIC agency spending contribute to a high efficiency of government spending. To put it simply, the overall efficiency gains could justify policy considerations regarding the introduction of e-commerce into the WIC formula distribution.

While our model is developed to study retail competition in the U.S infant formula market, its framework can be directly extended to other WIC-approved products. However, the extent of price distortion are expected to be smaller for those products, given their lower reliance on WIC consumers, the greater availability of substitutes, and the higher price elasticity of demand. Moreover, the model can potentially be applied to other public food assistance programs that distribute benefits through retailers. An essential consideration is that these programs enforce varying price regulations on partnering stores, which could influence the competitive dynamics analyzed in the model. Thus, policy adaptability must be carefully evaluated when extending the model to other programs.

Our model has several limitations, which open avenues for future research. First, we assume that the fraction of WIC consumers is exogenous to price fluctuations in the short run. However, given that WIC is a block grant, higher infant formula prices could constrain program enrollment. A more comprehensive framework should account for this endogenous response and examine its implications for retailers' pricing strategies and equilibrium market outcomes in the long run. Second, the model assumes that wholesale prices are exogenous to retail competition. This assumption, while reasonable, can be expanded in the future. Accounting for vertical interactions between manufacturers and retailers may provide deeper insights into how WIC influences retail competition. Finally, major online retailers such as Amazon and Walmart operate in multiple geographic markets. Future research could examine how the constraints and strategic advantages of uniform pricing shape competitive dynamics in retail markets of infant formula, given that WIC contracts vary across different regions.

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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:

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

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

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.

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

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

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

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

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

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

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

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

When calculating the welfare of consumers, we consider not only retail prices but also offline shopping costs (and online shopping costs, if applicable). The formulas and outcomes of WIC and non-WIC consumer surplus are outlined below:

$$\begin{aligned} CS_1^{NW*} &= 2N(1-\theta)\left[\int_0^{x_1^*}\left(V - p_{w,1}^* - tl\right)dl + \int_0^{y_1^*}\left(V - p_{nw,1}^* - tl\right)dl\right] \\ &= (V-c)(1-\theta) + \frac{t(45-54\theta+5\theta^2)}{72N(1-\theta)} \end{aligned}$$

$$\begin{aligned} CS_1^{W*} &= 2N\theta\left[\int_0^{z_1^*}(V - tl)\,dl\right] \\ &= (V - \frac{t}{4N})\theta \end{aligned}$$

The direct government spending on infant formula is the difference between retail prices and rebates. Here, we focus solely on the retail price and assume the rebate remains constant across three scenarios. Thus, we have

$$\begin{aligned} GS_1^* &= \theta p_{w,1}^* \\ &= \left[c + \frac{t}{2N} + \frac{2t\theta}{3N(1-\theta)}\right]\theta \end{aligned}$$

Required Conditions

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 market segment, which means that $S_w^{NW*} > 0$. It can be restated as $\theta < \frac{3}{5}$.

1(b). For W-retailers, engaging in market competition must be more profitable than setting prices at the regulatory caps.

Figure A1 illustrates the possible positions of $\bar{p}_w$, divided into two region by the cutoff point $c + \frac{3t}{2N}$. This cutoff is derived from $p_{w,1}^*(\theta = \frac{2}{3})$. For $\bar{p}_w < c + \frac{3t}{2N}$, W-retailers can secure a positive market share of non-WIC consumers by setting prices at $\bar{p}_w$; however, such a strategy is strictly dominated by competitive pricing and is, therefore, irrelevant for sustaining the Full-Engagement Equilibrium (FEE).

When $\bar{p}_w \geq c + \frac{3t}{2N}$, setting prices at $\bar{p}_w$ prevents W-retailers from attracting any non-WIC consumers. Nonetheless, if price caps are set sufficiently high, W-retailers may find it more profitable to strategically set prices at the caps rather than engage in competitive pricing. Therefore, to ensure the sustainability of the FEE, we impose the condition $(p_{w,1}^* - c)S_{w,1}^{Total*} > (\bar{p}_w - c)S_{w,1}^{W*} \Rightarrow (p_{w,1}^* - c)S_{w,1}^{Total*} > (\bar{p}_w - c)\frac{\theta}{N}$.

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

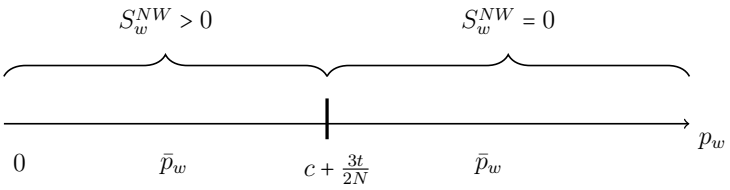


Figure A1.The Set of $\bar{p}_W$

Equilibrium Analysis

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

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

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

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

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

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

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:

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

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

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

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 as follows:

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

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

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

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

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 WIC and non-WIC consumer surplus, as well as government direct spending, are outlined below:

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

$$\begin{aligned} CS^{W*}_2 &= 2N\theta\left[\int_0^{z^*_2}(V - tl)\,dl\right] \\ &= (V - \frac{t}{4N})\theta \end{aligned}$$

$$\begin{aligned} GS^*_2 &= \theta p^*_{w,2} \\ &= \left[c + \frac{t}{12N} + \frac{\mu}{3} + \frac{7t\theta}{24N(1-\theta)}\right]\theta \end{aligned}$$

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 θ, we obtain $\frac{t}{4N(1-\theta)^2} > 0$, which means that an increase in θ relaxes the entry barrier for online retailers.

2(b). W-retails obtain a positive market share in the non-WIC market segment, i.e., $S_w^{NW*} > 0$. This condition can be restated as:

$$\theta < \frac{2t + 8N\mu}{7t + 8N\mu} \Leftrightarrow \theta < 1 - \frac{5t}{7t + 8n\mu}$$

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. Hence, we have

$$(p_{w,2}^* - c)S_{w,2}^{Total*} > (\bar{p}_w - c)\frac{\theta}{N}$$

Equilibrium Analysis

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

$$\frac{\partial p_{w,2}^*}{\partial \theta} = \frac{7t}{24N(1-\theta)^2} > 0$$

$$\frac{\partial p_{nw,2}^*}{\partial \theta} = \frac{t}{24N(1-\theta)^2} > 0$$

$$\frac{\partial p_{e,2}^*}{\partial \theta} = \frac{t}{12N(1-\theta)^2} > 0$$

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 $\frac{\mu}{t} > \frac{2-7\theta}{16(1-\theta)}$.

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

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

A3. Scenario 3

Proof of Proposition 3 (FEE)

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

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

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

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

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.

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

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

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

The corresponding equilibrium market shares and profits are as follows:

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

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

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

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

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

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

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

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

$$\begin{aligned} CS_3^{NW*} &= 2N(1-\theta)\left[\int_0^{x_3^*}\left(V - p_{w,3}^* - tl\right)dl + \int_0^{y_3^*}\left(V - p_{nw,3}^* - tl\right)dl\right] + S_{e,3}^{NW*}\left(V - p_{e,3}^* - \mu\right) \\ &= (V-c)(1-\theta) - \frac{t(11-12\theta)}{72N(1-\theta)} - \frac{\mu(10-23\theta+15\theta^2)}{18(1-\theta)} + \frac{N\mu^2(16-64\theta+73\theta^2)}{72t(1-\theta)} \end{aligned}$$

$$\begin{aligned} CS_3^{W*} &= 2N\theta\int_0^{z_3^*}(V - tl)\,dl + S_{e_3}^{W*}(V-\mu) \\ &= (V - \mu + \frac{N\mu^2}{t})\theta \end{aligned}$$

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

Required Conditions

There are several conditions that need to be satisfied in equilibrium.

3(a). The E-retailer must obtain a positive market share in the WIC market segment; otherwise, the game reverts to Scenario 2. Thus, we have $S_{e,3}^{W*} > 0 \Rightarrow \mu < \frac{t}{2N}$.

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

3(c). W-retailers must obtain a positive market share in the non-WIC market 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). The E-retailer benefits more from actively competing in the market than from setting prices 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

Given that $t > 0$, $N \in \mathbb{Z}^+$, $\theta \in (0,1)$, and $\frac{t}{2N} > \mu > 0$, we have

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

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

$$\frac{\partial p^*_{nw,3}}{\partial \theta} = \frac{t - N\mu}{12N(1-\theta)^2} > 0$$

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

$$\frac{\partial p^*_{e,3}}{\partial \theta} = \frac{t - N\mu}{6N(1-\theta)^2} > 0$$

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

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 $\mu > \frac{t}{N(8-\theta)}$.

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

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

A4. Welfare Comparison

To compare consumer surplus and government spending across the three scenarios, we must ensure that the conditions for the Full-engagement Equilibria (FEE) in each scenario are simultaneously satisfied. We summarize the welfare outcomes below for clarity and reference.

Non-WIC Consumer Surplus

$$CS_1^{NW*} = (V-c)(1-\theta) + \frac{t(45-54\theta+5\theta^2)}{72N(1-\theta)}$$
$$CS_2^{NW*} = (V-c)(1-\theta) - \frac{t(44-56\theta-\theta^2)}{288N(1-\theta)} - \frac{\mu(5-4\theta)}{9} + \frac{2N\mu^2(1-\theta)}{9t}$$
$$CS_3^{NW*} = (V-c)(1-\theta) - \frac{t(11-12\theta)}{72N(1-\theta)} - \frac{\mu(10-23\theta+15\theta^2)}{18(1-\theta)} + \frac{N\mu^2(16-64\theta+73\theta^2)}{72t(1-\theta)}$$

WIC Consumer Surplus

$$CS_1^{W*} = (V - \frac{t}{4N})\theta$$
$$CS_2^{W*} = (V - \frac{t}{4N})\theta$$
$$CS_3^{W*} = (V - \mu + \frac{N\mu^2}{t})\theta$$

Government Spending

$$GS_1^* = \left[c + \frac{t}{2N} + \frac{2t\theta}{3N(1-\theta)}\right]\theta$$
$$GS_2^* = \left[c + \frac{t}{12N} + \frac{\mu}{3} + \frac{7t\theta}{24N(1-\theta)}\right]\theta$$
$$GS_3^* = \left[c + \frac{t^2 - N\mu t(3-\theta) + N^2\mu^2(8-\theta)}{6Nt(1-\theta)}\right]\theta$$

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

(i) $\begin{cases} CS_2^{NW*} > CS_3^{NW*} > CS_1^{NW*}, & \text{if } \frac{t}{N\mu} > \frac{2(32-57\theta)}{8+\theta}, \\ CS_3^{NW*} > CS_2^{NW*} > CS_1^{NW*}, & \text{if } \frac{t}{N\mu} < \frac{2(32-57\theta)}{8+\theta}, \\ CS_2^{NW*} = CS_3^{NW*} > CS_1^{NW*}, & \text{if } \frac{t}{N\mu} = \frac{2(32-57\theta)}{8+\theta}, \end{cases}$

(ii) $CS_3^{W*} > CS_2^{W*} = CS_1^{W*}$,

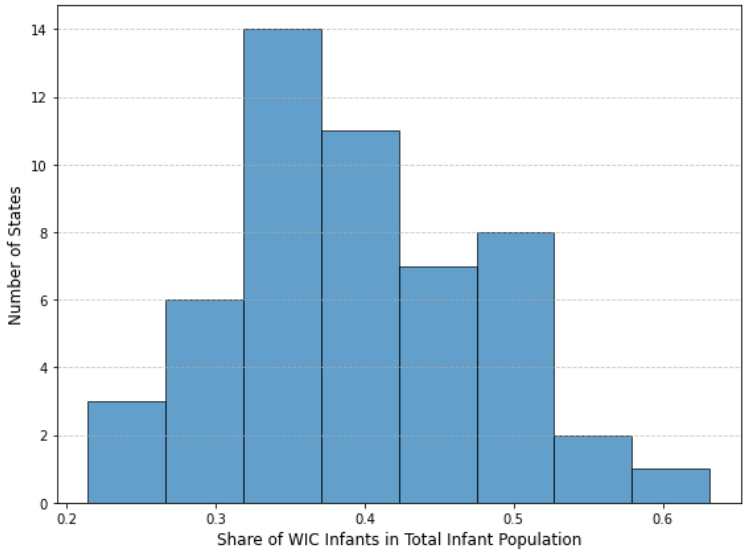
$$\text{(iii)} \begin{cases} GS_1^* > GS_2^* > GS_3^*, & \text{if } \frac{N\mu}{t} > \frac{2-5\theta}{8-\theta}, \\ GS_1^* > GS_3^* > GS_2^*, & \text{if } \frac{N\mu}{t} < \frac{2-5\theta}{8-\theta}, \\ GS_1^* > GS_2^* = GS_3^*, & \text{if } \frac{N\mu}{t} = \frac{2-5\theta}{8-\theta}. \end{cases}$$

The results were computed using Mathematica.

WIC Infant Share

Figure A1 shows the distribution of WIC infant shares across states in 2020. The information is derived from the WIC Infant data released by United States Department of Agriculture (2025) and the population data for infants provided by Centers for Disease Control and Prevention (2024). Among all states, Utah has the lowest share at 24.14%, while Mississippi has the highest at 63.13%. The majority of states have shares concentrated around 40%.

Figure A1. Distribution of WIC Infant Share Across States in 2024



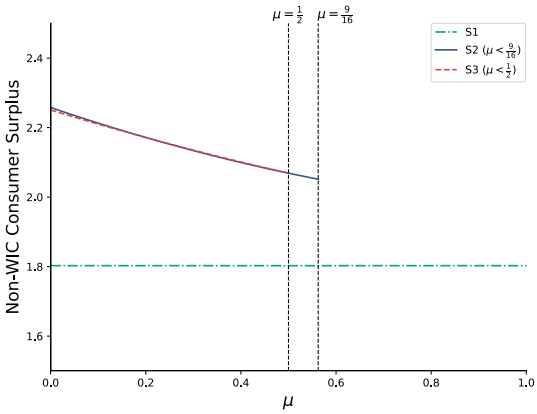
Return on Government Spending

$$\text{RGS in S1} = \frac{CS_1^{NW*} + CS_1^{W*} - CS_1^{NW*}(\theta = 0)}{GS_1^*} = \frac{72cN(-1+\theta)\theta + t(90 - \theta(81 + 13\theta))}{12\theta(6cN(-1+\theta) - t(3+\theta))}$$

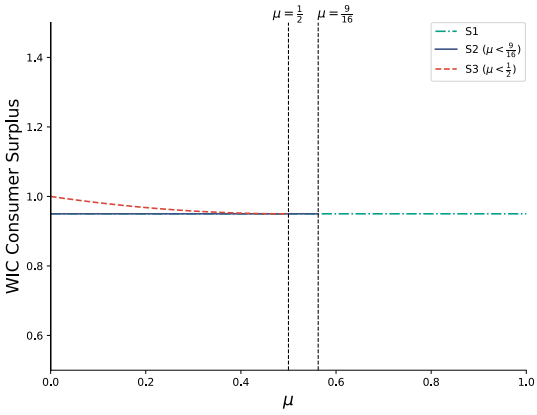
$$\text{RGS in S2} = \frac{CS_2^{NW*} + CS_2^{W*} - CS_2^{NW*}(\theta = 0)}{GS_1^*}$$
$$= \frac{t^2(-88 + \theta(28 + 73\theta)) + 64N^2(-1 + \theta)\theta\mu^2 - 32Nt(-1 + \theta)\theta(9c + 4\mu)}{12t\theta(-24cN(-1 + \theta) + t(2 + 5\theta) - 8N(-1 + \theta)\mu)}$$

$$\text{RGS in S3} = \frac{CS_3^{NW*} + CS_3^{W*} - CS_3^{NW*}(\theta = 0)}{GS_1^*}$$
$$= \frac{t^2 - 72cNt(-1 + \theta) + 4Nt(-5 + 3\theta)\mu + N^2(24 + \theta)\mu^2}{12\,(t^2 - 6cNt(-1 + \theta) + Nt(-3 + \theta)\mu - N^2(-8 + \theta)\mu^2)}$$

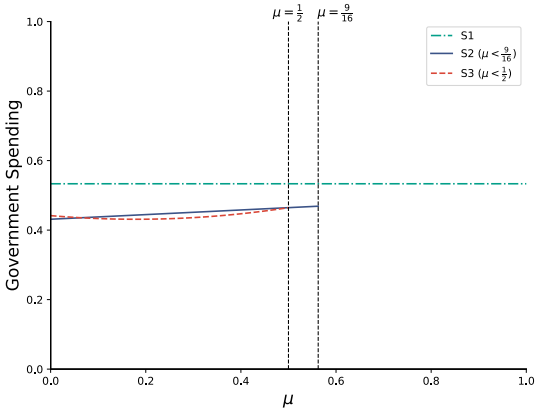
Figure 8: Welfare Comparisons, $\theta = 0.2$



6(a). Non-WIC Consumer Surplus



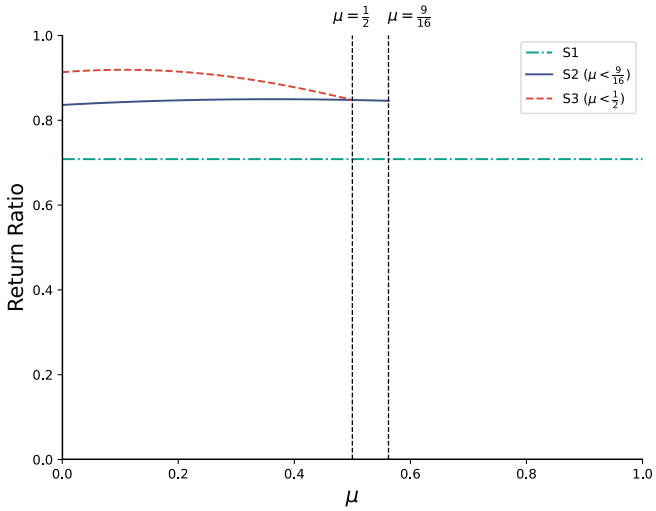
6(b). WIC Consumer Surplus



6(c). Government Spending

Note. The figures are generated using the parameter values $\theta = 0.2$, $V = 5$, $c = 2$, $N = 1$, and $t = 1$. Due to constraints in the FEE of Scenarios 2 and 3, μ cannot take all possible values: (1) When $\mu \in (\frac{1}{2}, \frac{9}{16})$, S3 reverts to S2; (2) When $\mu \geq \frac{2}{3}$, S2 reverts to S1.

Figure 9: Return on Government Spending Excluding Rebates, $\theta = 0.2$



Note. The figure is generated using the parameter values $\theta = 0.4$, $V = 5$, $c = 2$, $N = 1$, and $t = 1$. Due to constraints in the FEE of Scenarios 2 and 3, μ cannot take all possible values (1) When $\mu \in (\frac{1}{2}, \frac{9}{16})$, S3 reverts to S2; (2) When $\mu \geq \frac{2}{3}$, S2 reverts to S1.

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 this appendix, we adopt the framework of Scenario 1 as an illustrative example to outline the necessary conditions for CEE and the corresponding equilibrium outcomes.

Recall that two conditions are required for the Full-Engagement Equilibrium (FEE) to be sustained in Scenario 1. A violation of either condition will lead the market transition for FEE to CEE. The first condition relates 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 no longer have an incentive to lower prices to attract non-WIC consumers. Under these circumstances, W-retailers will align their prices with the caps to maximize their profits. The second condition is about the price caps, as excessively high levels of price caps could also discourage W-retailers from competing in the non-WIC market segment even when $\theta < \frac{3}{5}$. As discussed in Appendix A1, if $(p^{\star}_{w,1} - c)S^{Total*}_{w,1} < (\bar{p}_w - c)\frac{\theta}{N}$, W-retailers will strategicly price

In our settings, when W-retailers strategically price at the regulatory caps, they forgo the market share of non-WIC consumers. As a result, the entire market share of non-WIC consumers is captured by NW-retailers. When $N = 1$, a single NW-retailer will monopolize the non-WIC market segment and adjust its

pricing strategy in response to $\bar{p}_w$. When $N \geq 2$, multiple NW-retailers will compete with their neighboring NW-retailers. The corresponding equilibrium prices, market shares, and profits (CEE) are given by:

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

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

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

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

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

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

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

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

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

The WIC and non-WIC consumer surplus, as well as government direct spending, are outlined below:

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

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

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

Equilibrium Analysis

When $\theta \in (0, \frac{3}{5})$,

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

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

In summary, when the fraction of WIC consumers in the market is sufficiently large, or price caps are set excessively high, W-retailers strategically adjust their pricing to align with the caps. Consequently, the market transitions to a new equilibrium in which W-retailers cater exclusively to WIC consumers, while

NW-retailers capture the entire market share of non-WIC consumers. In markets with $\theta < \frac{3}{5}$, the price caps play a pivotal role in determining market outcomes. Setting excessively high price caps could lead to a substantial decline in non-WIC consumer surplus and a significant increase in government spending.

As observed in Scenario 1, Scenarios 2 and 3 are also subject to a transition from Full-Engagement Equilibrium (FEE) to Competitive Equilibrium (CEE) when WIC consumer shares or price caps reach sufficiently high levels. While the thresholds differ across scenarios, the derivation process and corresponding outcomes are analogous to those described above. Since CEE is not the primary focus of this study, a detailed analysis of Scenarios 2 and 3 is excluded.