WIC's Impact on Retail Competition and Welfare in the U.S. Infant Formula Market

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Abstract

Infant formula prices directly impact infants' nutritional well-being and equity. In the United States, recipients of the Special Supplemental Nutrition Program for Women, Infants, and Children (WIC) can obtain infant formula for free from offline WIC-authorized stores. Concerns arise as retailers may adjust their pricing strategies in response to the predictable increase in demand in WIC-authorized stores. To explain this phenomenon, we develop a spatial market competition model that integrates the role of WIC into retail competition. Our findings show that retail prices of infant formula, especially in WIC-authorized stores, tend to increase with the share of WIC consumers in the market. Once the share of WIC consumers reaches a certain threshold, market competition may no longer effectively restrain pricing in WIC-authorized stores. Price regulation could be crucial beyond this threshold. Furthermore, we compare competitive market equilibria in market structures with and without e-commerce involvement and conclude that enabling WIC recipients to shop online has the potential to improve total consumer welfare while reducing WIC's costs on infant formula and regulation. The findings of our paper will provide much-needed insights to WIC policymakers regarding the feasibility of partnering with online retailers to distribute food benefits.

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JEL: D43, I38, L11, L13

1 Introduction

Public food assistance programs are government initiatives designed to provide food, nutritional support, and basic material assistance to individuals and families facing economic hardship. These programs play an important role in reducing hunger, improving food security, and enhancing the overall well-being and quality of life for vulnerable populations. To distribute program benefits efficiently and cost-effectively, many programs choose to partner with local private stores and let recipients obtain necessities directly from these stores. Public concerns arise as private retailers, especially those program partners, may charge higher prices in response to the predictable increase in demand from the program recipients. The rapid increase in retail prices will not only escalate program spending but also place a financial burden on consumers who do not participate in these programs.

The Special Supplemental Nutrition Program for Women, Infants, and Children (WIC) is one of the public food assistance programs that partner with local private retailers to distribute benefits. WIC is the third-largest public food assistance program in the United States, offering supplemental foods, nutrition education, and health services to low-income pregnant and post-partum women, infants, and children up to age 5 who are at nutritional risk. Infant formula is one of the key benefits WIC provides to its recipients. Eligible WIC recipients can use vouchers or an electronic benefits transfer (EBT) card to redeem specific brands of infant formula for free at local WIC-authorized stores each month. WIC is an influential agent in the U.S. infant formula market as over 50% of infant formula sales are made through WIC. Empirical evidence suggests that WIC contributes to the rising prices of infant formula. (Oliveira, 2004).

While existing literature investigates how WIC influences the strategies of infant formula

manufacturers, the impact of WIC on retail competition is barely explored. In this paper, we employ a spatial retail competition model to explore how WIC could impact retailers' pricing strategies and market shares, consumer welfare, and government spending. Moreover, considering the growing prevalence of online shopping, we modify our model to investigate the implications of the presence of e-commerce and explore whether WIC could benefit from partnering with online retailers to distribute infant formula. As WIC policymakers have been actively preparing online shopping channels for WIC recipients, the findings of our paper provide valuable and much-needed insights for them.

To simulate realistic retail market environments, we model a circular spatial market, following Salop (1979) and Balasubramanian (1998). Salop's circular model has been widely used to study retail competition. The traditional setup is that, in a circular market, offline stores are located at equal distances from each other on the circumference, and consumers are uniformly distributed along the circumference. In the absence of e-commerce, due to the fact that consumers incur a transportation cost to visit any offline store, each retailer has market power in its surrounding market area. When e-commerce enters the market, retail competition becomes more intense. Consumers then decide where to shop based on two major factors: convenience, which is measured by offline transportation costs and online disutility costs, and product prices set by both online and offline retailers. To accommodate the role of WIC, we categorize consumers into WIC and non-WIC consumers, and retailers into WIC-authorized and non-authorized stores. Note that WIC-authorized stores serve both types of consumers, whereas non-authorized stores serve non-participants only.[1] We compute and analyze the market equilibrium under the following three scenarios: (i) a market without online retailers involved, serving as a benchmark; (ii) a market with a non-authorized online retailer; (iii) a market with a WIC-authorized online retailer. Scenario 3 is a hypothetical scenario but is expected to be realized in the next few years.

The results of our paper indicate that WIC may have a broader impact on the retail

[1]In most cases, WIC consumers have no incentive to purchase infant formula at non-authorized stores because they need to pay full retail prices out of pocket at these stores.

market. WIC-authorized and non-authorized stores tend to increase prices to different extents as the share of WIC consumers increases. When the share of WIC consumers reaches a certain level, the best strategy for W-retailers is to stop competing with non-authorized stores for the market share of non-WIC consumers and exclusively serve WIC consumers. As WIC consumers do not respond to price changes, WIC-authorized retailers can charge prices much higher than competitive market prices. Moreover, after comparing consumer welfare and government spending across three different scenarios, we find that implementing a dual-channel distribution system has the potential to improve consumer welfare, reduce WIC spending on infant formula, and lower regulatory costs for WIC-authorized stores.

Our paper contributes to three main areas of research. First and foremost, we contribute to the theoretical literature on spatial market competition. Since Hotbllino (1929) introduced the linear urban spatial competition model, the concept of spatial competition has been widely used for market competition under oligopoly. By extending the Hotelling model, Salop (1979) proposes a circular city model, which better simulates real-world retail competition. With the advent of e-commerce, many studies have modified Salop's circular model to analyze the competition between traditional brick-and-mortar stores and online retailers under various assumptions, e.g., incomplete market information (Balasubramanian, 1998), consumer heterogeneity (Shi, Zhou and Jiang, 2019), different numbers of online retailers (Ford, Li and Zheng, 2021). To the best of our knowledge, we are the first to introduce the role of public food assistance programs into the spatial competition model. The practice of integrating private retailers into the food distribution network has become increasingly common among public assistance programs worldwide. Examples include the United States' SNAP and WIC, the United Kingdom's Health Start, and Canada's NNC. These programs have already become an integral part of the local retail market, reshaping the dynamics of retail competition. Our paper focuses on WIc's impact on retail competition of infant formula and demonstrates how such subsidy methods could influence retailers' pricing strategies. The findings highlight the importance of considering the role of these programs, if applica-

ble, when analyzing contemporary retail competition.

Second, our paper is related closely to the body of research investigating the impact of WIC on infant formula prices. Two methods are commonly used in prior studies: (1) compare the retail prices and sales of WIC-contract brands with those of other brands; (2) compare the changes of a particular brand before and after it is awarded a WIC contract. By analyzing the retail prices of infant formula in supermarkets from 1994 to 2000, Oliveira (2004) find that while a WIC-contract brand is not necessarily the most expensive one on the market, winning a WIC contract leads to a higher retail price for that brand. Empirical evidence also shows that being a WIC-contract brand significantly boosts the sales of that brand on the market, attracting not only WIC but also non-WIC consumers (Huang and Perloff, 2014; Rojas and Wei, 2019; Wang, 2023; An et al., 2023). A theoretical study by Prell (2004) is most relevant to our study. The author employs a Cournot oligopoly model to explore how WIC-authorized stores adjust the supply quantities of WIC contract and non-contract infant formula to maximize their profits. The results show that as the relative size of WIC in the market increases, the equilibrium prices of WIC-contract formula rise, leading to a slight rise in non-contract formula prices due to the substitution effect. Unlike prior studies that compare prices across brands, our paper discusses the price competition among different types of retailers. We show that all types of retailers tend to raise formula prices as the share of WIC consumers increases.

Third, the paper is also related to a growing body of literature on efficiently using public funds to assist vulnerable populations. Wang (2023) and An et al. (2023) focus on the impact of the WIC rebate program on infant formula manufacturers' bidding and pricing strategies. Both studies conduct counterfactual analyses to explore alternative approaches to the current practice of contracting with a single manufacturer. Naylor, Deaton and Ker (2020) and Galloway and Li (2023) study Canada's Nutrition North (NNC) food subsidy in remote, mainly Indigenous communities with limited competition. They find that directly providing subsidies to retailers, the method NNC uses, enables approximately 67% of the

subsidy to be passed through to local consumers. In addition to partnering with private retailers, governments can provide essential goods in various other ways, such as direct provision. For instance, Jiménez Hernández and Seira (2022) explores direct government provision in the context of the milk market in Mexico, finding that government-operated stores participating in retail competition significantly lower market prices for milk and reduce private sellers' market power. Our paper explores efficient ways to distribute foods within the framework of the partnership with private stores. We find that incorporating e-commerce into food distribution systems has the potential to improve consumer surplus and lower program costs.

The rest of the paper is organized as follows. Section 2 provides details about the US infant formula market and the WIC purchasing process. Section 3 sets up the model. In Section 4, we characterize the equilibrium and provide a comparative statics analysis for each scenario. Section 5 conducts welfare comparisons among three scenarios in terms of consumer surplus and government spending. Section 6 concludes.

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). The main types of infant formula are milk- and soy-based, available in three physical forms: liquid concentrate, powder, and ready-to-feed. The milk-based powder is the dominant product in the market, capturing over 78% of the market share.

The wholesale infant formula market in the U.S. 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). Only these three manufacturers have become WIC infant formula suppliers. Both the strict US Food and Drug Administration (FDA) regulations for producing and selling formula[2] and the high tariffs (up to 17.5%) hinder new entrants into the wholesale market. Excessive market concentration has led to significantly higher infant formula procurement costs, which are ultimately passed on to consumers.

According to the Robinson-Patman Act of 1936, local retailers are expected to procure the same product at similar prices. In the wholesale market of infant formula, manufacturers periodically update the lowest national wholesale price for full truckload purchases. (Prell, 2004) states that retailers purchasing less than a full truckload may pay a few pennies more per unit. Therefore, we assume that the differences in procurement costs within local markets are negligible when analyzing retail competition.

Consumers exhibit a relatively inelastic demand for infant formula. The available infant formula brands are limited in the U.S. market, providing consumers with fewer alternatives to switch to. Moreover, although infant formula produced by these existing manufacturers contains similar ingredients, consumers are hesitant to switch brands or feeding methods once their babies develop a preference for a specific brand (Le Huërou-Luron, Blat and Boudry, 2010). It is one of the motivating factors for manufacturers to seek WIC contracts, as being a WIC–contract brand can gain endorsements from doctors (GAO, 1998; Oliveira, Frazao and Smallwood, 2011) and better shelf allocation in WIC-authorized stores (GAO, 2006). Both factors benefit WIC-contract brands in attracting consumers who are new to the market.

[2]The Infant Formula Act of 1980 set strict standards for manufacturers to ensure infant formula provides adequate nutrition. It also requires manufacturers to submit detailed formula information to the FDA and meet specific nutrient content standards.

2.2 WIC's Influence

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 reached 12.13 million, but only 51.2% received WIC benefits (Kessler et al., 2023). The number of eligible households WIC can support depends on the annual Congressional appropriation and the cost of operating the program.

Nowadays, all states choose to distribute WIC foods, including infant formula, through local retail grocery stores.[3] WIC recipients receive food instruments, either paper vouchers or electronic benefits transfer (EBT) cards, to redeem specific types and brands of foods at local authorized stores, and WIC state agencies then allocate funds to reimburse the stores for the total retail price. The food instruments also specify the maximum monthly allowances each recipient can obtain. The authorized quantities are intended to meet recipients' supplemental nutritional needs.

The cost of infant formula is the largest among all WIC food benefits. It was nearly 40% of total WIC food costs in the mid-1980s. To reduce the expenditure on formula, since 1987, WIC state agencies[4] have been using a competitive bidding process in which infant formula manufacturers offer discounts, in the form of rebates, to state WIC programs in order to be selected as the sole formula provider in the state. The manufacturer offering the lowest net wholesale price, calculated as the manufacturer's wholesale price subtracts the rebate, is awarded a three-year exclusive contract. The rebates are typically around 85% of

[3]There were two other ways to distribute WIC foods. Vermont employed a home delivery system to deliver the foods to recipients' homes. In Mississippi and parts of Chicago, IL, a direct distribution system was used, where recipients obtained the foods from storage facilities operated by WIC state agencies.

[4]Some WIC state agencies jointly determine their contract manufacturers to strengthen their bargaining power.

the wholesale price, reducing WIC's expenditure on formula by approximately $1.7 billion annually.

Even with the rebates, spending on infant formula still accounts for around 20% of WIC's total food costs. However, the primary costs of infant formula have shifted from wholesale prices to retail markups.[5] Apart from prohibiting price discrimination between WIC participants and non-WIC consumers, WIC does not impose stringent pricing regulations for WIC-contract infant formula at the WIC-authorized stores.[6] Instead, WIC primarily relies on market competition to ensure competitive retail prices maintained in WIC-authorized stores. However, considering that WIC purchases 57%–68% of infant formula sold in the US, concerns arise that WIC makes the aggregate demand for infant formula less sensitive to price changes, motivating retailers to charge higher prices. Identifying WIC-related price effects at the retail level is extremely difficult since too many other factors may influence retail prices in the real-world market.[7] Hence, in Section 3, we leverage a spatial competition model to explore WIC's impact on retail competition.

To serve WIC participants, private retailers must apply and receive approval from WIC agencies. While the application process is open to all retailers, WIC has established specific standards and eligibility criteria that retailers must meet to become authorized partners. For example, an eligible retailer must offer a variety of WIC-approved foods and meet the minimum stocking requirements for these products. Moreover, the retailer must accept WIC benefits using the designated payment methods, such as WIC EBT cards. WIC state agencies also consider local needs and their own management capacity when determining the maximum number and distribution of WIC-authorized stores. Once the limit is reached, the application process will be temporarily closed. In certain food desert areas, stores that do

[5]Cost to WIC = Net Wholesale Price + Retail Markup, where Net Wholesale Price = Wholesale Price – Rebate, and Retail Markup = Retail Price – Wholesale Price.

[6]Under WIC regulations, each WIC state agency needs to establish pricing ceilings for WIC-authorized stores on WIC food items, but these ceilings are typically set high to accommodate unusual circumstances (Neuberger and Greenstein, 2004).

[7]For example, Oliveira (2004) find that in many local market areas, the retail prices of certain infant formula products are even priced below their listed wholesale prices. It indicates that many retailers utilize infant formula as loss leaders to draw customers into their stores.

not fully meet the standard requirements may be approved to serve WIC consumers.[8]

2.3 Online Shopping

E-commerce has revolutionized the way consumers shop by offering unparalleled convenience and accessibility. With just a click of a button, consumers can purchase items from e-commerce retailers anytime and anywhere. Recognizing this shift, the USDA has been actively promoting online shopping channels for recipients of public food assistance programs.

One notable example is the Supplemental Nutrition Assistance Program (SNAP), another USDA-administered program, which has already partnered with online retailers to distribute food benefits. Currently, SNAP recipients in most states can use their SNAP EBT cards to purchase eligible items online from platforms like Amazon and other approved hybrid retailers. This initiative has proven especially beneficial during the pandemic, providing much-needed convenience to SNAP recipients. By analyzing SNAP online pilot data, Makioka (2018) find that allowing recipients to use benefits online can increase their welfare by at least $15 per quarter due to easier access to retail stores.

WIC is still in the preparation and pilot phase of developing its online shopping channels.[9] As part of this initiative, WIC has been gradually transitioning from paper vouchers to EBT cards. In mid-2024, the WIC agencies in Nebraska, Minnesota, and Iowa partnered with Hy-Vee, a hybrid retailer, to launch online shopping pilots in these three states. It is worth noting that while WIC recipients in these states have the option to order online using their WIC EBT card, the delivery fees must still be paid out of pocket.

According to a survey conducted by Nitto et al. (2022), a significant portion of WIC recipients are eager for the launch of online shopping channels. Once online shopping becomes available, some WIC recipients are expected to switch to this option, which will affect both

[8]For more information regarding WIC-authorized stores, visit https://www.fns.usda.gov/wic/retail-store-factsheet.

[9]For more details, visit https://www.fns.usda.gov/news-item/fns-005.23.

offline and online retailers' pricing strategies. Motivated by this, in Section 3, we also compute and analyze the market competitive equilibria with e-commerce involved, and in Section 4, we explore the potential benefits of WIC partnering with online retailers to distribute food benefits.

3 The Model

Table 1: Notations

Decision Variables	
p_i	Formula retail price set by i-retailers, where $i \in \{w, nw, e\}$.
Model Parameters	
N	Number of W-retailers and number of NW-retailers.
t	Travel costs per unit distance when visiting an offline store.
μ	Consumers' disutility from purchasing formula online.
V	Consumers' valuation of the formula.
θ	Fraction of WIC consumers in the market.
Other notations	
π_i	Profit earned by each i-retailer.
S_i^j	Market share of j-type consumers for i-retailer, where $j \in \{W, NW\}$.
CS^j	Surplus for j type of consumers.
l	Length between a consumer's location and an offline retailer.
x	The furthest distance a W-retailer serves non-WIC consumers.
y	The furthest distance a NW-retailer serves non-WIC consumers.
z	The furthest distance a W-retailer serves WIC consumers.

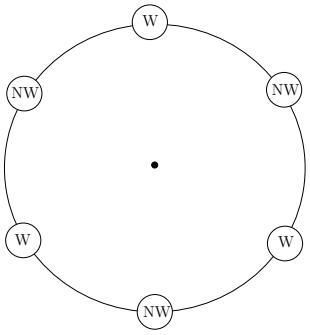
As mentioned earlier, we model a circular spatial market to analyze WIC's impact on retail competition for infant formula. We assume that several retailers engage in price competition for a single brand of infant formula. This specific brand is under contract with WIC in the local market.

The model setup is as follows: a measure 1 of consumers is uniformly distributed along a circular market. Each consumer needs to purchase a single unit of infant formula in each period. Consumers fall into two categories: a fraction θ (where $\theta \in [0, 1]$) are WIC consumers, while the remaining fraction, $1 - \theta$, are non-WIC consumers. V represents the consumer's

valuation of the formula.[10] We assume that consumer demand is inelastic, which means the consumer's valuation exceeds the expenses incurred to obtain the formula.

Offline retail stores, denoted by either W- or NW-retailers, are located at equal distances from each other on the circumference. W-retailers represent WIC-authorized stores serving both non-WIC and WIC consumers, while NW-retailers represent non-authorized stores serving non-WIC consumers only. To simplify, we assume that there are N of W-retailers and N of NW-retailers (where $N \geq 1$), located in an alternating pattern (See an example in *Figure 1*). p_w and p_{nw} represent the prices set by W-retailers and NW-retailers, respectively.

Figure 1: The Circular Market, N=3



Consumers incur travel costs at a (linear) rate t (t>0) per unit distance when visiting an offline retailer. As t increases, each consumer's preference for the nearest store is strengthened and offline retailers are increasingly differentiated. The travel distance for a consumer to an offline store is $|l_c|$. The travel distance varies for each consumer, depending on their location and the location of the offline retailer they visit. A non-WIC consumer's net utility from purchasing at a W-retailer is $V - t|l_c| - p_w$ and at a NW-retailer is $V - t|l_c| - p_{nw}$. A WIC consumer's net utility from purchasing at a W-retailer is $V - t|l_c|$.[11]

When an e-commerce retailer, denoted by E-retailer, enters the market, it is located at the center of the circular market. p_e represents the price set by the E-retailer. A non-WIC

[10]Here, we can define two parameters to separately represent the valuations of high-income and low-income consumers for the formula, such as V_h and V_l, where $V_h > V_l$, but this will not change our main conclusions.

[11]This expression is easily adjusted to fit other public assistance programs, such as $V - (p_w - a) - t|l_c|$, where a represents the subsidy provided by the program to its participants.

consumer's net utility from purchasing at the E-retailer is $V - \mu - p_e$. The parameter μ ($\mu > 0$) measures consumers' disutility from purchasing infant formula online. It refers to various costs associated with online shopping, such as delivery costs, membership fees, and the opportunity costs of waiting. The online channel will not be available to WIC consumers until the E-retailer becomes a WIC-authorized store. A WIC consumer's net utility from purchasing online is $V - \mu$.[12]

We assume that all retailers have the same marginal cost. This assumption holds due to the negligible differences in procurement costs. For simplicity, we continue to normalize retailers' marginal costs to 0. Since all retailers in our model are incumbents, we assume that their fixed costs are equal to 0 as well.

The timing of the game is the following. Given all stores' locations and types, each retailer sets the retail price of infant formula independently and simultaneously to maximize its own profit. Then, each consumer decides where to purchase the product to maximize her own utility.

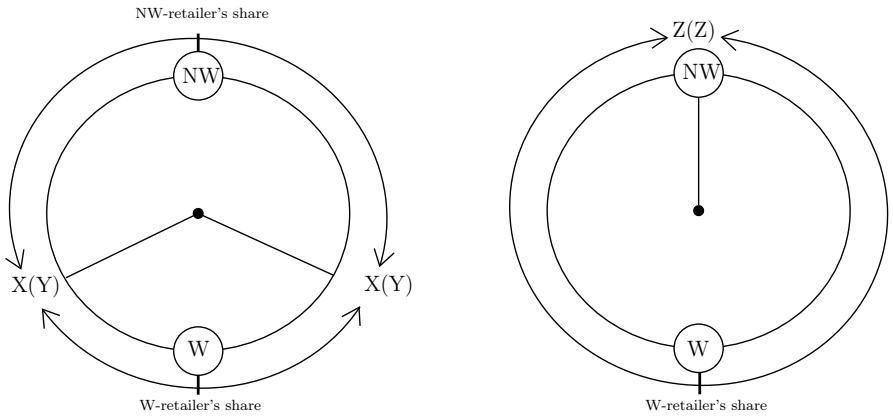
4 Equilibrium Analysis

4.1 Analysis of Scenario 1

We start with the simple scenario where e-commerce is not available in the market. In this scenario, multiple W-retailers and 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-retailer. To solve for the symmetric equilibrium of market competition, we follow Balasubramanian (1998)'s approach and derive the market equilibrium by initially locating the position of a marginal consumer.

Non-WIC consumers can purchase infant formula from either W-retailers or NW-retailers.

[12]We note that major online retailers, such as Amazon and Walmart, have introduced exclusive benefits for consumers participating in public assistance programs, such as discounted membership fees. However, here we still assume that μ remains consistent for both types of consumers.



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

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

When choosing where to shop, they consider both retail prices and transportation costs. We identify a point between a W-retailer and one of its neighboring NW-retailer, where a non-WIC consumer is indifferent between purchasing from these two retailers. As shown *Figure 2(a)*, the distance from the W-retailer to this point is x, while the distance from the NW-retailer to this point is y. Given that the distance between each W-retailer and its neighboring NW-retailer is $\frac{1}{2N}$, we can get $y = \frac{1}{2N} - x$. Thus, we have

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

which is equivalent to

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

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 $2(1-\theta)y$. From Equation (2), we obtain

$$S_w^{NW} = 2(1-\theta)x = (1-\theta)\left(\frac{1}{2N} + \frac{p_{nw} - p_w}{t}\right) \tag{3}$$

$$S_{nw}^{NW} = 2(1-\theta)y = (1-\theta)\left(\frac{1}{2N} - \frac{p_{nw} - p_w}{t}\right) \tag{4}$$

WIC consumers in this scenario can only obtain infant formula from a W-retailer. The only factor influencing their decision is the travel distance to W-retailers. Similarly, we find 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 z. The market share of WIC consumers for each W-retailer, denoted by S_w^W, is $2\theta z$. Based on our assumption that W-retailers are evenly distributed, all W-retailers receive an equal market share of WIC consumers. Thus, we have

$$S_w^W = 2\theta z = \frac{\theta}{N} \tag{5}$$

When there is only one W-retailer in the market, this W-retailer captures the entire market share of WIC consumers, as shown in *Figure 2(b)*.

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

$$\max_{p_w} \pi_w = p_w \left[(1-\theta)\left(\frac{1}{2N} + \frac{p_{nw} - p_w}{t}\right) + \frac{\theta}{N}\right] \tag{6}$$

$$\max_{p_{nw}} \pi_{nw} = p_{nw}(1-\theta)\left(\frac{1}{2N} - \frac{p_{nw} - p_w}{t}\right) \tag{7}$$

Proposition 1(a). *Under the assumptions of the model, a unique (pure strategy) Bertrand-Nash equilibrium exists when* $\theta < \frac{3}{5}$. *Equilibrium prices, market shares (market shares of non-WIC consumers, WIC consumers, and combined), and profits are given by:*

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

$$S_w^{NW*} = \frac{3-5\theta}{6N}; \qquad S_{nw}^{NW*} = \frac{3-\theta}{6N}$$

$$S_w^{W*} = \frac{\theta}{N}; \qquad S_{nw}^{W*} = 0$$

$$S_w^{Total*} = \frac{3+\theta}{6N}; \qquad S_{nw}^{Total*} = \frac{3-\theta}{6N}$$

$$\pi_w^* = \frac{t(3+\theta)^2}{36N^2(1-\theta)}; \qquad \pi_{nw}^* = \frac{t(3-\theta)^2}{36N^2(1-\theta)}$$

PROOF. See Appendix A1.

For the equilibrium above to be sustained, W-retailers must derive a positive market share of non-WIC consumers. Accordingly, we obtain the condition $\theta < \frac{3}{5}$. When $\theta = 0$, indicating the absence of WIC, there is no difference between W-retailers and NW-retailers. In this case, they set the same prices, equal to $\frac{t}{2N}$. With the presence of WIC ($\theta > 0$), W-retailers start to gain competitive advantage. We find that 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. The gaps in prices, market shares, and profits are increasing monotonically in θ with this range.

Moreover, when $\theta \in (0, \frac{3}{5})$, both p_w^* and p_{nw}^* are increasing in θ. The growth in p_{nw}^* is intuitive as the increase in the share of WIC consumers in the market motivates W-retailers to charge high prices. The logic regarding the growth of p_{nw} is that NW-retailers gain greater market power in the non-WIC market segment when W-retailers raise their prices.[13] This finding indicates that simply comparing prices in WIC-authorized stores and non-authorized stores may lead to inaccurate estimates of WIC's impact. Additionally, both p_w^* and p_{nw}^* are increasing in t and decreasing in N. An increase (decrease) in transportation costs makes consumers less (more) sensitive to price changes.

[13]The gap between S_{nw}^{NW*} and S_w^{NW*}, which is $\frac{2\theta}{3N}$, is increasing in θ. This means that as θ rises, more non-WIC consumers switch from their neighboring W-retailers to neighboring NW-retailers to purchase infant formula.

Proposition 1(b). *When $\theta \geq \frac{3}{5}$, W-retailers' optimal strategy is to serve WIC consumers only. As a result, their pricing is no longer constrained by market competition. All the market share of non-WIC consumers is obtained by NW-retailers. The equilibrium prices and market shares of NW-retailers are given by*

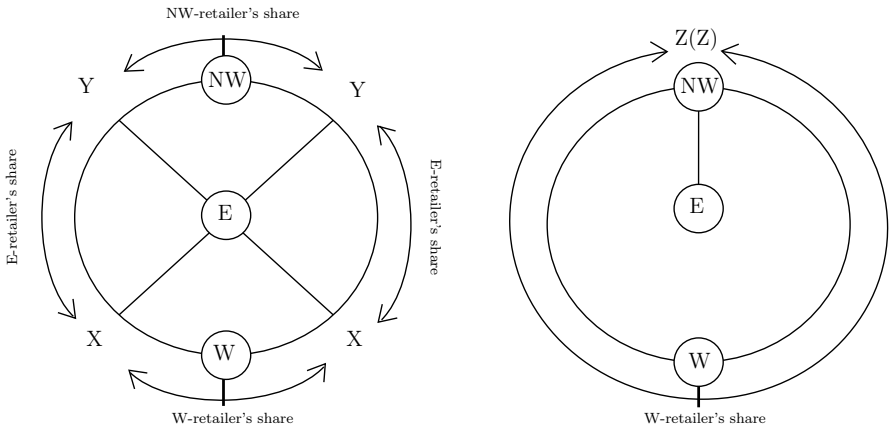
$$\begin{cases} \tilde{p}_{nw}^{*} = V - \frac{t}{2}; \tilde{S}_{nw}^{NW*} = 1 - \theta; \tilde{\pi}_{nw}^{*} = (V - \frac{t}{2})(1 - \theta) & \text{when } N = 1 \\ \tilde{p}_{nw}^{*} = \frac{t}{N}; \tilde{S}_{nw}^{NW*} = \frac{1-\theta}{N}; \tilde{\pi}_{nw}^{*} = \frac{t(1-\theta)}{N^2} & \text{when } N \geq 2 \end{cases} \tag{8}$$

The stores that exclusively serve WIC consumers are called WIC-only stores. Given that WIC consumers are completely price-insensitive, WIC-only stores can charge much higher than market-competitive prices. In this scenario, when $\theta \geq \frac{3}{5}$, W-retailers have no incentive to set competitive prices to attract non-WIC consumers anymore. At this point, price regulation by WIC is crucial to restrain W-retailers from charging extremely high prices.

Due to the high formula prices charged by W-retailers, all non-WIC consumers have no choice but to purchase infant formula from NW-retailers. When $N = 1$, a single NW-retailer monopolizes the non-WIC market segment and sets the price at $V - \frac{t}{2}$. When $N \geq 2$, due to competition among NW-retailers, the equilibrium price of each NW-retailer is fixed at $\frac{t}{N}$, and all NW-retailers receive an equal market share of non-WIC consumers, which is $\frac{1-\theta}{N}$.

4.2 Analysis of Scenario 2

In this scenario, we assume that an E-retailer enters the market and competes with offline retailers in the non-WIC market segment. With the presence of the E-retailer, W-retailers and NW-retailers no longer compete directly with each other, as non-WIC consumers who live far from their neighboring offline stores will choose to purchase formula from the E-retailer (See *Figure 3(a)*). Using a similar approach, we identify a point where a non-WIC consumer is indifferent between purchasing from his closest W-retailer and the E-retailer. The distance from the W-retailer to this point is x. Thus, we have,



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

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

$$V - tx - p_w = V - \mu - p_e, \tag{9}$$

which is equivalent to

$$x = \frac{p_e - p_w + \mu}{t}. \tag{10}$$

Similarly, a non-WIC consumer located at a distance y from a NW-retailer is indifferent between purchasing from his nearest NW-retailer and the E-retailer when

$$V - ty - p_{nw} = V - \mu - p_e, \tag{11}$$

which is equivalent to

$$y = \frac{p_e - p_{nw} + \mu}{t}. \tag{12}$$

Note that 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 $2(1-\theta)y$; and that for the e-commerce E-retailer, denoted by S_e^{NW}, is equal to $(1-\theta)(1-2Nx-2Ny)$. Thus we have

$$S_w^{NW} = 2(1-\theta)x = \frac{2(1-\theta)\left(p_e - p_w + \mu\right)}{t} \tag{13}$$

$$S_{nw}^{NW} = 2(1-\theta)y = \frac{2(1-\theta)\left(p_e - p_{nw} + \mu\right)}{t} \tag{14}$$

$$S_e^{NW} = (1-\theta)\left[1 - \frac{2N\left(p_e - p_w + \mu\right)}{t} - \frac{2N\left(p_e - p_{nw} + \mu\right)}{t}\right] \tag{15}$$

As online shopping is not available to WIC consumers in this scenario, they still need to obtain the infant formula from W-retailers, the same as in Scenario 1. The market share of WIC consumers for each W-retailer is

$$S_w^W = 2\theta z = \frac{\theta}{N} \tag{16}$$

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

$$\max_{p_w} \pi_w = p_w\left[\frac{2(1-\theta)(p_e - p_w + \mu)}{t} + \frac{\theta}{N}\right] \tag{17}$$

$$\max_{p_{nw}} \pi_{nw} = p_{nw}\frac{2(1-\theta)(p_e - p_{nw} + \mu)}{t} \tag{18}$$

$$\max_{p_e} \pi_e = p_e(1-\theta)\left(1 - \frac{2N\left(p_e - p_w + \mu\right)}{t} - \frac{2N\left(p_e - p_{nw} + \mu\right)}{t}\right) \tag{19}$$

Proposition 2(a). *Under the assumptions of the model, a unique (pure strategy) Bertrand-Nash equilibrium exists when* $\mu < \frac{t(2-\theta)}{4N(1-\theta)}$ *and* $\theta < \frac{2t+8N\mu}{7t+8N\mu}$*. Equilibrium prices, market shares, and profits are given by:*

$$p_w^* = \frac{t}{12N} + \frac{7t\theta}{24N(1-\theta)} + \frac{\mu}{3}; \quad p_{nw}^* = \frac{t}{12N} + \frac{t\theta}{24N(1-\theta)} + \frac{\mu}{3}; \quad p_e^* = \frac{t}{6N} + \frac{t\theta}{12N(1-\theta)} - \frac{\mu}{3}$$

$$S_w^{NW*} = \frac{2-7\theta}{12N} + \frac{2\mu(1-\theta)}{3t}; \quad S_{nw}^{NW*} = \frac{2-\theta}{12N} + \frac{2\mu(1-\theta)}{3t}; \quad S_e^{NW*} = \frac{2-\theta}{3} - \frac{4N\mu(1-\theta)}{3t}$$

$$S_w^{W*} = \frac{\theta}{N}; \quad S_{nw}^{W*} = 0; \quad S_e^{W*} = 0$$

$$S_w^{Total*} = \frac{2+5\theta}{12N} + \frac{2(1-\theta)\mu}{3t}; \quad S_{nw}^{Total*} = \frac{2-\theta}{12N} + \frac{2(1-\theta)\mu}{3t}; \quad S_e^{Total*} = \frac{2-\theta}{3} - \frac{4N(1-\theta)\mu}{3t}$$

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

PROOF. See Appendix A2.

For equilibrium to be sustained, both W-retailers and the E-retailer must obtain a positive market share in the non-WIC market segment. Accordingly, we obtain the conditions $\theta < \frac{2t+8N\mu}{7t+8N\mu}$ and $\mu < \frac{t(2-\theta)}{4N(1-\theta)}$. When $\theta < \frac{2t+8N\mu}{7t+8N\mu}$, W-retailers are willing to serve both WIC and non-WIC consumers. $\mu < \frac{t(2-\theta)}{4N(1-\theta)}$ is the prerequisite for the E-retailer to enter the non-WIC market segment. Let's first discuss the situation in which both conditions are satisfied.

When $\theta = 0$, the market equilibrium is consistent with that of Balasubramanian (1998).[14] Similar to what we find in Scenario 1, the presence of WIC ($\theta > 0$) leads to higher formula prices as p_w^*, p_{nw}^*, and p_e^* are increasing in θ. Moreover, p_w^*, p_{nw}^*, and p_e^* are increasing in t, and decreasing in N. While p_w^* and p_{nw}^* is increasing in μ, p_e^* is decreasing in μ.

Comparing the market equilibrium between two types of offline 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. The gaps between W-retailers and NW-retailers are increasing monotonically in θ.

Next, we compare the market equilibrium between W-retailers and the E-retailer. μ, defined as consumer disutility of shopping online, plays an important role in determining which type of retailers have a competitive advantage in the market. W-retailers set higher prices than the E-retailers when $\mu > \frac{t(2-7\theta)}{16N(1-\theta)}$, but lower prices when $\mu < \frac{t(2-7\theta)}{16N(1-\theta)}$. Comparing

[14] Note that in Balasubramanian (1998)'s model, N=1 represents a single offline retailer, while in my model, it represents two offline retailers: a W-retailer and an NW-retailer.

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, NS_w^{Total*} when $\mu > \frac{t(2-3\theta)}{8N(1-\theta)}$, but smaller when $\mu < \frac{t(2-3\theta)}{8N(1-\theta)}$.

Proposition 2(b). *When $\mu \geq \frac{t(2-\theta)}{4N(1-\theta)}$, the E-retailer does not enter the non-WIC market segment. Consequently, the game returns to Scenario 1.*

The E-retailer has no incentive to enter the non-WIC market segment if it cannot obtain a positive market share of non-WIC consumers. As a result, the game returns to Scenario 1 when $\mu \geq \frac{t(2-\theta)}{4N(1-\theta)}$. In Balasubramanian (1998), the E-retailer's entry threshold depends on N, t and μ. However, with the presence of WIC, the threshold is also affected by θ. The E-retailer is more likely to enter the non-WIC market segment as θ increases. It is because offline retailers charge higher prices as the share of WIC consumers goes up, lowering the entry barrier for the E-retailer.

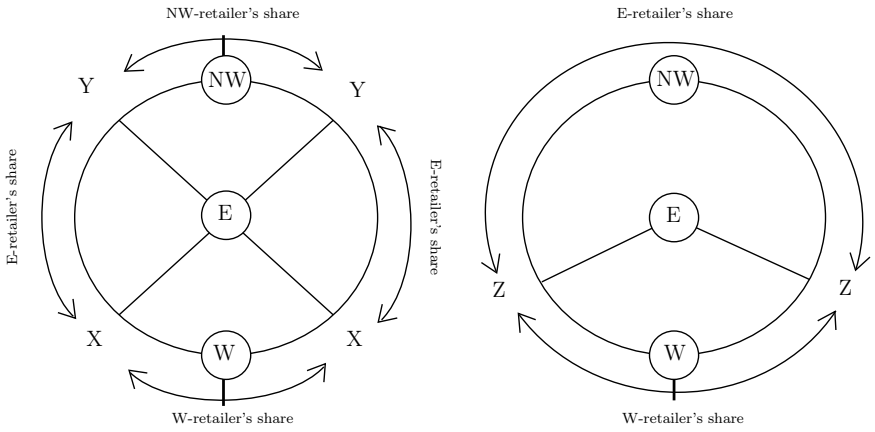
Proposition 2(c). *When $\mu < \frac{t(2-\theta)}{4N(1-\theta)}$ but $\theta \geq \frac{2t+8N\mu}{7t+8N\mu}$, the optimal strategy for W-retailers is to serve WIC consumers only. The entire market share of non-WIC consumers is obtained by NW-retailers and the E-retailer. The equilibrium prices of NW-retailers and E-retailers are given by:*

$$\tilde{p}_{nw}^* = \frac{t}{6N} + \frac{\mu}{3}; \quad \tilde{p}_e^* = \frac{t}{3N} - \frac{\mu}{3}$$

When $\theta \geq \frac{2t+8N\mu}{7t+8N\mu}$, W-retailers have no incentives to set competitive prices to attract non-WIC consumers. They serve WIC consumers only by charging extremely high prices. NW-retailers and the E-retailer continue to compete with each other in the non-WIC market segment. Since this situation is not our main focus, we will not delve into a deeper discussion.

3.3 Analysis of Scenario 3

This is a hypothetical scenario. In this scenario, we assume that the E-retailer is eligible to apply for WIC authorization and enter the WIC market segment. When the E-retailer is



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

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

approved as a WIC-authorized online retailer, the shopping strategy for non-WIC consumers remains the same as in Scenario 2, while WIC consumers gain an additional channel to purchase infant formula (See *Figure 4*). We skip the analysis 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 E-retailer when

$$V - tz = V - \mu, \tag{20}$$

which is equivalent to

$$z = \frac{\mu}{t}. \tag{21}$$

Thus, the market share of WIC consumers for each W-retailer is changed to

$$S_w^W = 2\theta z = \frac{2\theta\mu}{t} \tag{22}$$

and the market share of WIC consumers for the E-retailer is

$$S_e^W = \theta(1-2Nz) = \theta\left(1-\frac{2N\mu}{t}\right) \tag{23}$$

We assume that it takes a negligible cost for the E-retailer to become a WIC-authorized retailer (compared to its future payoff in the WIC market segment). Even so, the E-retailer has the incentives to enter the WIC market segment only when $S_e^{W*} > 0$, which means $\mu < \frac{t}{2N}$.

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

$$\max_{p_w} \pi_w = p_w\left[\frac{2(1-\theta)(p_e-p_w+\mu)}{t}+\frac{2\theta\mu}{t}\right] \tag{24}$$

$$\max_{p_{nw}} \pi_{nw} = p_{nw}\frac{2(1-\theta)(p_e-p_{nw}+\mu)}{t} \tag{25}$$

$$\max_{p_e} \pi_e = p_e\left[(1-\theta)\left(1-\frac{2N\left(p_e-p_w+\mu\right)}{t}-\frac{2N\left(p_e-p_{nw}+\mu\right)}{t}\right)+\theta\left(1-\frac{2N\mu}{t}\right)\right] \tag{26}$$

Proposition 3(a). *Under the assumptions of the model, a unique (pure strategy) Bertrand-Nash equilibrium in prices exists when* $\mu < \min\left(\frac{t}{2N}, \frac{t(2-3\theta)}{4N(1-2\theta)}\right)$ *and* $\theta < \frac{t+4N\mu}{11N\mu}$. *Equilibrium prices, market shares, and profits are given by:*

$$p_w^* = \frac{t}{12N(1-\theta)}+\frac{5\mu\theta}{12(1-\theta)}+\frac{\mu}{3}; \quad p_{nw}^* = \frac{t}{12N(1-\theta)}-\frac{\mu\theta}{12(1-\theta)}+\frac{\mu}{3}; \quad p_e^* = \frac{t}{6N(1-\theta)}-\frac{\mu\theta}{6(1-\theta)}-\frac{\mu}{3}$$

$$S_w^{NW*} = \frac{1}{6N}+\frac{\mu(4-11\theta)}{6t}; \quad S_{nw}^{NW*} = \frac{1}{6N}+\frac{\mu(4-5\theta)}{6t}; \quad S_e^{NW*} = \frac{2}{3}-\theta-\frac{4N\mu(1-2\theta)}{3t}$$

$$S_w^{W*} = \frac{2\theta\mu}{t}; \quad S_{nw}^{W*} = 0; \quad S_e^{W*} = \theta-\frac{2N\mu\theta}{t}$$

$$S_w^{Total*} = \frac{1}{6N}+\frac{(4+\theta)\mu}{6t}; \quad S_{nw}^{Total*} = \frac{1}{6N}+\frac{(4-5\theta)\mu}{6t}; \quad S_e^{Total*} = \frac{2}{3}-\theta-\frac{4N\mu(1-2\theta)}{3t}$$

$$\pi_w^* = \frac{[t+N\mu(4+\theta)]^2}{72N^2t(1-\theta)}; \quad \pi_{nw}^* = \frac{[t+N\mu(4-5\theta)]^2}{72N^2t(1-\theta)}; \quad \pi_e^* = \frac{[t-N\mu(2-\theta)]^2}{9Nt(1-\theta)}$$

PROOF. See Appendix A3.

Two conditions need to be satisfied in equilibrium. First, $\mu < \min\left(\frac{t}{2N}, \frac{t(2-3\theta)}{4N(1-2\theta)}\right)$ so that the E-retailer can obtain a positive market share in both market segments. Second, $\theta < \frac{t+4N\mu}{11N\mu}$ so that W-retailers can obtain a positive market share in the non-WIC segment market.

When $\theta = 0$, we obtain the same market equilibrium as in Scenario 2 with $\theta = 0$. Consistent with the findings from the previous two scenarios, the presence of WIC results in higher formula prices. p_w^*, p_{nw}^*, and p_e^* are increasing in θ and t, and decreasing in N. p_w^* is increasing in μ, while p_e^* is decreasing in μ. The effect of μ on p_{nw}^* depends on θ. When $\theta < \frac{4}{5}$, p_{nw}^* increase with μ; and vice versa.

In this scenario, W-retailers still have a competitive advantage over NW-retailers when $\theta > 0$. 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. The gap widens as θ increases, but it is smaller compared to Scenario 2.

Comparing the market equilibrium between W-retailers and the E-retailer, W-retailers set higher prices than the E-retailer when $\mu > \frac{t}{7N}$, but lower prices when $\mu < \frac{t}{7N}$; the total market share obtained by all W-retailers is greater than the total market share obtained by the E-retail when $\mu > \frac{t}{N(4-\theta)}$, but smaller when $\mu < \frac{t}{N(4-\theta)}$.

Proposition 3(b). *When $\mu \geq \frac{t}{2N}$, the E-retailer will not apply for WIC authorization even if it is eligible. Thus, the game returns to Scenario 2.*

When $\mu \geq \frac{t}{2N}$, the E-retailer cannot obtain a positive market share in the WIC segment of the market. In this situation, the E-retailer has no incentive to apply to become a WIC-authorized store. The game returns to Scenario 2.

Proposition 3(c). *When $\mu < \frac{t}{2N}$ but $\theta \geq \frac{t+4N\mu}{11N\mu}$, W-retailers exit the non-WIC segment of the market and serve WIC consumers only. When $\frac{t(2-3\theta)}{4N(1-2\theta)} \leq \mu < \frac{t}{2N}$, the E-retailer exits the non-WIC segment of the market and focuses on the WIC segment.*

When $\theta \geq \frac{t+4N\mu}{11N\mu}$, W-retailers will no longer consider to attract non-WIC consumers. A similar situation occurs with the E-retailer when $\frac{t(2-3\theta)}{4N(1-2\theta)} \leq \mu$. Both situations require WIC to implement price regulation; otherwise, retailers will set extremely high prices for WIC

consumers. Note that only when $\theta < 0.5$, $\frac{t(2-3\theta}{4N(1-2\theta)}$ is smaller than $\frac{t}{2N}$. Therefore, when the share of WIC consumers reaches half of the total share in the market, WIC agencies need to pay special attention to the pricing strategies of online retailers. In some circumstances, partnering with online retailers may increase WIC's regulatory costs.

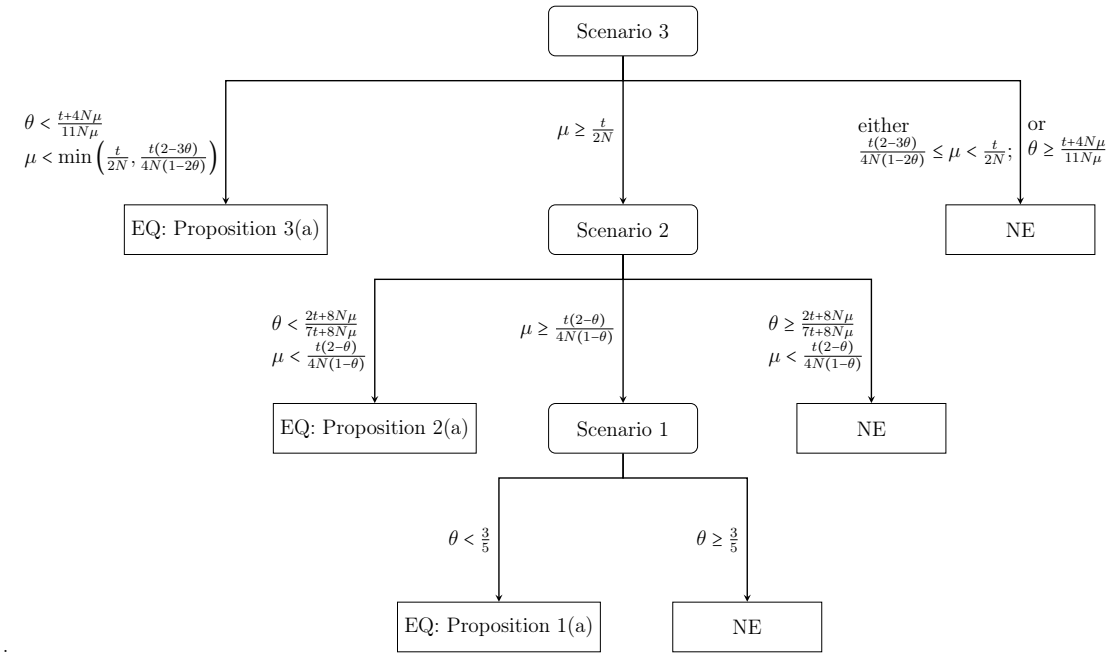


Figure 5: Market Structures without WIC regulation
EQ: competitive equilibrium; NE: no equilibrium.

Figure 5 summarizes all the situations we discussed in this section. It illustrates how market structures will vary based on different values of the parameter after the WIC market segment is open to online retailers. Further exploration of the corresponding consumer welfare and government spending is necessary to assess the advantages and disadvantages of promoting an online distribution channel.

5 Welfare Comparisons

In this section, we conduct a welfare comparison among these three scenarios to find the optimal market structure for different sets of parameter values. The derivations of consumer surplus and government spending for each scenario are detailed in Appendices A1 through

A3, respectively, and the outcomes are reported in *Table 2*. Note that we primarily focus on market competitive equilibria.

Table 2: Consumer surplus and government spending

Scenario	$\mathbf{CS^{NW*}}$	$\mathbf{CS^{W*}}$	$\mathbf{GS^{*}}$
1.	$V(1-\theta) - \frac{t(5\theta^2-54\theta+45)}{72N(1-\theta)}$	$(V - \frac{t}{4N})\theta$	$\frac{t\theta(3+\theta)}{6N(1-\theta)}$
2.	$V(1-\theta) + \frac{t(\theta^2+56\theta-44)}{288N(1-\theta)} + \frac{2N\mu^2(1-\theta)}{9t} - \frac{\mu(5-4\theta)}{9}$	$(V - \frac{t}{4N})\theta$	$\frac{t\theta(2+5\theta)}{24N(1-\theta)} + \frac{\mu\theta}{3}$
3.	$V(1-\theta) + \frac{N\mu^2(73\theta^2-64\theta+16)}{72t(1-\theta)} - \frac{t(11-12\theta)}{72N(1-\theta)} - \frac{\mu(15\theta^2-23\theta+10)}{18(1-\theta)}$	$(V - \mu + \frac{N\mu^2}{t})\theta$	$\frac{[t^2-Nt\mu(3-\theta)+N^2\mu^2(8-\theta)]\theta}{6N(1-\theta)}$

Note. All outcomes are computed assuming the required conditions are met.

The non-WIC consumer surplus is calculated by summing the difference, for each non-WIC customer, between the consumer's valuation of the infant formula and all the costs incurred by that customer to purchase the formula. The calculation of the WIC consumer surplus is similar to that of the non-WIC consumer surplus, with the only difference being that WIC participants do not bear the cost of infant formula. As mentioned earlier, WIC's costs on infant formula are primarily attributable to net wholesale price and retail markup. When calculating government spending, we focus solely on the retail markup, assuming that the net wholesale prices do not vary across different scenarios. Therefore, government spending is simply the sum of the retail prices paid by WIC for each WIC consumer.

To conduct a welfare comparison among the three scenarios, we need to ensure that all the required conditions are simultaneously satisfied. For all the required conditions, $\frac{t}{N\mu} > 2$ is the most important, as it is the prerequisite for the E-retailer to have the incentive to enter the WIC market segment. Based on this condition, we establish three levels for the ratio of $\frac{t}{N\mu}$: 2.5, 4, and 6, representing low, medium, and high levels, respectively.

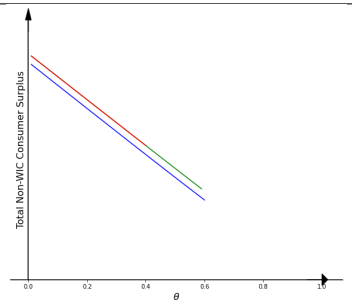
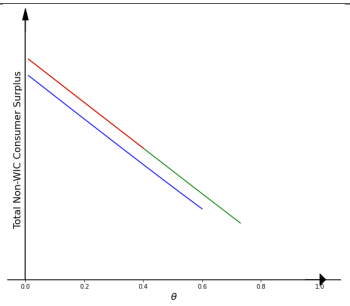
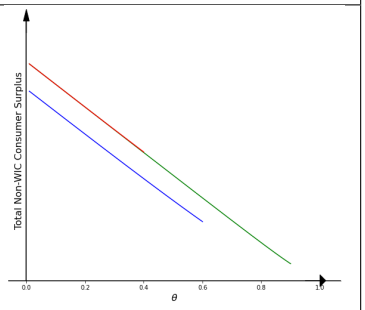
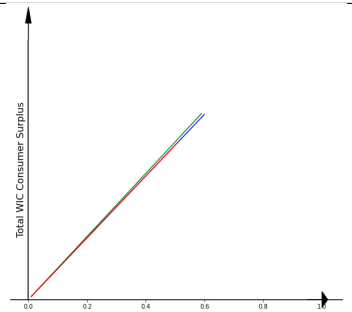
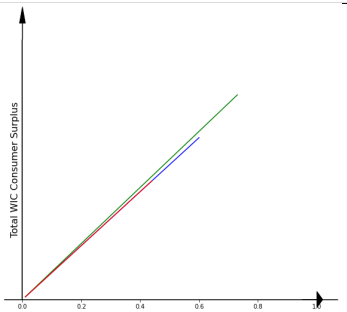
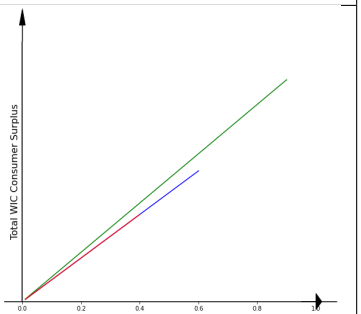
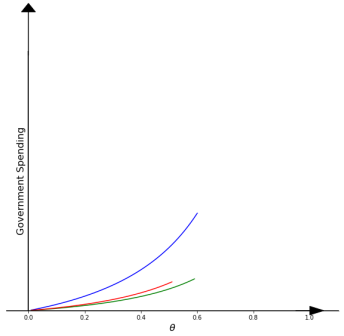
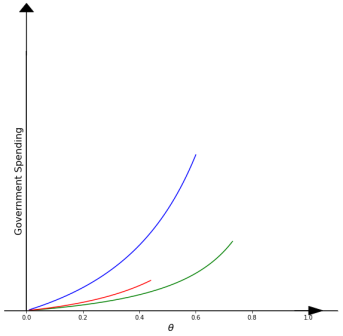
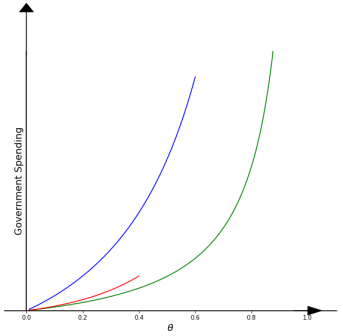
Table 3 presents the charts illustrating θ and each outcomes for each scenario at each level. The relationship between θ and non-WIC consumer surplus is shown in row 1, θ and WIC consumer surplus in row 2, and θ and government spending in row 3. In each chart, the blue line represents Scenario 1, red represents Scenario 2, and green represents Scenario 3.

It is straightforward that the non-WIC consumer surplus decreases while the WIC consumer surplus and government spending increase as θ, the share of WIC consumers in the market, increases.

Several key insights are provided in *Table 3*. First, let's compare the outcomes of Scenario 1 and Scenario 2. The green line is above the blue line in Row 1, which means the presence of the E-retailer significantly increases the non-WIC consumer surplus. The growth comes from two sources: on the one hand, some non-WIC consumers benefit from the convenience of online shopping; on the other hand, the entry of the e-retailer intensifies market competition and lowers retail prices. The latter's effect even extends to the WIC segment market in Row 3, significantly reducing government spending. Next, comparing the outcomes of Scenario 2 and Scenario 3, the E-retailer's transition from a non-authorized store to a WIC-authorized store has minimal impact on the non-WIC consumer surplus in Row 1 but increases the WIC consumer surplus in Row 2 due to the savings on shopping trips. The difference in the WIC consumer surplus is more salient as the ratio of $\frac{t}{N\mu}$ increases. More importantly, partnering with the E-retailer to distribute infant formula further reduces government spending in Row 3.

Lastly, Row 4 marks the thresholds at which the W-retailer's pricing strategies are no longer restrained by market competition for each scenario at each level. It is easily observed that the thresholds vary across scenarios and levels. The threshold is fixed at 0.6 in Scenario 1. In Scenario 2, the threshold drops from 0.51 to 0.4 as $\frac{t}{N\mu}$ increases, which suggests that the intense market competition in the non-WIC market segment drives W-retailers to exit early. In contrast, the threshold rises from 0.59 to 0.91 as $\frac{t}{N\mu}$ increases in Scenario 3. Since the E-retailer starts to capture the market share of WIC consumers, W-retailers delay their exit from the non-WIC market segment. Since WIC incurs considerable costs in monitoring and enforcing pricing regulations at WIC-authorized stores, developing a dual-channel distribution system could help maintain a competitive retail environment and thus reduce regulatory costs.

Table 3: Welfare Comparisons

	Low	Medium	High
Non-WIC CS			
WIC CS			
Gov Spend			
Note.	Scenario 1 ($\theta < 0.6$) Scenario 2 ($\theta < 0.51$) Scenario 3 ($\theta < 0.5$)	Scenario 1 ($\theta < 0.6$) Scenario 2 ($\theta < 0.44$) Scenario 3 ($\theta < 0.5$)	Scenario 1 ($\theta < 0.6$) Scenario 2 ($\theta < 0.4$) Scenario 3 ($\theta < 0.9$)

Note. The charts are created based on the equations in *Table 2* and the following parameter values: $N = 1$, $V = 10$, $\mu = 0.5$, and $t = 1.25, 2$, and 3 in Scenarios 1, 2, and 3, respectively.

To summarize, in markets where $\frac{t}{N\mu}$ is large, WIC would benefit from partnering with online retailers to distribute infant formula. This movement will not only enhance total consumer welfare but also reduce WIc's costs on infant formula and the regulation of WIC-authorized stores. As mentioned at the end of Section 3, even in some markets where $\frac{t}{N\mu}$ is low, this movement will not worsen the current retail market environment. Therefore, it is worthwhile for WIC policymakers to introduce online distribution channels, allowing online retailers to decide whether or not to apply for WIC authorization.

6 Conclusions

As public concern grows that WIC incentivizes retailers to charge higher prices for infant formula, this paper develops a spatial competition model to explore whether and how WIC influences the pricing strategies, market shares, and profits of both WIC-authorized and non-authorized offline retailers, as well as online retailers. The model reveals that all types of retailers tend to raise formula prices as the share of WIC consumers in the market increases. The effect is more pronounced in WIC-authorized offline retailers. Moreover, when the share of WIC consumers reaches a certain threshold, WIC-authorized may no longer set competitive prices to attract non-WIC consumers. Price regulation by WIC becomes crucial beyond the threshold. The theoretical evidence from our paper suggests that WIC contributes to the growth of infant formula prices in the retail market, which may increase WIC's cost and burden non-WIC consumers.

Another important aim of this paper is to explore the potential impact of introducing an online distribution channel for WIC consumers on retail competition. Currently, WIC is still in the preparation and pilot stages for implementing online shopping options. WIC's goal is to enable WIC consumers to enjoy the convenience of online shopping. By comparing the equilibrium outcomes between the current offline-only distribution system and a hypothetical dual-channel system, we identify additional benefits for WIC in partnering with online

retailers. First, the entry of online retailers will intensify market competition, leading to lower retail prices for infant formula. As a result, WIC's costs on infant formula will also decrease accordingly. Second, as a portion of the market share of WIC consumers is taken by the online retailer, it becomes less likely that WIC-authorized retailers exit the non-WIC market segment. It ensures that WIC-authorized retailers keep offering competitive prices to their consumers, which will significantly reduce WIC regulation costs. These insights suggest that integrating online options into the current distribution system could be a beneficial policy direction for both cost savings and participant satisfaction.

While our model is developed in the context of the retail market for infant formula, it can be easily adapted to study other public food assistance programs that partner with private retailers. The findings from the theoretical analysis can provide valuable insights for policymakers, helping them identify more efficient and cost-effective ways to distribute food benefits and mitigate the negative impact on non-participating consumers.

There are several avenues for future research. First, we focus exclusively on pure-type online retailers, but future studies could take hybrid retailers into consideration. As more hybrid retailers are expected to offer online shopping options to WIC consumers, it would be interesting to explore the implications of this shift on retail competition. Another potential direction is to treat the share of WIC consumers as endogenous. We treat it as exogenous in our model, assuming that retail pricing in a local market does not affect WIC enrollment size. However, if infant formula prices were to rise significantly across multiple markets, or even nationwide, this could likely impact the number of eligible households WIC can serve. Retailers may also take this factor into account when setting their prices. Lastly, considering that online retailers operate in multiple markets and often set uniform prices, it would be interesting to explore how it impacts the retailers' pricing strategies for infant formula.

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A Appendix

A1. Proof of Proposition 1

In Scenario 1, W-retailers and NW-retailers maximize their profits by:

$$\max_{p_w} \pi_w = p_w \left[(1-\theta) \left(\frac{1}{2N} + \frac{p_{nw} - p_w}{t} \right) + \frac{\theta}{N} \right] \tag{A1}$$

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

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

$$\begin{cases} 2p_w - p_{nw} &= \frac{\theta t}{N(1-\theta)} + \frac{t}{2N} \\ p_w - 2p_{nw} &= -\frac{t}{2N} \end{cases} \tag{A3}$$

Therefore, the equilibrium prices are:

$$p_w^* = \frac{t}{2N} + \frac{2\theta t}{3N(1-\theta)} \tag{A4}$$

$$p_{nw}^* = \frac{t}{2N} + \frac{\theta t}{3N(1-\theta)} \tag{A5}$$

Given the equilibrium prices, we can easily solve for the equilibrium market shares and profits for W-retailers and NW-retailers.

$$S_w^{NW*} = \frac{3-5\theta}{6N} \tag{A6}$$

$$S_w^{W*} = \frac{\theta}{N} \tag{A7}$$

$$S_w^{Total*} = S_w^{NW*} + S_w^{W*} = \frac{3+\theta}{6N} \tag{A8}$$

$$S_{nw}^{Total*} = S_{nw}^{NW*} = \frac{3-\theta}{6N} \tag{A9}$$

$$\pi_w^* = \frac{t(3+\theta)^2}{36N^2(1-\theta)} \tag{A10}$$

$$\pi_{nw}^* = \frac{t(3-\theta)^2}{36N^2(1-\theta)} \tag{A11}$$

$$x^* = \frac{3-5\theta}{12N(1-\theta)} \tag{A12}$$

$$y^* = \frac{3-\theta}{12N(1-\theta)} \tag{A13}$$

Therefore, non-WIC consumer surplus:

$$\begin{aligned} CS^{NW*} &= 2N(1-\theta)\left[\int_0^{x^*}(V-p_w^*-tl)\,dl + \int_0^{y^*}(V-p_{nw}^*-tl)\,dl\right] \\ &= 2N(1-\theta)\left(Vx^* - p_w^*x^* - \frac{tx^{*2}}{2} + Vy^* - p_{nw}^*y^* - \frac{ty^{*2}}{2}\right) \\ &= V(1-\theta) - \frac{t(5\theta^2-54\theta+45)}{72N(1-\theta)} \end{aligned} \tag{A14}$$

and WIC consumer surplus:

$$\begin{aligned} CS^{W*} &= 2N\theta\left[\int_0^{z^*}(V-tl)\,dl\right] \\ &= 2N\theta\left(\frac{V}{2N} - \frac{t}{8N^2}\right) \\ &= \theta(V - \frac{t}{4N}) \end{aligned} \tag{A15}$$

WIC expenditure on infant formula mainly consists of two parts: net wholesale price and retail markup. For simplicity, we assume the net wholesale price is fixed and focus on the retail markup. Thus, we have

$$\begin{aligned} GS^* &= \theta p_w^* \\ &= \frac{t\theta(3+\theta)}{6N(1-\theta)} \end{aligned} \tag{A16}$$

The required condition for the market equilibrium above to be sustained is $S_w^{NW*} > 0$. It can be restated as:

$$\theta < \frac{3}{5} \tag{A17}$$

When $\theta \geq \frac{3}{5}$, W-retailers are better off serving WIC consumers only. In the absence of price regulation, W-retailers' equilibrium prices cannot be computed since WIC consumers are completely price-insensitive.

In this situation, NW-retailers take all the market share of non-WIC consumers. When $N = 1$, an NW retailer becomes a monopoly in the non-WIC market segment. The price charged is up to the consumers' value V. If setting the price at $V - \frac{t}{2}$, the monopolistic NW-retailer will gain the entire market share of non-WIC consumers. For each $t|l|$ increase in prices, the NW-retailer loses $2|l|(1-\theta)$ non-WIC consumers. Therefore, the NW-retailer's profit function is

$$\pi_{nw} = \left(V - \frac{t}{2} + t|l|\right)(1 - 2|l|)(1-\theta) \tag{A18}$$

It is easy to prove that when $|l| \in [0,1]$, the profit function is monotonically decreasing. Therefore, the price charged by the NW-retailer is $V - \frac{t}{2}$. The NW-retailer's profit reaches its maximum when $l = 0$. Thus, we have

$$p_{nw}^* = V - \frac{t}{2} \quad \text{when N=1} \tag{A19}$$

When $N \geq 2$, NW-retailers will compete with each other in the non-WIC market segment. The equilibrium prices set by the NW-retailers are

$$p_{nw}^* = \frac{t}{N} \tag{A20}$$

$\frac{t}{N}$ is the ceiling of p_{nw}. Beyond this point, p_{nw} no longer increases with θ.

Note: When $\theta \geq \frac{3}{5}$, the market forces cannot ensure that W-retailers charge competitive pricing because they lack incentives to attract non-WIC consumers. It is necessary for WIC agencies to step in and monitor the formula prices set by W-retailers. Under WIC regulations, each state must establish a maximum reimbursement amount that it will pay WIC-approved vendors for WIC food items.[15]

A2. Proof of Proposition 2

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

$$\max_{p_w} \pi_w = p_w \left[\frac{2(1-\theta)(p_e - p_w + \mu)}{t} + \frac{\theta}{N} \right] \tag{A21}$$

$$\max_{p_{nw}} \pi_{nw} = p_{nw} \frac{2(1-\theta)(p_e - p_{nw} + \mu)}{t} \tag{A22}$$

$$\max_{p_e} \pi_e = p_e(1-\theta) \left[1 - \frac{2N\,(p_e - p_w + \mu)}{t} - \frac{2N\,(p_e - p_{nw} + \mu)}{t} \right] \tag{A23}$$

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^*.

$$\begin{cases} 2p_w - p_e & = \mu + \frac{\theta t}{2(1-\theta)N} \\ 2p_{nw} - p_e & = \mu \\ p_w + p_{nw} - 4p_e & = 2\mu - \frac{t}{2N} \end{cases} \tag{A24}$$

Therefore, the equilibrium outcomes are:

$$p_w^* = \frac{t}{12N} + \frac{7\theta t}{24N(1-\theta)} + \frac{\mu}{3} \tag{A25}$$

[15] See 7 C.F.R. § 246.12(g)(3)(i).

$$p_{nw}^{*} = \frac{t}{12N} + \frac{\theta t}{24N(1-\theta)} + \frac{\mu}{3} \tag{A26}$$

$$p_{e}^{*} = \frac{t}{6N} + \frac{\theta t}{12N(1-\theta)} - \frac{\mu}{3} \tag{A27}$$

$$S_{w}^{NW*} = \frac{2-7\theta}{12N} + \frac{2(1-\theta)\mu}{3t} \tag{A28}$$

$$S_{w}^{W*} = \frac{\theta}{N} \tag{A29}$$

$$\begin{aligned} S_{w}^{Total*} &= S_{w}^{NW*} + S_{w}^{W*} \\ &= \frac{2+5\theta}{12N} + \frac{2(1-\theta)\mu}{3t} \end{aligned} \tag{A30}$$

$$\begin{aligned} S_{nw}^{Total*} &= S_{nw}^{NW*} \\ &= \frac{2-\theta}{12N} + \frac{2(1-\theta)\mu}{3t} \end{aligned} \tag{A31}$$

$$\begin{aligned} S_{e}^{Total*} &= S_{e}^{NW*} \\ &= \frac{2-\theta}{3} - \frac{4N(1-\theta)\mu}{3t} \end{aligned} \tag{A32}$$

$$\begin{aligned} \pi_{w}^{*} &= -\frac{(t(2+5\theta) - 8N(-1+\theta)\mu)^2}{288N^2t(-1+\theta)} \\ &= \frac{[t(2+5\theta) + 8N\mu(1-\theta)]^2}{288N^2t(1-\theta)} \end{aligned} \tag{A33}$$

$$\begin{aligned} \pi_{nw}^{*} &= -\frac{(t(-2+\theta) + 8N(-1+\theta)\mu)^2}{288N^2t(-1+\theta)} \\ &= \frac{[t(2-\theta) + 8N\mu(1-\theta)]^2}{288N^2t(1-\theta)} \end{aligned} \tag{A34}$$

$$\begin{aligned} \pi_{e}^{*} &= -\frac{(t(-2+\theta) - 4N(-1+\theta)\mu)^2}{36Nt(-1+\theta)} \\ &= \frac{[t(2-\theta) - 4N\mu(1-\theta)]^2}{36Nt(1-\theta)} \end{aligned} \tag{A35}$$

$$x^* = \frac{2-7\theta}{24N(1-\theta)} + \frac{\mu}{3t} \tag{A36}$$

$$y* = \frac{2-\theta}{24N(1-\theta)} + \frac{\mu}{3t} \tag{A37}$$

$$\begin{aligned} CS^{NW*} &= 2N(1-\theta)\left[\int_0^{x^*}(V-p_w^*-tl)\,dl + \int_0^{y^*}(V-p_{nw}^*-tl)\,dl\right] + S_e^{NW*}(V-p_e^*-\mu) \\ &= 2N(1-\theta)\left(Vx^* - p_a^*x^* - \frac{tx^{*2}}{2} + Vy^* - p_b^*y^* - \frac{ty^{*2}}{2}\right) + S_{e,NW}^*(V-p_e^*-\mu) \\ &= V(1-\theta) + \frac{t\left(\theta^2+56\theta-44\right)}{288N(1-\theta)} + \frac{2N(1-\theta)\mu^2}{9t} - \frac{(5-4\theta)\mu}{9} \end{aligned} \tag{A38}$$

$$\begin{aligned} CS^{W*} &= 2N\theta\left[\int_0^{z^*}(V-tl)\,dl\right] \\ &= 2N\theta\left(\frac{V}{2N} - \frac{t}{8N^2}\right) \\ &= \theta(V - \frac{t}{4N}) \end{aligned} \tag{A39}$$

$$\begin{aligned} GS^* &= \theta p_w^* \\ &= \frac{t\theta(2+5\theta)}{24N(1-\theta)} + \frac{\theta\mu}{3} \end{aligned} \tag{A40}$$

Two conditions need to be satisfied in equilibrium. First, 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:

$$\mu < \frac{t(2-\theta)}{4N(1-\theta)} \tag{A41}$$

If this condition is not met, the game returns to Scenario 1.

The second condition is that each W-retail obtains a positive market share of non-WIC consumers, i.e., $S_w^{NW*} > 0$. This condition can be restated as:

$$\theta < \frac{2t+8N\mu}{7t+8N\mu} \Leftrightarrow \theta < 1 - \frac{5t}{7t+8n\mu} \tag{A42}$$

When the first condition is met but the second condition is not, W-retailers will serve WIC consumers only and leave the market share of non-WIC consumers to NW-retailers and the E-retailer. In this situation, the equilibrium prices of W-retailers cannot be computed. In the non-WIC market segment, NW-retailers compete with the E-retailer. The equilibrium prices are as follows.

When $\mu < \frac{t}{N}$, we have:

$$\tilde{p}_{nw}^{*} = \frac{t}{6N} + \frac{\mu}{3} \tag{A43}$$

$$\tilde{p}_{e}^{*} = \frac{t}{3N} - \frac{\mu}{3} \tag{A44}$$

When $\mu \geq \frac{t}{N}$, the E-retailer will not enter the market. The game returns to Scenario 1(b).

A3. Proof of Proposition 3

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

$$\max_{p_w} \pi_w = p_w \left[\frac{2(1-\theta)(p_e - p_w + \mu)}{t} + \frac{2\theta\mu}{t} \right] \tag{A45}$$

$$\max_{p_{nw}} \pi_{nw} = p_{nw} \frac{2(1-\theta)(p_e - p_{nw} + \mu)}{t} \tag{A46}$$

$$\max_{p_e} \pi_e = p_e \left[(1-\theta) \left(1 - \frac{2N\left(p_e - p_w + \mu\right)}{t} - \frac{2N\left(p_e - p_{nw} + \mu\right)}{t} \right) + \theta \left(1 - \frac{2N\mu}{t} \right) \right] \tag{A47}$$

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^*.

$$\begin{cases} 2p_w - p_e & = \frac{\mu}{1-\theta} \\ 2p_{nw} - p_e & = \mu \\ p_w + p_{nw} - 4p_e & = \frac{2N\theta\mu - t}{2N(1-\theta)} + 2\mu \end{cases} \tag{A48}$$

Therefore, the equilibrium outcomes are:

$$
\begin{aligned}
p_w^* &= \frac{t + 4N\mu + N\theta\mu}{12N - 12N\theta} \\
&= \frac{t}{12N(1-\theta)} + \frac{5\theta\mu}{12(1-\theta)} + \frac{\mu}{3}
\end{aligned}
\tag{A49}
$$

$$
\begin{aligned}
p_{nw}^* &= \frac{t + 4N\mu - 5N\theta\mu}{12N - 12N\theta} \\
&= \frac{t}{12N(1-\theta)} - \frac{\theta\mu}{12(1-\theta)} + \frac{\mu}{3}
\end{aligned}
\tag{A50}
$$

$$
\begin{aligned}
p_e^* &= \frac{t - 2N\mu + N\theta\mu}{6N - 6N\theta} \\
&= \frac{t}{6N(1-\theta)} - \frac{\theta\mu}{6(1-\theta)} - \frac{\mu}{3}
\end{aligned}
\tag{A51}
$$

$$
\begin{aligned}
S_w^{NW*} &= \frac{t + N(4 - 11\theta)\mu}{6Nt} \\
&= \frac{1}{6N} + \frac{(4 - 11\theta)\mu}{6t}
\end{aligned}
\tag{A52}
$$

$$
S_w^{W*} = \frac{2\theta\mu}{t} \tag{A53}
$$

$$
\begin{aligned}
S_w^{Total*} &= \frac{t + N(4 + \theta)\mu}{6Nt} \\
&= \frac{1}{6N} + \frac{(4 + \theta)\mu}{6t}
\end{aligned}
\tag{A54}
$$

$$
\begin{aligned}
S_{nw}^{Total*} = S_{nw}^{NW*} &= \frac{t + N(4 - 5\theta)\mu}{6Nt} \\
&= \frac{1}{6N} + \frac{(4 - 5\theta)\mu}{6t}
\end{aligned}
\tag{A55}
$$

$$
\begin{aligned}
S_e^{NW*} &= \frac{2t - 3t\theta - 4N\mu + 8N\theta\mu}{3t} \\
&= \frac{2}{3} - \theta - \frac{4N\mu(1 - 2\theta)}{3t}
\end{aligned}
\tag{A56}
$$

$$
S_e^{W*} = \theta - \frac{2N\theta\mu}{t} \tag{A57}
$$

$$
\begin{aligned}
S_e^{Total*} &= \frac{2(t + N(-2 + \theta)\mu)}{3t} \\
&= \frac{2}{3} - \frac{2N(2 - \theta)\mu}{3t}
\end{aligned}
\tag{A58}
$$

$$\pi_w^* = \frac{[t + N\mu(4+\theta)]^2}{72N^2t(1-\theta)} \tag{A59}$$

$$\pi_{nw}^* = \frac{[t + N\mu(4-5\theta)]^2}{72N^2t(1-\theta)} \tag{A60}$$

$$\pi_e^* = \frac{[t - N\mu(2-\theta)]^2}{9Nt(1-\theta)} \tag{A61}$$

$$x^* = \frac{t + 4N\mu - 11N\theta\mu}{12Nt(1-\theta)} \tag{A62}$$

$$y^* = \frac{t + 4N\mu - 5N\theta\mu}{12Nt(1-\theta)} \tag{A63}$$

$$z^* = \frac{\mu}{t} \tag{A64}$$

$$\begin{aligned} CS^{NW*} &= 2N(1-\theta)\left[\int_0^{x^*}(V - p_w^* - tl)\,dl + \int_0^{y^*}(V - p_{nw}^* - tl)\,dl\right] + S_e^{NW*}(V - p_e^* - \mu) \\ &= 2N(1-\theta)\left(Vx^* - p_a^*x^* - \frac{tx^{*2}}{2} + Vy^* - p_b^*y^* - \frac{ty^{*2}}{2}\right) + S_e^{NW*}(V - p_e^* - \mu) \\ &= \frac{\mathrm{t}^2(11-12\theta) + \mathrm{N}^2\left(-16+64\theta-73\theta^2\right)\mu^2 + 4\mathrm{Nt}\left[-18\ \mathrm{V}(-1+\theta)^2 + \left(10-23\theta+15\theta^2\right)\mu\right]}{72\mathrm{Nt}(-1+\theta)} \\ &= V(1-\theta) + \frac{N\mu^2(73\theta^2-64\theta+16)}{72t(1-\theta)} - \frac{t(11-12\theta)}{72N(1-\theta)} - \frac{\mu(15\theta^2-23\theta+10)}{18(1-\theta)} \end{aligned} \tag{A65}$$

$$\begin{aligned} CS^{W*} &= 2N\theta\int_0^{z^*}(V - tl)\,dl + S_e^{W*}(V - \mu) \\ &= \theta\left[V + \mu\left(-1 + \frac{N\mu}{t}\right)\right] \\ &= \theta(V - \mu + \frac{N\mu^2}{t}) \end{aligned} \tag{A66}$$

$$
\begin{aligned}
GS^* &= NS_w^{W*}p_W^* + S_e^{W*}p_e^* \\
&= -\frac{\theta\left[t^2 + Nt(-3+\theta)\mu - N^2(-8+\theta)\mu^2\right]}{6Nt(-1+\theta)} \\
&= \frac{\theta[t^2 - Nt\mu(3-\theta) + N^2\mu^2(8-\theta)]}{6N(1-\theta)}
\end{aligned} \tag{A67}
$$

There are several conditions that need to be satisfied in equilibrium. First, the E-retailer must obtain a positive market share in both segments of the market, i.e., $S_e^{NW*} > 0$ and $S_e^{W*} > 0$. They can be restated as:

$$
\mu < \frac{t(2-3\theta)}{4N(1-2\theta)} \tag{A68}
$$

$$
\mu < \frac{t}{2N} \tag{A69}
$$

Next, W-retailers and NW-retailers must obtain a positive market share in the non-WIC segments of the market, i.e., $S_w^{NW*} > 0$ and $S_{nw}^{NW*} > 0$. They can be restated as:

$$
\theta < \frac{t+4N\mu}{11N\mu} \tag{A70}
$$

$$
\theta < \frac{t+4N\mu}{5N\mu} \tag{A71}
$$

If *Equation A70* holds, *Equation A71* must be satisfied. Thus, we just need to ensure that *Equation A70* is met.

Let's simply discuss the situations where not all conditions are met. First of all, if $S_e^{W*} \leq 0$, which means $\mu \geq \frac{t}{2N}$, the game returns to Scenario 2 where the E-retailer serves non-WIC consumers only. If $\frac{t(2-3\theta)}{4N(1-2\theta)} < \mu < \frac{t}{2N}$, the E-retailer exits the non-WIC market segment and serves WIC consumers only. E-retail pricing is not restrained by market competition.

Last, when $S_w^{NW*} \leq 0$, which means $\theta \geq \frac{t+4N\mu}{11N\mu}$, W-retailers exit the non-WIC segment of the market and serve WIC consumers only. However, unlike the previous two scenarios, W-retailers will share the market share for WIC consumers with the E-retailers if $\mu < \frac{t}{2N}$.

A4. Welfare Comparison

To compare consumer surplus and government spending across the three scenarios, we must ensure that the conditions for market competitive equilibrium are satisfied in all of the scenarios. The key condition is $\frac{t}{N\mu} > 2$, which is the prerequisite for the E-retailer to enter the WIC market segment.

Non-WIC Consumer Surplus

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

$$
CS_3^{NW*} > CS_2^{NW*} = CS_1^{NW*} \tag{A72}
$$

WIC Consumer Surplus

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

It is evident that CS_1^{W*}, CS_2^{W*}, and CS_3^{W*} increases with N and decreases with t. CS_3^{W*} also increases with μ.

$$
CS_3^{W*} - CS_2^{W*} = \frac{\theta(t - 2N\mu)^2}{4Nt} > 0 \tag{A73}
$$

From the equation above, we conclude that $CS_3^{W*} > CS_2^{W*} = CS_1^{W*}$. The gap widens as t

increases but decreases with N and μ.

Government Spending

$$GS_1^* = \frac{t\theta(3+\theta)}{6N(1-\theta)}$$
$$GS_2^* = \frac{t\theta(2+5\theta)}{24N(1-\theta)} + \frac{\mu\theta}{3}$$
$$GS_3^* = \frac{[t^2 - Nt\mu(3-\theta) + N^2\mu^2(8-\theta)]\theta}{6N(1-\theta)}$$

It is evident that CS_1^{W*}, CS_2^{W*}, and CS_3^{W*} increases with N and decreases with t. CS_3^{W*} also increases with μ.