The Welfare Effects of WIC Purchasing in the Infant Formula Market

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Abstract

The Women, Infants, and Children nutritional program (WIC) acts as an intermediary in the infant formula market, providing vouchers to its participants–low-income mothers and their infants–that allow them to obtain specific brands of infant formula for free, and establishing competitive bidding contracts with manufacturers of these brands in exchange for reduced net prices. In this study, I investigate how this WIC purchasing process distorts WIC participants' choices and quantify its impact on the program's expenditures in the infant formula market. I do this by estimating a demand model where preferences and prices paid vary across WIC and non-WIC participants; and a supply model where contract manufacturers face price regulations. I explore an alternative approach of subsidizing WIC participants by using percentage discount coupons applicable to their brand of choice. My findings indicate that for each additional dollar of government spending, WIC participants receive 52.73 cents on average in the infant formula market. Though the current WIC purchasing process yields higher consumer surplus than the alternative discount coupon policy, it operates at a cost of increasing the WIC program's expenditures and reducing total welfare of the market.

JEL classification: H42, L33, L44, L66.

Keywords: Public nutrition assistance program; subsidize; vouchers; competitive bidding contracts; market concentration; infant formula.

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1 Introduction

Public food assistance programs are some of the largest safety net programs in the U.S., but typically they have a significant cost of food-related expenses. For instance, in 2019, the National School Lunch Program provided 4.9 billion lunches, incurring a cost of $14.2 billion[1]; and the Supplemental Nutrition Assistance Program (SNAP) had food expenses amounting to $113.9 billion in 2022[2]. The Special Supplemental Nutrition Assistance Program for Women, Infants, and Children (WIC) is the focus of this paper. WIC provides free food and nutritional assistance to low-income mothers ($\leq$ 185% Federal Poverty Line) and young children ($\leq$ 5 years old) through distribution of *vouchers*[3]. As reported by the USDA (2023), food-related costs has constituted between 65% and 85% of the overall expenses of the WIC program from 1974 to 2022. Among the various food items provided, infant formula products are the most costly. In 2010, the WIC program spent $927 million in the infant formula market alone (Carlson et al. (2017)).

To address the significant expenses in the infant formula market, WIC has implemented competitive bidding contracts since 1989. Under this scheme, WIC agency in each state grants exclusive selling rights to a selected manufacturer, known as the "contract manufacturer," in exchange for rebates per unit of infant formula supplied to program participants. Additionally, the infant formula market is structured as a classical oligopoly, dominated by three major suppliers Abbott, Nestle, and Mead Johnson. To prevent contract manufacturers using market powers to raise prices, the WIC program set price regulations on contract manufacturers in this market.[4].

In this paper, I investigate impacts of the WIC purchasing process on infant formula prices, consumer surplus, and government expenditures, with a particular emphasis on a policy trade-off: While the WIC program's method of purchasing and distributing serves to lower food-related expenses, it distorts its participants' choices and contract manufacturers' pricing strategies by imposing price regulations, raising questions about its efficiency as a means of subsidizing WIC participants.

Specifically, WIC participants can obtain infant formula products at no cost through the WIC program, however, there is a caveat: Participants can only redeem their vouchers for products by the contract manufacturer, meaning they must pay-out-of-pocket if they prefer other brands. This limitation, imposed by WIC vouchers, suppresses participants'

[1] *Source*: USDA National School Lunch Program Report Overview, 2023.

[2] *Source*: Supplemental Nutrition Assistance Program Participation and Costs Report (2023). Food costs are measured by all benefits value its participants received in 2022.

[3] By the mid-2010s, many states had fully transitioned to EBT for WIC benefits.

[4] Sources: Federal Regulation Code for WIC, title 7, subtitle B, Chapter II, subtitle A, Part 246.

preferences. In addition, the WIC purchasing process grants contract manufacturers with a substantial market shares from both WIC and non-WIC households. By this, they are given market powers to raise prices without fear of losing market shares. Existing literature highlights two mechanisms that help contract manufacturers maintain their shares: First, their products are given WIC labels on store shelves. This suggests to consumers these products must have a higher quality than others, given that they are government endorsed Huang & Perloff (2014); Second, the WIC program mandates that authorized grocery stores maintain minimum inventories of contract manufacturers' products at all times, guaranteeing shelf space and direct sales. Given this market power, it's ideal for the contract manufacturer to strike a balance between pricing that won't erode their market share among non-WIC participants and pricing that is high enough to *(i)* cover the costs of paying rebates to the WIC program and *(ii)* generate profit from price inelastic WIC participants who pay nothing. However, all the while, contract manufacturers must operate within price regulations imposed by the WIC program. The market power potentially grants to contract manufacturers is viewed as a force to drive down the consumer surplus, but imposing price regulations on contract manufacturers plays a forces drive up the consumer surplus. The interplay of market power and price regulations features this market, and a model is needed to determine the dominant force.

To quantify this policy trade-off, I estimate a discrete choice model of demand where WIC and non-WIC households differ in two ways. First, WIC participants incur no costs when they utilize vouchers in exchange for infant formula products from the contract manufacturer. In contrast, non-WIC participants pay the shelf price for their purchases. Second, these two type of households have heterogeneous preferences for the contract manufacturer. I model supply by assuming non-contract manufacturers compete their prices in a Bertrand Nash equilibrium, while contract manufacturers faces price restrictions. My method of estimating marginal costs (MC) is utilizing the contract manufacturer's marginal costs in other markets to predict its marginal costs in a given market where they hold WIC competitive bidding contracts.

I primarily use three data sets to estimate the model: Nielsen Retail Scan data (2006 – 2016), NIS-Child data (2006 – 2016), and the WIC rebate data (1989 – 2016). To estimate the demand, I use milk prices obtained from Nielsen retail scan data as an instrumental variable (IV) for prices. I find that own-price elasticity for non-WIC households is -1.509, indicating that the demand for the product is highly responsive to changes in price. To identify consumer preferences for the contract manufacturers' products, I rely on co-variations between percentage of WIC participants and market shares for the contract manufacturers across counties. I find that WIC and non-WIC households have slightly different preferences for the WIC-supplemented infant formula products.

I use the model's estimates to conduct two policy experiments. First, I study what happens when I remove the current WIC program's purchasing and distribution system. I find that for every additional dollar spent by the government, expected consumer surplus for WIC participants only raise by 52.73 cents. To compare the current WIC purchasing with laissez-faire, the current WIC purchasing process gives the higher consumer surplus.

The second experiment, inspired by SNAP's distribution method, investigated whether providing discount coupons to WIC participants would enhance total welfare compared to the current system. With these discount coupons, WIC participants can purchase whatever brands as they want, but must pay a certain percentage of the unit price of infant formula products, while the WIC program subsidizes the remaining portion. I find that the WIC program would need to give a 42% discount to its participants, to keep the government budget be neutral. This suggests that as WIC households pay a higher percentage of unit price, the WIC program's surplus increases, potentially even surpassing the benchmark surplus. However, it cannot match the current WIC purchasing scheme of consumer surplus for WIC participants.

This paper is closely related to recent work by An et al. (2023) and Abito et al. (2022), who are similarly studying the welfare effects of WIC program in infant formula markets. However, there are several important differences. In particular, Abito et al. (2022) examine demand spillover effects on non-WIC participants but does not delve into the price restrictions that contract manufacturers may encounter. An et al. (2023) places its focus on assessing the influence of competitive bidding contracts within the WIC program on infant formula prices. They employ a comprehensive approach, particularly estimating the competitive bidding model. However, recent report in FTC[5] concerned that one infant formula manufacturer colluded on bids for state WIC contracts. Given this reason, instead of modeling bids in a competitive setting, I take the competitive bidding process as exogeneous.

This paper is part of a recent body of literature that investigates the impact of competitive bidding contracts on market prices and concerns related to market efficiency. For instance, Ding et al. (2022) reveals that the introduction of an imperfect bidding mechanism can drive down market prices in medical devices market. Ji (2023) illustrates, using the health insurance market as an example, that the implementation of competitive bidding contracts can result in shortages. Additionally, Cao et al. (2022) delves into

[5]Sources: Baby-Formula Makers Face FTC Investigation for Collusion-Agency investigating whether formula manufacturers coordinated before bidding for state contracts

the Chinese pharmaceutical industry and emphasizes how consumers' preferences significantly influence the determination of consumer surplus for products from contract manufacturers. The policy implications of this paper align with the conclusions drawn in Cao et al. (2022).

This paper also contributes to the body of research focused on evaluating public nutrition assistance programs, particularly the WIC program. Several prior studies have shed light on different aspects of the WIC program: Chorniy et al. (2020) uncovers that WIC infant participants, on average, have higher birth weights compared to non-WIC peers within the same income group; Jacknowitz & Tiehen (2009) explores the reasons behind WIC participants leaving the program; Ambrozek (2022) investigates how the WIC program influences the entry and exit decisions of authorized retail stores, using California as an example; Hanks et al. (2019) examines the impact of transitioning from paper vouchers to electronic debit cards on the purchasing behaviors of WIC participants; Ludwig & Miller (2005) represents one of the early reports that explain how WIC rebates function. I add to this strand of literature by quantifying the welfare consequences for consumers and government expenditures. I achieves this by studying how the WIC purchasing process within the infant formula market affects the responses of suppliers.

The paper also contributes to research in studying the efficient way to use public funds to subsidize essential goods and services, from food to health cares, like Finkelstein et al. (2019), Hendren & Sprung-Keyser (2022), Kang & Vasserman (2022), Kang (2022). In a related context, Jiménez Hernández & Seira (2022) explores the impact of direct government provision of food (referred to as "direct provision") versus vouchers and unrestricted cash transfers, using the milk market in Mexico as an example. Unlike their approach, I find that issuing vouchers and implementing price regulations on infant formula contract manufacturers together generate a higher consumer surplus compared to restricted cash transfers, like discount coupons.

The rest of the paper is organized as follows. Section 2 provides the institutional backgrounds of the WIC purchasing process. Section 3 documents the data sources and the description of the infant formula market. Section 4 provides motivating evidences on the effect of the WIC competitive bidding contracts on market outcomes. Section 5 introduces a demand and supply model, which is estimated in Section 6. Section 7 shows the welfare analysis and counterfactual policies, and section 8 concludes.

2 Background

The WIC program operates across all 50 states in the United States, including the District of Columbia. Nearly [6] each state's respective WIC agency is independently responsible for determining its contract manufacturer and distributing the manufacturer's products to its participants. Each WIC agency functions as a buyer in the infant formula market, signing an approximate three-year-long exclusive contract with one infant formula manufacturer. During this contractual period, all infant formula products supplied to WIC participants in a given state are exclusively provided by this manufacturer.

Competitive bidding To determine this contract manufacturer, WIC agencies usually implement a competitive bidding scheme. In accordance with the industrial regulation 7 CFR Part 246 [7], manufacturers submit sealed bids, specifying rebates per unit of standardized infant formula product to their respective state's WIC agency. Manufacturers offering the highest rebates have a greater likelihood of winning the contract. Ideally, to facilitate the bidding process, each state's WIC agency provides essential program information to all potential bidders. After a 30-day period, the state's WIC agency publicly announces the contract winner. I do not model each manufacturer's bidding strategy in competitive bidding contracts, but take the auction as an external factor. The auctions' outcomes are from the WIC rebate data, collected by Davis (2012).

Minimum Inventory After knowing the contract manufacturer, each state's WIC agency requires all authorized retail stores to give minimum inventories to the contract manufacturer's infant formula products. Cachon & Kök (2010) stated that inventories increases sales directly. Hence, the minimum inventory policy set by the WIC program grants the contract manufacturers certain large market shares from both WIC and non-WIC participants.

Subsidizing WIC Participants WIC is a means tested program, using income level and health outcomes to determine the eligible participants. The income criteria is $\leq 185\%$ of the federal poverty line in the U.S. In grocery stores, consumers can easily recognize WIC supplemented infant formula products through WIC labels. Different from SNAP that gives money to participants directly, WIC participants use vouchers in exchange for contract manufacturers' infant formula products. Their vouchers clearly show the

[6] I said "nearly" because there are some state WIC agencies that determine their contract manufacturers jointly through forming an alliance.

[7] Sources: Federal Regulation Code for WIC, title 7, subtitle B, Chapter II, subtitle A, Part 246.

amount and brand of infant formula products a WIC household may receive. By the mid-2010s, many states had fully transitioned to Electronic Benefits Transfers (EBT) for WIC benefits. To avoid the impact of EBT, I choose the sample from 2006 quarter 1 to 2016 quarter 4.

Price Restrictions The WIC program imposes price regulations to prevent contract manufacturers from leveraging their market power to inflate prices. WIC also utilizes a competitive pricing scheme when selecting retailers to supply WIC-approved foods. Retailers with lower average retail prices for essential items such as fruits, vegetables, dairy products, and baby foods are more likely to be chosen as WIC suppliers. In order to secure contracts with the WIC program, while maintaining competitive pricing, retailers may transfer this price pressure to upstream food manufacturers.

3 Data and Descriptive Statistics

I primarily utilized three datasets: Nielsen retail scan data spanning from 2006 to 2016, WIC rebate data collected by Davis E. David covering the years 1989 to 2016, and the National Immunization Survey Child data ranging from 2006 to 2016. My choice of this specific time frame, from 2006 to 2016, is for two reasons. The first is that starting in 2017, many states began implementing E-vouchers for WIC participants. To ensure that the introduction of these E-vouchers would not influence my price analysis and model, I excluded time periods beyond December 2016. The second reason is that the WIC rebate data I rely on only extends up to 2016.

3.1 Data

Nielsen data The Nielsen retail scan data is a nation-wide retailer level dataset that records weekly sale quantities and unit prices for each product within selected stores. Nielsen data is generally regarded as representative of the broader American retail landscape. This dataset, spanning from 2006 onwards, is organized into three levels of information: product data, retailer data, and store-level transaction data. These three types of data can be merged together by using the store and UPC codes. The product data has a wealth of detailed information for each product; it includes details such as a product's UPC code, description, brand name, brand description, unit, size, ect. The retailer data provides the state, county, and zip code of each retailer, as well as the type of retailer they are (convenience store, gas station, or a chain supermarket). It also indicates whether retailers belong to the same parent company. However, for privacy reasons, specific retailer brands are anonymized and represented by numerical codes rather than brand names. The store-level transaction data provides a record of amount of product sold per week, as well as the corresponding weekly unit prices. Since most infant formula products are sold through retail, Nielsen data's wealth of information concerning each product's price and quantity makes it the most useful tool to assist me in answering my research question. I clean the data by referencing and combining methods from Döpper et al. (2022), Allcott et al. (2019), Moshary et al. (2023), Bronnenberg et al. (2015). See details in Appendix A.

NIS-Child Data The National Immunization Survey - Child data is an annual national survey that collects information on children's health. There are five variables in the sample: the year conceived; sample weights assigned on each household; whether or not children currently receive WIC benefits; whether or not children were exclusively breastfed by their mothers before reaching one year of age; and the counties and states in which the children reside.

WIC Rebate Data and USDA WIC Data The WIC rebate data, collected by David E. Davis from South Dakota State University, provides institutional details about the WIC competitive bidding contracts in each state 1989 to 2016. This dataset contains variables, including each bidder's bid in every auction, auction type (first price, second price, etc.), each auction's winner, predicted wholesale prices, contract start and end dates, and the type of infant formula being bid on rebates. I used this data to identify when each state's WIC contract underwent a change in contract manufacturer. To ensure the accuracy of these transition dates, I cross-referenced the data with each state's WIC program regulation from 2006 to 2016.

3.2 Sample Definition

I've defined the market at the county-year-quarter level by aggregating Nielsen's weekly store-level data into county-year-county-manufacturer data. The primary reason for this choice: I wanted to capture a wider range of price and quantity variations. By using the county-level market, my sample encompassed 1000 counties, spanning 10 years with 4 quarters in each year, providing the most variation for analysis.

To define the price variable, I first adjusted prices to the real price using the 2010 Consumer Price Index (CPI) as the baseline (the annual CPI data is sourced from FRED). Second, I aggregate the weekly store-level data to year-quarter-county level by taking a quantity weighted price [8].

After merging the Nielsen and NIS Child data[9], within each market denoted as "m," I calculate a breastfeeding ratio. This ratio represents the market share of the outside option. Given the outside option shares and by examining the ratios of market shares between any two manufacturers, I was able to calculate each manufacturer's updated market shares within each market.

3.3 Descriptive Statistics

Market Shares and prices Table 1 presents statistics for different manufacturers, including their weighted average shares, average retail prices, and the likelihood of winning WIC competitive bidding contracts. In the first column, we observe that Abbott holds the largest market share at 46.8% in the sample, followed by Mead Johnson at 38.6%. All other brands, aside from the top three, are grouped under "Others" and collectively represent only 6.1% of the market. This suggests that the top three manufacturers collectively control over 90% of the market, indicating that infant formula market features as a classical oligopoly market.

Moving to the second column, we see the mean and standard deviations of weighted average prices for each manufacturer. Mead Johnson stands out as the most expensive, with prices hovering around \$17.5, while Abbott follows closely with a price of \$16.

In the last column, we observe the probability of each manufacturer winning WIC competitive bidding contracts based on the sample data. Mead Johnson and Abbott both have a 40% chance of securing the contract between 2006 and 2016.

[8] since I want to study the county-year-quarter level market but the raw data is at the store-week level, I must aggregate the data and use the mean of weekly store-level prices. However, I am concerned that a simple average of prices might overlook the influence of store size, so I calculate the weighted average by using the market share of each store as weight.

$$P^w_{j,county,yq} = \sum_{store=1\in county}^{store=N\in county} \frac{\sum_{store=1}^{N} q_{j,store,yq}}{\sum_{j=1}^{4}\sum_{store=1}^{N} q_{j,store,yq}} \times P_{j,store,yq}$$

[9] One issue that arose is the inconsistency of the state variable between the NIS and Nielsen datasets. NIS uses the full state name, while Nielsen employs the state FIPS code. Therefore, I downloaded state-level data from the US Bureau of Labor Statistics (USPS State Abbreviations and FIPS Codes) to facilitate the merging of these two datasets. During the data cleaning process, I excluded individuals who provided responses such as "don't know," "refused to answer," or were missing data in two key variables of interest.

Table 1: Market Shares, Prices, and Winning Probabilities

Statistic	$s_{js,yq}$	$price_{js,yq}$	$\mathbb{1}_{j=g}$
Abbott	0.468	16.000	0.396
	(0.353)	(4.312)	(0.489)
Mead Johnson	0.386	17.499	0.420
	(0.347)	(5.545)	(0.494)
Nestle	0.198	14.602	0.255
	(0.246)	(4.226)	(0.436)
Others	0.061	14.170	0
	(0.098)	(4.206)	(0.000)
Note:		Sample Data: 2006-2016	

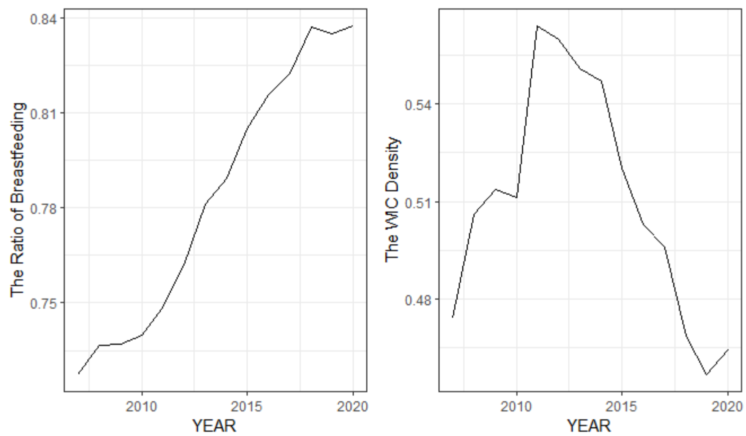
Notes: Column (1) shows the mean and standard deviations of market shares for different manufacturers. I focus on 12 – 13 oz milk-based liquid concentrated infant formula products, which is the most common WIC-supplemented infant formula from 2006 – 2016. The aggregate market share is the retail-level sold quantities of manufacturer *j*'s products divided by retail-level sold quantities of all manufacturers products. Column (2) shows the average retail price per bottle. Column (3) shows the likelihood that each manufacturer wins the competitive bidding contracts. *Sources:* Sample Data 2006 – 2016.

Breastfeeding ratio and WIC density Table 2 shows that on average 51% households in each state have ever received WIC benefits for their children. The breastfeeding ratio is 78.6% on average at the state level. Figure 1 shows the breastfeeding ratio increases from 70% to 85% in the past fifteen years. The right figure shows the percent of WIC eligible households who received food benefits for their children. From 2012 to 2020, the ratio declines by 30%.

Table 2: WIC Density and Breastfeeding Ratio

	Min.	1st Qu.	Median	Mean	3rd Qu.	Max.
WIC density	0.0200	0.4400	0.5100	0.5111	0.5800	0.7700
Breastfeeding ratio	0.150	0.730	0.800	0.786	0.860	1.000
Note:						NIS-Child Data: 2006-2016

Figure 1: Time Variations in WIC Density and Breastfeeding Ratio



Notes: The left figure shows changes in breastfeeding ratio from 2006 to 2020. It implies that the breastfeeding ratio increases from 70% to 85% in the past fifteen years. The right figure shows the percent of WIC eligible households who received food benefits for their children. From 2012 to 2020, the ratio declines by 30%. Ambrozek (2022) shows how closure of WIC authorized grocery stores impact the enrollment for the WIC program. This paper does not focus on explaining the changes in WIC enrollment. *Sources:* NIS-Child data 2006-2020.

Rebates and wholesale prices Table 3 presents the mean and standard deviations for rebates and wholesale prices from different manufacturers. On average, Mead Johnson offers the highest rebate values, aligning with the information in Table 1 that indicates Mead Johnson has the highest likelihood of securing the WIC contract from 2006 to 2016. These rebate data serves as input for calculating the profits of contract manufacturers later.

Table 3: Summary Statistics: WIC Rebate Data

	Mean ($)	SD	Min($)	Median($)	Max($)
Rebate					
Mead Johnson	5	4	0	3.2	15.7
Abbott	4.7	3.8	0	3.2	14.9
Nestle	3.1	4.2	0	1.1	14.9
Wholesale price					
Mead Johnson	6.5	4.6	1.3	4.1	15.8
Abbott	6.4	4.5	1.3	4.1	14.9
Nestle	6.1	4.3	1.6	4.2	15.1

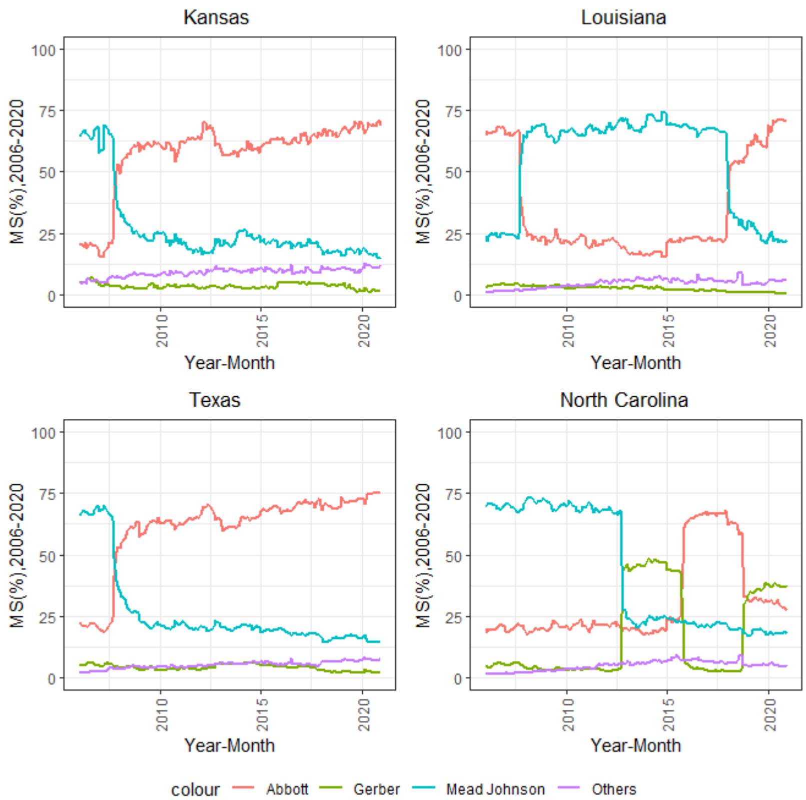
Note: WIC Rebate Data: 1986-2016

Notes: The table shows average rebates that each manufacturer submits in competitive bidding processes. Mead Johnson has the highest average rebates than other two manufacturers, it also aligns with the fact that Mead Johnson has the highest likelihood of winning the WIC contracts. *Sources:* WIC Rebate Data 1986 – 2016.

4 Motivating Evidence

Variations in market shares The Figure 2 proves the strong correlation between the contract manufacturers and their market shares. The first sub-figure depicts the market share changes in the State of Kansas from 2006 to 2020. It illustrates the correlation between manufacturers' market shares and the changing of contract winners. The x-axis indicates time, while the y-axis displays market shares in quantities. When Kansas changed its WIC contract manufacturer to Abbott in October 2007, the previous contract manufacturer, Mead Johnson, experienced an immediate decline in market shares within a month, while the new contract manufacturer, Abbott, saw an increase. Event study analysis for market shares are shown in the Appendix.

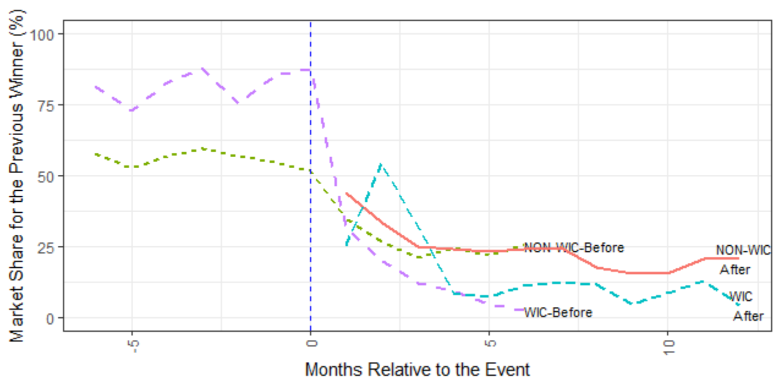
Figure 2: Correlation between Market Shares and Competitive Bidding Contracts

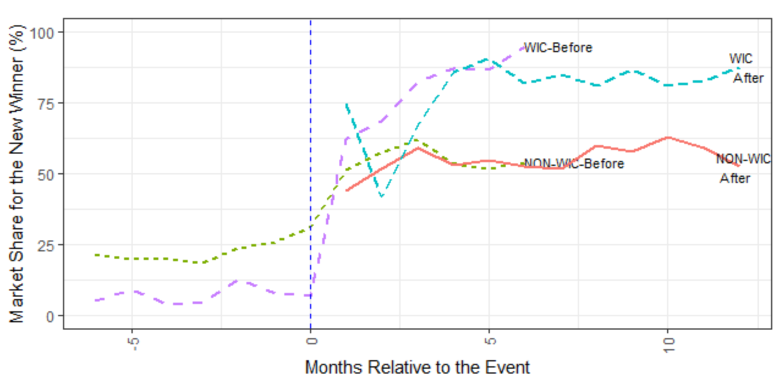


Notes: The figure shows strong correlation between the contract manufacturers and their market shares. The first sub-figure depicts the market share changes in the State of Kansas from 2006 to 2020. It illustrates the correlation between manufacturers' market shares and the changing of contract winners. The x-axis indicates time, while the y-axis displays market shares in quantities. When Kansas changed its WIC contract manufacturer to Abbott in October 2007, the previous contract manufacturer, Mead Johnson, experienced an immediate decline in market shares within a month, while the new contract manufacturer, Abbott, saw an increase. *Sources:* Nielsen Retail Scan Data 2006 – 2016.

Spillover effects Huang & Perloff (2014) pointed out that it may be extremely profitable for a manufacturer to secure this contract because of the potential spillover demand from non-WIC participants. As quantified in my other working paper, changes in contract manufacturers lead to shifts in market shares among non-WIC households. In Figure 3, I found that the spillover demand changes 30% to 40% on average within a single month. This effect occurs due to the WIC program's regulations on retailers' shelf space and minimum inventory requirements. In accordance with these regulations, retailers collaborating with WIC must maintain a certain quantity of the contract manufacturer's infant formula products on their shelves at ALL times. This dedicated shelf space attracts the attention of non-WIC consumers, subsequently increasing demand. Additionally, since the contract manufacturer's products are prominently associated with the WIC logo itself, non-WIC consumers may perceive these products as having higher quality due to government endorsement, further boosting demand.

Figure 3: Event Study: Spillover Effects on Non-WIC households





Notes: The upper figure shows changes in previous winners' market shares. It could be decomposed into four types of demands. The green dashed line shows that: After the contract switched, the previous contract winners' market shares from NON-WIC households with babies born before the contract changed declined from 55% to around 25%. It implies a strong spillover effect from switching WIC contracts on non-WIC households' consumption. Besides, the market shares from WIC households dropped around 70%, which indicates that WIC parents might have love brand loyalty for infant formula products. The bottom figure shows that new winners' market shares increase for WIC and NON-WIC households, which mirrors the upper graph and has almost the same implication as the upper graph: There is a spillover effect on non-WIC households. *Sources:* Nielsen Homescan data 2006-2020.

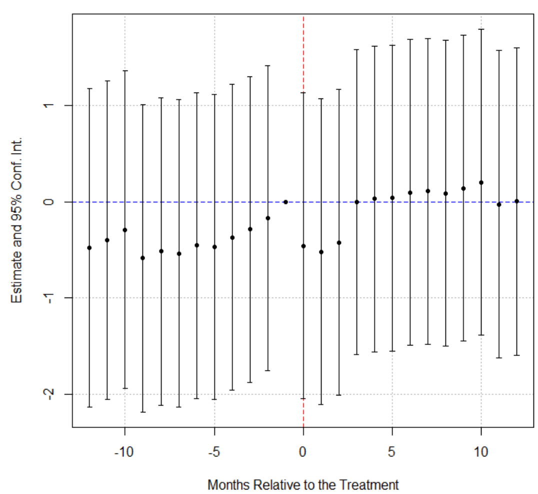
Price effects To access how contract manufacturers change their prices after winning a WIC competitive bidding contracts at the state-month level, I use the following event study specification

$$Y_{st}^{j=g} = \zeta_s + \zeta_t + \sum_{\tau \neq t} \gamma_\tau \times \mathbb{1}_\tau + \epsilon_{st} \tag{1}$$

where $Y_{st}^{j=g}$ are the weighted average prices for contract manufacturers in a state s in the year-month t; ζ_s is the state fixed effect, and ζ_t is year-month level time fixed effects; the coefficient that we are interested in is γ_τ, where τ represents 12 months before and 12 months after the WIC agency in state s changes its contract manufacturer.

Figure 4 illustrates that, on average, contract manufacturers' unit prices do not have any significantly change after winning WIC contracts. This suggests that the price restriction may effectively prevent contract manufacturers from increasing prices in practice.

Figure 4: Event Study: How contract manufacturer change their prices after win the contract?



Notes: The figure illustrates how contract manufacturers in different states adjust their prices following the successful acquisition of WIC contracts. This suggests that the pricing regulations imposed by the WIC program may be associated with the observation that contract manufacturers' unit prices do not exhibit significant changes after securing WIC contracts. *Sources:* Nielsen Retail Scan data 2006-2020, year-month-state level.

5 Model

I specify a static model of oligopoly price competition with differentiated goods. In the model, profit-maximizing manufacturers coexist with a manufacturer who wins the WIC competitive bidding contracts whose products WIC households can use vouchers to redeem.

Throughout the model, a geographic unit is a state-county area and a time unit is a quarter. A market is a combination of a geographic and time units, and is denoted by m to simplify notation, and the collection of markets is denoted as $\mathcal{M}$. Each consumer's choice is denoted as j, and the collection of all available choices in a market is denoted by $\mathcal{J}(m)$. I take *breastfeeding* as the outside option, and denote it as $j = 0$. There are totally 4 infant formula manufacturers in each market: $\left\{\text{Abbott}, \text{Mead Johnson}, \text{Nestle}, \text{Others}\right\}$. I denote the WIC contract manufacturer's product as $j = g$ [10]. Assuming all households are rational, their decisions on infant formula products reflect their preferences on the four primary manufacturers and breastfeeding. If I observe a consumer i chooses the option $x \in \mathcal{J}$ in my data (in other words, $d_{ix} = 1$), then I can say $x \gtrsim_R x^{'}$ for all $x^{'} \in \mathcal{J}$. Each household is facing a price vector $\mathbf{p} \in R_L^+$ in the market and wants to make a decision to maximize their utilities.

The purpose of the model is twofold. First, the model lays out: *(i)*: Two types of households' heterogeneous preferences on contract manufacturers' products; *(ii)*: How WIC participants faces the trade-off between using vouchers to exchange for WIC-supplemented infant formula products for free, and paying shelf-prices to get their preferred products. I use the flexible approach of Berry (1994) to estimate two types of consumers preferences from aggregated store-level market shares data over time and over markets. The estimated preferences facilitate predicting consumer responses to counterfactual subsidization policies.

Second, the model highlights that the regulated price for the contract manufacturer significantly affect other non-contract manufacturers' pricing strategies in each market. If the WIC program were to remove the price regulation on the contract manufacturer, it's ideal for the contract manufacturer to strike a balance between a price that doesn't erode their market shares among Non-WIC participants, while sufficiently high enough to cover the costs of paying rebates to the WIC program. It leads to different prices and consumer purchasing decisions. Accounting for such repsonces is thus important in the counterfactual analyses that follow.

[10] There are some concerns about whether consumers' choice sets are limited by WIC's minimum inventory regulations on retailers. The working paper Wang & Filipski (2023) showed that, at the extensive margin, 95% of retailers (according to the Nielsen retail scan data) provide both contract winner's and non-winner's products.

5.1 A Discrete Choice Model of Demand

I follow the large literature on discrete-choice demand system estimating using aggregate market share data (Berry et al. (1993), Berry (1994), Nevo (2001), Train (2009)) to model demand for infant formula products as a function of prices and product characteristics.

Household i's in market $m \in \mathcal{M}$ obtains the following indirect utility from consuming a bottle of infant formula $j \in \mathcal{J}(m)$:

$$u_{ijm} = \alpha \cdot P_{ijm} + \beta_i \cdot \mathbb{1}_{j=g} + \mathbf{H}_{jm} \cdot \gamma + \underbrace{\xi_{jm}}_{\text{unobserved}} + \underbrace{\epsilon_{ijm}}_{\sim T1EV} \tag{2}$$

where I normalize the outside option (breastfeeding)'s utility to zero. The $N \times \mathcal{M}$ matrix $\mathbf{H}_{jm} = \begin{bmatrix} \eta_c & \eta_{yq} & \eta_j \end{bmatrix}$ includes state-county fixed effects, time fixed effects, and observed manufacturer fixed effects. My main specification also includes the price of product j in the market m that consumer i faces with, which is denoted as P_{ijm}.

$$P_{ijm} = \begin{cases} 0, & \text{if i } \in \text{ WIC households and if j = contract manufacturer}(g) \\ P_{jm}, & \text{Otherwise} \end{cases} \tag{3}$$

It reflects that WIC participants use vouchers to obtain contract manufacturers' products for free, and purchase non-contract infant formula products at full prices. Non-WIC households always pay shelf-prices. Prices can be correlated with product-market-specific preference shock (ξ_{jm}), which are constant across households within a market. These are common knowledge to households, infant formula manufacturers, and the WIC program, but are unobserved by the econometrician. These shocks may reflect both unobserved product characteristics across markets, or unobserved variation in tastes across markets.

Another main specification is the WIC contract manufacturer dummy variable $\mathbb{1}_{j=g}$. The spillover Figure 3 shows that two types of households have heterogeneous preferences on contract manufacturer's products. Hence, the model allows β_i varies by the types of households.

$$\beta_i = \begin{cases} \beta_{nw}, & \text{if i } \notin \text{WIC} \\ \beta_w, & \text{if i } \in \text{WIC} \end{cases} \tag{4}$$

β_w represents the preferences of the contract manufacturer's infant formula products from WIC participants. β_{nw} represents non-WIC households' preferences on the contract manufacturers' products. Finally, ϵ_{ijm} is an idiosyncratic preference shock that is observed by consumers and is assumed to be *i.i.d* extreme value of type I error.

Given the above setting, the probability that a representative WIC participant i in the market m choosing manufacturer j's products are listed below:

$$\sigma_{ijm}^{WIC} = \frac{exp(\alpha \cdot p_{jm} \cdot \mathbb{1}_{j \neq g} + \beta_w \cdot \mathbb{1}_{j=g} + \mathbf{H}_{jm}\gamma)}{1 + \sum_{k \in \mathcal{J}(m)} exp(\alpha \cdot p_{km} \cdot \mathbb{1}_{k \neq g} + \beta_w \cdot \mathbb{1}_{k=g} + \mathbf{H}_{km}\gamma)} \tag{5}$$

Similarly, the probability that a representative non-WIC participant i in the market m choosing manufacturer j's products are listed below:

$$\sigma_{ijm}^{non-WIC} = \frac{exp(\alpha \cdot p_{jm} + \beta_{nw} \cdot \mathbb{1}_{j=g} + \mathbf{H}_{jm}\gamma)}{1 + \sum_{k \in \mathcal{J}(m)} exp(\alpha \cdot p_{km} + \beta_{nw} \cdot \mathbb{1}_{k=g} + \mathbf{H}_{km}\gamma)} \tag{6}$$

which varies across manufacturers and markets.

I aggregate individual-level choice probabilities to construct both the type-level market shares and the aggregate market shares for product j in market m[11]. I denote $\mathcal{J}(m,t)$ as the set of households in market m of type t, and there are only two types of households: WIC and non-WIC participants. Then the market shares for product j coming from type t households is given by the average of the choice probability of all type-t households within the market:

$$\sigma_{jm}^{(t)} = E_i\left[\sigma_{ijm} \mid i \in \mathcal{J}(m,t)\right] \quad \text{where } t \in \left\{\text{WIC}, \text{non-WIC}\right\} \tag{7}$$

where the expectation operator, $E_i\left[\cdot\right]$, denotes the average across individuals. The aggregate market share for product j in the market m is given by[12]

$$\sigma_{jm} = E_i\left[\sigma_{ijm}\right] = WIC\%_m \times \sigma_{jm}^{(WIC)} + (1 - WIC\%_m) \times \sigma_{jm}^{(non-WIC)} \tag{8}$$

This term appears is plugged into supplier j's profit function as aggregate market shares in the market m in the following.

5.2 An Oligopoly Model of Supply

I envision the supply-side as a two-state Stackelberg game where all manufacturers firstly bid for WIC competitive bidding contracts. I take this stage's auction as exogeneous. The outcomes of competitive bidding contracts are common knowledge to households,

[11] Here, I follow Jiménez Hernández & Seira (2022) to set notations for the common mixed logit model.
[12] See appendix B for proof details.

manufacturers, and the WIC program. Upon learning the outcomes of the auctions, non-contract manufacturers adopt pricing strategies to optimize their profits in a Bertrand-Nash equilibrium. The contract manufacturers face the price restrictions imposed by the WIC program.

In the model, infant formula manufacturers sell products directly to households, so I use manufacturers and sellers interchangeably. Infant formula manufacturer j produces one bottle infant formula product in the market m as a marginal cost of $c_{jm} > 0$. The marginal costs vary by markets because of the deliver costs.

Non-Contract Manufacturer Manufacturers who do not win the WIC competitive bidding contract in the market m choose the optimal prices that maximize their profits conditional on others' pricing strategies. I denote p_{jm} as the weighted average price for the non-contract manufacturer j's product in the market m. $\mathbf{p}_{-j,m}$ is the price vector that involves weight average prices for other non-contract manufacturers and for the contract manufacturer in the market m. A non-contract manufacturer $j \neq g$'s profit in the market m is

$$\max_{p_{jm}} \quad (p_{jm} - c_{jm}) \times \sigma_{jm}(p_{jm}, \mathbf{p}_{-j,m}) \tag{9}$$

where σ_{jm} is the aggregate market shares for a given manufacturer in a given market. Given the setup, the non-contract manufacturer j's first-order condition associated with Equation 8 with respect to price p_{jm} is given by:

$$\sigma_{jm}(p_{jm}) + (p_{jm} - c_{jm}) \times \frac{\partial \sigma_{jm}(p_{jm})}{\partial p_{jm}} = 0 \tag{10}$$

where $\frac{\partial \sigma_{jm}(p_{jm})}{\partial p_{jm}}$ reflects the responses in j's quantity sold to a change in weighted average prices.

Contract Manufacturer The contract manufacturer j faces the price regulation imposed by the WIC agency in the market m, so its price is an external factor, which is denoted as p_{jm}^{reg}. The contract manufacturer j exclusively supply infant formula products to the WIC program in the given market. I envision it as a three-step purchasing and distributing process. The WIC participants firstly use vouchers to exchange for contract manufacturer's infant formula products in the market m, and pay nothing. Their quantity demanded is denoted as $\sigma_{jm}^{t=wic}$. The non-WIC households who have demands for j's products pay shelf prices p_{jm}^{reg}. The aggregate demands for non-WIC households are denoted as $\sigma_{jm}^{t=non-wic}$. Secondly, the contract manufacturer j obtains vouchers from WIC households, and also receives revenues from non-WIC households. Lastly, the program reimburses the vouchers values for the contract manufacturer j, based on how many bottles of infant formula products that WIC households get in the given market. According to the outcomes of the auctions, the WIC program in fact pays $p_{jm}^{reg} - \text{Rebate}_{jm}$ for each unit bottles of infant formula to the contract manufacturer, where Rebate_{jm} is the promised discount value that contract manufacturer provides to the WIC program. A contract manufacturer $j = g$'s profit in the market m is

$$\pi_{jm}^{j=g} = \sigma_{jm}^{t=wic}(0) \times (p_{jm}^{reg} - \text{Rebate}_{jm}) + \sigma_{jm}^{t=non-wic}(p_{jm}^{reg}) \times p_{jm}^{reg} - \sigma_{jm}(p_{jm}^{reg}, \mathbf{p}_{-j,m}) \times c_{jm} \quad (11)$$

where σ_{jm} is the aggregate demands for the supplier j in the market m. In this equation, the first and second term reflects the supplier j's total revenue from the WIC program and from non-WIC households. To feed aggregate demands for infant formula products in the market m, the supplier j produces σ_{jm} bottles of infant formula at a marginal costs $c_{jm} > 0$. The aggregate costs is the last term in Equation 11.

5.3 Government Expenditures

Below are the total expenditures of the WIC program in the infant formula market.

$$E(gov) = \sum_{m \in M} \mathbb{1}_{j=g} \cdot (p_{jm}^{reg} - \text{Rebate}_{jm}) \cdot \sigma_{jm}^{t=wic}(0) \quad (12)$$

where the dummy variable $\mathbb{1}_{j=g}$, indicates that, under the current policy, the WIC program exclusively reimburses contract manufacturer's infant formula products for WIC participants. The second part reveals that the WIC program benefits from discounts and only incurs net costs in each market. In the later counterfactual analysis, the government's expenditure function will change when I switch to the alternative policy.

6 Identification and Estimation

The goal of this section is to identify the demand parameters and marginal costs for each manufacturer. In estimating demand, I face the common identification threat that the price p_{jm} within the utility function, is influenced by unobserved product attributes ξ_{jm}. To deal with this issue, I adopt the method proposed by Berto Villas-Boas (2007) and employ input prices as instrumental variables. In estimating supply, the main challenge is to estimate contract manufacturer's marginal costs in the given market, given that it faces with price regulations, not optimizing prices. To deal with this issue, I predict the contract manufacturers' marginal costs in given markets by using observations in alternative markets that contract manufacturers do not get the WIC contract. I estimate the model using the two-staged generalized method of moments (GMM).

6.1 Econometric Specification

Unobserved Product Attributes I follow the literature in decomposing the deterministic portion of the consumer's indirect utility into a common part shared across consumers, denoted as δ_{jm}

$$\delta_{jm} = \beta \times \mathbb{1}_{j=g} + \eta_c + \eta_{yq} + \eta_j + \xi_{jm} \tag{13}$$

where β is mean taste parameter, reflecting the common preferences of the contract manufacturer's infant formula products across WIC and non-WIC households; η_c is a state-county area fixed effect that captures variations in preferences across locations; η_{yq} is a year-quarter fixed effect that aims to get variations in tastes over time; η_j is a manufacturer fixed effect that intended to capture variations in demands over observed product features, except prices and whether manufacturer is the WIC contract manufacturer or not. The remaining structural error ξ_{jm} represents unobserved deviations across products within a market after controlling the above factors.

Input Costs Instrument for Prices To address the issue of price endogeneity, I use milk prices data obtained from Nielsen retail scan data to construct an instrumental variable (IV), which is similar to the instrument in Berto Villas-Boas (2007). The intuition of this instrument is that, milk serves as the primary ingredient in infant formula products Martin et al. (2016), it is reasonable to assume that the prices of input milk are uncorrelated with changes in unobserved product characteristics ξ_{jm}.

6.2 Identification Intuition and Estimation

Identification Intuition The identification assumption is that variations in unobserved product attributes ξ_{jm} in Equation 13 is orthogonal to the contract manufacturer dummy variable $\mathbb{1}_{j=g}$, the input milk price instrument z_{jm}, and manufacturer-market fixed effects $\mathbf{H}_{jm}$.

First, to identify the price coefficients (α), I use the correlation between variations in input prices and observed market shares. The identification assumption requires that the instrument satisfy both the exclusive and relevance restrictions. Since milk is both a close substitute and a primary ingredient in infant formulas, its price would have a correlation with the prices of infant formulas. The exclusive condition requires milk prices to be independent of the unobserved product characteristics of infant formula. Although infant formula manufacturers might observe changes in milk prices, it is unlikely that they change product's attributes as a response of changes in milk prices.

Second, to identify consumer preferences parameters (β_i), I rely on the correlation between the product characteristic–whether the product produced by the contract manufacturer and the market shares from type t households. The data allows me to distinguish β_w from β_{nw}, by interacting manufacturer's market shares with county-level percent of WIC households, as shown in Figure 3.

Estimation I estimate a two-step GMM following Petrin (2002), and take advantage of the large sample (1000 counties in 50 states and D.C., 40 quarters from 2006 to 2016, 4 main manufacturers covering 2000 unique products). The estimation process is standard, and I show it in the Appendix and summarize to two main steps. Firstly, given the initial guesses for mean taste parameters $\theta = \left\{\alpha, \beta\right\}$, I run a contraction mapping by setting constants[13] determined predicted market shares for each product equal actual shares. Secondly, I estimate the mean taste parameters by using the input costs instrument.

6.3 Demand Estimates

Table 4 presents the demand estimates, and average price elasticity of demands for non-WIC households.

Table 4: Demand Estimation Results

Meaning	Parameters	Estimates
Price coefficient	α	-0.098
WIC households' preferences on contract manufacturers	β_w	1.420
Non-WIC households' preferences on contract manufacturers	β_{nw}	1.318
Price elasticity of demands for non-WIC	ϵ_d	-1.509

[13] δ_{jm}: Common part of utility across all types of consumers.

6.4 Supply Costs and Markups

On the supply side, my goal is to estimate the marginal costs of all manufacturers. For those manufacturers who do not win the WIC competitive bidding contracts in a specific market, their marginal costs are straightforward through their first-order conditions derived from Bertrand-Nash, see Equation 10. Using observed data in weighted average prices, market shares, and demand estimates, can help me obtain their marginal costs.

For the contract manufacturers, I predict the contract manufacturers' marginal costs in given markets through two steps. First, I divide the dataset into four sub-samples based on four manufacturers. Then, in the second step, I further split these sub-samples based on whether manufacturer j is the contract winner in market m or not. Within the sub-sample where manufacturer j is not the contract manufacturer, I conduct ordinary least squares (OLS) regressions to derive cost estimates for each manufacturer j

$$Y_{jm}^{j\neq g} = \mathbf{P}_m \cdot \lambda + \mathbf{X}_{jtc} \cdot \pi + \epsilon_{jtc} \tag{14}$$

where $\mathbf{X}_{jm} = \begin{bmatrix} \nu_j & \nu_t & \nu_c \end{bmatrix}$ is a matrix including manufacturers fixed effect, year-month fixed effect, and county fixed effects; $Y_{jm}^{j\neq g}$ represents the calculated marginal costs for non-contract manufacturer j in the market m. Non-contract manufacturer's marginal costs depend on its main ingredients' prices: cow milk price and commodity milk price index[14], which are captured by $\mathbf{P}_m = \begin{bmatrix} P_t^{\text{index}} & P_{tc}^{\text{milk}} \end{bmatrix}$. The cost estimates are shown in the Appendix D. Given these cost estimates and the sub-sample where manufacturer j is the contract manufacturer, I can predict marginal costs for manufacturer j in markets that it wins the WIC contract.

7 Welfare Analysis

In this section, I perform two policy experiments. In the first experiment, I decompose the current WIC full policy into a Laissez-Faire, where there is no WIC contract manufacturer involved. The presence of contract manufacturer products, which receive special preferences and are subject to price regulations, adds complexity to the interpretation of welfare outcomes. As highlighted by Cao et al. (2022) in a similar context, the impact on consumer welfare resulting from the competitive bidding process heavily depends on how much consumers value the products of the contract winner. This factor introduces ambiguity into the welfare analysis. To handle that, I re-compute a equilibrium for the

[14]Data sources: Federal Reserve Bank of St. Louis, Producer Price Index by Commodity: Farm Products: Raw Milk, Index 1982 = 100, Monthly, Seasonally Adjusted

current policy by removing β_i from the utility function, and set this as the benchmark. This ensures that consumers' preferences are not across decomposition.

While the second, inspired by SNAP's distribution method, examines whether providing discount coupons to WIC participants would increase total welfare compared to the current world's use of vouchers.

7.1 Policy Experiment I: Laissez-Faire

The current WIC purchasing process can be captured by the following four steps.

1. **Exclusive selling right or extra preferences**: There is a contract winner in each market. In my model, it is captured by the dummy variable $1\left\{j = winner\right\}_{jm}$. This potentially implies: 1) Contract manufacturers consistently hold certain market shares coming from the WIC program, represented by demand estimates β_w; 2) Contract manufacturers consistently maintain market shares from non-WIC households, denoted as β_{nw}.

2. **Subsidizing WIC**: WIC households incur no costs when purchasing products from the WIC contract manufacturer using vouchers, which specify the quantities and brands of infant formula products available to them. This reflected in the WIC households' utility function.

3. **Rebates**: The contract manufacturer is obliged to provide rebates for each unit of infant formula that WIC households acquire. This is reflected in the contract manufacturer's profit function: $P_{jm} - \text{Rebates}_{jm}$. Since rebates are assumed to be exogenous, eliminating rebates would inherently increase the contract manufacturers' profits.

4. **Price restrictions**: The contract manufacturers, who are the winners of WIC contracts, encounter ambiguous price restrictions imposed by the WIC program. To examine the impact of price restrictions, I will relax this assumption and allow both contract and non-contract manufacturers to optimize their prices in Bertrand Nash in the counterfactual world.

Table 6 shows the simulated welfares in this policy experiment. All presents numbers in 10 million dollars. These numbers appear large due to the aggregation of market outcomes from 2006 to 2016. The first column depicts four cases that correspond to Table 5, the second column the average unit price per bottle of infant formula, and the third the government spending on infant formula markets. The fourth and fifth columns represent the combined consumer surpluses for WIC and non-WIC households. The sixth column depicts the total consumer surplus, which results from the sum of the fourth and fifth columns. The seventh column provides the total profits across markets and manufacturers. The total welfare column depicts the cumulative welfare, comprising consumer surplus, profits, and government spending. Finally, the last column reveals the WIC program's surplus, calculated by adding WIC households' consumer surplus and government spending.

The only difference between case 2 and the benchmark is that contract manufacturers no longer pay rebates to the WIC program. This can help us understand how the paying of rebates itself influences the producer surplus. Table 6 reveals that the unit price and consumer surplus for both WIC and non-WIC households remain unchanged when rebates are altered. This is because I consider the auction as exogenous, and auction outcomes-rebates is independent of unit price, hence, keeping the prices constant. However, government spending increased by 45.1 unit dollars, while profits also increased by the same amount. This results essentially in no change of total welfare. Rather it is only a transfer of funds from the WIC program to contract manufacturers. Under this case, the WIC program's surplus decreased significantly due to the increased cost.

Transitioning from case 2 to case 3, I remove the subsidization from the WIC program and make WIC households start paying shelf prices. First, the government spending dropped by 0, and WIC households' consumer surplus declined by 50%. However, non-WIC households' consumer surplus increases because the market prices declines in Lassize Faire. Table 6 also shows that for each additional dollar of government spending, WIC participants receive only 52.73 cents on average. The remainder subsidizes the market power of contract manufacturers.

Table 5: Welfare Analysis: Cases

	A. Subsidize	B. Price Restriction on the winner	C. Have rebates
Benchmark (Policy)	WIC HHs pay 0	The winner faces P^{reg}	The winner pays rebates
Case 2	WIC HHs pay 0	The winner faces P^{reg}	No rebates
Case 3	WIC HHs pay price	The winner faces P^{reg}	No rebates
Case 4 (Lassize Faire)	WIC HHs pay price	Bertrand Nash without P^{reg}	No rebates
Case 5	WIC HHs pay price	Perfect Competition	No rebates

Table 6: Welfare Analysis

	Price	Gov Spend	CS(wic)	CS(non-wic)	CS	profit	Total Welfare	CS(wic) and Gov
Benchmark	16.22	-151.0	203.5	78.9	282.4	220.7	352.2	52.5
Case 2	16.22	-196.1	203.5	78.9	282.4	265.8	352.2	7.4
Case 3	16.23	0	100.1	78.9	179.0	174.8	353.8	100.1
Case 4	16.29	0	99.0	78.0	177.0	175.1	352.1	99.0
Case 5	5.76	0	258.2	204.0	462.2	0	462.2	258.2

Moving case 3 to case 4, I eliminate the price restrictions on the contract manufacturer, allowing it to participate in Bertrand Nash equilibrium to maximize its profits. The results in Table 6 show that the price increases by 5 cents after lifting the price restrictions. This change led to a 1.1 unit dollar decrease in consumer surplus for WIC households, while also causing a 0.9 unit dollar decrease in consumer surplus for other non-WIC households. Interestingly, overall manufacturer profits only increase by 0.3 unit dollars.

The main difference between case 4 and Laissez-Faire is the transformation in market structure. In Laissez-Faire, the market shifts from an oligopoly to a perfect competition market, and suppliers start adopting pricing strategies of $p = mc$ in markets. According to Table 6, this change results in a \$10 decrease in price. As a result, consumer surplus increases by 160.8% for WIC households and 161.5% for non-WIC households. As we anticipated, this adjustment leads to the highest total welfare, amounting to 462.2 unit dollars. Last but not least, when we compare the total welfare under Laissez-Faire with the full policy benchmark, we can observe that the WIC program results in a deadweight loss of 110 unit dollars.

7.2 Policy Experiment II: Discount Coupons

I propose an alternative policy of, rather than using vouchers, offering discount coupons to WIC participants instead. Driven by this idea, I conducted Policy Experiment II.

In this experiment, I introduced a new setup where the WIC program provides discount coupons to its participants. Unlike the current system of vouchers, these discount coupons allow WIC participants to freely choose any brand of infant formula product they prefer. This change eliminates any potential distortion in purchasing behavior. With these discount coupons, WIC participants contribute a certain percentage of the unit price of infant formula products, while the WIC program subsidizes the remaining portion. Additionally, in this hypothetical scenario, I removed all β(s), lifted price restrictions on contract manufacturers, and eliminated the rebate system.

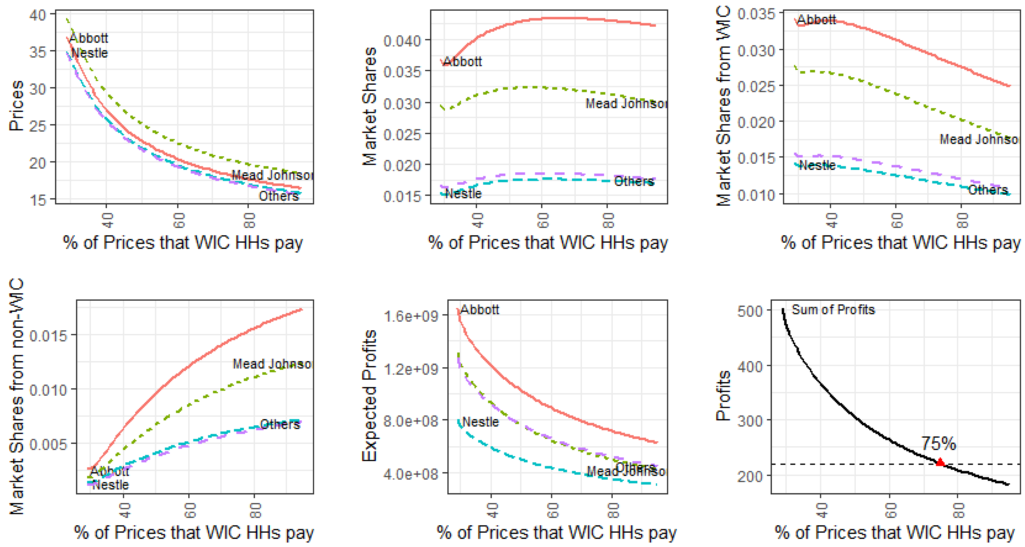
The leftmost graph of Figure 5 illustrates the changes in simulated consumer surplus as WIC participants contribute a higher percentage of the unit price for infant formula products. On the x-axis, we see the percentage that WIC households should pay for each bottle of infant formula ranging from 19% to 89%. The y-axis represents the expected consumer surplus in 10 million dollars unit. The red line shows that the consumer surplus for Non-WIC households increases as WIC households contribute a larger share of the unit price. However, the green line indicates that WIC households experience a decline in their consumer surplus as their share of the unit price increases. The total consumer surplus, represented by the blue line, exhibits a slightly increasing trend as WIC households contribute a higher percentage of the unit price. This trend is driven by the increasing consumer surplus of Non-WIC households.

Figure 5: Simulated Consumer Surplus and Unit Price

The middle graph in the illustration explains why this occurs. It shows that the market price decreases as WIC households contribute a higher percentage of the unit price. To capture market shares from these WIC participants, manufacturers must lower their unit price to compensate for WIC participants paying a larger share. This phenomenon benefits non-WIC households since they face lower market prices under this alternative policy, leading to an increase in their expected consumer surplus.

In addition, represented by the dashed horizontal line in the leftmost graph of Figure 5, I have included the benchmark consumer surplus for WIC households. It's evident that the alternative policy cannot attain this benchmark.

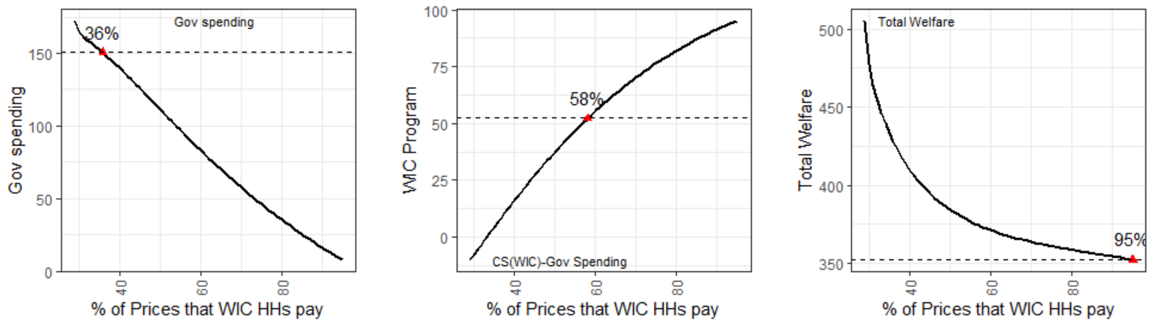
Figure 6: Simulated Profits, Unit Prices, Market Shares by Manufacturers



In Figure 6, the first graph demonstrates that as WIC households begin to pay a larger percentage of the unit price, the unit price decreases from \$35 to \$18 for all manufacturers. According to the law of demand, this leads to an increase in market share for all four manufacturers. I then proceed to decompose these market shares for WIC and non-WIC households. The third graph illustrates that market shares from WIC households decrease as they now face higher net prices, causing them to leave the market and opt for breastfeeding since they can't afford the infant formula products. Conversely, market shares from non-WIC households rise as they enjoy lower market prices. In summary, the fifth graph shows that the profits of the four infant formula manufacturers decline as WIC households start paying for the products. This is because the reduction in unit price outweighs the increase in overall market share.

In the last figure in Figure 6, I've depicted the benchmark profits with a dashed line. It's evident that the benchmark profits intersect with the alternative policy at the 75%. The economic interpretation is that if the WIC program provides 25% discount coupons to its participants, all manufacturers would be equally satisfied with the alternative policy as with the current voucher system.

Figure 7: Simulated Surplus for the WIC Program



In the context of the WIC program, its surplus is a combination of the expected consumer surplus and government spending. In the leftmost graph of Figure 7, you can observe that government spending declines as WIC households pay a larger percentage of the unit price. The benchmark government spending is represented by the dashed line. It signifies that if the government offers 64% discount coupons to WIC households, spending is consistent between the voucher and discount coupon systems. The graph on the right displays the WIC program's surplus. It shows that by issuing 42% discount coupons to participants, the WIC program should achieve the same surplus as in the benchmark. This suggests that as WIC households pay a higher percentage of unit price, the WIC program's surplus increases, potentially even surpassing the benchmark surplus.

Figure 7 total welfare surpasses the benchmark level when the WIC program issues coupons with a discount value of ≥ 5%.

8 Conclusion

This paper studies WIC acts as an intermediary in the infant formula market, providing strict vouchers to its participants–low-income mothers and their infants–enabling them to obtain specific brands of infant formula for free. Simultaneously, the WIC agency of each state, establishes competitive bidding contracts with manufacturers of these specific brands in exchange for reduced net prices. This study investigates how the WIC purchasing process distorts WIC participants' choices, as well as its impact on the WIC program's surplus by intervening manufacturers' pricing strategies. Additionally, I study an alternative approach of subsidizing WIC participants by providing discount coupons. I do this by estimating a mixed logit model for the demand side and a Bertrand Nash equilibrium for the supply side, utilizing data from the Nielsen Retail Scan, NIS-Child, and WIC rebate sources. My findings indicate that the current WIC purchasing process yields the highest consumer surplus for WIC participants, although it may not be the most efficient. For each additional dollar of government spending, WIC participants receive only 50 cents on average. The remainder subsidizes the market power of contract manufacturers. Ultimately, while the alternative policy increases the WIC program's surplus, it cannot match the current level of consumer surplus for WIC participants.

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Appendix

Appendix A: Sample Creation

Each state's WIC agency selects its contract manufacturer first, and then exclusively supplies certain brands of infant formula products produced solely by contract manufacturer. Hence, I needed to create a manufacturer variable to link WIC-supplemented infant formula brands with manufacturers within each state. The state variable could be readily obtained from the retailer data. Although, for the manufacture variable, because the Nielsen retail scan data does not show the manufacturers of each product directly, I had to create this variable based on existing brand information. To do so, I studied the brands associated with the three main manufacturers: Abbott, Nestle, and Mead Johnson. All other manufacturers were summarized as "Others." I then used brand data from the Nielsen dataset to classify 2000 unique products into four categories: Abbott, Nestle, Mead Johnson, and Others. I realized there is a consistent pattern in the brand codes, such as brands under Abbott commonly having codes starting with 604. A similar pattern was held for the other two major manufacturers. Upon realizing this rule-based insight, I efficiently created the manufacturer variable.

Appendix B: Market Shares Proof

The market shares of firm j in the market m, consists of the market shares from WIC households. and from NON-WIC households:

$$
\begin{aligned}
S_{jm} &= \frac{q_{jm}}{\sum_{j'} q_{j'm}} \\
&= \frac{q_{jm}^{NW} + q_{jm}^{w}}{\sum_{j'} q_{j'm}^{NW} + q_{j'm}^{W}} \\
&= \frac{q_{jm}^{NW}}{\sum_{j'} q_{j'm}^{NW} + q_{j'm}^{W}} + \frac{q_{jm}^{W}}{\sum_{j'} q_{j'm}^{NW} + q_{j'm}^{W}} \\
&= \frac{q_{jm}^{NW}}{\sum_{j'} q_{j'm}^{NW}} \frac{\sum_{j'} q_{j'm}^{NW}}{\sum_{j'} q_{j'm}^{NW} + q_{j'm}^{W}} + \frac{q_{jm}^{W}}{\sum_{j'} q_{j'm}^{W}} \frac{\sum_{j'} q_{j'm}^{W}}{\sum_{j'} q_{j'm}^{NW} + q_{j'm}^{W}} \\
&= S_{jm}^{W} \frac{I_0}{I_0 + I_1} + S_{jm}^{NW} \frac{I_1}{I_0 + I_1} \\
&= \frac{I_0}{I_0 + I_1} Pr(U_{ijm}^{W} \geq U_{i0m}^{W}) + \frac{I_1}{I_0 + I_1} Pr(U_{ijm}^{NW} \geq U_{i0m}^{NW}) \\
&= \frac{I_0}{I_0 + I_1} Pr(\alpha^{W}(p_{jm} 1\left\{j \notin WINNER\right\} - p_{0m}) + \beta^{W} X_{im} \geq \epsilon_{i0m}^{W} - \epsilon_{ijm}^{W}) + \frac{I_1}{I_0 + I_1} Pr(\alpha^{NW}(p_{jm} - p_{0m}) + \beta^{NW} \\
&= \frac{I_0}{I_0 + I_1} \frac{e^{\alpha^{W}(p_{jm} 1\left\{j \notin WINNER\right\} - p_{0m}) + \beta^{W} X_{im}}}{\sum_{k=1}^{4} e^{\alpha^{W}(p_{km} 1\left\{k \notin WINNER\right\} - p_{0m}) + \beta^{W} X_{im}}} + \frac{I_1}{I_0 + I_1} \frac{e^{\alpha^{NW}(p_{jm} - p_{0m}) + \beta^{NW} X_{im}}}{\sum_{k=1}^{4} e^{\alpha^{NW}(p_{km} - p_{0m}) + \beta^{NW} X_{im}}}
\end{aligned}
$$

- If j is a winner in the market m:

$$
\begin{aligned}
s_{jm} = wic \times & \frac{exp(\delta_{jm} + \beta_1 \times 1\left\{j = winner\right\}_{jm})}{1 + \sum_{j=1}^{4} exp(\delta_{jm} + \alpha_0 \times p_{jm} \times (1 - 1\left\{j = winner\right\}_{jm}) + \beta_1 \times 1\left\{j = winner\right\}_{jm})} \\
&+ (1 - wic) \times \frac{exp(\delta_{jm} + \alpha_0 \times p_{jm} + \beta_1 \times 1\left\{j = winner\right\}_{jm})}{1 + \sum_{j=1}^{4} exp(\delta_{jm} + \alpha_0 \times p_{jm} + \beta_1 \times 1\left\{j = winner\right\}_{jm})}
\end{aligned}
$$

- If j is not a winner in the market m:

$$s_{jm} = wic \times \frac{exp(\delta_{jm} + \alpha_0 \times p_{jm} + \beta_1 \times 1\left\{j = winner\right\}_{jm})}{1 + \sum_{j=1}^{4} exp(\delta_{jm} + \alpha_0 \times p_{jm} \times (1 - 1\left\{j = winner\right\}_{jm}) + \beta_1 \times 1\left\{j = winner\right\}_{jm})}$$
$$+ (1 - wic) \times \frac{exp(\delta_{jm} + \alpha_0 \times p_{jm} + \beta_1 \times 1\left\{j = winner\right\}_{jm})}{1 + \sum_{j=1}^{4} exp(\delta_{jm} + \alpha_0 \times p_{jm} + \beta_1 \times 1\left\{j = winner\right\}_{jm})}$$

- The general form of model market shares:

$$s_{jm} = wic \times \frac{exp(\delta_{jm} + \alpha_0 \times p_{jm} \times (1 - 1\left\{j = winner\right\}_{jm}) + \beta_1 \times 1\left\{j = winner\right\}_{jm})}{1 + \sum_{j=1}^{4} exp(\delta_{jm} + \alpha_0 \times p_{jm} \times (1 - 1\left\{j = winner\right\}_{jm}) + \beta_1 \times 1\left\{j = winner\right\}_{jm})}$$
$$+ (1 - wic) \times \frac{exp(\delta_{jm} + \alpha_0 \times p_{jm})}{1 + \sum_{j=1}^{4} exp(\delta_{jm} + \alpha_0 \times p_{jm})}$$

Appendix C: Estimation for GMM

Below shows the detailed steps of estimation:

Step 1: For the inside loop contraction mapping, given the initial guesses on (α_0, β_1), I calculate the model's market shares based on weighted prices, the percent of WIC households, and the winner dummy variables. This calculation takes a functional form shown below:

$$s_{jm} = wic \times s^{wic}(P_{jm}) + (1 - wic) \times s^{non-wic}(P_{jm}) \tag{15}$$

The proof is shown in the Appendix. Then, I update each δ_{jm}^{t+1} by:

$$\delta_{jm}^{t+1} = \delta_{jm}^{t} + ln(ms_{jm}^{data}) - ln(ms_{jm}^{model})$$

The convergence criteria is the maximum of the absolute values for differences between δ_{jm}^{t+1} and δ_{jm}^{t}. I choose the tolerance as $1e - 6$, and the maximum iteration as 10000.

Step 2: Next, given the results $\left\{\delta_{jm}\right\}_{j=1...4, m=1...M}$ from the first step, I run an IV regression. The dependent variable is δ_{jm}, and I control the independent variables: $1\Big\{j = winner\Big\}_{jm}$, state-county fixed effects, time fixed effects, and observed manufacturer fixed effects. In this IV regression the error term is the unobserved product attribute ξ_{jm}. We were concerned about a potential positive correlation between the winner dummy variable and the unobserved product attributes. For example, let's consider a scenario where manufacturer j secures the WIC exclusive contract in market m. The primary reason behind its victory is that manufacturer j submitted the highest discount during the auction. If we ask how manufacturer j was able to offer the highest discount, one of the potential answers could be that manufacturer j has relatively lower production costs than other manufacturers. These cost differentials are not observable in our dataset. To address this endogenous issue, I chose each market's WIC density as an Instrumental Variable for the winner dummy variable.

$$Z_{1,jm} = \begin{cases} \text{wic density}_{jm}, & \text{if j = winner} \\ 0, & \text{if j} \neq \text{winner} \end{cases}$$

The WIC density variable serves as a valid instrumental variable for two key reasons: First, WIC density should be independent of product j's unobserved product attributes, so $E(\xi_{jm}^{'} Z_{jm}) = 0$. Second, according to the WIC program's regulation: Before contract manufacturers submit bids, each state's WIC agency is required to provide information about the number of WIC infant participants to each bidder. Hence, $E(X_{jm}^{'} Z_{jm}) \neq 0$. After running the IV regression, I am able to predict the residual term $\hat{\xi}_{jm}$ and then store these residuals for the next step.

$$\hat{\xi}_{jm} = \delta_{jm} - (\hat{\beta}_0 \times 1\Big\{j = winner\Big\}_{jm} + \eta_j + \eta_{county} + \eta_t)$$

Step 3: I use residuals to establish the moment conditions. Since the prices of manufacturer j in the market m should be positively correlated with the unobserved product attributes, we face the endogeneous problem again. In this step, I need IVs for the outside loop. I use milk price as IV here. Specifically,

$$Z_{2,jm} = \begin{cases} (1 - wic_m) \times P_m^{milk}, & \text{if j = winner} \\ P_m^{milk}, & \text{if j} \neq \text{winner} \end{cases}$$

My intuition here is that the costs of infant formula products should play as the ideal instrument. By the existing literature, most infant formula products are produced from cow milk (need references here), so cow milk price should be an instrument. Just like IO papers studying cereal markets, these papers usually choose cereal's ingredient–sweetener's price as IV. However, the cow milk price, or commodity milk prices, do not vary by geographical areas. Hence, I use milk prices within grocery stores as IVs here. The logic is like this: Both milk and infant formula products are made from cow milk. The manufacturers of milk and infant formula products are potential competitors on the buyer-side markets. Hence, their prices should be correlated. However, the infant formula product's cost shock should not be correlated with the milk price. Driven by this idea, I created my first-moment condition:

$$gmm^1 = E(\xi_{jm} \times Z_{2,jm})$$

Similar to the endogenous problem in the step 2, I also need to estimate the coefficient β_1 in front of the winner dummy variable, but concern that the winner dummy variable might be correlated with the unobserved product attributes ξ_{jm}, so I create the second-moment condition:

$$gmm^2 = E(\xi_{jm} \times Z_{1,jm})$$

Then, I calculate the weighted matrix W.

Step 4: In the outside loop, the objective function of the GMM is listed below:

$$\min_{\alpha,\beta_1} \overrightarrow{g}'(\xi_{jm}, Z_{1,jm}, Z_{2,jm}) W \overrightarrow{g}(\xi_{jm}, Z_{1,jm}, Z_{2,jm})$$

Appendix D: Cost Estimates

Table 7: Infant Formula Marginal Costs and Input Costs

	Dependent variable:		
	Marginal Costs		
	Abbott	Mead Johnson	Nestle
Cow Milk Price Index	0.007^{***}	0.015^{***}	0.012^{***}
	(0.001)	(0.001)	(0.001)
Milk Price	0.313^{***}	-0.287^{***}	-0.571^{***}
	(0.021)	(0.028)	(0.029)
Constant	-0.319	-1.306^{***}	0.267
	(0.247)	(0.202)	(0.188)
Time FEs	✓	✓	✓
County FEs	✓	✓	✓
Observations	40,354	44,776	40,933
R^2	0.688	0.686	0.587
Adjusted R^2	0.688	0.685	0.586
Residual Std. Error	1.440 (df = 40308)	2.304 (df = 44724)	2.076 (df = 40877)

Note: *p<0.1; **p<0.05; ***p<0.01

Appendix E: Policy Experiment II

- **Households**:
- If the consumer i ∈ WIC program, then

$$u_{ijm}^{wic} = \alpha \times p_{jm} \times d + FEs + \epsilon_{ijm}$$

- If the consumer i ∈ non-WIC, then

$$u_{ijm}^{non-wic} = \alpha \times p_{jm} + FEs + \epsilon_{ijm}$$

- Given the above information, we can calculate the likelihood that each type of consumer willing to buy the product j in the market m:

$$s_{jm}^{wic} = \frac{exp(\alpha \times p_{jm} \times d + FEs)}{1 + \sum_{j=1}^{4} exp(\alpha \times p_{jm} \times d + FEs)}$$

- And

$$s_{jm}^{non-wic} = \frac{exp(\alpha \times p_{jm} + FEs)}{1 + \sum_{j=1}^{4} exp(\alpha \times p_{jm} + FEs)}$$

- Hence, the overall model's market shares

$$s_{jm} = wic_m \times s_{jm}^{wic} + (1 - wic_m) \times s_{jm}^{non-wic}$$

- **Firms**:
- For each firm, it has the profit maximization problem:

$$\max_{P_{jm}} (P_{jm} - mc_{jm}) \times s_{jm}(P_{jm})$$

- Taking FOC on the price, then we can get:

$$MC_{jm} = P_{jm} + \frac{s_{jm}}{\frac{\partial s_{jm}}{\partial P_{jm}}}$$

- Where

$$\frac{\partial s}{\partial P} = \alpha \times (wic \times s^{w} \times (1 - s^{w}) \times d + (1 - wic) \times s^{nw} \times (1 - s^{nw}))$$

- Hence,

$$P_{jm}^{counter} = MC_{jm} - \frac{wic_m \times s_{jm}^{wic} + (1 - wic_m) \times s_{jm}^{non-wic}}{\alpha \times (wic \times s^{w} \times (1 - s^{w}) \times d + (1 - wic) \times s^{nw} \times (1 - s^{nw}))}$$

- **Government**:

$$E^{gov} = -\sum_{m=1}^{M} (1 - d) \times P_{jm} \times s_{jm}^{w} \times wic_m$$