The Welfare Effects of WIC Purchasing in the Infant Formula Market

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Abstract

The Women, Infants, and Children nutritional program (WIC) serves as an intermediary in the infant formula market, providing vouchers to its participants – low-income mothers and their infants – and allowing them to obtain specific brands of infant formula for free. To determine these brands, each state's WIC agency exclusively contracts with a single manufacturer in exchange for rebates and an agreement to abide by pricing regulations. I quantify the effect of this purchasing program on consumer surplus and government expenditure; and explore an alternative approach to subsidize WIC participants by giving them a discount on any brand. 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 the contract manufacturer faces price regulations. I find that removing the WIC program, in a *lassize-faire* counterfactual, raises prices. This is because price regulation forces the contract manufacturer to set a lower price which strengthens competition. Though the current WIC purchasing process yields a higher aggregate consumer surplus than an alternative discount coupon policy, it also increases the WIC program's expenditures and reduces the total welfare of the market.

JEL classification: H42, I38, L33, L44, L66.

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

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1 Introduction

Public food assistance programs are among the largest safety net programs in the United States, with 37% of Americans receiving food assistance. Because these individuals have low incomes, food assistance programs account for a considerable amount of their participants' consumption. These programs, therefore, play a crucial role in addressing nutritional inequality and food insecurity. While the existing literature typically examines the welfare of participants, this paper investigates how the WIC program's purchasing process in the infant formula market can create spillovers to non-participants and explores the program's interaction with market power in a highly concentrated market.

The Women, Infants, and Children nutritional program (WIC) serves 45% of all infants in the U.S. (USDA, 2023). In 2010, the WIC program spent $927 million on infant formula alone (Carlson et al., 2017). To attempt to limit costs, WIC has implemented a competitive bidding system in the infant formula market since 1989. Under this scheme, each state's WIC agency grants exclusive supplying rights to a selected manufacturer, known as the "contract manufacturer," in exchange for rebates per unit of infant formula supplied to program participants.[1] As the infant formula market is highly concentrated (there are three main suppliers), the WIC program imposes price regulations on contract manufacturers to limit their use of market power.[2]

In this paper, I investigate the impact of the WIC purchasing process (WIC vouchers, competitive bidding, and price regulations) on infant formula prices, consumer surplus, and government expenditures. I focus on three sets of trade-offs: *(i)* WIC participants use vouchers to get the contract manufacturer's products for free, but have to pay full price for other brands. This distorts their choices towards the contract manufacturer, which could reduce welfare if there are heterogeneous tastes. Indeed, Le Huërou-Luron et al. (2010) suggests that babies often struggle to digest certain brands and parents often have strong brand preferences. *(ii)* Empirically, I observe that, households not enrolled in WIC also buy the contract manufacturer's brand at disproportionate rates, suggesting a spillover to non-WIC demand. There are a number of proposed mechanisms for this result, including WIC labels signaling quality (Chauvenet et al., 2019); grocery stores being required to stock the contract manufacturer (Wang and Filipski, 2022) and (Huang and Perloff, 2014); and hospitals stocking WIC products so WIC participants don't have

[1] Part of the exclusive supplying right is manifested in the form of WIC vouchers. WIC vouchers indicate that WIC participants can only use them to redeem contract manufacturers' products. The other part of this exclusive supplying right is demonstrated in the requirement of the WIC program for authorized grocery stores to maintain inventories of contract manufacturers' products.

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

to switch products (Bitler and Currie, 2005). *(iii)* Because the contract manufacturers receive considerable market share from both WIC and non-WIC participants, and the WIC participants pay nothing for the product, there is considerable potential for the manufacturer to raise prices after winning the contract. To counteract this, the WIC program restricts the manufacturer's ability to raise prices. Therefore, the extent of the market power created under price regulations is ultimately an empirical question.

To quantify these trade-offs, I estimate a discrete choice model of demand in which WIC and non-WIC households differ in two ways. First, WIC participants incur no monetary costs when they exchange vouchers for infant formula products from the contract manufacturer. By contrast, non-WIC participants pay the shelf price for their purchases. Second, these two types of households have heterogeneous preferences for the contract manufacturer. I model supply by assuming that non-contract manufacturers compete in price via a Bertrand Nash game, while contract manufacturers face price restrictions. Because this is true of contract manufacturers, I cannot back out their marginal costs by assuming they are setting profit maximizing prices. Instead, I estimate marginal costs (MC) by using the contract manufacturer's marginal costs in other markets to predict its marginal costs in a market where they hold WIC competitive bidding contracts.

To estimate the model, I use three data sets primarily: Nielsen Retail scanner data (2006 – 2016), NIS-child data (2006 – 2016), and WIC rebate data (1989 – 2016). To estimate demand, I use milk prices obtained from Nielsen retail scanner data as an instrumental for prices. I find that the own-price elasticity of demand for non-WIC households is -1.509, which indicates that demand for the product is highly responsive to changes in price.

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. In this *laissez-faire* scenario, removing price regulations results in a 0.4% price increase, suggesting that price regulations strengthen price competition. The contract manufacturer set prices below what it would have given unrestrained Bertrand-Nash competition. The consumer surplus for WIC participants falls by 51.35%, because they no longer get infant formula products for free, while the same price change results in a far more modest decline of 1.14% for non-WIC households. Meanwhile, the government's expenditure declines significantly, as WIC participants begin paying. In addition, I find that every additional dollar spent by the government increases the expected consumer surplus for WIC participants by 52 cents, and much of the remainder is captured as profit for manufacturers.

The second experiment is investigating whether providing percentage discounts for

WIC participants would enhance total welfare more than the current system. With these discount, WIC participants can purchase whichever brands as they want; but must pay a certain percentage of the unit price of infant formula products, while the WIC program subsidizes the remainder. I find that to keep the government budget neutral, the WIC program would need to give its participants a 42% discount. This suggests that as WIC households pay a higher percentage of unit price, the WIC program's expenditures decrease, potentially even surpassing the benchmark surplus. However, I find that no discount matches the current policy's consumer surplus. The issue is that at low discounts, WIC participants pay closer to full price; under the current policy, they receive the product for free. As the discount increases, WIC participants become less price elastic and manufacturers raise their prices. This lowers the surplus for non-WIC participants.

This paper is related closely to recent work by An et al. (2023) and Abito et al. (2022), who also study the welfare effects of the WIC program in infant formula markets. However, Abito et al. (2022) examine the demand spillover effects on non-WIC participants but do not delve into the price restrictions that contract manufacturers may encounter. Similarly, An et al. (2023) assess the influence of the WIC program's competitive bidding on infant formula prices, estimating the WIC program by using an auction model under the perfect competition. However, because a recent report on FTC described infant formula manufacturers colluding on bids for state WIC contracts (Whyte et al., 2023), I take the bidding process as exogeneous, rather than modeling bids in a competitive setting.

This paper is also related to the recent body of literature that investigates the effect of competitive bidding contracts on market prices and concerns related to market efficiency. For instance, Ding et al. (2022) reveal that the introduction of an imperfect bidding mechanism can drive down market prices in the medical devices market. Ji (2023) illustrates that the implementation of competitive bidding contracts can lead to shortages in the health insurance market. Additionally, Cao et al. (2022) studies the Chinese pharmaceutical industry to emphasize that the welfare implications of competitive bidding depend on consumer preferences for the contract manufacturers' products.

With this paper, I contribute to the body of research that evaluates the WIC program. Several earlier studies shed light on different aspects of the program: Chorniy et al. (2020) uncover that WIC infant participants have higher average birth weights than non-WIC peers in the same income group; Jacknowitz and Tiehen (2009) explore the reasons WIC participants leave the program; Ambrozek (2022) investigates how the WIC program influences the entry and exit decisions of authorized retail stores; Hanks et al. (2019) and Meckel (2020) examine the effects of transitioning from paper vouchers to electronic debit cards; Ludwig and Miller (2005) explain how WIC rebates function. I add to these works by quantifying the welfare consequences for consumers and government expenditures.

Finally, the paper also contributes to research on the efficient use of public funds for essential goods and services. That research includes the work of: Handbury and Moshary (2021) on the National School Lunch Program in retail markets, Finkelstein et al. (2019) on the effect of subsidized health insurance programs on healthcare demand, and Chetty et al. (2016)'s study of housing projects in low-income neighborhoods. In a related context, Jiménez Hernández and Seira (2022) explores the 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 the combination of vouchers and price regulations on infant formula contract manufacturers generates a higher consumer surplus than restricted cash transfers (such as discount coupons).

The rest of the paper is organized as follows. Section 2 provides details about the WIC purchasing process. Section 3 describes the data sources and shows descriptive statistics. Section 4 provides reduced-form evidence of the effect of the WIC's competitive bidding contracts on market outcomes. Section 5 introduces a demand and supply model, which is estimated in Section 6. Section 7 explores counterfactual policies, and Section 8 concludes.

2 Background

The WIC program operates across all 50 states and the District of Columbia. Each state's respective WIC agency is responsible for determining its contract manufacturer and distributing the manufacturer's products to its participants.[3] The state agencies function as buyers in the infant formula market, signing a three-year exclusive contract with one formula manufacturer.

Competitive Bidding To determine their contract manufacturer, agencies implement a competitive bidding scheme. In accordance with the industrial regulation 7 CFR Part 246, manufacturers submit sealed bids specifying per unit rebates of a standardized infant formula. Manufacturers who offer the lowest net price or the highest rebates are given the exclusive supplying right. To facilitate bidding, each state's WIC agency provides essential program information to all potential bidders. After a 30-day period, the agencies announce each winner. I do not model each manufacturer's bidding strategy,

[3]Some state WIC agencies determine their contract manufacturers jointly through forming an alliance.

but treat the auction as exogeneous.[4] The auctions' outcomes are from the WIC rebate data, collected by Davis (2012). The WIC program imposes price regulations to prevent contract manufacturers from leveraging their market power to inflate prices: *"Bid solicitations must require the manufacturer to adjust rebates for price changes subsequent to the bid opening. Price adjustments must reflect any increase and decrease, on a cent-to-cent basis, in the manufacturer's lowest national wholesale prices for a full truckload of infant formula."*[5]

Minimum Inventory After determining the contract manufacturer, state WIC agencies require all authorized retail stores to give a minimum amount of inventory to the contract manufacturer's infant formula products. Cachon and Kök (2010) show that inventories increase sales directly. Thus, the minimum inventory policy 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 and health outcomes to determine eligibility. Participants' income is below 185% of the federal poverty line. Different from SNAP that gives money directly to its participants, WIC participants use vouchers in exchange for contract manufacturers' infant formula products. The vouchers clearly state the amount and brand of infant formula products each 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 restrict my sample from 2006 quarter 1 to 2016 quarter 4.

3 Data and Descriptive Statistics

I use three datasets primarily: Nielsen retail scanner data from 2006 to 2016, the National Immunization Survey Child data from 2006 to 2016, and WIC rebate data collected by David E. Davis, spanning the years 1989−2016. I choose this specific period, from 2006 to 2016, for two reasons. The first is that, starting in 2017, many states began implementing E-vouchers for WIC participants. The second is that, the WIC rebate data I rely on only extends up to 2016.

[4]Recent reports in FTC concerned that infant formula manufacturers colluded on bids for state WIC contracts. Given this, I take the bidding process as exogeneous, instead of modeling bids in a competitive setting.

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

3.1 Data

Nielsen Data The Nielsen retail scanner 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 is organized into three levels of information: product data, retailer data, and store-level transaction data. The product data includes information about the products UPC code; product description; brand name; brand description; unit; and size. 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. Finally, store-level transaction data is a record of the amount of product sold per week and, the corresponding weekly unit prices. These three types of data are merged together by using the store and UPC codes. I clean the data by referencing and combining methods from Moshary et al. (2023); Döpper et al. (2022); Allcott et al. (2019); Bronnenberg et al. (2015), and so on. [6]

NIS-Child Data The National Immunization Survey - Child data is an annually national survey that collects information on children's health. I use five variables from this data: the year interviewed; sample weights assigned to each household; whether or not the children currently receives WIC benefits; whether or not the children were breastfed exclusively before reaching the age of one; and the state 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 between 1989 and 2016. This dataset contains each main manufacturer's bid in every auction; the auction type (first price, second price, and so on); each auction's winner; predicted wholesale prices by David E. Davis; contract start and end dates; and the size as well as the type of infant formula (liquid concentrated, powder, or ready-to-feed) being bid on rebates. I use these data to identify when each state's WIC contract underwent a change in contract manufacturer; and the rebates that the contract manufacturers paid. To ensure the accuracy of these transition dates, I cross-referenced the data with each state's WIC program regulation from 2006 to 2016.

[6] See details in Appendix A.

3.2 Sample Construction

I defined the market at the county-year-quarter level and aggregate Nielsen's weekly store-level data into state-county-year-quarter-manufacturer data. My sample includes 1,000 counties. I restrict my sample in terms of product, which I define as a combination of package size; manufacturer; milk-based or soy milk-based; and the type of infant formula (liquid concentrated, powder, or ready-to-feed). This product restriction is useful because the WIC agency in each state has clear regulations on the types, sizes, and brands of infant formula products they supply to their participants. To align with these regulations from 2006 to 2016, I restricted my sample's product to $12-13$ ounce, liquid concentrated milk-based infant formula products, which account for a 67.97% market share of all products. I adjust prices using the Consumer Price Index (CPI) and aggregate the weekly store-level data to the year-quarter-county level by taking a quantity-weighted price.[7]

3.3 Descriptive Statistics

Shares of WIC Households and Share of Households Breastfeeding I use *shares of WIC households* to quantify the percentage of parents who received WIC benefits for their children in each market. I also use the *shares of households breastfeeding* to establish the percentage of parents who choose to breastfeed exclusively in a given market. Table 1 shows that, on average, 54.9% of parents receive WIC benefits for their children,[8] and 76% of parents opt for exclusive breastfeeding. To analyze variations across states and over time, I calculate the coefficients of covariation individually for both states and time periods. [9] I observe that shares of WIC households and shares of households breastfeeding exhibit greater dispersion over time than they do across states.

[7] 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.

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

[8] I aim to find the percentage of parents who currently receive WIC benefits for children under 1 year old, as the USDA's definition of "infant". However, to the best of my knowledge, existing data can only provide demographic and health information for children under five years old. Due to this data limitation, I acknowledge that shares of WIC households in my sample are likely overestimated.

[9] The coefficients of covariation across states is computed by dividing the standard deviation by the mean, with the data grouped by different states, similar for the coefficient across time.

Table 1: Shares of WIC Households and Shares of Households Breastfeeding

	Statistics							Coeff. of Covariation	
	Min.	1st Qu.	Median	Mean	3rd Qu.	Max.	Sd	States	Time
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Shares of WIC households	0.070	0.470	0.560	0.549	0.620	0.770	0.097	0.069	0.173
Share of households breastfeeding	0.150	0.690	0.760	0.751	0.810	0.950	0.088	0.051	0.116

Notes: Columns (1) through (7) present the summary statistics for shares of WIC households and the share of households breastfeeding. Columns (8) and (9) display the coefficients of covariation across states and across year-quarters. These coefficients demonstrate that both variables exhibit higher relative variability relative to the mean across states and over time. These variation is crucial for ensuring the accuracy of our model identification. *Sources:* NIS-Child data 2006-2016

Prices Abbott (*"Similac"*, *"EleCare"*), Mead Johnson (*"Enfamil"*), and Nestle have all served as WIC suppliers for infant formula products. Table 2 presents their prices when these manufacturers are the WIC supplier and when they are not the contract supplier. The prices Abbott and Mead Johnson charge in markets where they are not the contract supplier are higher than in markets where they are. Specifically, Abbott's non-supplier price is $0.44 higher than its price as a WIC supplier, while Mead Johnson's non-supplier price exceeds its supplier price by a more substantial margin of $1.63. This finding aligns with the price regulations imposed by the WIC programs, suggesting that these manufacturers adopt a higher pricing strategy when they are not the contract suppliers. By contrast, Nestle had a different pricing strategy, despite having the lowest share of involvement in becoming WIC suppliers from 2006 to 2016. When it becomes a WIC supplier, its prices are higher ($16.42) than when it is not the contract supplier ($15.5). Mead Johnson stands out as the most expensive, with its prices hovering around $17.97, while Abbott has an average price of $15.95.

Market Shares Table 2, Column 3 presents the aggregate market shares for each manufacturer when breastfeeding is not considered as an outside option, while Column (4) displays aggregate market shares when breastfeeding is included as the outside option. There are three takeaways here. First, once a manufacturer becomes a WIC-supplier, it receives an average market share increase of 50%. Second, Abbott holds the largest average market share at 45%, followed by Mead Johnson at 38%. 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 percent of the market. Third, given that 75% of mothers breastfeed, each manufacturer's market share is proportionally lower than unconditional market shares.

Table 2: Prices and Market Shares

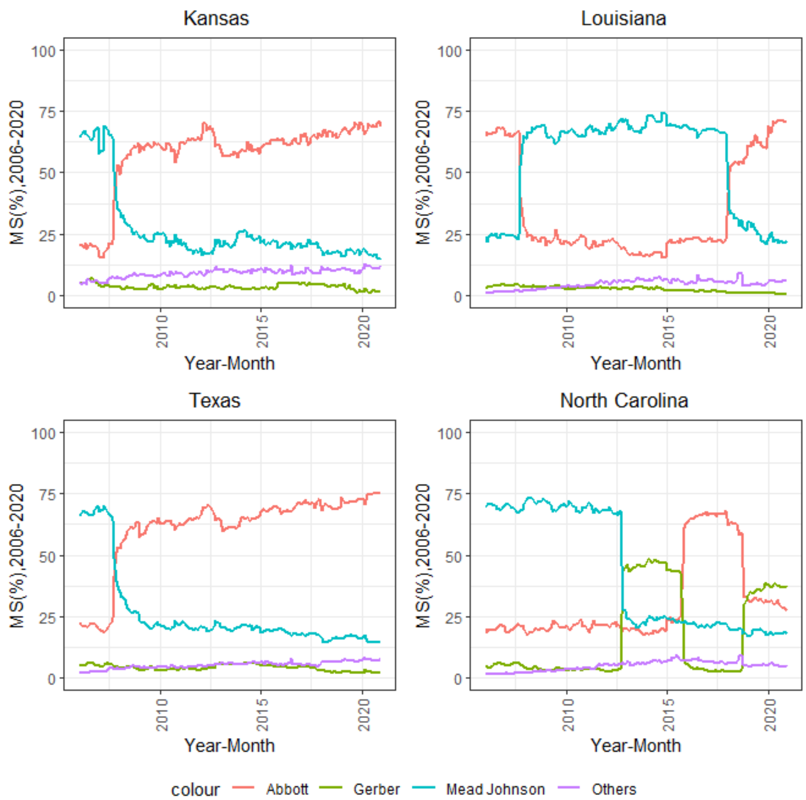
		Price ($)		Market Shares (%)		Freq. (%)
		Retail	Rebates	unconditional	conditional	of being WIC-supplier
		(1)	(2)	(3)	(4)	(5)
Abbott	Not contract supplier	16.14		26.46	4.98	
		(1.986)		(0.233)	(0.063)	
	WIC-supplier	15.70	3.61	78.20	19.48	40.3
		(2.108)	(0.395)	(0.181)	(0.083)	(0.491)
	Average	15.95		45	11	
		(2.050)		(0.337)	(0.102)	
Mead Johnson	Not contract supplier	18.47		16.87	3.00	
		(3.494)		(0.176)	(0.042)	
	WIC-supplier	16.83	3.61	66.97	18.83	36.8
		(2.819)	(0.398)	(0.253)	(0.093)	(0.483)
	Average	17.91		38	8	
		(3.341)		(0.333)	(0.099)	
Nestle	Not contract supplier	15.50		9.72	1.36	
		(2.630)		(0.117)	(0.021)	
	WIC-supplier	16.42	3.60	53.09	17.35	22.9
		(2.165)	(0.397)	(0.214)	(0.065)	(0.420)
	Average	15.76		24	5	
		(2.543)		(0.259)	(0.081)	
Others	Not contract supplier	15.33		6	1	0
		(2.834)		(0.075)	(0.020)	(0.000)
Breastfeeding					75	
					(0.088)	

Notes: Column (1) shows the mean and standard deviations of retail prices across various manufacturers, distinguishing between those that are WIC-suppliers and those that are not. These prices are adjusted to 2010 dollars; using the CPI. Column (2) presents the average rebates set by contract winners in competitive bidding processes. Column (3) provides each manufacturer's aggregate market share when breastfeeding is not considered as an outside option, while column (4) includes breastfeeding as the outside option. Finally, column (5) illustrates the shares that each manufacturer secures in competitive bidding contracts. Abbott is the most frequent WIC supplier. *Sources:* NIS-Child data 2006-2016; Nielsen Retail Scanner Data 2006-2016; WIC Rebate Data 2006-2016.

4 Motivating Evidence

In this section, I present results that illustrate the importance of the topic and highlight some of my modeling choices. In particular, I show that winning the contract drives considerable market share for the contract manufacturer, both from WIC and non-WIC participants. In addition, I show that the price regulation appears fairly strong. Prices are remarkably stable after a firm wins a contract.

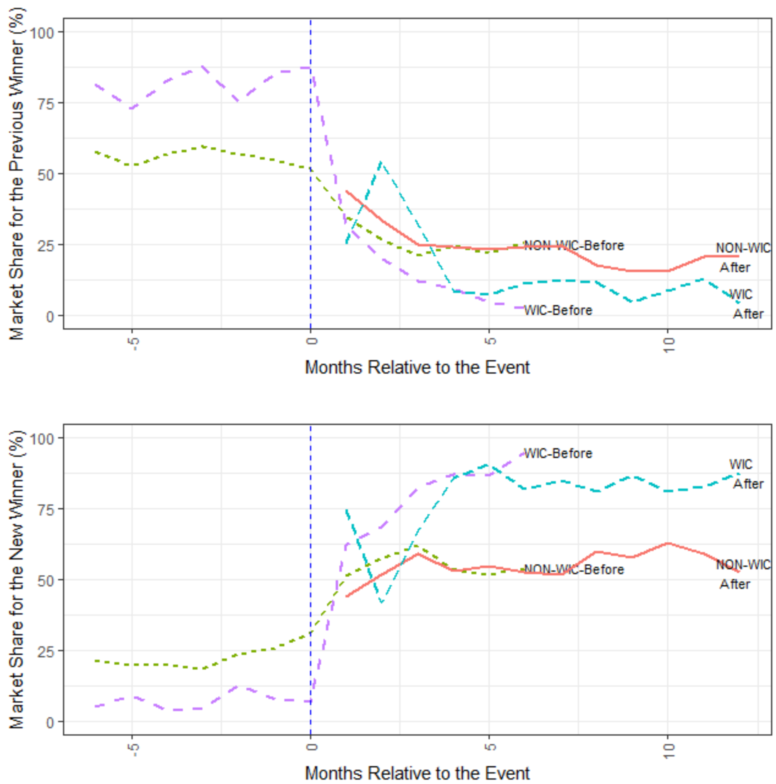
Figure 1: Correlation between Market Shares and Competitive Bidding Contracts



Notes: The figure shows the strong correlation between the contract manufacturers and their market shares. The first sub-figure depicts the market share changes in 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.

Variations in Market Shares Figure 1 proves the strong correlation between the contract manufacturers and their market shares. The first sub-figure depicts the market share changes in Kansas between 2006 and 2020, illustrating 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 one month, shares fell from 70% to 25%, while the new contract manufacturer, Abbott, saw an increase in shares from 20% to 65%. In the other three graphs, we can see a similar pattern for Louisiana, Texas, and North Carolina. Appendix B presents the event study analysis, which aggregates market shares across all contract changes in all states.

Figure 2: Event Study: Spillover Effects on Non-WIC households



Notes: The upper figure depicts changes in market shares among previous winners and can be broken down into four types of demands: demand from WIC and non-WIC households that had a preference for products from the previous WIC supplier both before and after the supplier change. The green dashed line illustrates that, following the contract switch, market shares of previous contract winners from NON-WIC households with babies born before the contract change decreased from 55% to approximately 25%. This suggests a significant spillover effect on the consumption of non-WIC households due to the switch in WIC contracts. Additionally, there was a drop of around 70% in market shares from WIC households, indicating potential brand loyalty among WIC parents for infant formula products. The implications are clear: the shift in WIC contracts has a substantial impact on both non-WIC and WIC households' consumption patterns. Turning to the bottom figure, it reveals an increase in market shares for new winners among both WIC and NON-WIC households. This pattern mirrors the trends observed in the upper graph and conveys a similar implication: a spillover effect on non-WIC households. *Sources:* Nielsen data 2006-2020.

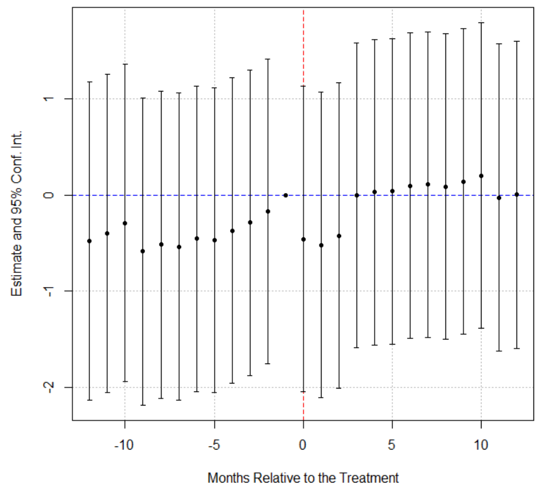
Spillover Effects Huang and Perloff (2014) point out that it may be extremely profitable for a manufacturer to secure this contract because of the potential spillover demand from non-WIC participants. As quantified in Wang and Filipski (2022), changes in contract manufacturers lead to shifts in market shares among non-WIC households. In Figure 2, I plot market shares for WIC and non-WIC participants using household level data from Nielsen. We should expect WIC participants to change their demand immediately because the product they get for free changes, while I find that households which are not eligible for WIC also change their shopping behavior. Their demand for the previous contract manufacturer changes from 55% to 25% on average within a single month. In accordance with the WIC's regulation on retailer's inventories, retailers who collaborate with the WIC program must maintain a specific quantity of the contract manufacturer's infant formula products on their shelves at *all* times. Because the contract manufacturer's products are more likely to be stocked by this regulation, its demand increases. (Wang and Filipski, 2022) Additionally, since the contract manufacturer's products feature the WIC logo itself, non-WIC consumers may assume these products are of have higher quality due to government endorsement, further boosting demand. Bitler and Currie (2005) and Huang and Perloff (2014) also point out that many hospitals stock infant formula products from WIC contract manufacturers. This ensures that parents of newborn, who have not yet applied for WIC benefits, do not need to switch brands for their babies once they become eligible for WIC benefits.

Price Effects The large shift in demand for both WIC and non-WIC participants, could create considerable market power in the absence of price regulation. In this sub-section, I explore whether WIC contract manufacturers raise their prices after winning the contract. To assess 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 are state fixed effect, and ζ_t are 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 after the contract manufacturer changes. This represents the sample average for prices in each month after netting out state and time fixed effects.

Figure 3: Event Study: Dynamics of Pricing Changes around Contract Changes



Notes: The figure illustrates how contract manufacturers in different states adjust their prices following the successful acquisition of WIC contracts. his suggests that manufacturers don't raise prices after becoming the WIC contract manufacturer, likely due to price regulations. *Sources:* Nielsen Retail Scan data 2006-2020.

Figure 3 illustrates that, on average, contract manufacturers' unit prices do not change significantly after winning WIC contracts. This suggests that the price restriction may prevent contract manufacturers from increasing prices.

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 *four* infant formula manufacturers in each market: $\{\text{Abbott}, \text{Mead Johnson}, \text{Nestle}, \text{Others}\}$. I denote the WIC contract manufacturer's product as $j = g$ [10]. Assuming all households

[10] There are some concerns about whether consumers' choice sets are limited by WIC's minimum in-

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 $j \in \mathcal{J}$ in my data (in other words, $d_{ij} = 1$), then I can say $j \succsim_R j^{'}$ for all $j^{'} \in \mathcal{J}$. Each household faces a price vector $\mathbf{p} \in R_L^+$ in the market and chooses consumption to maximize their utilities.

The purpose of the model is twofold. First, the model quantifies: *(i)*: the different preferences of WIC and non-WIC households; *(ii)*: How WIC participants face a trade-off between using vouchers to exchange for WIC-supplemented infant formula products for free, and paying shelf-prices to consume 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 the role of the regulated price for the contract manufacturer in affecting other non-contract manufacturers' pricing strategies in each market. If the WIC program removes the price regulation on the contract manufacturer, the contract manufacturer strikes 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 response is thus important in the counterfactual analyses that follow.

5.1 A Discrete Choice Model of Demand

I follow the large literature on discrete-choice demand system estimation 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 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

ventory 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.

$\mathbf{H}_{jm} = \begin{bmatrix} \eta_c & \eta_{yq} & \eta_j \end{bmatrix}$ 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 the fact 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 unobserved product characteristics across markets, or unobserved variations in tastes across markets.

Another key variable is the WIC contract manufacturer dummy variable $\mathbb{1}_{j=g}$. The spillover Figure 2 shows that two types of households have heterogeneous preferences for contract manufacturer's products. Hence, the model allows β_i vary between WIC and non-WIC 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 for the contract manufacturer's infant formula products for WIC participants. β_{nw} represents non-WIC households' preferences for the contract manufacturers' products. Finally, ϵ_{ijm} is an idiosyncratic preference shock that is observed by consumers and is assumed to be an *i.i.d* type I extreme value error.

Given this model, the probability that a representative WIC participant i in the market m chooses manufacturer j's products is:

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

Similarly, the probability that a representative non-WIC participant i in the market m

chooses manufacturer j's products is:

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

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 participants 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:

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

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]

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

On the left-hand side of the above equation, $WIC\%$ is the share of WIC parents in the market m, so the first term represents the market shares of product j coming from WIC participants. Similarly, the second term represents the market shares of product j coming from non-WIC households. In the following section, I show how this demand function is used to derive suppliers' profit functions.

Consumer Surplus An advantage of a structural model is that it enables us to assess equilibrium changes in welfare. At the price vector $\mathbf{p} \in R_L^+$, WIC and non-WIC households' expected consumer surplus in the market m is:

$$CS_m^{(t)} = \frac{1}{\alpha^*} \times \sum_{j \in \mathcal{J}(m,t)} exp\left[V_{jm}^{(t)}(p_{jm}, \mathbf{p}_{-j,m})\right] + C, \quad \text{where } t \in \left\{\text{WIC, non-WIC}\right\} \tag{9}$$

where α^* is the price estimate; $V^{(t)} = u_{ijm} - \epsilon_{ijm}$, which vary by the types of households; and C is an unknown constant on integration reflecting the fact that the absolute level of consumer utility cannot be measured.

[11] Here, I follow Jiménez Hernández and Seira (2022) to set notations for the common mixed logit model.

[12] See appendix B for proof details.

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, and in the second period choose prices. I take the first stage's auction as exogeneous. The outcomes of competitive bidding contracts are common knowledge to households, 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 of infant formula product in the market m at a marginal cost of $c_{jm} > 0$. The marginal costs vary by markets because of transportation 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 weighted 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

$$\max_{p_{jm}} \quad (p_{jm} - c_{jm}) \times \sigma_{jm}(p_{jm}, \mathbf{p}_{-j,m}) \tag{10}$$

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:

$$\sigma_{jm}(p_{jm}) + (p_{jm} - c_{jm}) \times \frac{\partial \sigma_{jm}(p_{jm})}{\partial p_{jm}} = 0 \tag{11}$$

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

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 supplies 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

$$\pi_{jm}^{j=g} = \sigma_{jm}^{t=wic}(0) \times (p_{jm}^{reg} - \text{Rebate}_{jm}) + \sigma_{jm}^{t=non-wic}(p_{jm}^{reg}) \times p_{jm}^{reg} - \sigma_{jm}(p_{jm}^{reg}, \mathbf{p}_{-j,m}) \times c_{jm} \quad (12)$$

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 12.

5.3 Government Expenditures

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

$$E(gov) = \sum_{m\in M} \sum_{j\in J} \mathbb{1}_{j=g} \cdot (p_{jm}^{reg} - \text{Rebate}_{jm}) \cdot \sigma_{jm}^{t=wic}(0) \quad (13)$$

where the dummy variable $\mathbb{1}_{j=g}$, indicates that j is a WIC supplier. 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 estimate 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 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, so I cannot use first order conditions to back out marginal costs. To deal with this issue, I predict the contract manufacturers' marginal costs in given markets by using observations in markets that manufacturers do not win 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}

$$\delta_{jm} = \beta \times \mathbb{1}_{j=g} + \eta_c + \eta_{yq} + \eta_j + \xi_{jm} \tag{14}$$

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 captures variations in tastes over time; η_j is a manufacturer fixed effect that captures variations in demand over product features, except prices and whether a 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 is the primary ingredient in infant formula products (Martin et al., 2016), so any shocks that impact milk prices will also drive formula prices. However, changes in input prices are likely uncorrelated with 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 14 are orthogonal to the contract manufacturer dummy variable $\mathbb{1}_{j=g}$, the input milk price instrument z_{jm}, and manufacturer-market fixed effects $\mathbf{H}_{jm} = \begin{bmatrix} \eta_c & \eta_{yq} & \eta_j \end{bmatrix}$.

First, to identify the price coefficient (α), I use the correlation between variations in input prices and observed market shares. The identification assumption requires that the instrument satisfy both the exclusion and relevance conditions. 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 exclusion 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.

Estimation I estimate a two-step GMM following Berry (1994), 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 demand estimation is standard, and I show details in the Appendix C. Here I summarize these steps. In the first step, given the data on the prices, the observed characteristics of the products, and initial guess on demand parameters $\theta = \left\{\alpha, \beta\right\}$, I calculate the model's market shares, and then minimize the distance of the model's shares predictions at the county-year-quarter level (σ_{jm}) to those in the data (s_{jm}). The moment condition to minimize is given by

$$\delta_{jm}^{t+1} = \delta_{jm}^{t} + ln(s_{jm}) - ln(\sigma_{jm}(\hat{\alpha}, \hat{\beta}, \mathbf{p}_m, \mathbb{1}_{j=g})) \tag{15}$$

Secondly, I use the estimated taste shifter (ξ_{jm}) and return to the full data to estimate θ using input prices as an instrument.

6.3 Demand Estimates

Table 3 presents the demand estimates. It shows that own-price elasticity for non-WIC households is -1.509, indicating that the demand for the product is responsive to changes in price. It also shows that WIC and non-WIC households have slightly different preferences for the WIC-supplemented infant formula products.

Table 3: 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

Notes: This table summarizes the most important demand-side parameters, and the own-price elasticity of demands for non-WIC households. The standard errors will be shown in the updated version soon.

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 back out from their first-order conditions derived, see Equation 11.

As contract manufacturers are restricted in the prices they set, I cannot use their prices to infer marginal costs. Instead, 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 estimate ordinary least squares (OLS) regressions to derive cost estimates for each manufacturer j

$$mc_{jm}^{j\neq g} = \mathbf{P}_m \cdot \lambda + \mathbf{X}_{jtc} \cdot \pi + \epsilon_{jtc} \tag{16}$$

where $\mathbf{X}_{jtc} = \begin{bmatrix} \nu_j & \nu_t & \nu_c \end{bmatrix}$ is a matrix including manufacturers fixed effect, year-month fixed effect, and county fixed effects; $mc_{jm}^{j\neq g}$ represents the calculated marginal costs for non-contract manufacturer j in the market m. Non-contract manufacturer's marginal costs also depend on its main ingredients' prices: cow milk price and commodity milk price index[13], which are captured by $\mathbf{P}_m = \begin{bmatrix} P_t^{\text{index}} & P_{tc}^{\text{milk}} \end{bmatrix}$. The cost estimates are shown

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

in the Appendix D. Given these cost estimates, I predict marginal costs for manufacturer j in markets that it wins the WIC contract.

Table 4: Supply Estimation Results

	Abbott		Mead Johnson		Nestle		Others
	Not contract supplier	WIC supplier	Not contract supplier	WIC supplier	Not contract supplier	WIC supplier	Not contract supplier
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
(a) Cost							
Cost per bottle	5.203	5.595	7.798	7.091	4.923	5.326	4.802
	(2.145)	(2.089)	(3.607)	(3.176)	(2.623)	(1.763)	(2.761)
(b) Implied Margins and Markups							
margins ($p-c$)	10.934	10.109	10.672	9.736	10.578	11.094	10.527
	(0.977)	(1.110)	(1.148)	(1.657)	(0.815)	(1.176)	(0.700)
markup ($\frac{p-c}{p}$)	0.688	0.631	0.599	0.571	0.700	0.682	0.709
	(0.103)	(3.273)	(0.130)	(3.224)	(0.119)	(0.084)	(0.132)

Notes: This table shows the average values along with the standard errors for the supply estimation. Panel *(a)* shows the implied marginal costs per bottle. Panel *(b)* shows margin (measured as price minus cost) and markups (as a percent of prices). Each manufacturer's statistics are disaggregated by whether it is a WIC-supplier.

Table 4, panel (a) shows that the marginal costs of producing one bottle of infant formula vary among manufacturers and depend on whether they are WIC suppliers. Estimated marginal costs range from \$4.8 to \$7.8 per 12-ounce bottle of infant formula, which equates to approximately 65 cents per ounce. This result aligns with the estimate of 54 cents per ounce found in the existing literature Simon (2023). Panel (b) presents the implied margins and markups for these manufacturers when they are WIC suppliers and when they are not the contract supplier. Specifically, Abbott's margin as a non-contract supplier is \$0.8 higher than its margin as a WIC supplier. Similarly, Mead Johnson's margin as a non-contract supplier exceeds its margin as a WIC supplier by more than \$0.9. In contrast, Nestle's estimated margins are higher when it becomes the WIC supplier than when it is not a contract supplier, aligning with Nestle's pricing strategy discusses in the data section. Lastly, all manufacturers have higher markups when they are not the contract supplier. This implies that some rules imposed by the WIC program may potentially limit manufacturers' market power. More details are discussed in the following section.

7 Welfare Analysis

In this section, I perform two policy experiments. In the first experiment, I decompose the current WIC full policy into several experiments, and a *laissez-faire* scenario where there is no WIC contract manufacturer involved, no price regulations, and no subsidies to WIC participants any longer. 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 contract winners' products. This factor introduces ambiguity into the welfare analysis. To handle it, I re-compute an equilibrium for the current policy by removing β_i from the utility function, and set this as the benchmark.

The second policy experiment is inspired by SNAP's distribution method, and examines whether providing discount coupons to WIC participants would increase total welfare compared to the current policy'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 $\mathbb{1}_{j=g}$. This potentially implies that 1) contract manufacturers hold certain market shares coming from the WIC program, represented by demand estimates β_w; 2) contract manufacturers maintain market shares from non-WIC households, denoted as β_{nw}.

2. **Subsidizing WIC**: WIC households incur no monetary cost when purchasing products from the WIC contract manufacturer using vouchers, which specify the brand and quantity of infant formula products available to them.

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

4. **Price restrictions**: The contract manufacturers encounter the WIC program's price restrictions. To examine these restrictions' effect, I allow both contract and non-

contract manufacturers to optimize their prices in Bertrand-Nash in the counterfactual policy.

Table 6 shows the simulated welfare in policy experiments, which correspond to Table 5. All numbers here are presented in increments 10 million dollars. The figures appear large due to the aggregation of market outcomes from 2006 to 2016. 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 paying rebates 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 assume the auction as exogenous and because auction outcome – rebate –is independent of price. However, government spending increases by 45.1 unit dollars and profits increase by the same amount. The result is essentially no change in total welfare; rather, it is only a transfer of funds from the WIC program to contract manufacturers.

In transitioning from Case 2 to Case 3, I remove the WIC subsidization and make WIC households pay shelf prices. Government spending is 0, and WIC households' consumer surplus declines by 50%. However, non-WIC households' consumer surplus increases because the market prices decline in *lassize-faire*. Table 6 also shows that for each additional dollar of government spending, WIC participants receive an average of 52.73 cents. 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

Notes: This table shows the decomposition of the full policy. Benchmark shows the WIC program's full policy; case 4 shows the lassize faire, and case 5 shows the perfect competition case.

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

Notes: This table shows the simulated welfare in this policy experiment. The first column depicts four cases that correspond to Table 5; the second column depicts the average unit price per bottle of infant formula; and the third column represents 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 columns four and five. Column seven provides the total profits across markets and manufacturers. The total welfare column depicts cumulative welfare, comprised of consumer surplus, profits, and government spending. The final column reveals the sum of WIC households' consumer surplus and government spending.

From Case 3 to Case 4, I eliminate the price restrictions on the contract manufacturer, allowing it to participate in the Bertrand-Nash equilibrium and maximize its profits. Since there is no WIC program in the case 4, it is a *laissez-faire* senario. The results in Table 6 show that the price increases by five cents after lifting the price restrictions. This change leads to a 1.1 unit dollar decrease in consumer surplus for WIC households, while causing a 0.9 unit dollar decrease in consumer surplus for non-WIC households. (Interestingly, overall manufacturer profits only increase by 0.3 unit dollars.)

The main difference between *laissez-faire* Case and the Case 5 is the transformation in market structure. Within the Case 5, the market shifts from an oligopoly to perfect competition, and suppliers start adopting pricing strategies of $p = mc$. 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 change in market structure lead to an increase in total welfare; which is 462.2 unit dollars.

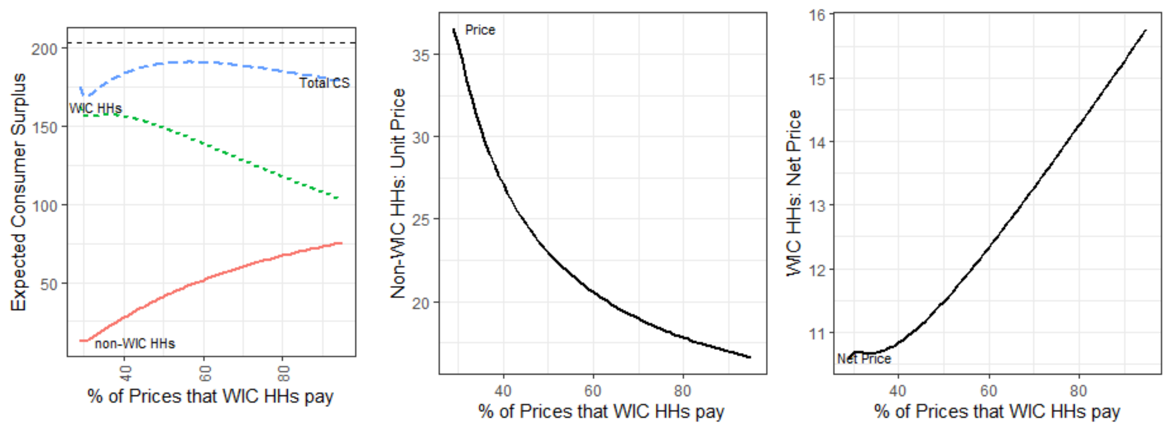
7.2 Policy Experiment II: Discount Coupons

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

In this experiment, I introduced a setup whereby the WIC program replaced its vouchers with discount coupons. Unlike the current system, these discounts allow WIC participants to choose any brand of infant formula. The change eliminates any potential distortion in purchasing behavior. WIC participants who use discounts contribute a certain percentage of the unit price of infant formula products and, 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. I do this because β represents households' additional preferences for contract manufacturers, and these additional preferences are determined by the purchasing process of the WIC program. The removal of the WIC program would result in the absence of β. However, in the counterfactual analysis, we require preferences to remain constant. To address this challenge, I structure the entire policy experiment II based on a setup with no β. The model for this policy experiment is presented in the Appendix F.

The leftmost graph of Figure 4 illustrates the changes in simulated consumer surplus when WIC participants contribute a higher percentage of the unit price for infant formula products. On the x-axis, the percentage WIC households should pay for each bottle of infant formula range from 19% to 89%. The y-axis represents the expected consumer surplus in units of 10 million dollars. The red line shows the consumer surplus for non-WIC households increasing, 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, increases slightly as WIC households contribute a higher percentage of the unit price. This trend is driven by non-WIC households' increasing consumer surplus. In addition, as represented by the dashed horizontal line, I have included the benchmark consumer surplus for WIC households. It is evident that the alternative policy cannot attain this benchmark.

Figure 4: Simulated Consumer Surplus and Unit Price

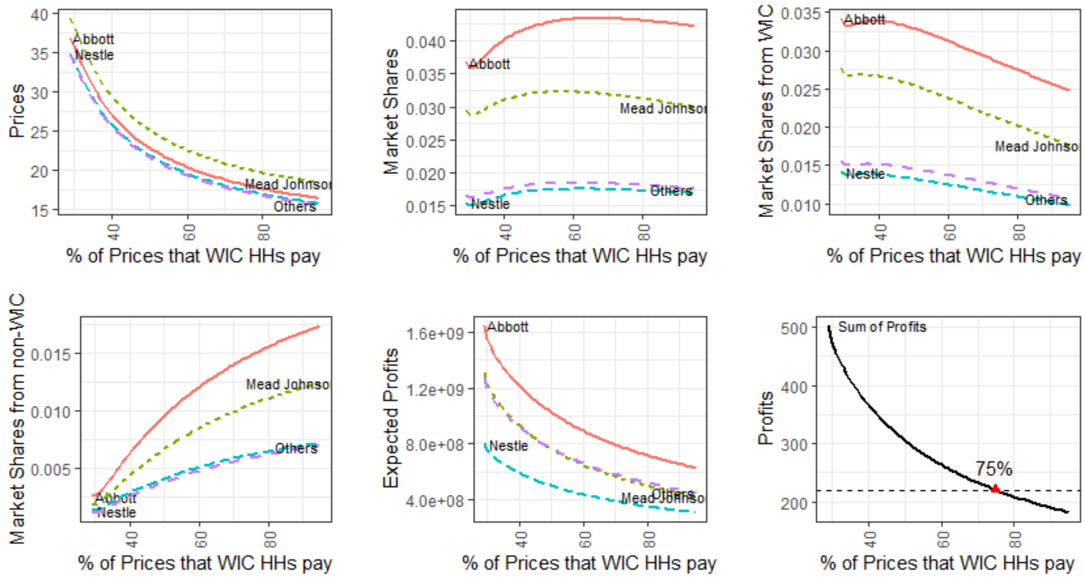


Notes: In the three figures above, the x-axis consistently represents the percentage of prices that WIC households pay. The figure on the top left illustrates how the simulated consumer surplus changes for both WIC and non-WIC households as the percentage of prices that WIC households pay varies. The dashed horizontal line in this figure represents the consumer surplus for WIC households under the current WIC policy. The middle figure shows the variation in prices that non-WIC households face as the percentage of prices that WIC households pay increases. Lastly, the figure on the right demonstrates the change in net prices for WIC households (calculated as $(1-\text{discount}\%) \times p_{jm}$) as the percentage of prices that WIC households pay increases.

The middle graph in Figure 4 explains why this occurs: 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 the prices to compensate for WIC participants paying a larger share. This phenomenon benefits non-WIC households, since this alternative policy means they face lower prices, leading in turn to an increase in their expected consumer surplus.

The figure on the right demonstrates the change in net prices for WIC households (calculated as $(1-\text{discount}\%) \times p_{jm}$) as the percentage of prices that WIC households pay increases. It implies that although manufacturers lower prices, however, all the while, WIC households start paying, and this becomes a dominant force. The interplay of these two forces leads to a reduction in WIC households' consumer surplus.

Figure 5: Simulated Profits, Unit Prices, Market Shares by Manufacturers

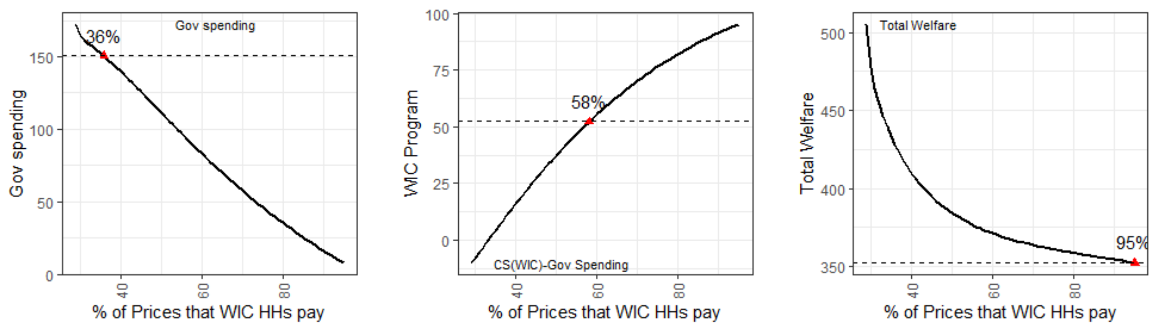


Notes: In the six figures above, the x-axis consistently represents the percentage of prices that WIC households pay. The top-left figure illustrates how simulated prices change by manufacturers. The top-middle figure shows the variation in market shares by manufacturers as the percentage of prices that WIC households pay increases. To understand the sources of these changes in market shares, I have divided it into shares from WIC households and shares from non-WIC households. The y-axis in the top-right figure represents market shares from WIC households. The bottom-left figure shows market shares from non-WIC households. The bottom-middle figure illustrates the simulated changes in profits as the percentage of prices that WIC households pay increases. Lastly, the bottom-right figure implies that if the WIC program provides a 25% discount to WIC participants in this policy experiment, then manufacturers' aggregate simulated profits equal their profits under the current WIC policy.

The first graph in Figure 5, demonstrates that as WIC households begin to pay a larger percentage of prices, the average 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, which is shown in the top-middle figure. To understand the sources of these changes in market shares, I have divided it into shares from WIC households and shares from non-WIC households. The top-right graph illustrates that market shares from WIC households decrease, as they face higher net prices, which causes them to leave the market and opt for breastfeeding. Conversely, because non-WIC households enjoy lower prices, their market shares rises. In summary, the fifth graph shows that the profits of the four infant formula manufacturers decline when WIC households pay for the products. This is because the reduction in unit price outweighs the increase in overall market share.

The final figure in Figure 5, depict the benchmark profits with a dashed line. These profits intersect with the alternative policy at 75%. The economic interpretation is that if the WIC program provides 25% discount coupons to its participants, all manufacturers would be as satisfied with the alternative policy as they are with the current voucher system.

Figure 6: Simulated Surplus for the WIC Program



Notes: The left figure aims to demonstrate the percentage discount that the WIC program should provide so that government spending in this policy experiment is equal to government spending under the current WIC purchasing process. The middle figure illustrates the discount needed to ensure that the sum of WIC participants' total surplus and government spending remains consistent between the current policy and the counterfactual policy. The right figure displays the values of total welfare-neutral discounts.

The leftmost graph of Figure 6 demonstrates, that government spending declines when 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 in the middle displays the sum of WIC participants' consumer surplus and government expenditures, denoted as 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. The result suggests that, as WIC households pay a higher percentage of the price, the WIC program's surplus increases, potentially even surpassing that of the benchmark surplus. In the rightmost of Figure 6, total welfare surpasses the benchmark level when the WIC program issues coupons with a discount value lower than 5%.

8 Conclusion

This paper studies how the WIC program acts as an intermediary in the infant formula market, providing 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 offering manufacturers' pricing strategies. 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 data.

My findings indicate that the current WIC purchasing process yields the highest consumer surplus for WIC participants than an alternative discount coupon scheme, 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 Construction

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: Event Study Analysis for Market Shares

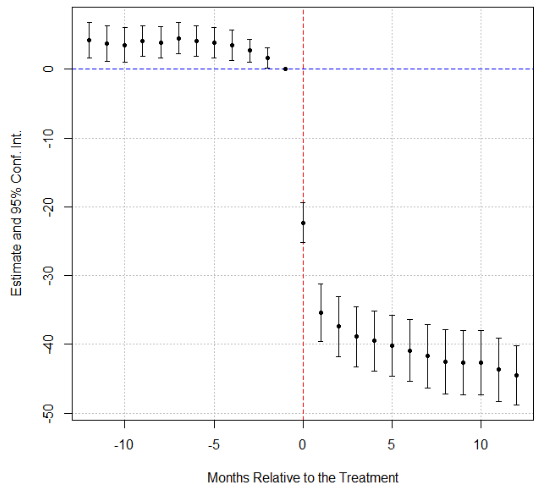
This section presents the event study analysis, which aggregates market shares across all contract changes in all states. The results is cited from my working paper Wang and Filipski (2022).

$$Y_{st}^{j=WIC_{t-1}} = \zeta_s + \zeta_t + \sum_{\tau \neq t} \gamma_\tau \times \mathbb{1}_\tau + \epsilon_{st} \tag{17}$$

where $Y_{st}^{j=g}$ are the aggregated market shares for the previous contract manufacturers in a state s in the 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 7 illustrates that, on average, previous contract manufacturers' aggregate market shares dropped more than 30% immediately after the WIC supplier changes.

Figure 7: Event Study: variations in Market Shares After Losing the WIC Contract



Notes: The event is that the competitive bidding contract switched the winner in the month m year y, in the state s. The reference time is -1, which means one month before the bidding contract switches winner. The above graph shows the estimates and confidence intervals for the previous winner's market shares at time t in state s. We find that the previous winner's market share dropped more than 30% immediately after the contract switches. 12 months after the contract changes, the previous winner's market shares become stable. *Sources:* Nielsen Retail Scanner data 2006-2020, year-month-state level.

Appendix C: 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 D: 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:

$$s_{jm} = wic \times s^{wic}(P_{jm}) + (1 - wic) \times s^{non-wic}(P_{jm}) \tag{18}$$

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: $1\left\{j = winner\right\}_{jm}$, 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.

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

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 E: 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 F: 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**:

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