



The World's Largest Open Access Agricultural & Applied Economics Digital Library

This document is discoverable and free to researchers across the globe due to the work of AgEcon Search.

Help ensure our sustainability.

Give to AgEcon Search

AgEcon Search

<http://ageconsearch.umn.edu>

aesearch@umn.edu

*Papers downloaded from **AgEcon Search** may be used for non-commercial purposes and personal study only. No other use, including posting to another Internet site, is permitted without permission from the copyright owner (not AgEcon Search), or as allowed under the provisions of Fair Use, U.S. Copyright Act, Title 17 U.S.C.*

No endorsement of AgEcon Search or its fundraising activities by the author(s) of the following work or their employer(s) is intended or implied.

Bidding for WIC infant formula contracts: Do non-WIC customers subsidize WIC customers?

Abstract

Although the WIC food assistance program purchases over one-half of all US infant formula, I find the program has little impact on the prices paid by non-WIC customers. I estimate infant-formula marginal cost and find that it is low compared to price, implying large price-cost markups. But, the WIC program is not to blame. Instead large price-cost markups are likely due to customer's price insensitivity. WIC's impact on non-WIC customers comes through an increase in sales owing to a WIC "spill-over" effect. The WIC approved brand attains a prominence in the market that makes it a natural choice for non-WIC customers, which makes attaining WIC approval valuable to firms. Firms bid with rebates to attain exclusive WIC approved status which results in significant reductions in the cost of infant formula to the US government.

David E. Davis*
January, 2011

Selected Paper prepared for presentation at the Agricultural & Applied Economics Association's 2011 AAEA & NAREA Joint Annual Meeting, Pittsburgh, Pennsylvania, July 24-26, 2011.

*Associate Professor, Department of Economics, South Dakota State University, Brookings, SD 57007, PH: 605-688-4859, email:David.davis@sdstate.edu

Copyright 2011 by David E. Davis. All rights reserved. Readers may make verbatim copies of this document for non-commercial purposes by any means, provided this copyright notice appears on all such copies.

Acknowledgment

This research benefited from financial support from the USDA Economic Research Service, cooperative research agreement No. 58-5000-6-0063

Introduction

Total infant formula sales in the US were \$3.4 billion in 2005 and over one-half of this total was purchased through the Special Supplemental Nutrition Program for Women, Infants, and Children (WIC) (Oliveira, Frazao, and Smallwood 2010). Government agencies are frequent purchasers of products in otherwise unregulated markets.¹ The economic consequences of such interventions are not well known. First-order effects are often obvious as the government uses its size to negotiate terms more favorable than other purchasers. However, government procurement can have other distortionary effects. For example, Fiona and Duggan (2006) find that Medicaid purchases of prescription drugs are associated with higher drug prices in general. WIC is the third-largest U.S. Federal food-assistance program and is administered by the U.S.D.A. Food Nutrition Service in conjunction with state and local health departments. It annually supplies grants to States to provide supplemental foods, and a variety of services to low-income women; infants; and children up to age five. Infant formula is an item supplied to participating infants less than one year old, and infant formula costs represent a large portion of overall food costs.² Because the cost of providing infant formula to WIC infants was increasing during the 70s and 80s, States became concerned the high cost of that item was severely limiting the number of eligible persons that could be served.³ To limit costs, States devised an auction format whereby infant-formula manufacturers could bid on the right to be a state's sole supplier of WIC infant formula. In exchange for this right, manufacturers paid a rebate on each can of infant formula

¹ The ingredients and production of infant formula are highly regulated, but infant formula prices to non-WIC customers are unregulated.

² The GAO reports that infant formula costs represented 16 percent of the \$5.2 billion allocated to WIC in 2005 (GAO 2006).

³ The GAO measured wholesale price increases, adjusted for the general rate of inflation, at about 3 percent, (1983-84), 6 percent (1985-86), and 2.5 percent (1987-1988) (GAO, 1998).

sold through the WIC program. Manufacturers provided sealed bids for the size of the rebate they would pay and the manufacturer supplying the largest rebate was awarded the exclusive right to supply formula.

Rebates are very effective at reducing costs; winning rebates have averaged about 85 to 90 percent of manufacturers' wholesale prices and have routinely returned over \$1.5 billion to the WIC program annually. This may be the government exercising monopsony power to acquire infant formula at lower prices than the general public. However, the magnitude of rebates relative to manufacturers' wholesale prices leads to questions about the relationship between wholesale price and marginal cost. It seems either manufacturers' sell formula at a substantial level below marginal cost to WIC customers, or that wholesale prices far exceed marginal cost. Wholesale price above marginal cost is perhaps expected given the highly concentrated structure of the formula market. Currently, three manufacturers (Mead Johnson, Ross, and Carnation) produce about 99 percent of domestic sales (Oliveira and Davis 2006). Wyeth, a fourth manufacturer, was active in the domestic infant formula market until 1996. And, brands likely possess pricing power because purchasers are likely very price insensitive as mothers are hesitant to make changes once an infant has grown accustomed to a brand (Samuels 1993).

Industry watchers have also noted the increase in the number of participating WIC infants and the dramatic rise in infant formula prices and speculated a causal relationship. Perhaps WIC removes the more-price sensitive customers from the market leaving firms with the ability to raise price to the remaining relatively price insensitive non-WIC customers (Prell 2004; Oliveira et. al. 2004; Betson 2009) Others have speculated that large rebates are subsidized by higher prices in the non-WIC market (GAO 1998)

The interplay of the WIC program, WIC's rebate system, and sales to non-WIC customers has been the source of congressional investigations and several government agency investigations. The Senate Subcommittee on Antitrust, Monopolies, and Business Rights held hearings on the pricing behavior of infant formula companies in 1990 (Oliveira et. al. 2004). The Federal Trade Commission investigated anticompetitive pricing practices of infant formula manufactures in early 1990s (Oliveira et. al. 2004). The General Accounting (Accountability) Office (GAO) has produced three investigative reports on these issues (GAO 1990, GAO 1998, and GAO 2006). Similarly, the Economics Research Service of USDA has produced several research reports examining WIC, WIC rebates, and infant formula prices (Oiveira, et. al. 2004; Prell 2004; Oliveira and Davis 2006; Oliveira, Frazao, Smallwood 2010). This article is the first to develop a comprehensive model of WIC's affect on infant formula pricing. It examines prices to non-WIC customers and WIC's affect on them, and it empirically identifies the benefit to firms of being the sole provider of infant formula to a WIC agency. I find marginal cost to be low relative to wholesale price, and so price-cost markups to non-WIC customers are large. While rebates are large, the net price paid (wholesale price minus rebate) by WIC is often above marginal cost and manufactures earn profits from WIC customers. However, net prices are sometimes below marginal cost. I show that the WIC program in its current form, with rebates, will not affect non-WIC price-cost markups if rebates change 1-to-1 with wholesale prices; I provide empirical evidence that this has been the case (until recently). Instead, the firm that holds the exclusive right to sell to WIC customers provides a sizable increase in sales to non-WIC customers, which provides an incentive for firms (occasionally) to offer net prices below marginal cost. I estimate a parameter that indicates that the two major WIC suppliers expect their

share of non-WIC sales to increase about 30-40 percent once they become the exclusive WIC supplier in an area.

Background and Literature

The WIC program, established in 1972, provides a variety of services and supplemental foods for low-income women, infants, and young children. The program is administered jointly by the U.S. Department of Agriculture (USDA) Food Nutrition Service (FNS) and authorized state agencies. Funding is provided through FNS to state agencies with annual congressional appropriations.⁴ Each state's cash grant includes a food grant and a Nutrition Services and Administration (NSA) grant. Because available funds are limited, state agencies have enacted a variety of measures to control costs attempting to ensure the efficient use of funds and the full participation for all eligible individuals.

Food benefits are typically distributed through retail outlets. Participants receive food vouchers that can be redeemed at authorized retail stores, insulating them from price considerations when purchasing supplemental foods. Federal mandates dictate allowable quantities of supplemental foods, which are noted on food vouchers. State regulations also frequently impose further restrictions on the types of foods (brands, package sizes etc) that can be purchased, in the interest of controlling costs (Davis and Leibtag 2005). Based on redeemed vouchers, States reimburse retail outlets for the items sold to WIC participants.

Infant formula is a food item available to participating infants less than one year old. Because of the large number of infants in the US who participate in WIC, WIC purchases of infant formula account for over 50 percent of the product's sales (GAO 1998; Oliveira, Frazao,

⁴ Some States supplement Federal funds with their own State funds.

and Smallwood 2010).⁵ During the 1970s and 1980s infant formula prices increased more than the rate of inflation and the rising cost of infant formula limited the ability of state agencies to serve all eligible individuals leading them to investigate ways to limit infant-formula costs. While most agencies distribute formula through retailers, a few agencies use other methods of distribution. Vermont currently uses a home-delivery system and Mississippi uses a direct-distribution system, and some counties in Ohio and Maryland have used direct-distribution methods in past years (Harvey et. al. 1988). These States were successful in providing infant formula at reduced costs by using a variety of methods that gave preference to one brand of infant formula. In particular Mississippi used a system of warehouses across the state to distribute infant formula and purchased infant formula in bulk. Starting in 1984 Mississippi used a competitive bidding process to select the manufacturer that would sell formula to the state at the lowest cost (Harvey et. al 1988). Using the experiences of these States as examples, in 1986 WIC officials in Tennessee developed a system whereby a single manufacturer was awarded the exclusive right to provide infant formula in that state in exchange for a rebate on each unit sold through the program in that state. Distribution remained through approved retail vendors. Manufacturers offered their rebates for consideration via sealed bids and the contract was awarded to the manufacturer who offered the highest rebate per unit sold (subsequently, agencies have moved to a process whereby the firm offering the lowest net price, wholesale price minus rebate, received the exclusive right to sell to WIC customers). The success of this system led other States to adopt similar systems, although some developed systems that did not use competitive bidding. Contracts that provide exclusive selling rights and that solicit sealed-rebate bids have become known as “competitive sole-source” contracts. Wyoming and Florida

⁵ In 2005, 49.5 of all US infants participated in the WIC program.

developed a system whereby the States negotiate with manufactures for contracts to provide rebates for their products sold in the state. These so-called “open-market” contracts did not provide manufacturers the exclusive right to sell in a state, and did not usually use sealed bids when asking manufactures for their rebate offer. The method that would provide the greatest cost savings was in doubt during the early years of adoption.⁶ In April 1988, Florida requested bids under both an open-market system and a competitive sole-source system. Because the competitive system resulted in a higher rebate, the state adopted the competitive system. A few other States adopted the “Florida” method of requesting rebate bids under both systems, attracted by the opportunity for hard data suggesting which method provided the greatest cost savings. This usually led to the adoption of a sole-source competitive bidding system.

In October 1988, federal law required all WIC agencies to explore implementing cost-containment methods for procuring infant formula and to begin implementing cost-containment practices if they proved to lower costs. In 1989, federal law required all state agencies to adopt a competitive bidding process or another process that provided equal or greater savings. The law defined “competitive bidding as a procurement process in which the State WIC agency selects the single source offering the lowest price for the infant formula, as determined by the submission of sealed bids (Oliveira et. al. 2004).”

State agencies’ rebate systems have been very successful reducing the cost of procuring infant formula. Figure 1 shows winning rebates, wholesale prices, and net prices (wholesale price minus rebate) for winning contracts from mid 1998 to 2006 (13-ounce can of milk-based liquid concentrate). Clearly, net prices are low compared to wholesale prices.

⁶ For example, in Texas in 1998 Ross Laboratories contended that open market contracts would provide equal or greater cost savings over sole-source competitive contracts.

Development of the WIC rebate system has been a boon to WIC agencies as procurement costs have been reduced allowing more eligible WIC participants to be served. In a 1990 report, The General Accounting Office (GAO, now the General Accountability Office) examined the implementation and success of various infant formula cost containment practices (GAO 1990). They concluded that most agencies had implemented cost-containment measures and that sole-source, sealed bid contracts lead to the greatest cost savings.

More recently the size of the rebates has led to speculation, and some research, about the source for large rebates. Selling below cost may be profit maximizing if manufactures are able to subsidize the loss with increased profits from non-WIC customers. For example, if WIC produces a “spillover effect” whereby the WIC contract brand is given preference by non-WIC customers, then there may be an incentive for manufacturers to secure the WIC contract even if that means selling to WIC customers at a loss. In a 1998 report, GAO identified two potential sources for a spillover effect. Doctors may give preference to the WIC brand of infant formula when recommending a brand to mothers. Or, WIC contracts may give the WIC brand greater shelf-space on store shelves increasing sales to non-WIC customers (GAO 1998). Because sales to WIC customers represent over one-half of all sales, it seems likely the WIC brand would receive a more prominent location, and a larger share of shelf-space. While the GAO’s 1998 report recognized the possibility of a spillover effect, it discounted the possibility of it being large enough to entice manufactures to sell to WIC below cost. In a 2006 report, GAO again visited the topic of infant formula rebates. That study reiterated the possibility that a “spillover effect” may be an important determinant of manufacturer rebate bids. The report stated that all three major infant formula manufactures noted the importance of product placement and shelf

space in their marketing strategies, and that 31 of 51 WIC directors responding to a survey stated they believed shelf-space was an important determinant of rebate bids.

Oliveira, et. al. (2004) noted that since the implementation of rebate programs, the retail price of infant formula has risen faster than inflation.⁷ They suggest that WIC and its rebate program may affect retail prices to non-WIC customers in two ways. WIC may remove many of the price sensitive, low-income customers from the market, leaving only less price sensitive high-income customers paying for infant formula out of their own pockets. With few price-sensitive customers actually paying for infant formula, manufactures may be able to charge higher prices. Alternatively, they suggest a spillover effect from sole-source contracts may increase demand for the contract brand from non-WIC customers, leading to higher retail prices. An event study analysis and a multiple regression analysis suggested that being the contract brand of infant formula increased that brand's price and that the larger the size of the WIC market relative to the non-WIC market the higher the price of the contract and non-contract brands of infant formula.

Betson (2009) is most similar to this article. Betson develops a theoretical model of manufacturer behavior, given the presence of the WIC program and sole-source contracts and makes the case that a WIC program with rebates should result in lower wholesale prices than a WIC program without rebates. In his model, the WIC program turns WIC mothers into perfectly inelastic customers, and firms must consider their purchasing decisions when setting wholesale price. The result is a pricing decision that considers a weighted average of WIC mothers' perfectly inelastic demand and non-WIC mothers somewhat elastic demand. A rebate program

⁷ The 1998 GAO report also notes that infant formula prices increased at a real rate of about 9 percent annually after sole-source contracts were mandated, compared to about 3 percent in other time periods.

allows firms to identify the WIC customers with perfectly inelastic demand and effectively charge them a different price, price minus the rebate. Because WIC customers are no longer considered in pricing to non-WIC customers, the firm's pricing decision is now based only on the remaining non-WIC customers' relatively more-elastic demand. The result is a lower price to non-WIC customers as compared to a world with a WIC program but without WIC rebates.

Betson notes that implementation of a WIC program should increase wholesale prices as compared to a world without a WIC program, but leaves it unclear whether wholesale prices are higher or lower in a world with a WIC program and a rebate program, as compared to a world with neither. Betson's model also does not model a spillover effect and also implicitly assumes that rebates adjust cent-for-cent with wholesale prices. The model below demonstrates that both of these considerations are important when considering WIC's affect on prices.

Huang and Perloff (2007) demonstrate that the spillover effect is likely an important consideration for infant formula manufacturers when setting prices. They use a multinomial-logit model to estimate market shares of different brands of infant formula when they hold and do not hold the WIC contract. They find that after a brand gains the WIC contract, their share of the market increases substantially immediately. However, they find that the brand's share grows even more, gradually over time. Market shares of winning firms grow from less than 20 percent to over 70 percent in less than two years. The authors also find a similar, but opposite, reaction in the brand that loses the WIC contract, and demonstrate that changes in brand shares are not driven by changes in brand prices. However, the paper does not distinguish WIC sales from non-WIC sales and so cannot isolate how much of the increase in share is due to an increase in sales from non-WIC customers. In the model below, I explicitly model the spillover effect as an increase in sales to non-WIC customers.

A Theoretical Model of Rebate Bids and Wholesale Prices

Infant formula manufacturers (potentially) derive profit from two distinct markets: the WIC market (Q^W) and the non-WIC (Q^N) market. I assume the number of units sold in the WIC market is exogenous and perfectly price inelastic.⁸

WIC contracts are offered by WIC state agencies (in some cases multiple States form an “alliance” to jointly offer a contract) to infant-formula manufacturers. Hereafter, I will refer to infant-formula manufacturers as firms and state agencies/alliances as agencies. The market coincides with the state, or group of States, served by an agency. Each agency serves WIC customers in its market, and non-WIC customers are also present in that market. Firms bidding decisions are based on potential contracts with agencies which have implications for sales in the WIC and non-WIC market.

Let h_j^N represent infant formula demand at an arbitrary non-WIC household j with children of the appropriate age to consume formula. There are two types of non-WIC households; the first type denoted $h_{j,1}^N$, buys no infant formula. These households choose to solely breastfeed because of the cost of formula feeding or personal preferences. Their marginal rate of substitution is such that maximizing utility at prevailing prices, results in a corner solution, with $h_{j,1}^N = 0$. The second type of household ($h_{j,2}^N$) purchases a positive amount of infant formula, equal to a_j , where a_j is normally distributed with mean μ and standard deviation σ_h^2 , or $h_{j,2}^N = a_j \sim N(\mu, \sigma_h^2)$. At prevailing prices, these households maximize utility such that they

⁸ WIC infants are determined by program eligibility standards, and total amount of formula a family can purchase for an infant is set by Federal mandate.

demand a positive amount of infant formula. But once that decision is made the household must purchase the amount of infant formula the infant needs to be healthy.

Let h_i^N represent the total number of non-breastfeeding, non-WIC infants in market i.

Total demand for formula from non-WIC customers in market i is $Q_i^N(P_1 \dots P_M) =$

$\sum_{j=1}^J h_{j,1}^N + \sum_{j=1}^J h_{j,2}^N = 0 + \sum_{j=1}^J a_j = h_i^N * \frac{\sum_{j=1}^J a_j}{h_i^N} = h_i^N * \mu$. Total market demand is dependent on price because each household's decision for whether to consume infant formula is dependent on price.⁹

Participating WIC households are treated similarly. h_k^W is infant formula demand by arbitrary WIC household k. There are two types of households, and type 1 households demand no infant formula, but type 2 households demand a positive amount equal to b_k , where b_k is normally distributed with mean μ and standard deviation σ_b^2 , or $h_{k,2}^W = b_k \sim N(\mu, \sigma_b^2)$. I assume, on average, WIC and non-WIC infants in market i consume the same amount of infant formula. Let h_i^W represent the total number of participating non-breastfeeding WIC infants in market i.

Total demand for formula from WIC customers in market i is $Q_i^W = \sum_{k=1}^K h_{k,1}^W + \sum_{k=1}^K h_{k,2}^W = 0 + \sum_{k=1}^K h_{k,2}^W = h_i^W * \frac{\sum_{k=1}^K b_k}{h_i^W} = h_i^W * \mu$.

Huang and Perloff (2007), GAO (1998), and GAO (2006) speculate that a WIC contract may produce a spillover effect. I assume firms expect some share of the non-WIC market if they win the WIC contract and a smaller share if they do not win the contract. Represent firm m's winning share as $s_{m,i,w} = \frac{q_{m,i,w}}{Q_i^N}$ and its losing share as $s_{m,i,l} = \frac{q_{m,i,l}}{Q_i^N}$, where $q_{m,i,w}$ and $q_{m,i,l}$ are

⁹ Demand is contingent on each manufacturer's price, because each household chooses whether to purchase, and which brand to purchase, based on relative brand prices and household preferences.

the firm's residual (non-WIC) demands when winning or losing the WIC contract.¹⁰ Non-WIC demand in market i is written,

$$(1) \quad Q_{m,i}^N = \begin{cases} s_{m,i,w} Q_i^N & \text{if awarded the contract in market } i \\ s_{m,i,l} Q_i^N & \text{if not awarded the contract in market } i \end{cases}$$

Let $s_{m,i,w} = s_{m,w} + v_{i,m}$ and $s_{m,i,l} = s_{m,l} + v_{i,m}$, where $v_{i,m}$ and $v_{i,m}$ are mean zero stochastic elements. Letting $\rho_{m,i}$ equal the probability of firm m winning the contract in market i , non-WIC demand can be written as

$$(2) \quad Q_{m,i}^N = \rho_{m,i} s_{m,w} Q_i^N + (1 - \rho_{m,i}) s_{m,l} Q_i^N + \xi_i$$

$$(3) \quad = (s_{m,l} + \theta_m \rho_{m,i}) Q_i^N + \xi_{m,i}$$

where $\theta_{m,i} = (s_{m,w} - s_{m,l})$ and $\xi_{m,i}$ is a zero mean stochastic element representing the compound error from $s_{m,w}$, and $s_{m,l}$. Note that θ_m is a measure of the spillover effect. It measures the increase in demand from non-WIC customers as a consequence of holding the WIC contract.

Let $(Q_i^W + \tau_i)$ represent formula demand from WIC customers in the market i (τ_i is a zero mean stochastic element). Total formula demand for firm m from market i , can be written as:

$$(4) \quad Q_{m,i}^T = Q_{m,i}^N + Q_{m,i}^W = (s_{m,l} + \theta_m \rho_{m,i}) Q_i^N + \rho_{m,i} Q_i^W + \xi_i + \rho_{m,i} \tau_i$$

Oliveira and Davis (2006) demonstrate that firms change wholesale prices infrequently, with durations of about 12 - 18 months between increases. Rebate contract auctions do not generally coincide with changes in wholesale prices, suggesting that wholesale prices and rebates are determined at different points in time so one is predetermined at the time the other is determined. While the strategic interactions that led to the “rebate program” (and firms’ participation in it) are not well understood, I leave that investigation for future research and here

¹⁰ Residual demand is firm m 's demand, $q_{m,i} = Q_i - \sum_{m \neq o} q_{o,i}$.

assume that firms make decisions under the current rebate format. I assume some rebates contracts are already in existence for firm m, and it must, at different points in time, make decisions about wholesale prices and rebates. I consider the wholesale price decision first.

Since rebate contracts are already in force $\rho_{m,i}$ is equal to one in these markets and let ρ_m equal the proportion of the I markets for which firm m holds the WIC contract. Let $R_m = \frac{\sum_{i=1}^I R_{m,i}}{I}$ represent the average rebate paid by firm m, $c_m = \frac{\sum_{i=1}^I c_{m,i}}{I}$ equal the average marginal cost from firm m, and let $Q^N = \sum_{i=1}^I Q_i^N$ represent total non-WIC demand and $Q^W = \sum_{i=1}^I Q_i^W$ represent total WIC demand for all I markets.¹¹ Total expected profit for firm m from all markets is (dropping the m subscript for convenience),

$$(5) \quad E[\pi] = P(s_l + \theta\rho)Q^N + (P - R)\rho Q^W - c((s_l + \theta\rho)Q^N + \rho Q^W).$$

Firm m chooses price to maximize expected profit,

$$(6) \quad \frac{\partial E[\pi]}{\partial P} = P \left[(1 - \rho) \frac{\partial q_l}{\partial P} + \rho \frac{\partial q_w}{\partial P} + \frac{\partial \rho}{\partial P} (q_w - q_l) \right] + (1 - \rho)q_l + \rho q_w + Q^W \left[\rho \left(1 - \frac{\partial R}{\partial P} \right) + \frac{\partial \rho}{\partial P} (P - R) \right] - c \left[(1 - \rho) \frac{\partial q_l}{\partial P} + \rho \frac{\partial q_w}{\partial P} + \frac{\partial \rho}{\partial P} ((q_w - q_l) + Q^W) \right] = 0$$

Equation 6 can be rearranged to give the optimal price as¹²

$$(7) \quad P = c - \frac{(1-\rho)q_l + \rho q_w + Q^W \left[\rho \left(1 - \frac{\partial R}{\partial P} \right) + \frac{\partial \rho}{\partial P} (P - R - c) \right]}{(1-\rho) \frac{\partial q_l}{\partial P} + \rho \frac{\partial q_w}{\partial P} + \frac{\partial \rho}{\partial P} (q_w - q_l)}$$

Once firms set their wholesale price, they determine optimal rebate bids. Because P is predetermined, the firm's decision to find the optimal rebate is to choose R_i to maximize expected profit from market i

$$(8) \quad E[\pi] = P(s_l + \theta\rho_i)Q_i^N + (P - R_i) \rho_i Q_i^W - c_i ((s_l + \theta\rho_i)Q_i^N + \rho_i Q_i^W)$$

¹¹ I have data for only US markets, so "I" includes all WIC agencies in the US.

¹² Note that firm m is not a monopoly because residual non-WIC demands, q_w , q_l , are functions of the prices of rival firms. So, for example, $\frac{\partial q_l}{\partial P_m} = \frac{\partial q_l}{\partial P_o} + \sum_{m \neq o} \frac{\partial q_l}{\partial P_o} \frac{\partial P_o}{\partial P_m}$, and firm m considers the reactions of rivals when setting prices.

Let $np_i = (P - R_i)$ represent net price in market i . Because P is predetermined, choosing np_i is equivalent to choosing R_i and the first-order condition is

$$(9) \quad \frac{\partial E[\pi]}{\partial np_i} = \theta P Q_i^N \omega_i + \rho_i Q_i^W + np_i Q_i^W \omega_i - c_i(\theta Q_i^N \omega_i + Q_i^W \omega_i) = 0$$

where $\omega_i = \frac{\partial \rho_i}{\partial np_i} < 0$ is the marginal change in the probability of winning an auction, from a change in the net price (rebate) bid. Solving equation 10 gives the optimal net price (rebate) to bid in market i ,

$$(10) \quad np_i = c_i - \frac{\rho_i}{\omega_i} - \theta(P - c_i) \frac{Q_i^N}{Q_i^W}$$

The optimal net price equals the marginal cost of supplying market i , adjusted higher by $\frac{\rho_i}{\omega_i}$, a measure representing bid shading, and adjusted lower by the additional profits earned from the non-WIC market, per unit of items sold to WIC participants (i.e., $\theta(P - c_i) \frac{Q_i^N}{Q_i^W}$). These additional profits are earned only if firm m holds the WIC contract.

To see that $\frac{\rho_i}{\omega_i}$ represents the amount of bid shading, reorder 10 as

$$\frac{((np_i - c_i) Q_i^W + \theta(P - c_i) Q_i^N)}{Q_i^W} = -\frac{\rho_i}{\omega_i}. \text{ The left-hand side is now the total profit from holding the WIC}$$

contract, per unit of items sold to WIC participants. The right-hand side is the probability of winning the contract, normalized by the response in probability from a change in bid. The right-hand side is an indicator of the competitiveness of the auction; larger values imply larger profits and are desired by firms (See Crespi and Sexton 2005 for a similar application to cattle procurement.). Higher profits are a consequence of a larger probability of winning, or a smaller response in probability from change in bid. Larger ω_i suggests a more competitive auction and smaller profits for firm m .

Equation 10 shows that it may be optimal to bid a net price below marginal cost to gain a WIC contract if the additional profit earned from holding the contract is greater than the amount of bid shading allowed by the competitiveness of the auction, $np_i < c_i$ if $\left| \frac{\rho_i}{\omega_i} \right| < \theta(P - c_i) \frac{Q_i^N}{Q_i^W}$. Net price below cost may occur, for example, when auctions are very competitive, $\left| \frac{\rho_i}{\omega_i} \right|$ is small, or when a market offers a large profit from non-WIC customers, $\theta(P - c_i) \frac{Q_i^N}{Q_i^W}$ is large.

An Empirical Specification to Identify Marginal Costs and Spillover Effects

Equations 7 and 10 represent a system of equations that, in principle, could be simultaneously estimated. However, data limitations do not allow for a full-information approach; equation 7 is the most problematic in that it requires estimates of residual non-WIC demand and other parameters not easily attained. However, a limited-information approach to estimate equation 10 is detailed below.

Equation 10 shows how firms determine net-price bids. Firms know c_i and P , and likely have accurate estimates of θ , $\frac{Q_i^N}{Q_i^W}$, ρ_i , and ω_i based on their knowledge of previous auctions and information provided by WIC agencies.¹³ The present challenge is to use equation 10 to formulate a specification of observable variables that enables identification of the unobservable parameters of interest. The strategy will be to specify a reasonable method to estimate $\frac{\rho_i}{\omega_i}$ for each auction and for each manufacturer. Assuming firms use a multinomial choice model to estimate winning and marginal probabilities, then $\frac{\hat{\rho}_i}{\hat{\omega}_i}$ can be estimated as the predicted values from that model. The left-hand side of equation 10 is the net price bid offered to market i , and is

¹³ For example, WIC agencies provide bidders with information on WIC infant participation.

observable and available with estimates of $\frac{\hat{p}_i}{\hat{\omega}_i}$ in hand. Rearranging 10 and adding the estimates of $\frac{\hat{p}_i}{\hat{\omega}_i}$ to the net-price bids gives

$$(11) \quad np_i + \frac{\hat{p}_i}{\hat{\omega}_i} = c_i - \theta(P - c_i) \frac{Q_i^N}{Q_i^W}.$$

Consider equation 11 a potential equation to be estimated using econometric methods. θ can be identified from variations in $P \frac{Q_i^N}{Q_i^W}$ if it is observed. P is readily available, while $\frac{Q_i^N}{Q_i^W}$ is the ratio of non-WIC to WIC infant formula demand and under normal conditions could be estimated using the appropriate methods. In the current application however, estimating these demand functions is not possible. Data are not available that distinguish sales to WIC customers from sales to non-WIC customers. However, equation 11 requires the ratio of non-WIC to WIC demand, and given reasonable assumptions data for this ratio are available.

Recall that non-WIC demand in market i is $Q_i^N = h_i^N * \mu$ and WIC demand is $Q_i^W = h_i^W * \mu$, and $\frac{Q_i^N}{Q_i^W} = \frac{h_i^N}{h_i^W}$. That is, if WIC infants consume, on average, the same amount of infant formula as non-WIC infants, the ratio of non-WIC to WIC demand is equal to the ratio of non-breastfeeding non-WIC infants to non-breastfeeding WIC infants.¹⁴ Now, relax the assumption that WIC and non-WIC infants have a common average demand, if $\frac{Q_i^N}{Q_i^W} - \frac{h_i^N}{h_i^W} = \varsigma_i$ where $\varsigma \sim N(0, \sigma_\varsigma^2)$ standard econometric techniques can be applied as long as equation 11 is treated as

¹⁴ The fact that WIC customers breastfeed at a lower rate than non-WIC customers is inconsequential. What matters is that WIC infants consume on average the same amount of infant formula as non-WIC infants. I am not aware of evidence to confirm or deny this supposition, but it is not clear why WIC infants would differ in their nutritional needs from non-WIC infants.

an identity without error.¹⁵ For tractability, I also assume firms base bids on a single average marginal cost, $\frac{\sum_l c_l}{I} = c$, and that $c_i - c_m = \zeta_i$, where $\zeta \sim N(0, \sigma_\zeta^2)$. The structural equation is summarized as,

$$(12) \quad np_i + \frac{\hat{p}_i}{\hat{\omega}_i} = c - \theta \frac{ph_i^N}{h_i^w} + \delta \frac{h_i^N}{h_i^w} + \kappa_i,$$

where $\kappa_i = \varsigma_i \theta p + \varsigma_i \delta + \zeta_i$ and $\kappa \sim N(0, \sigma_\kappa^2)$. Equation 12 suggests that θ , a measure of the spillover effect, can be identified as a parameter in a linear regression with $np_i + \frac{\hat{p}_i}{\hat{\omega}_i}$ as the dependent variable; firm-specific marginal costs can be identified by firm-specific constants in the same regression.

Estimating Probabilities and Marginal Probabilities $\left(\frac{\hat{p}_i}{\hat{\omega}_i}\right)$

Firms are awarded WIC contracts by offering to sell infant formula to a WIC agency at a lower net price than other firms. Firms must estimate their probability of winning a contract in order to formulate their optimal net-price bid according to equation 10. Suppose firms assume the indirect utility agencies receive is a function of their costs based on net-price bids, such that $U_{i,m} = \alpha * np_{i,m}$, where α is some (negative) weight. The WIC agency chooses the firm with the lowest net price, giving it the greatest utility, $U_{i,m} > U_{i,o}$ for $o \neq m$. Firms know that an agency will choose the firm that offers the net-price bid that results in the lowest cost, but firms do not observe agency costs, since they do not observe their rivals' net price bids. Assume firms estimate net-price bids as $\hat{np}_{i,m} = z_i \beta'_m$ where z_i is a vector of observable variables from agency i that firms use to formulate their net price bids and β_m is vector of weights applied by firm m .

Let $np_{i,m} = \hat{np}_{i,m} + \epsilon$ and substituting for $\hat{np}_{i,m}$ gives $np_{i,m} = z_i \beta'_m + \epsilon$. Assuming

¹⁵ If equation 11 is not treated as an identity, equation 12 is plagued by measurement error bias which can be corrected with an instrumental variable (IV) estimator (Green, pp 379). I offer an IV estimator as an alternative specification in the empirical work that follows.

$\epsilon \sim N(0, \sigma_\epsilon^2)$, then β_m can be estimated using standard regression methods given data on np and z . Substituting $\widehat{np}_{i,m}$ into the utility function gives, $U_{i,m} = \alpha \widehat{np}_{i,m} + \eta$, where $\eta = \alpha \epsilon$. Assuming that η is distributed multivariate normal gives rise to a multinomial probit model that can estimate choice probabilities (i.e., $\frac{\hat{p}_i}{\hat{\omega}_i}$) (Wooldridge, p 502)). While the multinomial probit has many attractive characteristics, it has many practical limitations (Wooldridge, p 502).¹⁶ Instead, I assume firms use a multinomial logit choice model to estimate probabilities, or equivalently that η follows a type I extreme value distribution.

Let y_i denote the choice of agency i that maximizes agency utility from the M firms, $y_i = \text{argmax}(y_{i1}, y_{i2}, \dots, y_{iM})$. Then

$$\text{Prob}(y_i = m | \widehat{np}_{i,m}) = \left(\frac{\exp(\widehat{np}_{i,m} \alpha')}{\sum_{o=1}^M \exp(\widehat{np}_{i,o} \alpha')} \right)$$

is McFadden's conditional logit model (Maddala, pp 61).

Data

The primary data in this study are a time-series, cross-section of each firm's winning and losing rebate bids for all contract auctions from 1986 through 2007. The firms in the data are Mead Johnson, Ross, Wyeth and Carnation, the dominant suppliers of infant formula in the US. Wyeth regularly participated in WIC auctions until 1996 at which time they exited the domestic infant formula market. Carnation began selling infant formula domestically in 1990 and has participated in WIC rebate auctions since 1992. Cross-sections are state WIC agencies, or alliances of multiple state agencies. Typically, agencies offer contracts for terms of about 3 years, and so over the duration of the data agencies have a time-series of multiple contracts.

¹⁶ For example, the response probabilities are very complicated which in practice usually requires arbitrary restrictions on model parameters. However, a benefit of the multinomial probit is that it does not assume independence of irrelevant alternatives (IIA).

Agencies initiated rebate systems in different years, and contracts can be extended so the number of contracts per agency varies.

I compiled the data from a variety of sources including records kept by the FNS and the Center for Nutrition Policy Promotion. Infant formula is marketed in three forms: dry powder, liquid concentrate, and ready-to-feed. Powder and liquid concentrate have been the primary types of formulas sold to WIC customers. Formulas are available that use a milk base and alternatives intended for infants with special medical requirements. For example, soy-based formulas are intended for lactose-intolerant infants (See Oliveira and Davis (2006) for a discussion of the various formula types and their usage within the WIC program). Data were collected as available for both milk- and soy-based formula in both powder and 13-ounce cans of liquid concentrate. Bids for soy-based formula are only sporadically available, and bids for powder-based formula are available for only the years since mid-1998. However, a nearly complete data set of bids for 13-ounce cans of milk-based liquid concentrate are available from 1986 to 2007 documenting winning and losing bids for each contract auctioned by WIC agencies. In a typical auction, agencies determine the winning net-price bid based on a weighted average, where the weights are the anticipated proportions of powder and liquid concentrate in milk and soy forms.¹⁷ Oliveira and Davis (2006) show that liquid-concentrate and powder bids are highly correlated suggesting that bids for either type should be a good proxy for the other, and for the weighted average bid. So, given the dearth of data on powder bids, the analysis in this report uses bids for milk-based liquid concentrate.

The data include 563 observations, including 213 bids from Mead Johnson, 222 bids from Ross, 87 from Wyeth, and 41 from Carnation. However, only a portion of these

¹⁷ Typically, non-standard formulas are approved for WIC customers only with verified medical documentation.

observations are for sole-source competitive contracts; 49 observations are for open market contracts. Sole-source contracts are necessary to estimate a multinomial choice model, because a unique choice must be made from the alternatives in each auction.¹⁸

As noted above, contracts can have a variety of provisions. For example, contracts can have different lengths, and some required a “composite” bid, to represent an equal net price for both soy and milk-based formulas.¹⁹ Table 1 details each of these provisions and how they are quantified for use in an estimation of agency costs.

The data also include the national wholesale prices for a truckload-size shipment of infant formula; the price agencies use when evaluating which rebate bid will provide the lowest net price. Rebates and wholesale prices are adjusted to constant 2007 dollars using the consumer price index.

The number of participating WIC infants comes from the Food and Nutrition Service of USDA (FNS). The FNS is the federal agency that manages and coordinates the individual state agencies. They regularly monitor state caseloads and other program characteristics, including the number of participating WIC infants.

Non-WIC infants are estimated by taking the number of births in a state and subtracting the number of participating WIC infants. Births for 1986-2000 are from the National Centers for Disease Control. Census estimates of births are used for 2000-2007. Counts of WIC and non-

¹⁸ I assume each firm expects each active rival to bid in each auction. So, $\hat{\pi}_i$ is calculated for each firm in each auction as long as that firm was an active participant in WIC auctions, even though, post hoc, the firm may not have bid in that auction. Firms do not have prior information for which rivals will participate in a given auction.

¹⁹ Composite rebate provisions seem to be added as a convenience for agencies; it is easier to request a single rebate for each unit, rather than separate rebates for soy versus milk. Firms likely know the approximate proportion of soy and milk units to be sold to WIC, and so can easily offer a single weighted-average rebate for soy and milk that leaves the total rebate amount unchanged.

WIC infants are adjusted with breastfeeding rates as estimated by the Ross Mothers' Survey so that they measure only non-breastfeeding infants.²⁰

Estimating Agency Costs and Choice Probabilities

I use a linear regression to estimate $np_{i,m} = z_i\beta'_m + \epsilon$. The data set does not have enough observations to precisely estimate complete sets of firm-specific parameters, so I use the following strategy to arrive at a parsimonious model. I begin with a regression that includes firm dummies, year dummies, alliance dummies, and firm dummies interacted with all auction variables (table 2 shows firm specific means). Effectively, each firm has their own constant, and a vector of parameters for the auction variables, but all firms share year and alliance dummies. I then delete any interaction variable whose coefficient is not significantly different from zero. I conduct a likelihood ratio test, and cannot reject the null that the restricted model fits the data as well as the unrestricted model.

Table 3 reports the results from the net price regression. While the regression is mostly concerned with an accurate prediction of agency costs and not necessarily in the relationship between variables and net price, most coefficients follow intuitive expectations. Births and non-WIC infants usually lead to lower net price bids. Firms with plants distant from an alliance seem to bid higher net prices, likely reflecting higher transportation costs. Sole-source, sealed-bid contracts elicit lower net price bids than other contract types.

Multinomial Logit Estimates

The theory above suggests that choice probabilities should be estimated using the predicted values of a net price regression. Table 4 shows the parameter estimates from a multinomial logit

²⁰ Ross' Mothers Survey provides state-specific breast feeding rates for 1990-2004. Attempts to acquire rates for 1986-1989, and 2004-2007 from Ross were unsuccessful. Rates for these years were estimated using a 1-period lag forecast.

estimation. As expected, the probability of winning is negatively related to net price. Table 5 shows actual winning proportions and predicted winning probabilities, which are very close. $\hat{\omega}$ is the marginal effect of net price, and suggests that, for example, a \$.10 increase in Mead Johnson's net-price bid, is associated with a .12 decrease in the probability of winning (other firm's marginal effects are interpreted analogously). $-\frac{\hat{p}}{\hat{\omega}}$ is each firm's "bid shade" or the amount that each firm adjusts, or "marks-up," their net price bid, given the competitiveness of the auction. Bid markups range from \$.34 (Mead Johnson) to \$.228 (Carnation). Considering the net prices in table 1, Mead Johnson's markup represents a 40% increase, Ross' markup represents a 37.4% increase, Wyeth's markup represents a 23.5% increase, and Carnation's markup represents a 49.5% increase.

Spillover Effects and Marginal Costs

With estimates of $-\frac{\hat{p}}{\hat{\omega}}$ in hand, the left-hand side of equation 12 is available. Table 6 shows results from estimating 8 specifications of equation 12. The first 4, starting with OLS1, are ordinary least squares estimates, and the second 4, starting with IV1, are instrumental variable (IV) estimates. In the IV specifications, I instrument for P_m and $\frac{h^N}{h^W}$ and conduct a Hausman endogeneity test for significant bias, and cannot reject the null that only IV estimates are efficient and consistent.²¹

²¹I use births, WIC breastfeeding rates, and state and year dummies as instruments for $\frac{h^N}{h^W}$, and I use a non-fat dry milk price index, a dry whole milk price index, dry whey prices, the dairy producer price index, and firm-dummies as instruments for P_m .

The estimates in IV1 are from the most restricted specification and estimates adjusted net prices as a function of the all-firm average marginal cost and an all-firm average θ .²² Estimates in this column suggest that the average marginal cost over all firms is \$.37 for a 13-ounce can of milk-based liquid concentrate (in 2007 dollars). The average wholesale price is about \$3.02, and it appears firms price far above marginal cost. It is important to note that price above marginal cost does not necessarily imply supra-normal profits. Mead Johnson and Ross are both divisions of pharmaceutical companies and market infant formula using a method commonly used to market pharmaceuticals known as medical detailing (Samuels 1993; GAO 1998). In this practice, infant formula is marketed through endorsements from the medical establishment—physicians and hospitals—rather than through direct advertisement to consumers. Carnation markets infant formula directly to consumers. Medical detailing may involve high fixed costs not reflected in marginal cost estimates here.

The estimate of an all-firm average spillover effect, θ , is about .35. This is the expected increase in unit sales from non-WIC customers that results from a firm winning the WIC contract. Huang and Perloff (2007) examine the spillover effect in infant formula markets using scanner data. They examine the pattern in brand shares of the firms that win or lose the WIC contract. They show that the brand holding a WIC contract maintains a share above 70%, while other firm's shares are below 20%. If the WIC contract holder changes, then the market shares

²² It is tempting to test the predictions of the theoretical model by testing the hypothesis that $\frac{\delta_m}{\theta_m} = c$. But θ is identified through variation in both P and $\frac{h_i^N}{h_i^W}$ and therefore $\frac{d(anp)}{d\left(\frac{h^N}{h^W}\right)} =$

$-\theta \left(P + \frac{h^N}{h^W} \frac{dP}{d\left(\frac{h^N}{h^W}\right)} - c \right)$ (*anp* represents the left-hand-side of 12, i.e., adjusted net price).

Hypothesis tests of δ require knowledge of the sign and magnitude of $\frac{dP}{d\left(\frac{h^N}{h^W}\right)}$, which are unavailable. And, it is beyond the scope of this paper to estimate them as they require examining firms' wholesale-price setting behavior.

reverse. The new winner's share increases over time to about 70% and the losers share falls to about 20%. Hence, it is reasonable to conclude that market shares increase about 50% as a consequence of holding the WIC contract. However, Huang and Perloff cannot discern how much of the increase in share comes from non-WIC customers. Remember that rebates are large and the net price earned from WIC customers is consequently low. Even so, it appears net price bids are frequently above marginal cost. However, another attraction of holding the WIC contract is an increase in sales to non-WIC customers, who appear to be very profitable considering that I estimate marginal costs far below wholesale price.

Results in IV2 are from relaxing the restriction that all firms have a common marginal cost, while results in IV3 are from the least restricted model in that θ and marginal cost are estimated for each firm. Note that θ is not statistically significant for Wyeth or Carnation in column IV3, and the specification in IV4 drops these parameters. In this final specification, marginal costs range from \$.226 per can (Carnation) to \$.808 per can (Wyeth). Mead Johnson and Ross have very similar marginal costs at about \$.304 and \$.384 per can. Estimates of the spillover effect, θ , are 30.4 percent and 40 percent from Mead Johnson and Ross, respectively.

Note that I cannot identify a significant spillover effect for Wyeth or Carnation. This may help explain why Wyeth chose to exit the infant formula market even though it appears wholesale prices exceed marginal cost. In IV4, Wyeth's marginal costs are estimated at \$.808 per can, much higher than Mead Johnson and Ross's. If Ross or Mead Johnson bid their marginal cost to the WIC market, then Wyeth would lose about \$.50 per can if they chose to compete for the WIC contract (many observed net prices bids are lower than \$.30 per can). Without a large spillover effect (θ) to offset that loss, it is likely Wyeth found the WIC infant formula market unprofitable. If non-WIC sales are minimal, the infant formula market in total may be

unprofitable once fixed marketing costs are considered. Contrast Wyeth's situation with Carnation. Carnation also does not appear to anticipate a spillover effect as their θ is estimated to be zero. But their marginal costs are lower than both Mead Johnson and Ross, at about \$.23 per can. Carnation can compete with Mead Johnson and Ross for WIC contracts, and bid up to their marginal cost, and still make a profit from sales to WIC customers. Even if they do not anticipate an increase in non-WIC sales, participating in the WIC market is profitable because of their low marginal cost.

Implications for Non-WIC Purchasers

A concern for policy makers has been the effect of the WIC program on non-WIC customers. GAO was asked to address this issue and offered commentary on the likelihood in their 1998 report. Betson (2009) contends that rebates play no role in firms' price setting decisions.

Equation 7 shows this proposition is true only if $\frac{\partial R}{\partial P} = 1$, which Betson recognizes is a maintained hypothesis in his model. While $\frac{\partial R}{\partial P} = 1$ is undoubtedly correct for specific WIC contracts in the short run because contracts include inflation provisions that require (essentially) cent-for-cent increases in rebates if wholesale prices increase during the duration of the contract. However, subsequent contracts may result in an agency paying a higher or lower net-price. That is, $\frac{\partial R}{\partial P} < 1$, which is a key determinant for whether the WIC program with rebates affects firms' pricing decisions.

Firms set prices and rebates according to equations 7 and 10 to maximize profits, rearranging equation 7 provides a convenient way to demonstrate WIC's effect for non-WIC customers,

$$(13) \quad \frac{(P-c)}{P} = - \frac{\left\{ (s_l + \theta \rho) + \frac{Q^W}{Q^N} \left(\rho \left(1 - \frac{\partial R}{\partial P} \right) + \frac{\partial \rho}{\partial P} (P - R - c) \right) \right\}}{(1-\rho)s_l \varepsilon_l + \rho s_w \varepsilon_w + \varepsilon_\rho \rho \theta},$$

where ε_w and ε_l are the firm's residual demand elasticities evaluated at q_w and q_l and ε_ρ is the firm m's price elasticity of WIC contracts won. As long as the winning proportion is a linear function of net price, then $\frac{\partial \rho}{\partial P} = -\frac{\partial \rho}{\partial R}$ and $\frac{\partial \rho}{\partial P} = \frac{\partial \rho}{\partial P} \left(1 - \frac{\partial R}{\partial P}\right)$, and after substituting 13 becomes,

$$(14) \quad \frac{(P-c)}{P} = - \frac{\left\{ (s_l + \theta \rho) + \left(1 - \frac{\partial R}{\partial P}\right) \frac{Q^W}{Q^N} \left(\rho + \frac{\partial \rho}{\partial P} (P - R - c) \right) \right\}}{(1-\rho)s_l \varepsilon_l + \rho s_w \varepsilon_w + \varepsilon_\rho \rho \theta}.$$

Equation 14 shows the optimal price-cost markup for infant formula manufacturers. In the absence of the WIC program, i.e., $Q^W = 0$ and $\rho = 0$, then $\frac{(P-c)}{P} = -\frac{1}{\varepsilon_l}$ which is the familiar Lerner Index, adapted to oligopoly, similar to the concept developed in Baker and Bresnahan (1988); a firm's price-cost markup is inversely related to its residual demand elasticity.²³ Equation 14 shows that the effect of the WIC program on price-cost markups (and price since marginal costs are constant) depends on the magnitude and sign of $\frac{\partial R}{\partial P}$.

Proposition 1: If $\frac{\partial R}{\partial P} < 1$, the effect of the WIC program is to increase price-cost markups.

Proof:

$$\frac{\partial \left(\frac{(P-c)}{P} \right)}{\partial Q^W} = - \left\{ \frac{\left\{ \left(1 - \frac{\partial R}{\partial P}\right) \left(\rho + \frac{\partial \rho}{\partial P} (P - R - c) \right) \right\}}{Q^N [(1-\rho)s_l \varepsilon_l + \rho s_w \varepsilon_w + \varepsilon_\rho \rho \theta]} \right\} > 0.$$

The denominator is negative, since $\varepsilon_l < 0$, $\varepsilon_w < 0$ and $\varepsilon_\rho < 0$. The numerator is the change in profit from an increase in Q^W . An increase in Q^W will lead to a price increase if increasing price increases profits from the WIC market (the numerator), while not losing too many non-WIC customers (the denominator).

The numerator is positive if $\left(1 - \frac{\partial R}{\partial P}\right) > 0$ and $\left(\rho + \frac{\partial \rho}{\partial P} (P - R - c)\right) > 0$. Since

²³ Baker and Bresnahan (1988) show that a firm's residual demand elasticity can be represented as $\varepsilon_1^D \approx \eta_{1,1} + \sum_{o \neq 1} \eta_{1,o} \varepsilon_{1,o}$ where $\eta_{1,1}$ is the firm's own-price elasticity, $\eta_{1,o}$ are cross-price elasticities, and $\varepsilon_{1,o}$ is the firm's conjectured price reactions of rivals. If conjectured price reactions are consistent in the sense that actual reactions equal conjectured reactions, then the inverse of the residual demand elasticity accurately estimates price-cost markups. It seems almost inconceivable that the three firms in the infant formula market would not be able to accurately estimate their rival's price reactions.

$\frac{\partial \rho}{\partial P} < 0$, it must be that $\rho > \left| \frac{\partial \rho}{\partial P} (P - R - c) \right|$ in order that the numerator be positive; table 7 provides evidence that this is the case. Table 7 shows each firm's average share of the US WIC market from 1987-2007, and the average winning price and rebates. $\frac{\partial \rho}{\partial P} = \omega$ and is reproduced from table 4. If $\frac{\partial R}{\partial P} < 1$, then the numerator is positive and the overall expression is positive.

Because rebates are not matched cent-for-cent with price increases, increases in price increase profits from each unit sold to the WIC market, minus the change in the rebate. If rebates decrease, or increase by less than the price increase (i.e., net price increases), then profit from the WIC market will increase. The incentive to increase price is offset by the loss of sales to the non-WIC market which is in the denominator. Larger values here counteract the price increasing effect of sales to the WIC market.

Proposition 2: If $\frac{\partial R}{\partial P} > 1$, the effect of the WIC program is to decrease price-cost markups.

Proof:

$$\frac{\partial \left(\frac{P - c}{P} \right)}{\partial Q^W} = - \left\{ \frac{\left\{ \left(1 - \frac{\partial R}{\partial P} \right) \left(\rho + \frac{\partial \rho}{\partial P} (P - R - c) \right) \right\}}{Q^N [(1 - \rho) s_l \varepsilon_l + \rho s_w \varepsilon_w + \varepsilon_\rho \rho \theta]} \right\} < 0.$$

If rebates are negotiated to increase at a rate greater than increases in P (e.g., net prices decrease), then profits decline from the WIC market. WIC customers do not create an incentive to increase P because profits do not increase from the WIC market as rebates are negotiated to increase more than prices. Indeed the WIC program creates an incentive to decrease price-cost margins. (I again assume $\left(\rho + \frac{\partial \rho}{\partial P} (P - R - c) \right) > 0$ based on the evidence in table 7.)

Proposition 3: If $\frac{\partial R}{\partial P} = 1$, the WIC program has no effect on price-cost markups.

Proof:

$$\frac{\partial \left(\frac{P - c}{P} \right)}{\partial Q^W} = - \left\{ \frac{\left\{ \left(1 - \frac{\partial R}{\partial P} \right) \left(\rho + \frac{\partial \rho}{\partial P} (P - R - c) \right) \right\}}{Q^N [(1 - \rho) s_l \varepsilon_l + \rho s_w \varepsilon_w + \varepsilon_\rho \rho \theta]} \right\} = 0.$$

The propositions above suggest that identifying $\frac{\partial R}{\partial P}$ is key to understanding the

implications of WIC for non-WIC purchasers. Equation 10 represents the optimal rebate bid, and rearranging it slightly gives,

$$(15) \quad R = P - c + \frac{\rho}{\omega} + \theta(P - c) \frac{Q^N}{Q^W}.$$

Totally differentiating 15 suggests that the change in rebate from a price change is ambiguous,

$$(16) \quad \frac{dR}{dP} = 1 + \frac{d\left(\frac{P}{\omega}\right)}{dP} + \left[\frac{P}{dP} (dq_w - dq_l) + (q_w - q_l) \right] \frac{1}{Q^W} + \frac{c}{Q^W} \frac{dQ^N}{dP} \gtrless 1.$$

The theoretical model does not provide unambiguous guidance for the sign or magnitude of $\frac{\partial R}{\partial P}$.

But, the relationship can be estimated with data on rebates and wholesale prices.

Figure 2 shows real annual-average wholesale prices from all manufactures, and average annual rebates (using rebates that are newly negotiated in that year).²⁴ The two series are trending upward suggesting they are related, but also suggesting that they may not be stationary; regressing one non-stationary variable on another can lead to spurious correlations when none exist (Greene, pp. 778-789). Considering the cross-section, time-series nature of the data, with gaps between time periods, it is difficult to identify unit-roots using standard techniques. My estimation strategy is to create a time-series of rebates and wholesale prices from each new contract at each agency, and then to difference each series. The differences are between consecutive rebate contracts at an agency and do not represent consecutive years. I then regress differenced rebates on differenced wholesale prices. Including wholesale price on the right hand side of a rebate regression may induce endogeneity bias and I conduct a Hausman test using a non-fat dry milk price index, a dry whole milk price index, dry whey prices, and the dairy producer price index as instruments. I find no evidence of significant bias and conduct OLS regressions with standard errors corrected for clustering within agencies. Table 8 presents results when observations are from competitive sole-source contracts.

The first three columns of table 8 include all years of data, and include no dummies, firm dummies only, and then firm dummies and alliance dummies. The wholesale price coefficient is

²⁴ The average rebate is comprised from different subsets of all agencies in each year. The figure only demonstrates the general tendency for rebates to increase with wholesale prices.

about 1 in each of these specifications. The hypothesis that it is statistically equal to 1 cannot be rejected in each case. The evidence suggests support for proposition 3; increases in WIC demand have no impact on the prices paid by non-WIC customers.

Anecdotal reports from WIC agencies suggest that recent rebates have not kept pace with wholesale price increases. To investigate whether the relationship between rebates and wholesale prices is weaker in recent years, I restricted the sample to only more recent years. The results are in the last 4 columns of table 8. There does seem to be some support for the notion that rebates have not kept pace with wholesale price increases in recent years as the size of coefficient declines as the sample is restricted to only more recent years. However, except when the sample is restricted to the most recent period, 2004-2007, the coefficient is not statistically different from 1. For the most recent time period, 2004-2007, the coefficient falls to nearly .5 and is different from 1 at the 10% level. While it is difficult to conclude whether this is a temporary development or whether it indicates a dramatic change in the rebate/price relationship, the result does suggest the situation bears monitoring as decreasing rebates portend larger government expenditures and increasing prices for non-WIC customers.

Conclusions

The WIC program has developed a creative way to limit the cost of procuring infant formula for participating infants by offering manufacturing firms the exclusive right to sell to WIC customers in exchange for a per unit rebate. While saving the government over \$1.5 billion annually, WIC rebates have generated considerable debate concerning their implications for non-WIC purchasers. WIC infant formula rebates were born as a reaction to rising infant formula prices to WIC agencies, yet debate has centered around rebates as a cause of increasing wholesale prices. The evidence presented here suggests that high and increasing infant formula

prices result from market conditions independent from WIC's rebate system. Indeed it appears the WIC rebates enhance competition for WIC customers. Firms are enticed to bid aggressively for the exclusive WIC contract in part because of the 30-40 percent increase in sales to the highly profitable non-WIC customers.

I develop a method to estimate the marginal cost of infant formula and find that it is very low when compared to wholesale prices. WIC's effect turns on the relationship between rebates and wholesale prices. The model suggests that if rebates respond to price changes at a rate greater than one, then the WIC program will depress price-cost margins. If on the other hand, rebates respond to price changes at a rate less than 1, then the WIC program will increase price cost margins. The empirical evidence suggests that rebates and wholesale prices adjust at a rate equal to 1. However, that relationship appears to be weaker for contracts negotiated in more recent years.

It is interesting to note the implications of the spillover effect. First, the spillover effect leads to larger rebates. In equation 10, net price decreases with increases in θ . The implication for the WIC program is clear; anything that decreases θ , will decrease rebates. Some have been concerned about "WIC Only" stores that cater solely to WIC customers (Neuberger and Greenstein 2004).²⁵ If WIC customers are lured away from traditional retail stores, then these stores will have less reason to stock relatively more of the WIC brand of infant formula. If the shelf-space argument is a large proportion of the spillover effect, then WIC only stores imply smaller rebates. Finally, note that the spillover effect mitigates the price increasing effect of the WIC program to non-WIC customers. A larger θ decreases price-cost margins in equation 12.

²⁵ "WIC Only" stores sell only WIC approved foods and cater to WIC customers by locating close to WIC offices.

Counter-intuitively, an increase in sales to non-WIC customers will lead to smaller price-cost margins and not larger price cost margins, as has been speculated by some (e.g., GAO 1998).

Table 1. Variable Names and Definitions

Variable Name	Definition
Wholesale price	Wholesale price for a truckload size shipment of milk-based, 13 oz liquid concentrate
Rebate	The amount a firm will rebate to WIC for each can sold through WIC
Net Price	Wholesale price – rebate
Alliance births*	The sum of the births in each state included in an alliance of WIC agencies
Alliance non-WIC infants*	Births - WIC infants, summed for each state in an alliance, adjusted with breastfeeding rates
Alliance min. Distance*	The minimum distance from a firm's plant to the largest city in an alliance
Enhance	A firm's rebate bid was based on formula enhanced with AHA/DHA (yes=1, no=0)
Competitive	The auction used a sole-source, sealed-bid format (yes=1, no=0)
Previous	Bidding firm held the agency's previous contract (yes=1, no=0)
Contract Length	The specified length of the contract at the date of the RFP (in days)
Number of Bidders	The number of firms submitting bids in an auction.
Composite	The agency required a single composite rebate bids for soy and milk products (yes=1, no=0)
Uncoupled	The agency required separate bids for soy and milk-based products, and separate contracts were offered for soy or milk-based products (yes=1, no=0)

* If an agency does not belong to an alliance, then the alliance is a single state agency.

Table 2. Variable Means Variable Name	Company Name			
	Mead Johnson	Ross	Wyeth	Carnation
Wholesale price (2007\$)	3.12	3.13	2.89	2.92
Rebate (2007\$)	2.27	2.31	1.75	2.46
Net Price (2007\$)	0.85	0.81	1.14	0.46
Alliance births (0,00s)	11.69	11.27	11.32	9.14
Alliance non-WIC infants	4.93	4.74	5.29	3.69
Alliance min. Distance (miles)	1014	803	1322	2063
Enhance	0.14	0.13	0.00	0.24
Competitive	0.73	0.73	0.90	1.00
Previous	0.23	0.22	0.14	0.24
Contract Length (days)	927.04	924.39	948.93	932.93
Number of bidders	2.52	2.50	2.94	3.20
Composite	0.38	0.37	0.32	0.56
Uncoupled	0.08	0.09	0.11	0.20
Number of observations	213	222	87	41

Table 3. Net Price Regression

Variable name	Coefficient
Constant	1.845*** (0.293)
Ross=1	-0.0700** (0.033)
Wyeth=1	0.039 (0.059)
Carnation=1	-0.086 (0.069)
Alliance births (0,00s)	-0.0387*** (0.011)
Alliance births x Wyeth	0.0572** (0.022)
Alliance non-WIC infants x Wyeth	-0.111** (0.045)
Alliance min. Distance (miles)	5.90e-05* (3.55E-05)
Alliance min. Distance x Ross	4.94e-05** (2.50E-05)
Enhance	0.096 (0.159)
Enhance x Carnation	-0.267** (0.128)
Competitive	-0.256*** (0.051)
Previous	-0.043 (0.036)
Contract Length (days)	9.420E-05 (6.70E-05)
Number of bidders	-0.009 (0.038)
Composite	-0.083 (0.052)
Uncoupled	-0.150* (0.082)
Uncoupled x Wyeth	0.512*** (0.118)
Number of observations	563
R-squared	0.718

The regression includes alliance and year dummy variables. Standard Errors in (). *=.10 significance
 =.05 significance, *.01 significance

Table 4. Multinomial Logit

Variables	Company	Mead Johnson	Ross	Wyeth
$\hat{\eta}_p$	-5.179*** (1.319)			
Constant		1.710*** (0.397)	1.363*** (0.354)	2.045*** (0.562)
Observations	514	514	514	514
Log pseudolikelihood	-165.66			

Std. errors in () adjusted for clustering in alliance.
 *=.10 significance **=.05 significance, ***.01 significance

Table 5. Choice Probabilities and Marginal Effects

	Mead Johnson		Ross		Wyeth		Carnation	
	Value	Std. Error	Value	Std. Error	Value	Std. Error	Value	Std. Error
Proportion of auctions won	0.410	0.493	0.353	0.479	0.253	0.438	0.142	0.350
$\hat{\rho}$	0.410	0.101	0.353	0.082	0.253	0.134	0.142	0.096
$\hat{\omega}$	-1.201	0.094	-1.147	0.130	-0.887	0.371	-0.582	0.288
$\hat{\rho}/\hat{\omega}$	-0.340	0.083	-0.303	0.041	-0.268	0.057	-0.228	0.031
Number of Observations	156		156		75		127	

$\hat{\omega}$, $\hat{\rho}$ and $\hat{\rho}/\hat{\omega}$ are calculated at each observation in the data. The figures reported are the mean and standard deviation calculated from this sample.

Table 6. Net Price Bids Adjusted with Auction Probabilities

Variable	OLS 1	OLS 2	OLS 3	OLS 4	IV 1	IV 2	IV 3	IV 4
C	0.255*** 0.061				0.370*** (0.068)			
$C_{Mead\ Johnson}$		0.239*** (0.067)	0.197** (0.079)	0.197** (0.079)		0.367*** (0.086)	0.304*** (0.110)	0.304*** (0.110)
C_{Ross}		0.243*** (0.068)	0.239*** (0.082)	0.239*** (0.081)		0.372*** (0.089)	0.384*** (0.101)	0.384*** (0.101)
C_{Wyeth}		0.626*** (0.081)	0.778*** (0.115)	0.808*** (0.051)		0.696*** (0.079)	0.772*** (0.119)	0.808*** (0.051)
$C_{Carnation}$		0.115* -0.060	0.210** (0.099)	0.226*** (0.042)		0.148** (0.058)	0.276*** (0.077)	0.226*** (0.042)
θ	0.0948* (0.055)	(0.058) (0.061)			0.350*** (0.099)	0.314** (0.129)		
δ	0.453*** (0.151)	0.299* (0.169)			1.105*** (0.260)	0.958*** (0.342)		
$\theta_{Mead\ Johnson}$			-0.192** (0.086)	-0.192** (0.085)			0.304* (0.165)	0.304* (0.165)
θ_{Ross}			-0.148* (0.080)	-0.148* (0.080)			0.400*** (0.143)	0.400*** (0.142)
θ_{Wyeth}			-0.227* (0.128)				-0.303 (0.252)	
$\theta_{Carnation}$			-0.045 (0.083)				0.191 (0.175)	
$\delta_{Mead\ Johnson}$			0.763*** (0.250)	0.763*** (0.249)			0.996** (0.435)	0.996** (0.433)
δ_{Ross}			0.583*** (0.207)	0.583*** (0.206)			1.214*** (0.369)	1.214*** (0.367)
δ_{Wyeth}			-0.619* (0.312)				-0.819 (0.662)	
$\delta_{Carnation}$			-0.106 (0.202)				0.471 (0.509)	
R^2	0.079	0.523	0.545	0.541	0.109	0.535	0.546	0.545
F-statistic	9.860	43.160	29.430	36.680	14.360	48.430	33.020	37.760
Prob > F	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Hausman ^a	28.110	21.411	7.349	5.473				
Hausman p-value	1.000	1.000	0.975	0.935				

Standard errors in () adjusted for correlation and heteroskedasticity (clustering) within alliance.

*=.10 significance **=.05 significance, ***.01 significance

a: Hausman test for endogeneity of (q^N/q^W) and P_m

Table 7. Average WIC Share - Price, and Rebate from Winning Bids

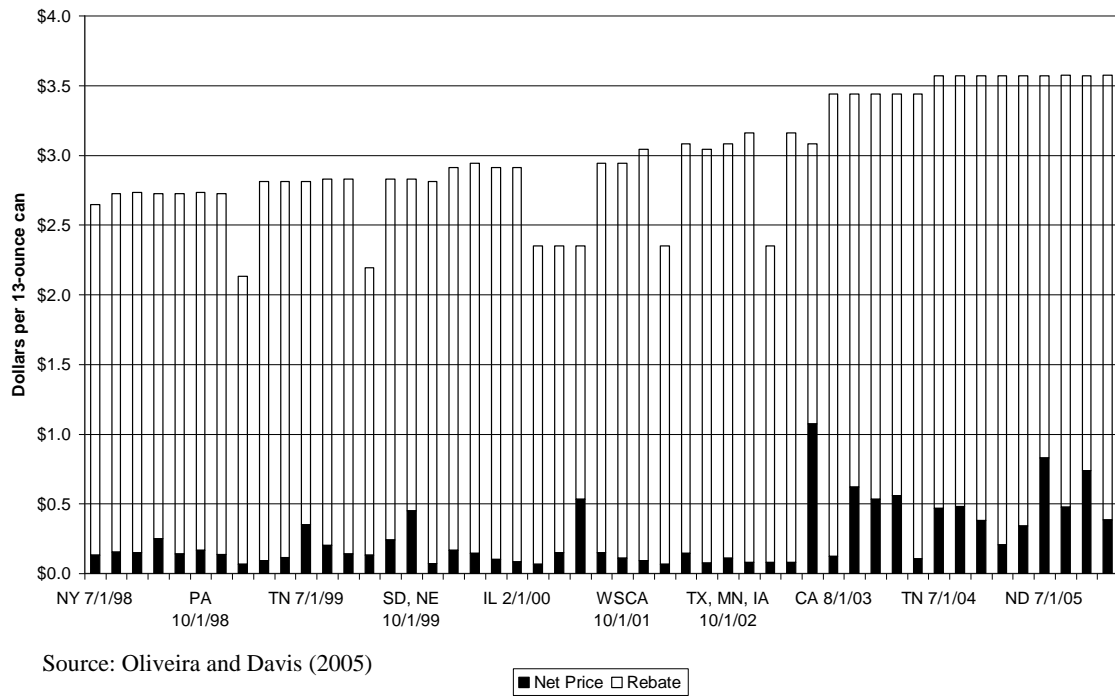
	Average Share	$\frac{\partial \rho}{\partial P}$	P	R	c	$\rho + \frac{\partial \rho}{\partial P} (P - R - c)$
MJ	0.469	-1.201	3.324	2.870	0.304	0.289
Ross	0.386	-1.147	3.294	2.839	0.384	0.303
Wyeth	0.180	-0.887	2.911	2.059	0.808	0.141
Carnation	0.091	-0.582	3.112	2.751	0.226	0.013

Table 8. Rebate First-Differences

	Years included in sample						
	1988-2007	1988-2007	1988-2007	1992-2007	1996-2007	1999-2007	2004-2007
WP	1.04*** (0.10)	1.06*** (0.11)	1.07*** (0.13)	1.14*** (0.12)	0.93*** (0.17)	0.80*** (0.21)	0.54** (0.26)
Constant	0.02 (0.02)	-0.07 (0.06)	-0.04 (0.08)	-0.10 (0.06)	0.00 (0.09)	-0.02 (0.15)	0.13 (0.35)
$Pr(H_0: WP=1)$	0.67	0.57	0.61	0.26	0.67	0.34	0.09
R-squared	0.20	0.21	0.26	0.23	0.20	0.23	0.39
Firm Dummies	No	Yes	Yes	Yes	Yes	Yes	Yes
Alliance Dummies	No	No	Yes	No	No	No	No

Standard errors in () adjusted for correlation and heteroskedasticity (clustering) within alliance. *.10 significance **=.05 significance, ***.01 significance

Figure 1. Winning Rebates and Wholesale prices, by Agency



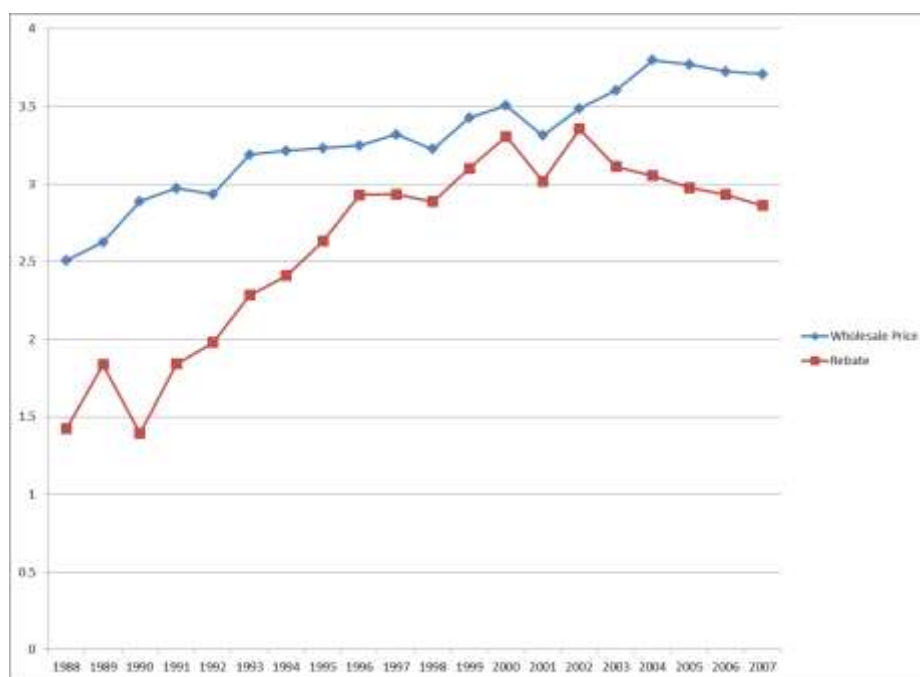


Figure 2. Wholesale Prices and Rebates

References

- Baker, Johnathon B., and Timothy F. Bresnahan, "Estimating the Residual Demand Curve Facing a Single Firm," *International Journal of Industrial Organization*, 6 (1988), 283-300.
- Betson, David, *Impact of the WIC Program on the Infant Formula Market*, U.S. Department of Agriculture, Economic Research Service, Contractor and Cooperator Report, no 51. 2009.
- Crespi, John M., and Richard J. Sexton, (2005) "A Multinomial Logit Framework to Estimate Bid Shading in Procurement Auctions: Application to Cattle Sales in the Texas Panhandle," *Review of Industrial Organization*, 27: 253-278.
- Davis, David E. and Ephraim S. Leibtag, *Interstate Variation in WIC Food Package Costs: The Role of Food Prices, Caseload Composition, and Cost-Containment Practices*, FANRR-41, U.S. Department of Agriculture, Economic Research Service, 2005.
- Greene, W. H. (2000) *Econometric Analysis*, 4th edn. Upper Saddle River, NJ: Prentice Hall.
- Harvey, Stephan, Robert Greenstein, and Scott Barancik, *Saving to Serve More: Ways to Reduce WIC Infant Formula Costs*. Center on Budget and Policy Priorities, 1988
- Huang, Rui and Jeffrey M. Perloff, (2007), "WIC Contract Spillover Effects" University of California, Berkeley Working Paper
- Long, J. Scott and Jeremy Freese, *Regression Models for Categorical Dependent Variables Using Stata*, Stata Press, College Station, TX (2006)
- Maddala, G. S., *Limited-dependent and qualitative variable in econometrics*, Cambridge University Press, Cambridge, MA, (1983)
- Neuberger, Zoë and Robert Greenstein, *WIC Only Stores and Competitive Pricing in the WIC Program* Center on Budget and Policy Priorities Food Assistance Report, May 17, 2004.
- Oliveira, Victor, Mark Prell, David Smallwood, and Elizabeth Frazao, *WIC and the Retail Price of Infant Formula*, U.S. Department of Agriculture, Economic Research Service, FANRP-39-1, May, 2004.
- Oliveira, Victor and David E. Davis, *Recent Trends and Economic Issues in the WIC Infant Formula Rebate Program*, U.S. Department of Agriculture, Economic Research Service ERR-22, August, 2006
- Oliveira, Victor, Elizabeth Frazão, and David Smallwood. *Rising Infant Formula Costs to the WIC Program: Recent Trends in Rebates and Wholesale Prices*, ERR-93, U.S. Department of Agriculture, Economic Research Service, February 2010.
- Prell, Mark, *An Economic Model of WIC, the Infant Formula Rebate Program, and the Retail Price of Infant Formula*, U.S. Department of Agriculture, Economic Research Service, Food Assistance and Nutrition Research Report Number 39-2, December 2004.
- Samuels, Simonetti, "Infant Formula WIC Rebates: Altruism or Exclusionary Practices," *Journal of Pharmacy and Law*, Vol. 2:1993:185-219.
- U.S. General Accounting Office, Resource, Human Resources Division, *Infant Formula: Cost Containment and Competition in the WIC Program*, GAO/HRD-90-122, September 1990
- U.S. General Accounting Office, Resource, Community and Economic Development, *Food Assistance: Information on WIC Sole-Source Rebates and Infant Formula Prices*, GAO/RCED-98-146, May 1998
- U.S. General Accounting Office, *FNS Could Take Additional Steps to Contain WIC Infant Formula Costs*, Report to Congressional Requesters, GAO-06-380, March 2006.
- Wooldridge, Jeffrey M., (2002), *Econometric Analysis of Cross-Section and Panel Data*, The MIT Press, Cambridge, MA.