Sole-Source Contracts in WIC Infant-Formula Rebate Auctions and their Effect on Manufacturers' Markups

Abstract

The WIC program uses an auction to procure infant formula. Manufacturers bid on the right to be an agency's sole supplier of formula by offering a rebate on formula sold through WIC. Rebates reduce costs, averaging about 90 percent of wholesale prices. However, because rebates are so large, some question the industry's competitiveness. This paper develops a model for optimal rebates and shows that marginal cost can be estimated from model coefficients and program characteristics. Marginal cost estimates suggest large markups, and elasticities consistent with these markups suggest manufactures price on the demand curve where demand is nearly unit elastic.

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Introduction

Government agencies are frequent purchasers of products in unregulated markets. 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. This paper examines the market for infant formula, a market in which the government facilitates and influences a large proportion of purchases. Over one half of all infant formula sold in the United States is purchased through the Special Supplemental Nutrition Program for Women, Infants, and Children (WIC). WIC, the third-largest Federal food-assistance program, 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.

Because the cost of providing infant formula to WIC infants (the most costly food item) was increasing during the 70s and 80s, states became concerned the high cost was severely limiting the number of eligible persons that could be served. 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 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 have proven very effective at reducing costs to states, as winning rebates have averaged about 90 to 95 percent of manufacturers' wholesale prices and have routinely returned over $1.5 billion to the WIC program on an annual basis. However, the size of rebates relative to manufacturers' wholesale prices naturally leads to questions about the relationship between wholesale prices and marginal costs. It seems either manufactures' sell formula at a substantial level below marginal cost in the WIC market, or that wholesale prices far exceed marginal cost. The latter possibility seems likely given the highly concentrated structure of the formula market. Currently, three manufacturers produce about 99 percent of domestic sales (Oliveira and Davis, 2006). Throughout the history of the rebate auction process, rarely have more than 3 manufacturers bid on a given contract, and in a majority of cases, only 2 manufacturers bid on a contract.

In this paper, I develop a method to measure markups of price over marginal cost for firms that price discriminate and sell in separate markets. I adapt and generalize an approach first developed in Crespi and Sexton (2005) to estimate a manufacturer's probability of winning a rebate auction which suggests a method to estimate marginal cost and price markups. When applied to data on wholesale prices and rebates for infant formula manufacturers, estimates suggest marginal costs are low relative to wholesale prices, and that markups are large, and the effect of the WIC rebate system is to dramatically increase pricing power, and therefore markups.

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. 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, insolating 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).[1] During the 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-

[1] In 2005, 49.5 of all US infants participated in the WIC program.

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. The state purchased infant formula in bulk and starting in 1984 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, 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 to provide the highest rebate per unit sold. 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 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.[2] In April, 1988 Florida requested bids under both an open-market system and a competitive sole-source system. Because the competitive system

[2] 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.

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. This is also reflected in total rebates returned to states in figure 2. Currently, rebates annually return over $1.5 billion to state agencies.

Development of the WIC rebate systems has been a boon to WIC agencies as procurement costs have been reduced allowing more eligible WIC participants to be served. However, the size of the rebates has led to speculation, and some research, about the source for such large rebates. It seems that either manufactures set wholesale prices much greater than marginal costs, or that they sell infant formula at a price below cost in the WIC market. 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 brand of infant formula holding the WIC contract 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. The General Accounting Office (GAO, now the General Accountability Office) in 1998 identified two potential sources for a spillover effect. Doctors may give preference to the WIC brand of infant formula when recommending a brand of infant formula to new mothers. Or, WIC contracts may give the WIC brand greater shelf-space on grocery-store shelves increasing sales to non-WIC customers (GAO, 1998). While the GAO's 1998 report recognized the possibility of a spillover effect, it discounted the possibility of the effect being large enough to entice manufactures to sell to WIC below cost.

Oliveira, et. al, (2004) note that since the implementation of state rebate programs, the retail price of infant formula has risen faster than the rate of inflation.[3] 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 have the ability 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

[3] 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.

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 (2007) develops a theoretical model of manufacturer behavior, given the presence of the WIC program and sole-source contracts. Betson's primary conclusion is that the effect of the WIC program will be to decrease prices to non-WIC consumers, rather than to increase them. A substantial weakness of the Betson model is the lack of attention to the possibility of a spillover effect. Huang and Perloff (2007) show the importance of spillover effects for infant formula markets. 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 a period of time less than two years. The authors also find a similar, but opposite, reaction in the brand that loses the WIC contract.

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 insensitive.[4] The WIC market includes persons participating in the WIC program. Once a person no longer qualifies for the WIC program, or does not participate in the WIC program, they become part of the non-WIC market if they continue to purchase infant formula.

[4] 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.

WIC contracts are between WIC state agencies, or alliances if multiple states negotiate contracts jointly, and infant-formula manufacturers. Hereafter, I will refer to infant-formula manufacturers as firms and state agencies/alliances as agencies. Firms bidding decisions are based on potential contracts with agencies which have implications for sales in the WIC and non-WIC market. Define the demand for formula from non-WIC customers in market i as $Q_i^N = Q_i^N(P_{m,\ldots}P_M)$, where $P_m \ldots P_M$ represent firm-specific prices for the m=1 to M firms selling to customers in market i. Market i includes customers in the geographic area corresponding to agency i; that is, states or groups of states if states are allied in contract negotiations. Huang and Perloff (2007) suggest that a WIC contract produces a spillover effect for a firm and this "shelf-space" effect seems exogenous to the firm's decision. Considering Huang and Perloff 's evidence, a firm should 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, therefore demand for firm m is written

$$Q_{m,i}^N = \begin{Bmatrix} s_w Q_i^N \text{ if awarded the contract} \\ s_l Q_i^N \text{ if not awarded the contract} \end{Bmatrix}, \quad (1)$$

where $\mathbf{s_w} > \mathbf{s_l}$ are market shares when awarded or not awarded the WIC contract. Letting $\boldsymbol{\rho_{m,i}}$ equal the probability of firm m winning the contract in market i, the non-WIC demand can be written as

$$Q_{m,i}^N = \rho_{m,i} s_w Q_i^N + (1 - \rho_{m,i}) s_l Q_i^N + \zeta_i \quad (2)$$

$$= (s_l + \theta_i \rho_{m,i}) Q_i^N + \zeta_i, \quad (3)$$

where ζ_i is a mean-zero stochastic element, and $\boldsymbol{\Theta}_i = (s_w - s_l)$. Let $(Q_i^W + \eta_i)$ represent (uncertain) formula demand from WIC customers in the market area represented by agency i. (η_i is a zero mean stochastic element). Expected formula demand for firm m from agency (market i), can be written as:

$$E[Q_{m,i}] = E[Q_{m,i}^N] + E[Q_{m,i}^W] = (s_l + \theta_i \rho_{m,i})Q_i^N + \rho_{m,i} Q_i^W . \qquad (4)$$

Expected profit for firm m is:

$$E[\Pi_{m,i}] = P_{m,i}(s_l + \theta_i \rho_{m,i})Q_i^N + (P_{m,i} - R_{m,i})\rho_{m,i} Q_i^W - c_{m,i}\left((s_l + \theta_i \rho_{m,i})Q_i^N + \rho_{m,i} Q_i^W\right), \quad (5)$$

where $R_{m,i}$ is firm m's rebate bid and $c_{m,i}$ is a the constant marginal cost of producing, transporting, and selling a unit of infant formula in market i.

It may seem inappropriate to model marginal cost as being constant. It is arguable that there may be economies of scale and that selling in the WIC market allows the firm to lower per unit costs by operating at a higher scale. However, the assumption here is that marginal costs are invariant only in market i.

I assume that firms have two choice variables, ***P*** and ***R***, but that they make optimizing decisions in two steps. Evidence suggests that firm's choose ***P*** before they choose ***R.*** Wholesale prices change infrequently (Oliveira and Davis), while rebate auctions occur in various markets quite frequently and at times that do not generally coincide with wholesale price changes, suggesting the rebate bids are formulated at different times than prices. So, firm m chooses price in market i:

$$\partial E\left[\Pi_i\right] \big/ \partial P_{m,i} = P_{m,i}(s_l + \rho_{m,i}\theta_i)\frac{dQ_i^N}{dP_{m,i}} + (s_l + \rho_{m,i}\theta_i)Q_i^N + \rho_{m,i} Q_i^W - c_{m,i}(s_l + \rho_{m,i}\theta_i)\frac{dQ_i^N}{dP_{m,i}} = 0 \quad (6)$$

Solving equation (6) provides the optimal price to charge in market i

$$P_{m,i} = c_{i,m} - \left(\frac{dQ_i^N}{dP_{m,i}}\right)^{-1}\left[\left(Q_i^N\right) + \left(\frac{\rho_{m,i} Q_i^W}{s_l + \theta_i \rho_{m,i}}\right)\right], \qquad (7)$$

where $\frac{dQ_i^N}{dP_{m,i}} = \frac{\partial Q_i^N}{\partial P_{m,i}} + \sum_{m \neq o} \frac{\partial Q_i^N}{\partial P_{o,i}} \frac{dP_{o,i}}{dP_{m,i}}$ is the total derivative of non-WIC demand with respect to firm m's price. It is the change in non-WIC demand in market i from a change in firm m's price, recognizing that competing firms may react to m's price change. In short, it recognizes oligopolistic reactions in light of the concentrated industry structure.

Infant formula manufactures contend they do not price discriminate geographically and charge a single price in all markets. Lacking any guidance for how a single price might be determined, I assume the single national price is determined by averaging over all i markets. Letting

$$\overline{\rho}_m = \frac{\sum_i^I \rho_i}{I},\ \overline{\theta} = \frac{\sum_i^I \theta_i}{I},\ \overline{\partial Q}^N \Big/ \overline{\partial P_m} = \frac{\sum_i^I \partial Q_i^N \big/ \partial P_{m,i}}{I},$$
$$\overline{P}_m = \frac{\sum_i^I P_{m,i}}{I},\ \overline{Q}^N = \frac{\sum_i^I Q_i^N}{I},\ \overline{Q}^W = \frac{\sum_i^I Q_i^W}{I},\ \overline{c}_m = \frac{\sum_i^I c_i}{I}$$

equation 7 becomes,

$$\overline{P}_m^* = \overline{c}_m - \left(\frac{\overline{\partial Q}^N}{\overline{\partial P_m}}\right)^{-1} \left[\left(\overline{Q}^N\right) + \left(\frac{\overline{\rho_m Q}^W}{s_l + \overline{\theta \rho_m}}\right)\right]. \qquad (7a)$$

An interesting comparative static examines the effect of a change in the WIC market on the wholesale price of infant formula.

$$\partial \overline{P}_m \Big/ \partial \overline{Q}^W = -\left(\overline{\partial Q_i}^N \Big/ \overline{\partial P_m}\right)\left(\frac{\overline{\rho_m}}{s_l + \overline{\rho_m \theta}}\right) > 0 \qquad (7b)$$

Equation 7b shows that a profit maximizing firm with market power will increase price as the size of the average WIC market increases.

Equation 7a can be rearranged to give the markup of price over marginal cost in a Lerner index as,

$$\frac{\overline{P_m} - \bar{c}_m}{\overline{P_m}} = \left(\frac{-1}{\varepsilon_m}\right)\left[\left(\frac{\left(s_1 + \overline{\theta}\overline{\rho}_m\right)Q^N + \overline{\rho}_m \overline{Q}^W}{\left(s_1 + \overline{\theta}\overline{\rho}_m\right)\overline{Q}^N}\right)\right], \tag{8}$$

where $\varepsilon_m = \left(\partial \overline{Q^N} \big/ \partial \overline{P}_m\right)\left(\frac{\overline{P}_m}{\overline{\overline{Q^N}}}\right) = \left(\frac{\partial \overline{Q}^N}{\partial \overline{P}_m}\right)\left(\frac{\overline{P}_m}{\overline{Q}^N}\right) + \sum_{m \neq o}\left(\frac{\partial \overline{Q}^N}{\partial \overline{P}_o}\right)\left(\frac{\overline{P}_o}{\overline{Q}^N}\right)\left(\frac{d\overline{P}_o}{d\overline{P}_m}\right)\left(\frac{\overline{P}_m}{\overline{P}_o}\right)$, is

the total price elasticity of demand faced by manufacturer m. The portion of equation 8 in the square brackets is the effect of the WIC program on price-cost markups. It is clearly greater than 1 which suggests that the effect of the WIC program is to increase price-cost markups for infant formula sold in the non-WIC market.

Denote the optimal price for firm m, determined from equation 7a, as $\overline{P}^*$. Because $\overline{P}^*$ is predetermined, the firm's decision to find the optimal rebate is to simply choose $R_{m,i}$ by maximizing

$$E[\Pi_{m,i}] = \overline{P}^*_m (s_l + \theta_i \rho_{m,i}) Q_i^N + (\overline{P}^*_m - R_{m,i})\rho_{m,i} Q_i^W - c_{m,i}\left((s_l + \theta_i \rho_{m,i}) Q_i^W + \rho_{m,i} Q_i^W\right). \tag{5a}$$

The first-order condition is

$$\frac{\partial \Pi_{m,i}}{\partial R_i} = \left(\overline{P^*_m} - R_{m,i}\right) Q_i^W \left(\frac{\partial \rho_{m,i}}{\partial R_{m,i}}\right) - \rho_{m,i} Q_i^W - c_{m,i}\left(\frac{\partial \rho_{m,i}}{\partial R_{m,i}}\right)\left(Q_i^N \theta_i - Q_i^W\right) = 0. \tag{9}$$

Solving equation 9 gives the optimal rebate in market i,

$$R^*_{m,i} = R_{m,i} = \overline{P}^*_m - \left(\rho_{m,i} \big/ \omega_{m,i}\right) - c_{m,i}\left(1 + \theta_i \frac{Q_i^N}{Q_i^W}\right), \tag{10}$$

where $\overline{\omega}_{m,i} = \frac{\partial \rho_{m,i}}{\partial R_{m,i}} > 0$ is the marginal change in the probability of winning an auction, from a change in the rebate bid.[5]

Estimating marginal cost

Rearranging equation 10, marginal cost in market i equals

$$c_{m,i} = \left(\overline{P_m^*} - R_{m,i}^* - \rho_{m,i} / \omega_{m,i} \right) \left(\frac{Q_i^W}{Q_i^W + \theta_i Q_i^N} \right). \quad \textbf{(11)}$$

Assuming that firms choose prices and rebates optimally, then the marginal cost of providing infant formula to market i can be calculated from equation 11. $\overline{P}^*$ and R_i^* are observable. Q_i^N and Q_i^W represent the total WIC and non-WIC demand in market i. While not directly observable, approximations for them are available. It seems reasonable to assume that a non-breastfeeding infant in the WIC market consumes, on average, the same amount of formula as a non-breastfeeding infant in the non-WIC market. Let a equal the average amount of infant formula consumed by infants. Let $q_{i,w}$ represent a single formula consuming infant in the WIC market i, then $Q_i^W = \sum_w^W a q_{i,w}$ for w=1 to W WIC infants in market i.[6] Let $q_{i,n}\left(\overline{P}^*\right)$ represent a single non-WIC infant for whom $\overline{P}^*$ is less than their parent's reservation price, then $Q_i^N = \sum_n^N a q_{i,n}$ for n = 1 to N non-breastfeeding infants not in the WIC market. Focusing momentarily on the term in the second set of brackets in equation 11,

[5] See Crespi and Sexton, 2005 for an application of this method to cattle procurement.
[6] Note that if a_w is the amount of formula consumed by infant w, then $\Sigma a_w q_{i,w} = a \Sigma q_{i,w}$ where the summation is over the w infants in market i.

$$\left(\frac{\mathbf{Q}_{\mathrm{i}}^{\mathrm{W}}}{\mathbf{Q}_{\mathrm{i}}^{\mathrm{W}}+\theta\mathbf{Q}_{\mathrm{i}}^{\mathrm{N}}}\right)=\left(\frac{a\sum_{w=1}^{W} q_{i,w}}{a\left(\sum_{w=1}^{W} q_{i,w}+\theta_i\sum_{n=1}^{N} q_{i,n}\right)}\right)=\left(\frac{\sum_{w=1}^{W} q_{i,w}}{\left(\sum_{w=1}^{W} q_{i,w}+\theta_i\sum_{n=1}^{N} q_{i,n}\right)}\right), \quad \textbf{(11a)}$$

under this formulation, WIC and non-WIC demand can be approximated by the number of (non-breastfeeding) WIC and non-WIC infants in each market.

Finally, equation 11 requires parameters θ_i, $\rho_{m,i}$, and $\overline{\omega}_{m,i}$. I rely on Huang and Perloff who estimate market shares for infant formula manufactures when they hold a WIC contract compared to when they do not hold a contract to provide an estimate of θ_i. The final parameters needed to calculate marginal cost in equation 11 are the probability, and marginal probability of supplying the winning WIC rebate. I detail a method to estimate these parameters below.

Estimating the probability of winning a contract

Firms are awarded WIC contracts by offering to sell infant formula to a WIC agency at a lower net price, wholesale price minus rebate, than other manufacturers. Manufacturers' bids are a function of their probability of winning. I assume manufacturers assess their probability of winning from their own bid relative to their wholesale price, the expected bids and wholesale prices of rivals, and any informational advantages from previously holding an agency's contract. To begin, I estimate a linear regression where rebate serves as the dependent variable, and wholesale price, the number of births in a market, and WIC infants in a market are independent variables. I also include annual dummy variables and a dummy variable that takes a value of one when a manufacture held the WIC agency's previous contract. So for each manufacturer m, I estimate a regression of the form,

$$Rm = a_0 + \delta_t + \beta_P P_m + \beta_b Births + \beta_W WICInfants + PCH_M + \varepsilon. \quad (12)$$

I assume each manufacturer forms expectations for other manufactures' bids as the predicted value from these regressions.

Let $\vartheta_m^i(P_m, R_m) = \alpha_m P_m + \gamma_m R_m + \xi_m$ indicate the cost of infant formula to WIC agency i, if they award the contract to manufacturer m, where α_m, γ_m are parameters to be estimated and ξ_m is a well-behaved error term arising from manufacturers' inability to fully observe costs. WIC chooses the manufacturer with the lowest cost, $\vartheta_m^i(P_m, R_m) < \vartheta_o^i(P_o, R_o)$. However, manufactures cannot observe rivals' bids before the auction and so estimate the cost to WIC from rivals as $\vartheta_o = \alpha_o P_o + \gamma_o \hat{R}_o + \xi_o$ where $\hat{R}_o$ is the rival's expected bid. Let Y^i represent a random variable indicating that the WIC agency chooses manufacturer m when $\vartheta_m < \vartheta_o$ for all o ≠ m. Each manufacturer's probability of being chosen is, $\rho_{m,i} = \Pr ob(Y^i = m)$, where

$$\rho_{m,i} = F\left[\alpha P_m + \gamma R_{m,i} + \sum_{o \neq m} \alpha P_o + \gamma \hat{R}_{o,i} + \sum_{o \neq m} \xi_o\right] \quad (13)$$

I assume $\sum_{o \neq m} \xi_o$ is normally distributed and estimate equation 13 with a probit regression.

To estimate marginal cost, I need the probability that an agency would choose a particular manufacturer, $\rho_{m,i}$ and the marginal effect, $\overline{\omega}_{m,i}$, of that manufacturer's rebate bid on the probability of being chosen. I can estimate these from the parameters in equation 13.

Data

The primary data in this study are a time-series, cross-section of firms' winning and losing rebate bids for all contract auctions from 1986 through 2007. 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. Agencies initiated rebate systems in different years, and contracts can be extended so the number of contracts per agency varies. The data were compiled from a variety of sources including bidding records kept by the FNS and the Center for Nutrition Policy Promotion. Data were collected as available for both milk- and soy-based formula in both powder and 13-ounce cans of liquid concentrate forms. Bids for soy-based formula are only sporadically available, and bids for powder-based are available for only the years since 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. While agencies determine winning based on a weighted average net price, where the weights are the anticipated proportions of powder and liquid concentrate in milk and soy forms, Oliveira and Davis 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 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 (wholesale price minus rebate). 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-WIC infants are adjusted with breastfeeding rates as estimated by the Ross Mothers' Survey.

Table 1 presents the means and standard deviations for rebates and wholesale prices in constant 2007 dollars. It is interesting to note that wholesale prices are quite similar for the two dominant firms, Mead Johnson and Ross, and for the two secondary firms Wyeth and Carnation. It is also interesting that firms did not bid for every contract available. The number of available auctions is given by the number of wholesale price observations, while the number of bids offered is given by the number of rebate observations. Future research will examine the determinants of bid submission.

Probit results and markup estimates

Table 2 shows the results from estimating equation 12 for each manufacturer with OLS regressions. An auction is included in each sample conditional on a positive rebate bid to reflex that manufacturers' expectations are based on positive bids only. The predicted values from these regressions are independent variables in the probit regressions that follow.

Table 3 shows the results from probit regressions for each manufacturer. Mead Johnson and Ross bid in nearly every auction, but Wyeth and Carnation bid in only a subset of auctions. In only a very few auctions do Wyeth and Carnation both bid in the same auction. To facilitate estimation of Mead Johnson and Ross probabilities, I create variables Third Bidder Rebate and Third Bidder Wholesale Price. If Wyeth bids in an auction with Mead Johnson and Ross, then Wyeth is the third bidder. If Carnation bids in an auction with Mead Johnson and Ross, then Carnation is the third bidder. If both firms bid, then the third bidder is the average of Wyeth and Carnation.

Fit statistics at the bottom of the table suggest the model fits the data reasonably well. A manufacturer's own rebate and wholesale price are the most consistently significant predictors of the probability of winning an auction. As expected, the higher manufacturer's own rebate the greater the probability of winning, holding wholesale price constant. Conversely, higher wholesale price decreases the probability of winning. Being the previous contract holder seems important for Mead Johnson and Ross. This reflects that all else constant, Mead Johnson and Ross are likely to be awarded a contract if they also held the previous contract, likely because changing suppliers is costly. Changing suppliers is costly because vendors and WIC participants must be notified of the change in the brand acceptable to WIC. Agencies are also likely sensitive to infant participants, whose mothers do not want to change brand of infant formula once feeding has begun with another brand.

Table 4 shows the marginal effects with standard errors for each manufacturer's rebate. The estimates suggest that a \$0.10 increase in rebate increases the probability of winning, by .0887, .0924, .0697, .167 for Mead Johnson, Ross, Wyeth, and Carnation respectively.

Table 5 shows the results from estimating marginal cost according to equation 11. Equation (11a) shows that counts of non-breastfeeding infants and the difference in market share with and without a WIC contract are needed to estimate marginal cost. I use the estimate of the difference in market share estimated in Perloff and Huang. Their analysis suggests that within the length of a typical contract (that is to say, in a period of time less than 3 years) market shares of the non-contract brands fall to less than 20%, while market shares of contract brands increased to over 70%. Given this evidence, I use .55 as a measure of θ in equation 11. WIC infant counts and Non WIC infants are readily available, as noted above, and there ratio is multiplied times $\left(\overline{P}_m - R_{m,i} - \frac{\rho_{m,i}}{\varpi_{m,i}}\right)$ is used to calculate marginal costs in accordance with equation 11.

I estimate marginal cost for each observation included in each manufacturer's sample, and estimate a standard error for each observation using the delta method. Marginal costs appear small when compared to wholesale prices and rebates. Estimates for Mead Johnson, Ross, and Carnation are all below 30 cents per 13-ounce can of liquid concentrate (in constant 2007 dollars). In contrast, average wholesale prices for a 13-ounce can were \$3.29 for Mead Johnson, \$3.27 for Ross, \$2.91 for Wyeth, and \$2.92 for Carnation.

Implications of the WIC rebate program for non-WIC purchases

Equation 8, reproduced below, suggests the effect of the WIC program on price-cost margins.

$$\frac{\overline{P_m} - \bar{c}_m}{\overline{P_m}} = \left(\frac{-1}{\varepsilon_m}\right)\left[\left(\frac{\left(s_1 + \bar{\theta}\bar{\rho}_m\right)\bar{Q}^N + \bar{\rho}_m \bar{Q}^W}{\left(s_1 + \bar{\theta}\bar{\rho}_m\right)\bar{Q}^N}\right)\right], \tag{8}$$

Because I have estimated marginal costs and have data on prices, I can calculate the left hand side of equation 8. The markup of price over marginal cost is .9200 (Mead Johnson), .9258 (Ross), .8251 (Wyeth), and .9342 (Carnation). I also have estimates for the parameters in the square brackets in equation 8. Let s_l =.2, ϴ=.55 based on Huang and Perloff. Table 4 gives estimates of ρ_m for Mead Johnson, Ross, Wyeth, and Carnation. Divide the numerator and denominator by $1/Q^w$ and let the ratio of Q^N/Q^W = 1.632174. With these estimates, the value of the terms in the square brackets equals 1.6117 for Mead Johnson, 1.5494 for Ross, 1.4571 for Wyeth, and 1.4987 for Carnation. Solving 8, the total elasticities of demand are -1.75 (Mead Johnson), -1.67 (Ross), -1.77 (Wyeth), and -1.60 (Carnation).

It is interesting to consider the effect of the WIC rebate program on price setting. The markup without the WIC program would be equation 8 without the value of the term in square brackets, or 1/(1.75) = 0.5708, 1/1.67=.5975, 1/1.77=.5663, 1/1.60=.6233, for Mead Johnson, Ross, Wyeth, and Carnation. The effect of the WIC rebate program is increase markups by 92-57.08=34.92, 92.58-59.75=32.83, 82.51-56.63=25.88, 93.42-62.23=31.09 percent for Mead Johnson, Ross, Wyeth, and Carnation. Alternatively, I can solve for the elasticity of demand that gives the observed markups. These effective elasticities are 1.09, 1.08, 1.21, and 1.07. Assuming that a monopolist will not set price on a portion of the demand curve with an elasticity of demand less than 1, since raising price when demand is inelastic will always increase profits, we see that the effect of the WIC rebate program is to allow manufacturers to set price at the point on the demand curve providing nearly the highest possible profit. The intuition for these results is that the benefit from owning the sole-source contract is very large. Once the firm has the sole-source contract the exogenous increase in market share from the spillover effect, and the sales to WIC customers, effectively isolates demand from price increases. Consumers buy the product based on non-price factors, like prominence on the shelf and doctors recommendations. It seems clear that in such circumstances firms would have much greater ability to increase price.

Conclusion

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 considerable implications for non-WIC purchasers of infant formula. The results of this study suggest that infant formula manufacturers possess considerable market power allowing them to set wholesale prices in excess of marginal cost. I estimate marginal costs below 30 cents per 13-ounce can of milk-based liquid-concentrate infant formula for each of the manufacturers currently selling infant formula. Wholesale prices average over $2.50 for all manufacturers and over $3.00 per can for the two dominant firms (Mead Johnson and Ross). Given the estimate for marginal cost, I am able to estimate price cost margins and to examine the effect of the WIC rebate program on margins. I find that WIC contract holders are effectively isolated from price competition which allows them to price as if demand were nearly unit elastic. In contrast, without the WIC program, firms would price according to their demand elasticities, which I find range from -1.60 to -1.75. The result is that firms can set prices about 26 to 35 percent higher than they could without the effect of the WIC program.

Table 1. Variable Means

	Mean	Observations
Mead Johnson Rebate	2.60	158
Mead Johnson Wholesale Price	3.28	158
Ross Rebate	2.61	166
Ross Wholesale Price	3.27	166
Wyeth Rebate	1.82	79
Wyeth Wholesale Price	2.90	79
Carnation Rebate	2.46	42
Carnation Wholesale Price	2.92	42
Births	13.20	172
WIC Infants	5.59	172

Table 2. Rebate OLS Regressions

	Mead Johnson	Ross	Wyeth	Nestle
Wholesale Price	1.2940***	0.9943***	2.2713***	1.2076***
	(0.1636)	(0.1901)	(0.7076)	(0.2319)
Births	-0.00091	0.00380	0.00902	0.02593
	(0.0069)	(0.0081)	(0.0127)	(0.0221)
WIC Infants	0.01066	0.00646	-0.01112	-0.02680
	(0.0151)	(0.0177)	(0.0351)	(0.0561)
Previous Contract Holder	0.1097*	0.0346	0.3011***	-0.1005
	(0.0584)	(0.0619)	(0.1181)	(0.1181)
Constant	-1.9818***	-0.9647	-4.5257***	-1.2299**
	(0.6355)	(0.7377)	(1.7248)	(0.6447)
Adjusted R2	0.8578	0.7978	0.4141	0.8194

Annualy dummy variable included, std. errors in parentheses.

*** p<0.01, ** p<0.05, * p<0.1

Table 3. Winning Proabilitiy Probit Regressions

	Manufacturer			
Variables	Mead Johnson	Ross	Wyeth	Carnation
MJ Rebate	2.397***	-1.912***	-4.429*	0.715
	(0.528)	(0.636)	(2.442)	(1.368)
MJ Wholesale Price	-3.188*	1.425	8.333	-2.87
	(1.897)	(2.098)	(5.987)	(5.415)
Ross Rebate	-0.351	2.741***	1.088	-3.782*
	(0.57)	(0.573)	(1.797)	(1.993)
Ross Wholesale Price	0.189	-3.392*	-6.58*	8.412*
	(1.83)	(2.018)	(3.553)	(5.020)
Wyeth Rebate			3.185***	
			(0.810)	
Wyeth Wholesale Price			-1.331	
			(4.264)	
Carnation Rebate				4.172***
				(1.473)
Carnation Wholesale Price				-3.861*
				(2.166)
Third Bidder Rebate	-0.15	0.271		
	(0.491)	(0.534)		
Third Bidder Wholesale Price	0.758	0.434		
	(0.757)	(0.789)		
Previous Contract	0.523**	0.531**	0.327	0.094
	(0.260)	(0.252)	0.662	(0.549)
Constant	2.143	1.568	-1.293	-9.463
	(1.621)	(1.543)	3.667	(7.883)
Observations	157	164	78	42
Percent Correctly Predicted	72.61%	75.00%	87.18%	73.81%
Predicted Winning Probability	0.408	0.349	0.249	0.428
Actual Winning Percent	0.408	0.348	0.244	0.429
Psuedo R^2	0.2069	0.1933	0.4061	0.331
Log liklihood	-84.17179	-85.4527	-25.7185	-19.1872

Standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Table 4. Rebate Marginal Effects

Manufacturer	Marginal Effect
Mead Johnson	0.887***
	(.184)
Ross	0.924***
	(.174)
Wyeth	0.697***
	(.189)
Carnation	1.607***
	(.559)

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 5. Estimated Marginal Costs Per 13 oz. can of milk-based liquicd concentrate

	Mead Johnson	Ross	Wyeth	Carnation
Marginal Cost	0.263	0.243	0.508	0.192
Marginal Cost Standard Error	0.043	0.039	0.044	0.040

Figure 1. Rebates, net prices, and wholesale prices of milk-based liquid concentrate, by State

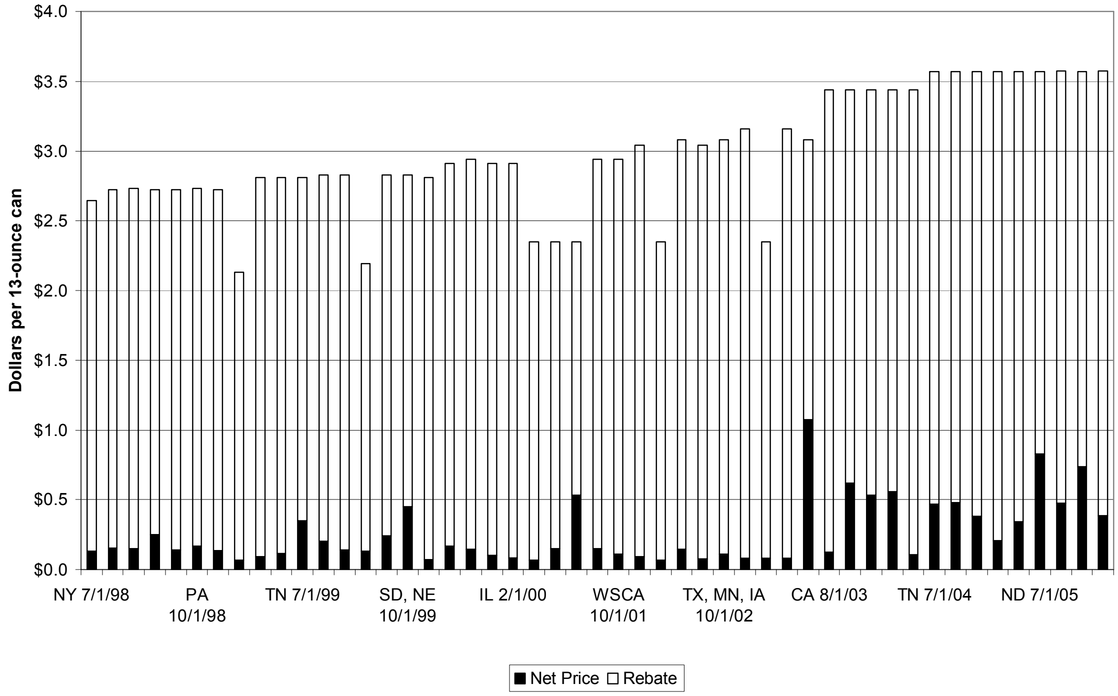
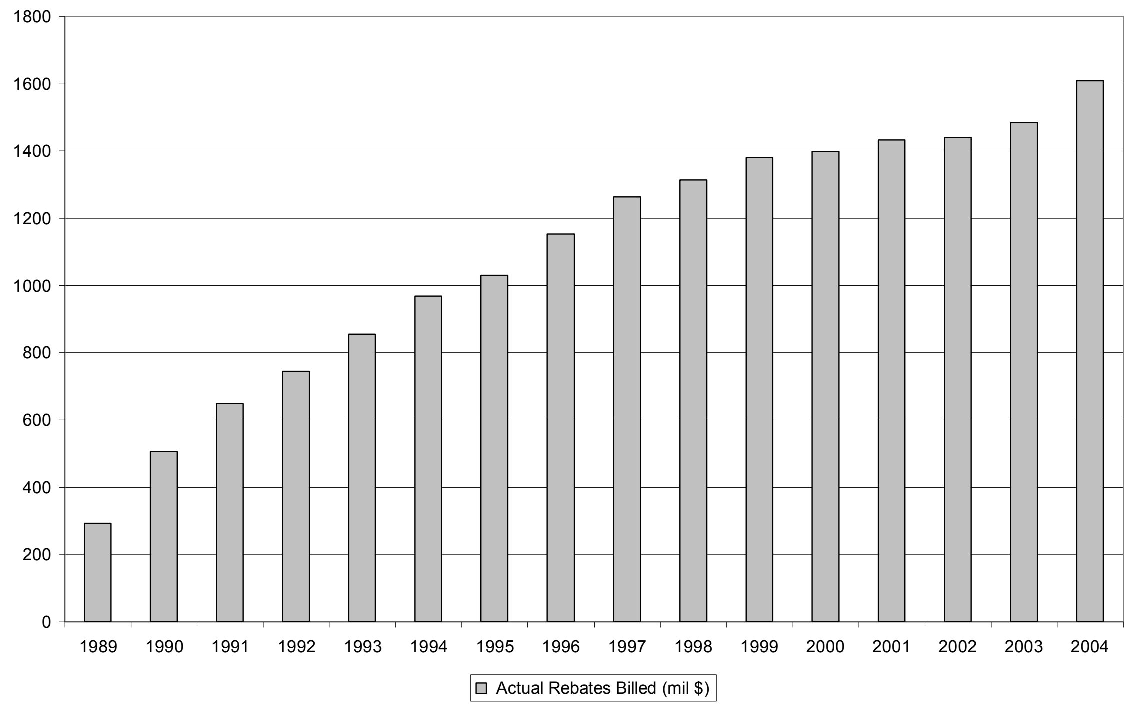


Figure 2. Rebates Billed (mil $): Domestic, Retail Delivery



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