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

Abstract: Although the Women, Infants, and Children (WIC) food-assistance program purchases over half of all US infant formula, I find it does not affect wholesale prices. I estimate infant-formula marginal cost and find it low compared to wholesale price, implying large price-cost markups. But, I find the program does not affect markups. Instead, the program gives preference to one firm's brand, and that brand attains a prominence in stores that results in larger sales to non-participants. The preference is valuable to firms and they bid with rebates to attain exclusive approved status which results in significant cost savings to the program.

Key Words: auctions, food assistance, food prices, infant formula, oligopoly, WIC.

JEL codes: I18, L113, L11, L66, D12

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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). WIC is a U.S. federal food-assistance program administered by the U.S.D.A. Food and Nutrition Service (FNS) with state and local health departments. It supplies grants to states annually that provide participating low-income women, infants, and children up to age five supplemental foods and some health services. Providing infant formula to participating infants less than one year old represents a large portion of program costs (16 percent in 2005 (GAO 2006). Infant formula prices rose faster than inflation during the 1970s and 1980s and states became concerned the high cost was severely limiting the number of eligible persons that could be served (GAO 1998). To limit costs, states devised an auction whereby infant-formula manufacturers bid on the right to be a state's sole supplier to WIC. In exchange for this right, manufacturers pay a rebate on each can of infant formula sold through WIC.

Rebates are very effective at reducing costs; winning rebates have averaged about 85 to 90 percent of manufacturers' wholesale prices and have routinely reduced federal WIC costs by $1.5 billion annually. The magnitude of rebates relative to wholesale prices leads to questions about the relationship between wholesale price and marginal cost. It seems either manufacturers sell formula substantially below marginal cost through WIC, or that wholesale price far exceeds marginal cost. Wholesale price above marginal cost is perhaps expected given the highly concentrated structure of the market. Three manufacturers, Mead Johnson, Ross, and Carnation, produce about 98 percent of domestic sales (Oliveira, Frazao, and Smallwood 2010). Wyeth, a fourth manufacturer, was active in the domestic 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).

Infant-formula pricing has long been a source of debate. Beginning in the 1990s, industry watchers noted the increase in participating WIC infants and formula price increases that exceeded inflation and speculated a causal relationship. After the introduction of rebates, some speculated that large rebates are subsidized by higher prices to non-WIC buyers (GAO 1998). The Senate Subcommittee on Antitrust, Monopolies, and Business Rights held hearings on the pricing behavior of infant formula manufacturers in 1990 (Oliveira et al. 2004). The Federal Trade Commission investigated anticompetitive pricing practices of infant formula manufacturers in the early 1990s (Oliveira et al. 2004). The General Accounting Office (GAO) has produced three investigative reports on these issues (GAO 1990; GAO 1998; GAO 2006). Similarly, the Economic Research Service of USDA has produced several research reports examining WIC, WIC rebates, and infant formula prices (Oliveira et al. 2004; Prell 2004; Oliveira and Davis 2006; Oliveira, Frazao, and Smallwood 2010; Oliveira, Frazao, and Smallwood forthcoming).

In this article, I develop a model of infant-formula wholesale prices, WIC, and rebates. 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 (wholesale price minus rebate) paid by WIC is often, but not always, above marginal cost. I show that the WIC program in its current form, with rebates, will not affect price-cost markups if new rebates change 1-to-1 with wholesale price changes; I provide empirical evidence that this has been the case. 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 50-60 percent once they become the exclusive WIC supplier.

Background and Literature

WIC 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, which are noted on food vouchers. States reimburse retail outlets for the items sold to WIC participants based on redeemed vouchers.

In the mid-80s some state agencies investigated ways to limit formula costs in response to rising prices. Most agencies distribute formula through retailers, but some use other methods and some of those were able to procure formula at reduced costs by giving preference to one brand (Harvey et al. 1988). Using these systems as examples, in 1986 a few states developed a system whereby a single manufacturer was awarded the exclusive right to provide formula in that state in exchange for a rebate on each unit sold through WIC. Distribution remained through authorized retail vendors. Manufacturers offered their rebates for consideration via sealed bids and the contract was awarded to the manufacturer that offered the highest rebate per unit sold (subsequently, agencies moved to a process whereby the firm offering the lowest net price). 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. Early on so-called “open-market” contracts did not provide manufacturers the exclusive right to sell in a state, and did not usually use sealed bids. Some states compared savings from both contract types and because the competitive system resulted in greater savings, most adopted that system. Currently, federal law requires all agencies to adopt a competitive bidding process or another process that provides equal or greater savings (Oliveira et al. 2004).

Development of the rebate system has been a boon to WIC agencies as procurement costs have been greatly reduced. Recently the size of rebates has led to speculation, and some research, about the source for large rebates. Selling below cost may be profit maximizing if manufacturers 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 there may be an incentive to secure the WIC contract even if that means selling to WIC at a loss. In a 1998 report GAO identified two potential sources for a spillover effect. Doctors may preferentially recommend the WIC brand to mothers. Or, WIC demand may result in the WIC brand receiving greater shelf space on store shelves increasing non-WIC sales (GAO 1998). WIC sales represent over one-half of all sales and so the WIC brand may receive a more prominent location on, and a larger share of, store shelves. The report recognized the possibility of a spillover effect but discounted its ability to entice manufacturers to sell to WIC below cost. In a 2006 report GAO reiterated that a spillover effect may be an important determinant of rebate bids. The report stated that all three major manufacturers 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 had risen faster than inflation.[1] They suggest that 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 pocket. With few price-sensitive customers actually paying for formula, manufacturers may be able to charge higher retail prices. An event study analysis and a multiple regression analysis suggested that being the contract brand increased that brand's retail price and that the larger the WIC market relative to the non-WIC market the higher the retail price of the contract and non-contract brands of infant formula.

Prell (2004) models retail infant-formula pricing and assumes retailers set brand quantities as in a Cournot oligopoly. Prell's model shows that as WIC demand becomes a larger share of total demand, retailers face more price-inelastic demand and raise formula prices. WIC affects demand elasticities and drives a wider wedge between retail price and marginal cost.

Betson (2009) is most similar to this article in that he develops a theoretical model of wholesale price that includes the WIC program and sole-source rebate contracts. Betson shows that a WIC program with rebates should result in lower wholesale prices than a WIC program without rebates. 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 price comprised of a weighted average of WIC mothers' perfectly inelastic demand and non-WIC mothers' somewhat elastic demand. A rebate program allows firms to identify the WIC customers with perfectly inelastic demand and effectively charge them a different price, price minus rebate. Because WIC customers are no longer considered when 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 wholesale 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 does not model a spillover effect and implicitly assumes that rebates adjust cent-for-cent with wholesale prices. The model below demonstrates that both of these considerations are important.

Huang and Perloff (2007) and Oliveira, Frazao, and Smallwood (forthcoming) demonstrate that a spillover effect is likely important for formula manufacturers when setting prices. Huang and Perloff use a multinomial-logit model to estimate market shares of different brands of formula when they hold and do not hold the WIC contract. Their supermarket scanner data are from 1997-1999 and they find that after a brand gains the WIC contract their share of the market increases substantially immediately and eventually grows from below 20 percent to over 70 percent. Oliveira, Frazao, and Smallwood use a larger data set from 2004-2009 and update Huang and Perloff. They find that the contract brand's share is about 84 percent of the top three manufacturers' sales and that a brand's share increases 74 percent on average after acquiring a WIC contract. Both papers demonstrate that changes in brand shares don't seem to be driven by changes in brand prices. But, neither paper distinguishes 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.

Most prior WIC research has empirically analyzed infant-formula retail prices, highlighting that retailers distribute infant formula and that WIC may affect retailers' incentives. Indeed, Oliveira and Davis (2006) find a large gap between retail and wholesale prices suggesting large retail markups. This article is most interested in the effect of rebates and models their effect on manufacturer behavior and wholesale prices. WIC and spillover effects may also affect retailers' strategic interactions and additional retail research is warranted. I briefly discuss potential retail effects in the conclusion, but leave a more thorough model for future research.

A Theoretical Model of Rebate Bids and Wholesale Prices

Infant formula manufacturers potentially derive profit from two markets: the WIC market and the non-WIC market. I assume the number of units sold in the WIC market is exogenous and perfectly price inelastic.

WIC contracts are offered by WIC agencies and in some cases multiple agencies form an alliance to jointly offer a contract. Hereafter, I refer to infant-formula manufacturers as firms and state agencies/alliances as agencies. The market coincides with the state or 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 WIC contracts with agencies which have implications for sales in the WIC and non-WIC markets.

Let h_j^N represent infant-formula demand at arbitrary non-WIC household j with children of the appropriate age. 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. 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 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 $Q_i^N(P_1 \dots . P_M) = H_i^N * \mu$. Total market demand is dependent on prices because each household decides whether to purchase and which brand to purchase based on prices.

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 $b_k \sim N(\mu, \sigma_b^2)$. Although mothers may supplement breastfeeding with formula-feeding, I assume WIC and non-WIC infants consume the same average amount of infant formula.

Let H_i^W represent the total number of participating non-breastfeeding WIC infants in market i. Anecdotal evidence suggests that some WIC households purchase infant formula without vouchers, but Oliveira, Frazao, and Smallwood 2010 suggest the amount is likely very small and total demand for formula from WIC households is $Q_i^W = H_i^W * \mu$.[2]

To model 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 $s_{m,i}^* = \frac{q_{m,i}^*}{Q_i^N}$ and its losing share as $s_{m,i} = \frac{q_{m,i}}{Q_i^N}$, where $q_{m,i}^* = Q_i^N - \sum_{m \neq o} q_{o,i}$ and $q_{m,i} = Q_i^N - q_{p,i}^* - \sum_{m \neq o \neq p} q_{o,i}$. $q_{m,i}^*$ is the firm's residual demand if they win the contract and $q_{m,i}$ is the firm's residual demand if they do not win the contract. Non-WIC demand to firm m can be written,

(1) $$Q_{m,i}^N = \begin{Bmatrix} s_{m,i}^* Q_i^N if\ awarded\ the\ contract\ in\ market\ i \\ s_{m,i}\, Q_i^N if\ not\ awarded\ the\ contract\ in\ market\ i \end{Bmatrix}$$

Let $s_{m,i}^* = s_m^* + v_{m,i}^*$ and $s_{m,i} = s_m + v_{m,i}$, where $v_{m,i}^*$ and $v_{m,i}$ are mean zero stochastic elements. Letting $\rho_{m,i}$ equal the probability of winning the contract, expected non-WIC quantity demanded can be written,

(2) $$Q_{m,i}^N = \left(s_m + \theta_m \rho_{m,i}\right) Q_i^N + \xi_{m,i}$$

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

Let $(Q_i^W + \tau_i)$ represent formula demand from WIC customers in the market i where τ_i is a zero mean stochastic element. The total expected quantity-demanded from market i, can be written,

(3) $$Q_{m,i}^N + Q_{m,i}^W = \left(s_m + \theta_m \rho_{m,i}\right) Q_i^N + \rho_{m,i} Q_i^W + \xi_i + \rho_{m,i} \tau_i.$$

Oliveira and Davis (2006) demonstrate that wholesale prices change infrequently, with durations of about 12 - 18 months between increases. Rebate changes do not generally coincide with wholesale price changes suggesting that one is predetermined when the other is determined. I leave the investigation of the strategic interactions that led to the rebate program and firms' participation in it for future research and assume that firms make decisions under the current system. Assume some contracts are in place for firm m and it must make decisions about wholesale prices and rebates. I consider the wholesale-price decision first.

Firms contend they offer a single national wholesale price so I model a single price for all markets but allow agency-specific rebates. Since contracts are already in place $\rho_{m,i}$ is equal to one in these markets and let Γ_m equal the proportion of the I markets for which firm m holds the WIC contract. Let R_m represent the average rebate and c_m the average marginal cost for firm m, and let Q^Nrepresent total non-WIC demand and Q^W total WIC demand for all I markets. Total expected profit for firm m from all markets is (dropping the m subscript for convenience),

(4) $$E[\pi] = P(s+\theta\Gamma)Q^N + (P-R)\Gamma Q^W - c\big((s+\theta\Gamma)Q^N + \Gamma Q^W\big).$$

Firm m chooses price to maximize expected profit,

(5) $$\frac{\partial E[\pi]}{\partial P} = P\left[(1-\Gamma)\frac{\partial q}{\partial P} + \Gamma\frac{\partial q^*}{\partial P} + \frac{\partial \Gamma}{\partial P}(q^*-q)\right] + (1-\Gamma)q + \Gamma q^* + Q^W\left[\Gamma\left(1-\frac{\partial R}{\partial P}\right) + \frac{\partial \Gamma}{\partial P}(P-R)\right] - c\left[(1-\Gamma)\frac{\partial q}{\partial P} + \Gamma\frac{\partial q^*}{\partial P} + \frac{\partial \Gamma}{\partial P}\big((q^*-q)+Q^W\big)\right] = 0.$$

Equation 5 can be rearranged to give the optimal price as[3]

(6) $$P = c - \frac{(1-\Gamma)q + \Gamma q^* + Q^W\left[\Gamma\left(1-\frac{\partial R}{\partial P}\right) + \frac{\partial \Gamma}{\partial P}(P-R-c)\right]}{(1-\Gamma)\frac{\partial q}{\partial P} + \Gamma\frac{\partial q^*}{\partial P} + \frac{\partial \Gamma}{\partial P}(q^*-q)}.$$

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

(7) $$E[\pi_i] = P(s+\theta\rho_i)Q_i^N + (P-R_i)\,\rho_i Q_i^W - c_i\left((s+\theta\rho_i)Q_i^N + \rho_i Q_i^W\right).$$

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

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

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 bid. Rearrange 8 to get the optimal net price to bid in market i,

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

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 sold to WIC participants (i.e., $\theta(P - c_i)\frac{Q_i^N}{Q_i^W}$), which are earned only if firm m holds the WIC contract.

To see that $\frac{\rho_i}{\omega_i}$ represents the bid shade, reorder 9 as $\frac{\left((np_i - c_i)Q_i^W + \theta(P - c_i)Q_i^N\right)}{Q_i^W} = -\frac{\rho_i}{\omega_i}$. The left-hand side is now the total profit from holding the WIC contract per unit sold to WIC. 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 a change in bid. A larger ω_i suggests a more competitive auction and smaller profits for firm m.

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 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 6 and 9 represent a system that could be simultaneously estimated. However, data limitations do not allow for a full-information approach; equation 6 is the most problematic in that it requires estimates of residual non-WIC demand and other parameters not easily attained. A limited-information approach to estimate equation 9 is detailed below.

Equation 9 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. The present challenge is to formulate a specification of observable variables that can identify the unobservable parameters of interest. The strategy will be to estimate $\frac{\rho_i}{\omega_i}$ for each auction and for each manufacturer then use the predicted values from that model to estimate the other parameters in equation 9.

I assume firms use a multinomial choice model to estimate winning and marginal probabilities and that $\frac{\hat{\rho}_i}{\hat{\omega}_i}$ are the predicted values from that model. Rearranging 9 gives

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

Consider equation 10 an equation potentially to estimate; the left-hand side is the net price bid offered to market i and is observable and available with $\frac{\hat{\rho}_i}{\hat{\omega}_i}$ in hand. 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. In the current application estimating these demand functions is not possible because data are not available that distinguish sales to WIC customers from sales to non-WIC customers. However, equation 10 requires the ratio of non-WIC to WIC demand and given reasonable assumptions data for this ratio are available.

Recall non-WIC demand is $Q_i^N = H_i^N * \mu$ and WIC demand is $Q_i^W = H_i^W * \mu$, so $\frac{Q_i^N}{Q_i^W} = \frac{H_i^N}{H_i^W}$. If WIC infants consume the same average 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. If the assumption that WIC and non-WIC infants have a common average demand is relaxed, then if $\frac{Q_i^N}{Q_i^W} - \frac{H_i^N}{H_i^w} = \varsigma_i$ where ς is a well behaved error term standard econometric techniques can be applied as long as equation 10 is an identity without error. For tractability, I also assume firms base bids on their average marginal cost, c. The structural equation is summarized as,

(11) $$np_i + \frac{\hat{\rho}_i}{\hat{\omega}_i} = c - \theta \frac{PH_i^N}{H_i^w} + \delta \frac{H_i^N}{H_i^w} + \kappa_i$$

where κ_i is a zero mean error term.[4]

Estimating Probabilities and Marginal Probabilities

Firms are awarded WIC contracts by offering the lowest net price and they must estimate their winning probability in order to formulate their net-price bid according to equation 9. 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 a 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 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' bids until after bidding closes. Assume firms estimate net-price bids as $\widehat{np}_{i,m} = \boldsymbol{z_i \beta'_m}$ where $\boldsymbol{z_i}$ is a vector of observable variables from agency i and $\boldsymbol{\beta_m}$ is vector of weights. Let $np_{i.m} = \widehat{np}_{i,m} + \epsilon$ and substituting for $\widehat{np}_{i,m}$ gives $np_{i.m} = \boldsymbol{z_i \beta'_m} + \epsilon$. Assuming ϵ is a well behaved error term $\boldsymbol{\beta_m}$ can be estimated with a regression given data on *np* and **z**. Substituting $\widehat{np}_{i,m}$ gives $U_{i,m} = \alpha \widehat{np}_{i,m} + \eta$, where $\eta = \alpha\epsilon$. I assume that η follows a type I extreme value distribution and therefore that firms use a multinomial-logit model to estimate probabilities.

Data

The data are a time-series cross-section of each firm's winning and losing rebate bids for all contract auctions from 1986 through 2007 (see Davis (2008) for a complete description of the data). 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. Carnation began selling formula domestically in 1990 and has participated in WIC auctions since 1992. Cross-sections are 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 contracts. 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, with powder being the dominate form recently. Formulas are available that use a milk base and alternatives for infants with special medical requirements (e.g., soy-based formulas for lactose-intolerant infants (See Oliveira and Davis (2006) for a discussion of the various formula types and their usage in WIC)). I collected data as available for milk- and soy-based formula in powder and liquid concentrate forms. Bids for soy formula are only sporadically available and bids for powder formula are available only since mid-1998. However, a near complete data set of bids for 13-ounce cans of milk-based liquid concentrate is available from 1986 to 2007. Typically, 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. Oliveira and Davis (2006) demonstrate that liquid concentrate and powder bids are highly correlated. I use the long time-series of liquid concentrate bids for most analysis, but add powder bids for some analysis.

There are 213 liquid-concentrate bids from Mead Johnson, 222 from Ross, 87 from Wyeth, and 41 from Carnation. Only a portion of these observations are for sole-source competitive contracts; 49 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.[5]

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. Table 1 details each of these provisions and how they are quantified for use in estimation.

The data also include national wholesale prices for truckload-size shipments 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 FNS. Non-WIC infants are estimated by taking the number of births in a state and subtracting the number of participating WIC infants. Births are from the National Centers for Disease Control. Counts of WIC and non-WIC infants are adjusted with breastfeeding rates as estimated by the Ross Mothers' Survey so that they measure only non-breastfeeding infants.[6]

Estimating Agency Costs and Choice Probabilities

I use a regression to estimate $np_{i,m} = \boldsymbol{z_i}\boldsymbol{\beta}'_{\boldsymbol{m}} + \epsilon$. The data do not have enough observations precisely to estimate complete sets of firm-specific parameters, so I use the following strategy to arrive at a parsimonious model. I begin by including firm dummies, year dummies, alliance dummies, and firm dummies interacted with all auction variables. Table 2 shows firm-specific summary statistics. Each firm has its own constant and a vector of parameters for the auction variables, but 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, many coefficients follow intuitive expectations. I anticipate that more infants in an alliance present an attractive profit opportunity leading to lower bids; the coefficient on births is negative. Longer transporting distances likely increase costs leading to higher bids; the coefficient on alliance distance is positive. I expect firms to bid more aggressively for sole-source contracts and the coefficient on the competitive dummy-variable is negative.

Multinomial Logit Estimates

Table 4 shows the parameter estimates from a multinomial-logit estimation. As expected, the probability of winning is negatively related to net price. Table 4 also 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.

$-\frac{\hat{\rho}}{\hat{\omega}}$ 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 \$.345 (Mead Johnson) to \$.232 (Carnation). Considering the net prices in table 1, Mead Johnson's markup represents a 41% increase, Ross' markup represents a 38% increase, Wyeth's markup represents a 24% increase, and Carnation's markup represents a 50% increase.

Spillover Effect and Marginal Cost

Table 5 shows results from estimating four specifications of equation 11. The first two, starting with OLS1, are ordinary least squares estimates and the second two, starting with IV1, are instrumental variable (IV) estimates.[7] The estimates in OLS1 and IV1 are suggested by equation 11. Recently manufacturers have supplemented formula with docosahexaenoic acid and arachidonic acid (DHA/ARA formula) that some studies have shown to influence infant health. Manufacturers now regularly use these formulas as the base product when offering rebate bids. Results in columns OLS2 and IV2 include a dummy variable that takes a value of 1 when a firm based their bid on DHA/ARA formula (DHA/ARA). Presumably, DHA/ARA formulas are more costly to produce and the dummy variable allows marginal cost to shift when bids are based on these formulas. In the IV specifications, I instrument for P_m, $\frac{H^N}{H^W}$, and the DHA/ARA dummy. I conduct a Hausman endogeneity test for significant bias and cannot reject the null that only IV estimates are efficient and consistent.[8]

Based on the Hausman test and because the DHA/ARA dummy is statistically significant, the results in IV2 are most appropriate and I focus discussion on them. Estimates in the column suggest that marginal cost of a 13-ounce can of milk-based liquid concentrate (in 2007 dollars) is \$.27 for Mead Johnson, \$.34 for Ross, \$.80 for Wyeth, and \$.17 for carnation. Average wholesale prices in table 2 are much higher ranging from \$2.89 to \$3.13 and it appears firms' wholesale prices far exceed 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 physicians and hospitals rather than by marketing directly to consumers. Carnation markets directly to consumers. Medical detailing may involve high fixed costs not reflected in the marginal cost estimates here.

I interpret the coefficient on the DHA/ARA dummy as the increase in marginal cost for producing formula with DHA/ARA fatty acids. The coefficient suggests that costs increase about $.22 per 13-ounce can.

The estimate of the spillover effect for Mead Johnson is 28.9 percent in IV1 and 49 percent in IV2; for Ross it is 40.2 percent in IV1 and 59.7 in IV2. Including the DHA/ARA dummy variable significantly affects the estimates. While all are statistically different from zero, their standard errors are large and Mead Johnson's IVI estimate is not statistically different from its IV2 estimate. The estimates for Ross are also statistically the same in IV1 and IV2.

The data contain 563 milk-based liquid-concentrate observations, but 147 powder observations are also available. I attempted to estimate the model with only powder observations but estimates were not reasonable. Because the results using liquid-concentrate observations conform to theory, I speculate that the small sample for powder bids does not provide enough information accurately to estimate parameters. But powder is the dominate form of infant formula currently consumed and it is important to investigate powder bids as much as possible (Oliveira, Frazao, Smallwood 2010).

Bids for liquid concentrate are for 13-ounce cans that reconstitute to 26 fluid ounces. I calculate powder bids as if they were for 26 reconstituted ounces and test whether means are equal between samples assuming both populations are normally distributed. The difference between means was -.15 for Ross, -.25 for Mead Johnson, and .16 for Carnation. I reject the null that means are equal at the .025 significance level for all brands. I investigate further by re-estimating the model including both liquid concentrate and powder bids where all bids are based on 26 reconstituted ounces. So, some contracts will have two observations, one for the powder bid and one for the liquid concentrate bid. I report standard errors that are robust to clustering within alliance to control for the bias associated with using multiple dependent variable observations with replicated independent variable observations (Moulton 1990). I include a powder dummy variable that takes a value of one for powder bids. The results are in table 6.[9]

Results in table 6 are similar to those in 5. Marginal-cost estimates are uniformly lower in table 6, but within one standard error of those in 5. The DHA/ARA dummy is larger at $.31 per 26 reconstituted ounces, but again it is within one standard error of the table 5 estimate. And, the spillover effects are larger, but within one standard error of those in table 5. I interpret the powder coefficient as the change in marginal cost for powdered formula. The estimate is -$.14 per 26 reconstituted ounces.

Huang and Perloff (2007) and Oliveira, Frazao, and Smallwood (forthcoming) examine the spillover effect using scanner data. Both show a dramatic increase in share for the brand holding the contract. Huang and Perloff find the contract brand's share increases from below 20 percent to over 70 percent, while Oliveira, Frazao, and Smallwood find an average increase in share of 74 percent. It is straightforward to calculate the non-WIC spillover effect from these data. It must be that the change in share for the contract brand must equal a weighted average of the change in the brand's WIC share and the non-WIC spillover effect. Let ΔS equal the total change in share, ΔW the change in WIC share and θ the spillover effect. If half of sales come from WIC, then $\Delta S = .5\,\Delta W + .5\,\theta$. Assuming Oliveira, Frazao, and Smallwood's estimate of ΔS is correct and equal to .74, and since $\Delta W = 1$ then $.74 = .5 + .5\,\theta$ and $\theta = .48$, which is within a 95 percent confidence interval for all estimates of the spillover effect in tables 5 and 6.[10]

I do not find a significant θ for Wyeth or Carnation. It is possible the data do not provide enough information accurately to estimate a spillover effect for these firms since they have relatively few observations compared to Mead Johnson and Ross. But, if the estimates are accurate, they may explain why Wyeth exited the infant-formula market. Wyeth's marginal cost in table 5 is estimated to be \$.804 per can, much higher than the estimates for Mead Johnson and Ross. If Ross or Mead Johnson bid their marginal cost to the WIC market, then Wyeth would lose about \$.45 per can if they chose to compete for the WIC contract. Because Wyeth does not seem to benefit from a spillover effect to offset that loss, it is likely they 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's.

Because Carnation's marginal costs are lower than both Mead Johnson and Ross at about $.17 per can, they 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. Participating in the WIC market is profitable because of their low marginal cost even if they do not experience a spillover effect.

Implications for Non-WIC Purchasers

A concern for policy makers has been the effect of the WIC program on non-WIC customers (GAO 1998; Betson, 2009). Betson (2009) contends that rebates play no role in firms' price setting decisions. Equation 6 shows this proposition is true only if $\frac{\partial R}{\partial P} = 1$, which Betson recognizes is a maintained hypothesis in his model. $\frac{\partial R}{\partial P} = 1$ is correct for a given WIC contract while it is in effect because contracts include inflation provisions that require cent-for-cent increases in rebates if wholesale prices increase during the duration of the contract. Inflation protection is assured by federal law (42 USC§1786(h)(8)(A)(vii)). However, each year some WIC agencies request rebate bids for new contracts. No law dictates that firms must offer a rebate to keep the net price constant from one contract to the next.

The model below allows $\frac{\partial R}{\partial P} \neq 1$ and allows *new* rebates to react to wholesale price changes other than one-to-one. It is a stylized model because rebates are modeled to change instantaneously to a wholesale-price change while in reality there is a time lag (as mentioned earlier). It is convenient to think of wholesale price as determined in period t and rebate determined in period $t + \Delta t$. The stylized model approaches reality as $\Delta t \to 0$.

If the winning proportion is a linear function of net price, then $\frac{\partial \Gamma}{\partial P} = -\frac{\partial \Gamma}{\partial R}$ and $\frac{\partial \Gamma}{\partial P} = \frac{\partial \Gamma}{\partial P}\left(1 - \frac{\partial R}{\partial P}\right)$. Substituting into equation 6 and rearranging provides a convenient way to demonstrate WIC's effect on price to non-WIC customers.

(12) $$\frac{(P-c)}{P} = -\frac{\left\{(s+\theta\Gamma)+\left(1-\frac{\partial R}{\partial P}\right)\frac{Q^W}{Q^N}\left(\Gamma+\frac{\partial \Gamma}{\partial P}(P-R-c)\right)\right\}}{(1-\Gamma)s\varepsilon+\Gamma\, s^*\varepsilon^*+\varepsilon_\Gamma\theta},$$

where ε^* and ε are the firm's residual demand elasticities evaluated at q^* and q and ε_Γ is the firm's price elasticity of WIC contracts won. Equation 12 shows the optimal price-cost markup for infant formula manufacturers. In the absence of the WIC program, i.e., $Q^W = 0$ and $\Gamma = 0$, then $\frac{(P-c)}{P} = -\frac{1}{\varepsilon}$ 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.[11] Equation 12 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:

$$\frac{\partial\left(\frac{(P-c)}{P}\right)}{\partial Q^W} = -\left\{\frac{\left\{\left(1-\frac{\partial R}{\partial P}\right)\left(\Gamma+\frac{\partial \Gamma}{\partial P}(P-R-c)\right)\right\}}{Q^N[(1-\Gamma)s\varepsilon+\Gamma\, s^*\varepsilon^*+\varepsilon_\Gamma\theta]}\right\} > 0.$$

The denominator is negative since $\varepsilon < 0$, $\varepsilon^* < 0$, and $\varepsilon_\Gamma < 0$. The numerator is the change in profit from an increase in WIC demand. An increase in WIC demand 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 both expressions in parentheses are positive. The first expression is positive since $\frac{\partial R}{\partial P} < 1$ and the second is positive if $\Gamma > -\frac{\partial \Gamma}{\partial P}(P - R - c)$. Table 7 provides evidence that the second expression is almost certainly positive. It shows each firm's average share of the US WIC market from 1987-2007 and their average winning net price and rebate. I assume $\frac{\partial \Gamma}{\partial P} = \omega\left(1 - \frac{\partial R}{\partial P}\right)$ and let $\frac{\partial \Gamma}{\partial P} = \omega$ to be conservative and the second expression is positive for each firm except Carnation. Carnation's value is positive if $.175 < \frac{\partial R}{\partial P}$.

If rebates increase by less than the price increase so that net price increases, sales to the WIC market become more profitable and an increase in WIC demand creates an incentive to increase price. That incentive is offset by the loss of sales to the non-WIC market which is in the denominator. Larger values here counteract the incentive to increase price.

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

Proof:

$$\frac{\partial\left(\frac{(P-c)}{P}\right)}{\partial Q^W} = -\left\{\frac{\left\{\left(1-\frac{\partial R}{\partial P}\right)\left(\Gamma + \frac{\partial \Gamma}{\partial P}(P-R-c)\right)\right\}}{Q^N[(1-\Gamma)s\varepsilon + \Gamma\, s^*\varepsilon^* + \Gamma\varepsilon_\Gamma\theta]}\right\} < 0.$$

If rebates are negotiated to increase at a rate greater than increases in P (i.e., net price decreases), 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. ($\left(\Gamma + \frac{\partial \Gamma}{\partial P}(P - R - c)\right) > 0$ when $\frac{\partial R}{\partial P} > 1$ and net price is greater than marginal cost.)

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

Proof:

$$\frac{\partial\left(\frac{(P-c)}{P}\right)}{\partial Q^W} = -\left\{\frac{\left\{\left(1-\frac{\partial R}{\partial P}\right)\left(\Gamma + \frac{\partial \Gamma}{\partial P}(P-R-c)\right)\right\}}{Q^N[(1-\Gamma)s\varepsilon + \Gamma\, s^*\varepsilon^* + \Gamma\varepsilon_\Gamma\theta]}\right\} = 0.$$

The propositions above suggest that identifying $\frac{\partial R}{\partial P}$ is key to understanding the implications of WIC for non-WIC purchasers. Equation 9 represents the optimal rebate bid and rearranging it slightly gives,

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

Differentiating 14 suggests the magnitude of a rebate change from a price change is ambiguous,

(14) $$\frac{\partial R}{\partial P} = 1 + \frac{\partial\left(\frac{\rho}{\omega}\right)}{\partial P} + \left[P\left(\frac{\partial q^*}{\partial P} - \frac{\partial q}{\partial P}\right) + (q^* - q)\right]\frac{1}{Q^W} + \frac{c}{Q^W}\frac{\partial Q^N}{\partial P} \gtrless 1.$$

Because the theoretical model does not provide unambiguous guidance for the sign or magnitude of $\frac{\partial R}{\partial P}$, I estimate it with data on rebates and wholesale prices.

I examined the relationship between real annual-average wholesale prices and average-annual rebates with a plot of the two series over time; it showed that the series trend upward together suggesting they may be related, but 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). Because the data are cross-section time series with gaps between time periods, it is difficult to identify unit-roots using standard techniques. My strategy is to create a time-series of rebates and wholesale prices from each new contract for each agency and then to difference each series. The differences are between consecutive rebate contracts at an agency and do not represent consecutive years.

Oliveira and Davis (2006) suggest that the relationship between rebates and wholesale prices may have changed after the introduction of DHA/ARA formulas. I regress differenced rebates on differenced wholesale prices and a differenced DHA/ARA dummy variable. I also interact the DHA/ARA dummy variable with wholesale price to test whether the rebate-wholesale price relationship is different after DHA/ARA formulas are introduced.

Including wholesale price on the right hand side of a rebate regression may cause endogeneity bias. It is also unlikely that the DHA/ARA dummy is exogenous. I conduct a Hausman test and cannot reject the null that only IV estimates are consistent and efficient and so present results from IV estimation.

Table 8 presents results when observations are from competitive sole-source contracts. The first three columns include all years of data and include no dummies, firm dummies only, and then firm dummies and alliance dummies. The wholesale price coefficient is about 1 in each specifications I test the hypothesis that it is statistically equal to one and the row labeled Pr(H_0:WP=1) gives the p-value for a chi-square test. The results in the first three columns suggest support for proposition 3; increases in WIC demand have no impact on the prices paid by non-WIC customers as the coefficient on wholesale price is not different from one.

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.

I find little evidence that the relationship between rebates and wholesale price is different when the sample is restricted. Except when the sample is restricted to 1999-2007, the coefficient on wholesale price is not different from one. When the sample is restricted to that last eight years, the coefficient on wholesale price is different from one, but it is greater that one.

There does seem to be some support for the notion that rebates are lower for DHA/ARA formulas because their dummy coefficient is negative. But, it is not statistically significant except when the sample is restricted to the final 5 years. The results for the DHA/ARA-wholesale price interaction term are similar; the coefficient is negative, but not statistically significant. I cannot conclude from this evidence that the relationship between rebates and wholesale price has changed since the introduction of DHA/ARA formulas.

Conclusions

This article models infant-formula manufacturers in the presence of a WIC program with rebates; manufacturers' incentives seem likely to be affected by rebates and a spillover effect. I develop a method to estimate manufacturers' marginal costs and find them low compared to wholesale prices. I find a large spillover effect suggesting a 50-60 percent increase in a brand's share of non-WIC demand once that brand attains the WIC contract. The model suggests that WIC's effect on wholesale prices turns on the relationship between new rebates and wholesale prices. 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 one and consequently that WIC has no impact on wholesale price.

Even though this article suggests minimal wholesale price effects from WIC, that conclusion does not necessarily follow for retail prices. Evidence from Huang and Perloff (2007) and Oliveira, Frazao, and Smallwood (forthcoming) suggests that the WIC brand is likely to be the dominant seller for a retailer and inter-brand retail price-competition is minimal. The likely explanation is that even though brand shares vary when the WIC brand changes, brand marginal costs do not. Lowering price for non-WIC brands in response to a decrease in demand would likely only shift sales to a lower-margin brand which is unlikely to enhance profits. It is possible that lowering price for non-WIC brands may attract sales from rivals, but it is also easy to imagine scenarios in which

WIC has a role in horizontal competition with other retailers. For example, suppose retailers' competitive interactions amount to tacitly coordinating price above marginal cost in a repeated game (Salop, 1986). WIC may facilitate cooperation by reducing the number of items over which retailers must coordinate prices easing price agreement. When customers shop between stores they may effectively be comparing prices for only one brand since the WIC brand dominates shelves. WIC may also facilitate cooperation by reducing the benefit from undercutting rivals' prices. Assume retailers have tacitly set a coordinated price and consider a retailer's incentive to cut price, deviate from the coordinated price, and increase profits by attracting customers from rivals. Cutting price for the WIC brand will not attract WIC customers since their price is zero no matter where they buy. Cutting price may attract non-WIC customers of the WIC brand, but the retailer must lower price to all WIC customers as well. The lost profits from lowering price to the perfectly price inelastic WIC customers likely offsets any increase in profits from increased sales to non-WIC customers given their share of formula sales. Finally, a change in WIC brand seems unlikely to affect inter-retailer price-competition for non-WIC brands. Although the WIC brand may periodically change, it is not clear why that change would affect non-WIC brand pricing incentives.

At wholesale, WIC extracts some of manufacturers' excess profits through the rebate program. The rebate system works so well because of the large spillover effect and large wholesale price-cost markups. At retail, it is not clear why brand prices do not seem to respond to changes in demand that appear to occur after there is a change in the WIC contract brand (Huang and Perloff 2007; Oliveira, Frazao, and Smallwood forthcoming).

WIC may create a disincentive to cut price and inadvertently facilitate price coordination among retailers. Future research should further investigate retail infant-formula pricing. Such research may suggest methods to extract retailer's excess profits. For example, the profitability of infant formula may give retailers an incentive to pay a fee to be an approved WIC infant-formula provider.

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
DHA/ARA	A firm's rebate bid was based on formula enhanced with DHA/ARA (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)

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

Table 2. Variable Means

	Company Name			
Variable Name	Mead Johnson	Ross	Wyeth	Carnation
Wholesale price ($2007)	3.12	3.13	2.89	2.92
	(.425)	(.409)	(.271)	(.511)
Rebate ($2007)	2.27	2.32	1.75	2.46
	(.807)	(.800)	(.527)	(.53)
Net Price ($2007)	0.85	0.81	1.14	0.46
	(.499)	(.513)	(.472)	(.267)
Alliance births (thousands)	11.69	11.27	11.32	9.14
	(12.22)	(11.98)	(11.47)	(6.21)
Alliance non-WIC infants	4.93	4.74	5.29	3.69
	(5.10)	(4.98)	(5.72)	(2.76)
Alliance min. Distance (miles)	1014	803	1322	2063
	(2278)	(1536)	(2556)	(3652)
DHA/ARA	0.14	0.13	0.00	0.24
	(.344)	(.333)	(0)	(.435)
Competitive	0.73	0.73	0.90	1.00
	(.446)	(.445)	.(306)	(0)
Previous	0.23	0.22	0.14	0.24
	(.422)	(.413)	.(345)	(.435)
Contract Length (days)	927.04	924.39	948.93	932.93

	(341)	(343)	(307)	(354)
Number of bidders	2.52	2.50	2.94	3.20
	(.611)	(.607)	.(578)	(.511)
Composite	0.38	0.37	0.32	0.56
	(.485)	(.484)	(.47)	(.502)
Uncoupled	0.08	0.09	0.11	0.20
	(.279)	(.28)	.(321)	(.401)
Number of observations	213	222	87	41

Note: Standard deviations in parentheses.

Table 3. Net Price Regression

Variable name	Coeff.
Constant	1.845***
	(0.293)
Ross=1	-0.071**
	(0.033)
Wyeth=1	0.038
	(0.059)
Carnation=1	-0.083
	(0.069)
Alliance births (0,00s)	-0.0392***
	(0.011)
Alliance births x Wyeth	0.057**
	(0.022)
Alliance non-WIC infants x Wyeth	-0.111**
	(0.044)
Alliance min. Distance	5.90e-05*
	(3.55E-05)
Alliance min. Distance x Ross	4.94e-05**
	(2.50E-05)
AHA/DHA	0.086
	(0.158)
AHA/DHA x Carnation	-0.267**
	(0.128)
Competitive	-0.256***
	(0.05)
Previous	-0.04
	(0.036)
Contract Length	8.940E-05
	(6.70E-05)
Number of bidders	-0.009
	(0.038)
Composite	-0.08
	(0.052)
Uncoupled	-0.15*
	(0.08)
Uncoupled x Wyeth	0.51***
	(0.118)
Number of observations	563
R-squared	0.72

Note: Dependent variable = net price in $2007. The regression includes alliance and year dummy variables. Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

Table 4. Multinomial logit results, choice probabilities, and marginal effects

Variable name	Coefficient	Mead Johnson	Ross		Wyeth
$\widehat{np}$	-5.103*** (1.32)				
Constant		1.696***	1.349***	2.015***	0.142
		(0.397)	(0.354)	(0.560)	(0.350)
Proportion won		.41	.35	.25	.14
		(.49)	(.48)	(.44)	(.35)
$\hat{\rho}$		0.410	0.353	0.253	0.142
		(0.101)	(0.081)	(0.134)	(0.096)
$\hat{\omega}$		-1.186	-1.132	-0.875	-0.575
		(0.091)	(0.126)	(0.364)	(0.283)
$\hat{\rho}/\hat{\omega}$		-0.345	-0.308	-0.272	-0.232
		(0.083)	(0.040)	(0.058)	(0.031)
Number of Observations		156	156	75	127
Percent correct predictions		46.80			
Log pseudo-likelihood		-165.88			

Note: Robust standard errors in parentheses for coefficient estimates. *** $p<0.01$, ** $p<0.05$, * $p<0.1$. $\hat{\rho}$, $\hat{\omega}$, $\hat{\rho}/\hat{\omega}$ are calculated at each observation in the data. The means and standard deviations in parentheses are calculated from that sample.

Table 5. Net Price Bids Adjusted with Auction Probabilities

Variable name	OLS 1	OLS 2	IV 1	IV 2
$c_{Mead\ Johnson}$	0.216**	0.145	0.259**	0.268**
	(0.092)	(0.092)	(0.117)	(0.117)
c_{Ross}	0.204**	0.132	0.325***	0.341***
	(0.095)	(0.101)	(0.102)	(0.105)
c_{Wyeth}	0.804***	0.804***	0.804***	0.804***
	(0.051)	(0.051)	(0.05)	(0.05)
$c_{Carnation}$	0.223***	0.151***	0.223***	0.169***
	(0.042)	(0.05)	(0.042)	(0.049)
DHA/ARA		0.294***		0.223**
		(0.071)		(0.087)
$\theta_{Mead\ Johnson}$	0.211**	0.286***	0.288*	0.490***
	(0.102)	(0.102)	(0.174)	(0.164)
θ_{Ross}	0.114	0.170*	0.402***	0.597***
	(0.09)	(0.101)	(0.146)	(0.146)
$\delta_{Mead\ Johnson}$	0.799***	1.052***	0.994**	1.574***
	(0.276)	(0.278)	(0.461)	(0.424)
δ_{Ross}	0.503**	0.700***	1.278***	1.832***
	(.218)	(.250)	(.396)	(.402)

Observations	432	432	432	432
R-squared	0.539	0.561	0.529	0.533

Note: Dependent Variable = Net price adjusted with auction probabilities in $2007.

Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

Table 6. Adjusted Net Price with Powder Observations

Variable name	IV
$c_{Mead\ Johnson}$	0.217*
	(0.121)
c_{Ross}	0.306***
	(0.10)
c_{Wyeth}	0.767***
	(0.050)
$c_{Carnation}$	0.150**
	(0.059)
DHA/ARA	0.308***
	(0.082)
Powder=1	-0.141***
	(0.036)
$\theta_{Mead\ Johnson}$	-0.548***
	(0.194)
θ_{Ross}	-0.632***
	(0.160)
$\delta_{Mead\ Johnson}$	1.741***
	(0.506)
δ_{Ross}	1.918***
	(0.441)
Observations	571
R-squared	0.462

Note: Note: Dependent Variable = Net price bids adjusted with auction probabilities, in $2007. Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

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

	Average Share	$\frac{\partial \Gamma}{\partial P}$	P	R	c	$\Gamma + \frac{\partial \Gamma}{\partial P}(P - R - c)$
MJ	0.469	-1.186	3.324	2.870	0.268	0.248
Ross	0.386	-1.132	3.294	2.839	0.341	0.257
Wyeth	0.180	-0.875	2.911	2.059	0.804	0.138
Carnation	0.091	-0.575	3.112	2.751	0.169	-0.019

Table 8. Rebate First-Difference Instrumental Variable Estimates

	Years included in sample						
Variable names	1988-2007	1988-2007	1988-2007	1992-2007	1996-2007	1999-2007	2002-2007
WP	1.084***	1.183***	1.092***	1.334***	1.490*	1.976***	1.952**
	(0.201)	(0.243)	(0.258)	(0.382)	(0.797)	(0.488)	(0.793)
DHA/ARA	0.366	0.634	0.550	-0.328	-0.938	-0.777	-0.874*
	(0.607)	(0.734)	(0.669)	(0.611)	(0.653)	(0.520)	(0.474)
WP x DHA/ARA	-1.047	-2.168	-2.137	-0.550	0.911	-0.520	-0.0237
	(1.495)	(2.227)	(2.159)	(1.978)	(2.896)	(1.682)	(1.724)
Constant	-0.0033	0.441	0.600	0.124	-0.306	0.00495	-0.410
	(0.051)	(0.543)	(0.621)	(0.417)	(0.718)	(0.654)	(0.876)
Pr(Ho:WP=1)	0.678	0.452	0.721	0.383	0.538	0.0455	0.230
Firm Dummies	No	Yes	Yes	Yes	Yes	Yes	Yes
Alliance Dummies	No	No	Yes	No	No	No	No

Observations	313	313	313	231	152	106	71
R-squared	0.123	0.069	0.160	0.382	0.381	0.375	0.376

Note: Robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1

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[1] The 1998 GAO report 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.

[2] If λ represents the proportion of infant formula that WIC households purchase with WIC vouchers, μ_V represents the average amount of infant formula purchased with WIC vouchers, and μ_{NV} represents the average amount purchased by WIC households without WIC vouchers, then $\mu = \lambda\mu_V + (1-\lambda)\mu_{NV}$ and $\mu = \mu_V$ if $\lambda = 1$.

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

[4] If equation 10 is not treated as an identity equation 11 is plagued by measurement error. Measurement error bias can be corrected with instrumental variable (IV) estimation and I offer an IV estimator as an alternative specification in the empirical work that follows (Green, pp. 379).

[5] I assume each firm expects each active rival to bid in each auction. So, $\widehat{np}$ 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.

[6] 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.

[7] I begin with an unrestricted model in which I estimate firm-specific constants, θ, and δ. Estimates of θ and δ were jointly zero for Wyeth and Carnation and I dropped them from the estimation. All results are available in a supplementary appendix online.

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[8]I 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 development of DHA/ARA formulas is the result of technological advance and so I use a time trend and its square as instruments for the DHA/ARA dummy variable.

[9] I eliminate three Ross powder bids because they are unreasonably high; I speculate a data entry error or that Ross submitted courtesy bids. I estimate the entire model including the net-price regressions and the multinomial logit model, but present only the results from equation 11. These other results are qualitatively similar to those without powder presented in the text. They are available in the supplementary appendix online.

[10] Oliveira, Frazao, and Smallwood (2010) estimate WIC's share of formula sales may be as much as 68 percent in 2005, but the share of participating WIC infants has grown over time. GAO estimated WIC's share at 50 percent in 1998 and I use that number because it seems a reasonable average for 1987-2007.

[11] 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.