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An Economic Model of WIC, the Infant Formula Rebate Program, and the Retail Price of Infant Formula

Mark Prell

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Abstract

This report develops an economic model that provides the theoretical framework for the econometric analyses presented in the report's companion volume, *WIC and the Retail Price of Infant Formula* (FANRR-39). The model examines supermarket retail prices for infant formula in a local market area, and identifies the theoretical effects of the Special Supplemental Nutrition Program for Women, Infants, and Children (WIC) and its infant formula rebate program. Special attention is given to the rebate program's sole-source procurement system by which a single manufacturer becomes a State's "contract brand"—the State's one supplier of formula to WIC infants—in exchange for paying rebates to WIC. When a manufacturer's brand is designated a State's contract brand, the model predicts that supermarkets increase that brand's retail price. The model also predicts that an increase in the ratio of WIC to non-WIC formula-fed infants in a local market results in an increase in the price of the contract brand and, through demand substitution, a relatively small price increase for noncontract brands.

Keywords: WIC program, infant formula, cost containment, rebates, food package costs, Special Supplemental Nutrition Program for Women, Infants, and Children, child nutrition, food assistance

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Contents

Summary

This report develops an economic model to examine supermarket retail prices for infant formula in local market areas, and to identify the theoretical effects of the Special Supplemental Nutrition Program for Women, Infants, and Children (WIC) and its infant formula rebate program. The model adapts a multi-firm Cournot oligopoly model to a new setting that incorporates two differentiated products: heterogeneous consumers segmented by income, and the roles of WIC and its rebate program. This report provides the theoretical framework for the specification and interpretation of the econometric model presented in the report's companion volume, *WIC and the Retail Price of Infant Formula* (Oliveira et al., 2004).

Using this framework, the influence of WIC in a local market area is measured by the *relative size of WIC*, defined as the ratio of WIC to non-WIC formula-fed infants. While non-WIC consumers are sensitive to the price of formula, WIC households are not price sensitive because they do not pay for formula out of pocket. Holding other factors constant, the model predicts that as the relative size of WIC increases, retailers increase infant formula retail prices. The model also predicts that retail prices depend on the type of contract used by the WIC State agency to procure infant formula. Currently, WIC State agencies use competitive bidding to award a contract to a single manufacturer of infant formula for the exclusive right to provide its product to WIC participants in the State. Under sole-source or exclusive-rights procurement, *all* of the WIC demand is channeled to the formula provided by the contract-winning manufacturer and *none* of the WIC demand goes to other national brands. When the retail price of the formula made by the contract-holding manufacturer increases due to an increase in the relative size of WIC, some non-WIC households respond by switching to other infant formula brands. The retail prices of these other infant formula brands increase as a result, although by a smaller amount than the initial price increase of the contract-holding manufacturer's formula.

The report also examines how retail prices can be affected by different types of distribution systems; socioeconomic factors; the degree of competition faced by the supermarket *sector* (inclusive of all supermarkets) due to the presence of discount stores; the degree of competition faced by a supermarket *chain* (which may own one or more stores) due to the presence of other supermarket chains; and a formula manufacturer's wholesale cost. The model focuses on the retail markup, treating manufacturers' wholesale prices for infant formula as exogenous.

Introduction

This report develops an economic model (the "WIC model") that examines supermarket retail prices for infant formula in a local market area, and identifies the theoretical effects of the Special Supplemental Nutrition Program for Women, Infants, and Children (WIC) and its infant formula rebate program (hereafter, "rebate program"). The foundation of the WIC model is a multi-firm Cournot oligopoly model, but the WIC model generalizes the Cournot model to a new setting. The WIC model features two differentiated products, heterogeneous consumers that are segmented by income, and the roles of WIC and its rebate program. The WIC model provides the theoretical framework for the specification and interpretation of the econometric model presented in this report's companion volume *WIC and the Retail Price of Infant Formula* (Oliveira et al., 2004).

This chapter describes background information on WIC and the rebate program. Chapter 2 presents the WIC model's assumptions and mathematical structure, and the model's solution is derived in Chapter 3. A central variable of the WIC model that captures the importance of WIC in a local market area is the *relative size of WIC*, measured by the ratio of WIC to non-WIC formula-fed infants. Chapter 4 uses the model to determine the theoretical effect on retail prices due to changes in the relative size of WIC and other WIC-related factors.[1] The WIC-related factors that are considered are:

- the presence of the WIC program (without rebates) relative to the absence of the WIC program;
- an increase in the relative size of WIC (without rebates);
- an increase in the relative size of WIC if WIC has rebates generated by open market contracts;
- the use of open market contracts relative to the absence of any rebate contracts;
- an increase in the relative size of WIC if WIC has rebates generated by sole-source contracts;
- the use of sole-source contracts relative to the use of open market contracts;
- the use of sole-source contracts relative to the absence of the WIC program; and
- the use of home delivery or direct distribution relative to the use of the retail food delivery system for distribution of WIC formula.

WIC safeguards the health of low-income pregnant, breastfeeding, and postpartum women, infants, and children up to age 5 who are at nutritional risk, by providing a package of supplemental foods, nutrition education, and health care referrals. Although WIC encourages mothers to breastfeed, a majority of participating infants receives infant formula through WIC. In the mid-1980s, infant formula accounted for nearly 40 percent of total WIC food costs, and infant formula retail prices were rising more quickly than prices for other foods. These factors led Tennessee and other States to look into cost containment practices to reduce infant formula costs. Tennessee

[1]The WIC model resembles nearly all other economic models in that it does not generate predictions of the *magnitudes* of price effects, but instead yields theoretical predictions of the *direction*—rise or fall—of price effects that result from changes in economic, demographic, and policy factors. The empirical analyses in the companion volume are designed to estimate the magnitudes of price effects.

initiated a rebate contract system in 1987. In 1989, P.L. 100-147 required States to use competitive bidding—or an alternate method that would yield savings equal to or greater than those produced by competitive bidding—to procure infant formula. Indian State agencies with 1,000 or fewer WIC participants are exempt from this requirement.

Currently, WIC State agencies use competitive bidding to award a contract to a single manufacturer of infant formula for the exclusive right to provide its product to WIC participants in the State. The contract-winning manufacturer is then billed for the amount of the rebates on the formula issued to WIC participants. During the 1994-2000 study period covered by the empirical analyses in Oliveira et al., four manufacturers held one or more WIC State contracts (for at least part of the study period): Mead-Johnson, Ross, Carnation, and Wyeth. In fiscal year 2000, infant formula rebates totaled $1.4 billion, an amount that supported 27 percent of WIC participants (USDA, 2001).

WIC is an influential agent in the infant formula market: ERS estimates that infants participating in WIC consume about 54 percent of all formula sold in the United States. In most States, WIC participants use food vouchers or food checks to purchase their infant formula, free of charge, at participating retail grocery stores. WIC then reimburses the retail grocery stores for the amount of infant formula purchased. Some observers have hypothesized that WIC and its rebate program may significantly affect the retail infant formula prices faced by non-WIC consumers, either indirectly, through their impact on wholesale prices, or directly, through their effect on the retail markup (the difference between the retail price and the wholesale price). The WIC model focuses on the retail markup, with the model's structure and language developed to analyze supermarket pricing decisions. The manufacturers' wholesale prices for infant formula are exogeneous in the model.

The WIC model focuses on supermarket infant formula retail prices as opposed to prices established by other retailers because the price data analyzed in Oliveira et al. are obtained from supermarket surveys. The retail price data cover many major U.S. market areas for the study period 1994-2000 and are used, in part, for price regressions for the separate national brands of each of the major manufacturers selling formula as of September 2000.

In principle, WIC-related factors that could affect retail prices in a local market area—for any given levels of manufacturers' wholesale prices—include:

- the relative size of WIC
- the presence of a WIC rebate contract, and the type of contract (i.e., whether the contract is a sole-source contract or an open market contract)
- the delivery system used to provide infant formula to WIC households.

The WIC model predicts that, holding other factors constant, profit-maximizing supermarkets establish a higher retail price if the relative size of WIC is larger. Economic reasoning suggests that WIC lowers the price sensitivity of demand in the infant formula market. WIC provides food checks or food vouchers (hereafter, "vouchers") to WIC households, thus taking a group of (low-income) households that would otherwise be price-sensitive and enabling them to obtain infant formula without bearing the retail price themselves. WIC makes these households insensitive to the retail price, and retail prices are higher when a price-insensitive component of the local market is larger. In the WIC model it turns out that retail prices are affected not by the *absolute* size of the WIC program, as measured by the number of WIC formula-fed infants, but rather the *relative* sizes of the WIC and non-WIC market segments.

The second set of WIC-related factors listed above concerns the presence and type of WIC contract. As of September 2000, each of the 50 WIC State agencies used a single manufacturer as a supplier of formula for WIC households. In contrast, under an open market contract—a form of contract that some WIC State agencies used in the early 1990s—any and all infant formula manufacturers could voluntarily participate in a State's rebate program. A participating manufacturer would pay a rebate, chosen by the manufacturer, when its particular formula was provided to a WIC household. Under the open market contract, WIC households themselves chose which brand of formula to obtain and each manufacturer's national brand receives at least *some* of the infant formula demand of WIC households (hereafter, "WIC demand"). In contrast, under sole-source procurement, the formula provided by the contract-winning manufacturer receives *all* of the WIC demand and all other national brands receive *none* of the WIC demand.[2] The WIC model predicts that retail prices depend on the type of contract. Most notably, under a sole-source contract, the prices of the contract and noncontract brands can be expected to respond differently to a change in WIC demand.

[2] An exception to this general statement is that the WIC State agency can issue formula provided by a different manufacturer when medical documentation supports the use of another infant formula product or a noncontract brand of formula is needed for religious reasons.

The bulk of the analysis of the WIC model is devoted to the retail food delivery system inasmuch as 48 of the 50 States utilized that system during the study period in Oliveira et al. Under the home distribution system, which Vermont uses, infant formula is delivered to the WIC participant's home. Under the direct distribution system, which Mississippi uses, WIC participants pick up infant formula from storage facilities operated by a State or local agency. The WIC model identifies how retail price depends on the type of delivery system used by a WIC State agency.

The list of WIC-related factors that may affect the retail prices (for given wholesale prices) does *not* include the amount of the rebates (on either a per-can basis or in total). Infant formula manufacturers—not retailers—bear the legal incidence for the rebate payments. If a manufacturer increases its wholesale price in response to its rebate payments or other WIC-related factors, then retail prices would be affected in turn (assuming retail markups are unchanged). This economic mechanism is discussed briefly in this report, but it is excluded from the formal WIC model so that the model can isolate retailer behavior. Manufacturers' wholesale prices are included in the econometric analysis in Oliveira et al. as independent variables in brand-specific regressions for retail prices.

In addition to its examination of WIC-related factors and the wholesale price, the WIC model identifies various socioeconomic factors and market-structure conditions that can affect retail prices in a local market area. These other factors include median household income; the poverty rate; the degree of competition faced by the supermarket *sector* (inclusive of all supermarkets) due to the presence of discount stores; and the degree of competition faced by a supermarket *chain* (which may own one or more stores) due to the presence of other supermarket chains.

Oliveira et al. found that, within market areas, there is not a clear and consistent relationship between a formula's being the WIC contract brand and its being sold at the highest average retail price. However, comparing the retail prices of contract and noncontract brands of formula may not identify WIC-related price effects since, as just noted, *other factors may affect retail prices too*. The WIC model identifies conditions under which, theoretically, the retail price of the contract brand would be higher than the prices for noncontract brands. It also identifies alternative conditions under which that expectation would not be met.

Structure of the WIC Model

The WIC model builds on existing economic theory by generalizing the standard multi-firm single-product Cournot oligopoly model to a new setting. The WIC model features differentiated brands of formula, heterogeneous consumers that are segmented by income, and the roles of WIC and its rebate program. A key feature of the WIC model's specification is the presence of not one but two formula brands (two "products"), a feature that is required to identify the simultaneous interactions between the prices of contract and noncontract brands of formula under a sole-source contract.

The theoretical device of aggregating products or brands into a "composite" product is common in economic theory. Although there were as many as four manufacturers in a given market area at some time during the companion volume's 1994-2000 study period, a two-brand model is sufficient to capture the basic theoretical interactions between a contract brand and a single "noncontract brand" which represents an aggregation of all other (noncontract) brands.

Basic Assumptions

In the WIC model, the geographic extent of the market corresponds to a local market area, i.e., retail prices are determined by factors that exist locally.[3] This treatment ignores retail prices prevailing in other market areas and assumes, reasonably, that households do not travel to any other market area to obtain formula. So, for example, households in San Diego would not buy infant formula in Los Angeles.

Households obtain formula not only from supermarkets, but also from mass merchandisers and drugstores. Supermarkets are the major source of infant formula, with 69 percent of infant formula products (in 2000) provided by supermarkets, while mass merchandisers accounted for about 28 percent and drugstores for less than 4 percent. For the empirical analysis in Oliveira et al., data were available for estimating the number of *discount stores* (such as Wal-Mart, K-Mart, and Target) that sell infant formula in a market area. The WIC model and the empirical analysis both include the number of discount stores (adjusted for population) as a determinant of demand for infant formula in the *supermarket* sector. The opportunity for consumers to substitute between supermarkets and discount stores limits the ability of supermarkets to raise their formula prices.

The supermarket sector is characterized by a set of chains each of which owns a set of supermarkets (or "stores") distinguished by geographic location. The WIC model treats a chain, rather than an individual supermarket, as the decisionmaking "firm."[4] It is assumed that the chain establishes a single price for the one or more supermarkets it owns: price differences across supermarkets within a chain are ruled out. Although not all supermarkets are equally convenient to a representative consumer, it is assumed that a representative consumer has a choice between various supermarkets belonging to *separate* chains in a market area, which limits the ability of any one chain to raise the price of formula in the supermarkets it owns.

[3] In the empirical implementation of the WIC model, the geographic extent of the market corresponds to a U.S. "market area" as defined by Information Resources, Inc. (IRI).

[4] Any measure of supermarket concentration is based on the market shares of "firms." To adopt any measure, a modeling decision must be made for whether an individual supermarket or a chain constitute the "firm." The empirical analysis in Oliveira et al. uses the shares of chains to measure concentration, prompted by the notion that chains "compete" with other chains but stores within chains do not economically "compete" with one another due to their common ownership. (The concentration measure in Oliveira et al. does include the share of an individual supermarket if that store is a so-called "independent.")

As in the Cournot model, market price in the WIC model is the same for all firms (chains) and is determined as a result of a Nash game in which any given chain treats the output (quantity of formula) of the *other* chains as exogenous when choosing its own output to maximize its profits. All chains choose their outputs simultaneously.

Previous models of oligopoly suppose either that M firms each produce a single homogeneous product or that M firms each produce a differentiated product of which there are M varieties, one for each firm. In either type of model, each firm has but a *single* choice variable (either quantity or price) for its single product. A distinctive feature of the WIC model is that it contains not one but *two* brands of infant formula that are offered by *each* of the M different supermarket chains.[5] A chain must therefore choose two levels of output—one for each brand—for its supermarkets. Thus, interdependency exists not only between firms, as in the Cournot model, but also between brands: a chain takes into account the effect on its profits from brand 1 when it is considering brand 2, and vice versa. The incentive a chain has to raise or lower its price for any one brand is affected by the extent to which its customers would substitute to the other brand on the chain's own shelf. The interdependency between the two brands' prices gives rise to a corresponding interdependency between the WIC model's two inter-firm Nash games.

[5] An appendix to the paper defines all symbols used in the paper, in order of introduction.

Cost Factors

The marginal cost to a chain for a unit (can) of formula includes its wholesale cost plus the retailing costs of inventory, shelf space, stocking, and checkout. The wholesale cost is thought to be far larger than retailing costs. The WIC model allows the two brands to have different marginal costs, c_1 and c_2, but assumes that marginal costs do not vary across chains within local markets. A chain's total cost function for a brand of infant formula (as a "stand-alone" product, separate from the chain's many other products) is given by:

$$(1)\quad C_{k,i}\left(q_{k,i}\right)=c_k q_{k,i},\ k=1,2 \quad i=1,\dots,M$$

The wholesale price schedules of infant formula manufacturers incorporate bulk discounts. Buyers who purchase formula by the truckload (i.e., 40,000-44,000 pounds) obtain the manufacturer's lowest wholesale price. For example, in 2000 (the last year of the study period in Oliveira et al.) Mead-Johnson charged a truckload price of $2.94 per unit (13-ounce can) for its milk-based liquid concentrate formula. A chain that bought half that paid a few pennies more, totaling $2.98 per unit. Thus, in general, a chain's marginal cost does in fact depend on the amount purchased, in contrast to the specification in (1).

Although a chain that bought a single 12-can case of that same formula paid substantially more—$3.41 per unit—a key feature of the price data examined in Oliveira et al. prompts the WIC model's assumption that marginal cost is the same across chains. The supermarket retail price data are not chain-specific but instead are averages across a market area's supermarkets based on data from a survey. To be included in the survey a chain had to have at least $2 million in sales annually (in total for all items in all stores). Thus, prices charged by local corner grocery stores and others with sales below that threshold are not included. It was thought the surveyed chains typically pay the truckload price for formula. For large-scale chains that purchase by the truckload or more, wholesale prices can indeed be treated as constant on the margin and identical across such chains.

Even though the supermarket price data could include prices for medium-sized chains that pay more than the truckload price, the truckload price can be a proxy for their wholesale costs. After all, wholesale cost differences across chains on the order of a few pennies are small relative to the retail price differences across market areas that the regressions seek to explain. Furthermore, wholesale prices charged by a manufacturer tend to move together: changes in the wholesale price paid by the medium-size firms parallel the changes in the truckload price that was included in the regression. For these reasons, the regression specification in Oliveira et al. included a single wholesale price for a brand—the truckload price—thereby setting aside bulk discounts. Thus, the WIC model's assumption that a chain's marginal cost is constant and equal across chains—at least for the chains in the price survey—was thought to be reasonable for the WIC model's purposes of supporting and coinciding with the regression analysis.

A final issue is whether marginal cost would increase if all chains in a local market area increase their purchases simultaneously due to an increase in market demand. Infant formula manufacturers establish national price schedules, so that the wholesale prices faced by any one local market area are constant not only at the chain level but for the local market area as well.

Demands of Out-of-Pocket Households

In the market area, there are N households with one infant who is fed infant formula. Each household is a member of one of three distinct formula-buying groups or market segments: high-income households (H), low-income non-WIC households (L), or low-income households that receive vouchers in the WIC program (W), where $H + L + W = N$. It is useful for the income "cutoff" that divides low-income from high-income households to be set above the income threshold for WIC income eligibility (185 percent of poverty) instead of equal to or below that threshold. This assumption means that, by definition of the term *low-income*, there is some positive number of low-income non-WIC households ($L > 0$) even under full funding for WIC and full participation by eligible households; otherwise an entire category of households, L, awkwardly "appears" or "disappears" based on whether or not WIC has full funding and full participation by eligible households.[6]

The WIC model contains two brands of infant formula. The pair of brands will be interpreted two different ways when analyzing sole-source contracts:

- the two brands each represent two different manufacturers' national brands in a given market area;

[6] In this framework, the term "low-income households" refers to the total $L + W$, which includes the low-income households that participate in WIC (W) and the low-income non-WIC households (L) who purchase formula out of pocket.

- the two brands each represent a *single* national brand in a given market area, under the alternative conditions of being the contract brand or being a noncontract brand.

The first interpretation is the most straightforward one. It will be used to compare the retail price of a national brand (e.g., Carnation) that is the contract brand in the market area with the retail price of a different national brand (e.g., Mead-Johnson) that is a noncontract brand in the same market area; alternatively, the model's noncontract brand could represent an aggregation of all noncontract brands. The second interpretation applies to a particular national brand (e.g., Carnation) as it transitions in a given market area between being a noncontract brand and being a contract brand. This second interpretation is adopted to isolate the effects of a change in contract brand status, holding constant which national brand (and its brand-specific factors) is examined. Under either interpretation, brand 1 will be treated as the contract brand and brand 2 as the noncontract brand.

Per-household demand curves for brands 1 and 2 for supermarket infant formula purchased by the representative out-of-pocket low- and high-income households are:

(2a) $q_{1,j}\left(P_1, P_2\right) = a_1 + u - b_j P_1 + sP_2,\ j = L, H$

(2b) $q_{2,j}\left(P_1, P_2\right) = a_2 - u - b_j P_2 + sP_1,\ j = L, H$

where b_j, $j = L, H$, is an own-price slope term the value of which depends on the income level of the household, s is a cross-price slope term, u is a parameter capturing what the model calls the *tag-along effect*, and a_1 and a_2 are brand-specific constants. Each of the parameters is considered in turn.

The own-price slope terms b_L and b_H in (2) reflect how readily the two groups of out-of-pocket consumers, L and H, substitute away from (towards) supermarket formula in response to an increase (decrease) in the supermarket price. Substitutes for supermarket formula include home-prepared formula, the introduction of cow's milk and/or solid foods into the infant's diet at an earlier age, and formula obtained from a discount store. As substitutes become closer, out-of-pocket consumers become more price-sensitive and the two slope terms become larger (in absolute value). For example, the greater the presence of discount stores in a local market, the greater the price sensitivity of supermarket customers to the supermarket price, and the larger (in absolute value) will be the own-price slope terms slope terms b_L and b_H. The relative importance of the various substitutes is not identified; however, intuition suggests that most households would use discount store formula rather than, say, switch to home production of formula in response to a supermarket price increase. [7] The combined strength of all substitution possibilities is reflected in the magnitudes of b_L and b_H.

[7] Another imaginable substitution behavior in response to an increase in the supermarket price of infant formula is for a household to switch from formula-feeding to breastfeeding. However, the empirical analysis in Oliveira et al. treats the household's decision to breastfeed or to formula-feed as exogenous, depending on such factors as level of education of the mother, supportiveness of breast-feeding by the mother's mother and other family and friends, social acceptance of breastfeeding activities, and availability and ease of obtaining breastfeeding counseling.

A fundamental aspect of the model's structure is that out-of-pocket low- and high-income households differ in their own-price sensitivities, specifically, that $b_L > b_H$.[8] Thus, if price rises by a given dollar amount, *both* types of households purchase *less* supermarket formula—but a low-income non-WIC household is relatively *more* responsive to the price increase, switching to substitutes (perhaps especially discount store formula) more readily than high-income households.[9]

The cross-price term s shows how readily a household's reduction in quantity demanded for a brand (in the supermarket sector), due to an increase in that brand's (supermarket) price, is retained within the supermarket sector by an increase in quantity demanded for the substitute brand off the supermarket shelf. For example, if P_1 increases then $q_{1,j}$ falls by b_j in (2a) and $q_{2,j}$ rises by s in (2b). It is assumed that only *part* of the decrease in $q_{1,j}$ is shifted to $q_{2,j}$, i.e., that a (representative) household makes *some* use of substitutes other than the alternative brand on the supermarket shelf (perhaps especially formula obtained at a discount store). Mathematically, this assumption means that $b_j > s$ for both out-of-pocket groups. Because allowing group-specific differences in s does not yield additional insight, s is assigned the same value for both the high-income and low-income non-WIC households (unlike the own-price terms b_j, which do differ by group). The assumption that the own-price effect on a brand's quantity demanded is larger than the cross-price effect is economically reasonable. This assumption also allows the model's mathematical solution to yield positive prices in equilibrium.

The introduction of the parameter s into the WIC model makes the model interesting and powerful. If instead s is omitted from the model by setting $s = 0$, then households exhibit *no* inter-brand substitution at all and respond to a brand's price increase in the supermarket sector by buying the same brand in the discount store sector (or by making other substitutions). If $s = 0$, demands for the two brands are independent and the two-product WIC model separates into two one-product models, in which case supermarkets would establish each brand's price without any particular reference to the other brand's price (in the same way supermarkets establish prices for, say, apples and hairbrushes). Although a strength of the model is that it *allows* for s to be positive, it is worth noting that s is not *required* to be positive either for solving the theoretical model or for estimating its empirical counterpart, which estimates statistically from price data whether or not s is positive.

The non-negative term u is common to the demand functions for both brands, although it differs in sign: for brand 1 (the contract brand) a positive u adds to quantity demanded in (2a), while for brand 2 (the noncontract brand) a positive u diminishes quantity demanded in (2b) by precisely the same amount. The parameter u represents the combined influence of two conceptually distinct effects that the model calls a *medical promotion effect* and a *shelf-space effect*. Either of these effects augments demand for the contract brand at the expense of the noncontract brand under sole-source (but not open market) contracts.

[8] The price elasticity of demand ε, (the percentage change in quantity demanded that results from a 1-percent change in price, in absolute value) is the most common measure of price sensitivity. In (2), out-of-pocket low-income consumers are more price sensitive than high-income consumers at any given price regardless of whether slopes or elasticities are used to measure price sensitivity. For the WIC model, with its Cournot-like linear demand curves, group-specific slopes are easier to discuss and compare than are elasticities.

[9] The own-price demand terms b_L and b_H differ only between income groups and not across brands. It was thought that the econometric specification in Oliveira et al. would be little changed if the WIC model were to specify own-price terms that differ by both income group and by brand.

When a State has a single contract brand, doctors or hospitals may tend to promote that brand either through recommendations or the provision of formula samples. Such promotions may lead to a brand-inducement behavior by which the (representative) non-WIC household favors the contract brand when making its out-of-pocket formula purchase. The model does not require that all out-of-pocket households must behave this way, but if some proportion of them do then u will be positive for the representative household.[10]

A second, distinct effect occurs if (at least some) non-WIC households favor the brand that has a greater presence on the supermarket shelf. Given that a sole-source contract is in effect, and that WIC formula is estimated to account for over half of infant formula sales, the contract brand is likely to have more shelf space than the noncontract brand. This greater shelf space may contribute, in itself, to greater sales to non-WIC households.[11]

The medical detailing and shelf-space effects are combined in the model to form a single effect, u, which the model calls the *tag-along effect*. This effect captures the extent to which the designation of brand 1 as the WIC contract brand results in sales to *non-WIC* households that accompanies or "tags along" with the sales to *WIC* households. The two components of the tag-along effect were identified as theoretical possibilities for infant formula demand by the U.S. Government Accounting Office (1998), which referred to them as "spillover" effects. The tag-along effect is modeled as a one-for-one tradeoff or substitution between the contract and noncontract brands. The tag-along effect is zero ($u = 0$) if:

- consumers do not respond to additional medical promotion or shelf space that the contract brand receives; or
- the contract brand does not receive additional medical promotion or shelf space; or
- there is no single contract brand, i.e., there is an open market contract or if there is no rebate program in effect.

An interpretation of the brand-specific constants a_1 and a_2 in (2) is based on considering consumption outcomes given that infant formula is free to households (making $P_1 = P_2 = 0$) and given any of the conditions above that make $u = 0$. Let z represent any household's *saturation level* of formula, an amount of formula beyond which a household would not consume (per unit of time) even if formula were available to the household in unlimited quantities for free.[12] If there were but one brand of formula, say brand 1, then that brand's constant in (2a) would itself equal z. However, given that there are two brands, then on average across households the consumption level z would be divided based somehow on households' *non-price brand preferences*, for which a_1 and a_2 are measures. Non-price brand preferences reflect some combination of "innate" tastes, recommendations by doctors or hospitals, and other non-price factors. If brand preferences are "symmetric," then for the representative household, $a_1 = a_2 = a = z/2$, in which case each brand would be consumed by half of the households. More generally, the share of total formula consumption in the market that brand k would receive would be $a_k/(a_1 + a_2)$.

[10] Whether a manufacturer is the contract or a noncontract brand in a given area, the manufacturer has an incentive to promote its brand in the medical community so that doctors and hospitals may recommend the brand to patients. Some purchases by some patients may be attributable to this promotion activity, and such behavior could be incorporated in the WIC model through the demand-specific constants a_1 and a_2. A relatively successful medical promotion by the manufacturer of brand 1 would, other factors constant, be captured by $a_1 > a_2$. The "medical promotion effect" that is incorporated into u specifically represents one-for-one demand gains and losses between brands that are attributable strictly to whether or not a brand is designated the contract brand in the area.

[11] Empirical work on wine sales (Folwell and Moberg, 1993) found that "facings" (a measure of shelf space) had an effect, separate from the effect of price, on the quantities purchased of wine. A study on juices (Brown and Lee, 1996) found that the number of facings affected the prices of juices.

[12] In fact, saturation levels would differ across households due to physiological differences of infants. The term z can be thought of as the average consumption of formula for the representative household if formula were free and unlimited.

Demand of WIC Households

In the absence of the WIC program, WIC households would be paying out of pocket, in which case it will be assumed that their demand would resemble the demand of out-of-pocket low-income households given in (2a) and (2b). Under the WIC program, WIC households receive vouchers for a fixed amount of formula (the *WIC allocation*). It will be assumed the WIC allocation equals the saturation level z.[13] The per-household demand curve for brands 1 and 2 of supermarket formula for the W households in WIC is given by:

(2c) $q_{k,W} = \delta\theta_k vz, k = 1,2$

where v represents the *fraction* of vouchers that a representative WIC household redeems in the supermarket sector (as opposed to other retail outlets), θ_k represents the share of supermarket formula demand by a representative WIC household that is provided by brand k; and δ is a zero-one dummy variable signifying whether or not the WIC State agency uses the retail food delivery system to distribute WIC formula. Each parameter is considered in turn.

The term v reflects *cross-sectoral* substitution behavior of *WIC* households. It is likely that the opportunity to substitute between supermarket formula and discount store formula is important mainly for *non-WIC* households: WIC households have no particular reason to seek out infant formula from discount stores (which are assumed to be more distant and less convenient, in general) because WIC households do not pay out of pocket for formula. If WIC households simply obtain *all* of their formula in supermarkets (at the same time they do grocery shopping), then $v = 1$. More generally, other values for v allow changes in the presence of discount stores in a market area to have some impact on WIC households.

Under sole-source WIC contracts, the term θ_k is a dummy variable: the contract brand (brand 1) receives all of the formula demand of WIC households, making $\theta_1 = 1$, while $\theta_2 = 0$ for the noncontract brand (brand 2). In contrast, a WIC household uses vouchers for the brand of its choice under either open market contracts or under the counterfactual scenario in which WIC has no rebate program at all. The WIC model assumes for these two cases that θ_k in (2c) equals $a_k/(a_1 + a_2)$, the same values already identified for out-of-pocket households when formula is free based on non-price brand preferences. Regardless of the presence and type of contract, the brand-share terms θ_1 and θ_2 sum to 1.

The dummy variable δ equals 1 if the WIC State agency uses the food delivery distribution system to distribute WIC formula, and 0 otherwise. As of September 2000, $\delta = 1$ for all but two States.

A key feature of the specification in (2c) is that supermarket prices do not appear in the expression. The formula demand of WIC households is completely insensitive to price (perfectly inelastic) because the WIC program—not the WIC household—pays for the formula.

[13] If, instead, the WIC allocation were sufficiently close to zero, WIC households would likely be willing to pay the retail price (at least at sufficiently low retail prices) to supplement their relatively "small" allocation with out-of-pocket purchases. Because supplementation is not considered to be a widespread phenomenon, supplementation is excluded here by the assumption the WIC allocation and the saturation level are equivalent.

Even though it may be reasonable to model the demand of any one WIC household using (2c), overall WIC demand for all *W* households as a group may not be price insensitive. Suppose retail price increases are not offset by Congressional appropriations for WIC, and—despite WIC's priority system—some number of eligible infants are not able to participate in WIC as a result. *W* then depends negatively on retail price and overall WIC demand is price-sensitive. Nevertheless, even if overall WIC demand is not perfectly inelastic, it is presumed that the degree of price sensitivity is sufficiently low and/or the retail price at which these effects would be felt is sufficiently high that this possibility can be neglected. At least to a first approximation, it will be assumed that *W* is fixed and that overall WIC demand is perfectly inelastic (at least within the relevant retail price range). This assumption yields WIC-related price effects that are both mathematically tractable and relatively easy to interpret. Despite the inelastic specification for WIC demand, any possibility of an infinite price/infinite profits outcome is simply ruled out *a priori*.

Brand Demand for the Supermarket Sector

Summing (2a), (2b), and (2c) across market segments for each brand yields two total demand equations given by:

$$\text{(3a)}\quad Q_1(P_1,P_2) = Hq_{1,H}(P_1,P_2) + Lq_{1,L}(P_1,P_2) + Wq_{1,W} = A_1 + \theta_1 Q_W + U - BP_1 + SP_2$$

$$\text{(3b)}\quad Q_2(P_1,P_2) = Hq_{2,H}(P_1,P_2) + Lq_{2,L}(P_1,P_2) + Wq_{2,W} = A_2 + \theta_2 Q_W - U + SP_1 - BP_2$$

where the market-level terms are aggregates of per-household terms given by $A_1 = (H + L)a_1$, $A_2 = (H + L)a_2$, $U = (H + L)u$, $S = (H + L)s$, and $B = Hb_H + Lb_L$. The term Q_W equals $W\delta vz$, the market-level WIC demand for all formula; the division of Q_W between brands depends on the brand-share terms θ_1 and θ_2.

As in any model that involves aggregation of market segments, the location of equilibrium in relation to the "kink" points of total market demand needs to be addressed. It will be assumed that, in Nash equilibrium, supermarket chains serve *both* out-of-pocket segments (rather than just the high-income households alone). This assumption in effect stipulates that the equilibrium price of each brand is sufficiently low that each brand's equilibrium output exceeds the output level of the kink point between the demands of the *H* and *L* households. The possibility of serving only the WIC segment (an infinite price/infinite profits outcome) was ruled out above. All three segments—*L*, *H*, and *W*—are in fact served in the actual formula market, and that observed outcome follows from the assumption that price is sufficiently low to serve the *L* households.

The assumption that $b_j > s$ for both *L* and *H* households was already adopted for both economic plausibility and meaningfulness of the model's solution. The assumption implies that B > S in (3).

As noted previously, one factor that affects supermarket price is the ease of switching to formula sold in the discount store sector. Thus, b_L and b_H in (2) and *B* in (3) may depend positively on the number of discount stores, holding other factors constant—the price sensitivity of demand for *super-*

market formula increases due to an increase in the number of *discount* stores. However, a scaling factor is needed because market areas differ in "size." Oliveira et al. use the size of a market area's total population as a scaling factor. Thus, no effect on supermarket formula demand—and, in turn, no effect on retailer's profit-maximizing price—would be predicted if one market area has double the number of discount stores of another but also serves twice the population, making a "typical" discount store equally convenient or accessible to the representative household in the two market areas. Let D represent the ratio of the number of discount stores to total population. An increase in D increases the price sensitivity of either out-of-pocket segment and increases B in (3).

Another parameter in (3) that may be affected by D is v, the fraction of vouchers that are redeemed in supermarkets (under the assumption that WIC households consider the availability and convenience of discount stores when making their plans for shopping trips). An increase in D is likely to result in WIC households making larger overall expenditures in the discount store sector, increasing voucher redemptions at discount stores and decreasing v.

Finally, the size of the tag-along effect U is unlikely to be a simple constant that is independent of any other factors. In particular, the amount of additional shelf space or medical promotion gained by a brand due strictly to its status as the contract brand may depend largely on how much formula is provided to WIC households. For simplicity, it will be assumed that under the sole-source contract the tag-along effect is given by:

$$(4)\quad U = hQ_w,\ 0 \le h < 1$$

so that U is simply proportional to the amount of WIC formula.[14]

Solving (3a) and (3b) simultaneously, with (4), results in market demand curves (inverse demand functions) once prices are expressed as functions of quantities demanded:

$$(5a)\ P_1 = \frac{BA_1 + SA_2 + [B(\theta_1 + h) + S(\theta_2 - h)]Q_W}{B^2 - S^2} - \frac{B}{B^2 - S^2}Q_1 - \frac{S}{B^2 - S^2}Q_2 = \alpha_1 - \beta Q_1 - \gamma Q_2$$

$$(5b)\ P_2 = \frac{BA_2 + SA_1 + [B(\theta_2 - h) + S(\theta_1 + h)]Q_W}{B^2 - S^2} - \frac{B}{B^2 - S^2}Q_2 - \frac{S}{B^2 - S^2}Q_1 = \alpha_2 - \beta Q_2 - \gamma Q_1$$

where the derived parameters α_1, α_2, β, and γ are introduced to simplify further development of the model. The assumption that $b_j > s$ means that $B > S$, which in turn implies that β and γ are each positive.

If consumers exhibit no substitution behavior at all between brands, so that $s = 0$ at the household level, then $S = 0$ in (3), $\gamma = 0$ in (5), and each brand's demand curve becomes a function of the brand's quantity only and is independent of the quantity of the other brand.

[14] It should be noted that the tag-along effect may be influenced by the distribution system. After all, there can be no shelf-space effect for the contract brand if WIC formula is not distributed through the retail food delivery system. On the other hand, the medical promotion effect may operate independently of the distribution channel. Rather than separating out these influences, the model simply assumes that the tag-along effect U requires that distribution be conducted through the retail food delivery system (implicitly giving full weight to the shelf-space effect, and none to the medical promotion effect).

Solution of the WIC Model

The chain's profit function for the two brands of infant formula (separate from the other products offered by the chain) is:

$$(6)\ \pi_i\left(q_{1,i}, q_{2,i}\right)=\left[\alpha_1-\beta\left(q_{1,i}+\sum_{j\neq i} q_{1,j}\right)-\gamma\left(q_{2,i}+\sum_{j\neq i} q_{2,j}\right)-c_1\right]q_{1,i}$$
$$+\left[\alpha_2-\beta\left(q_{2,i}+\sum_{j\neq i} q_{2,j}\right)-\gamma\left(q_{1,i}+\sum_{j\neq i} q_{1,j}\right)-c_2\right]q_{2,i}$$

For each of the M chains, the first-order conditions are[15]:

$$(7a)\ 0=\alpha_1-\beta\left(\sum_{j\neq i} q_{1,j}\right)-\gamma\left(\sum_{j\neq i} q_{2,j}\right)-c_1-2\gamma q_{2,i}-2\beta q_{1,i}$$
$$(7b)\ 0=\alpha_2-\beta\left(\sum_{j\neq i} q_{2,j}\right)-\gamma\left(\sum_{j\neq i} q_{1,j}\right)-c_2-2\gamma q_{1,i}-2\beta q_{2,i}$$

In contrast to the Cournot model, for which there is but one best response function (BRF) for each firm, the WIC model's two first-order conditions in (7) each constitute a BRF. Each of the two BRFs exhibit two types of interdependencies. As usual in a Cournot model, (7) exhibits *cross-firm interdependency* for each given brand, i.e., the profit-maximizing level of a brand's output for a chain depends on the given levels of the brand's output chosen by the other chains. In addition, given cross-brand substitution behavior so that $\gamma > 0$, each of the chain's two BRFs exhibit *cross-brand interdependency*, i.e., the profit-maximizing level of output for a chain's brand 1 depends on the firm's own chosen level of output (and its rival's chosen levels of output) for brand 2, and vice versa.

To solve in reduced form for the two optimal quantities of chain *i*, q_{1i}*and q_{2i}*, the BRFs must be solved for both cross-firm and cross-brand interactions. As in a Cournot model in which all firms have identical constant marginal costs, each chain's quantity (for a given brand) is identical. Using the result that the output of the $(M-1)$ rivals for chain *i* is simply $(M-1)q_{k,i}$, k = 1, 2, (7) becomes, in partially reduced form:

$$(8a)\ q_{1,i}\left(q_{2,i}\right)=\frac{\alpha_1-c_1}{(M+1)\beta}-\frac{\gamma}{\beta}q_{2,i}=\frac{BA_1+SA_2\left[B(\theta_1+h)+S(\theta_2-h)\right]Q_W-c_1}{(M+1)B}-\frac{S}{B}q_{2,i}$$

$$(8b)\ q_{2,i}\left(q_{1,i}\right)=\frac{\alpha_2-c_2}{(M+1)\beta}-\frac{\gamma}{\beta}q_{1,i}=\frac{BA_2+SA_1\left[B(\theta_2-h)+S(\theta_1+h)\right]Q_W-c_2}{(M+1)B}-\frac{S}{B}q_{1,i}$$

[15] The second-order conditions $\pi_{11}^i < 0$, $\pi_{22}^i < 0$, and $\pi_{11}^i\pi_{22}^i - (\pi_{12}^i)^2 > 0$ are met at the point at which the first-order conditions are satisfied, given typical assumptions about the magnitude of marginal cost relative to other parameters (to exclude a corner solution of zero output). The solution to (7) constitutes a local profit-maximizing set of output levels for the chain. This local maximum will be the focus of attention, since the infinite price/infinite profits outcome was already ruled out.

Solving (8) simultaneously yields equilibrium quantities for the two brands at the level of a chain:

$$(9a)\ q_{1,i}* = \frac{\beta(\alpha_1 - c_1) - \gamma(\alpha_2 - c_2)}{(\beta^2 - \gamma^2)(M+1)} = \frac{[A_1 + (\theta_1 + h)Q_W] - Bc_1 + Sc_2}{(M+1)}$$

$$(9b)\ q_{2,i}* = \frac{\beta(\alpha_2 - c_2) - \gamma(\alpha_1 - c_1)}{(\beta^2 - \gamma^2)(M+1)} = \frac{[A_2 + (\theta_2 - h)Q_W] - Bc_2 + Sc_1}{(M+1)}$$

Total production (in the market area) of either brand is the sum across (identical) chains of that brand's output levels, which is simply *M* times greater than the output of any one chain in (9). Equilibrium total production of each brand can be written as:

$$(10a)\ Q_1^* = \frac{M}{(M+1)}[a_1 + (\theta_1 + h)\delta wvz - bc_1 + sc_2]Y$$

$$(10b)\ Q_2^* = \frac{M}{(M+1)}[a_2 + (\theta_2 - h)\delta wvz - bc_2 + sc_1]Y$$

where $Y = H + L$, the number of non-WIC households; $w = W/Y$, the ratio of WIC to non-WIC households who buy formula; and $b = B/Y$, a weighted average of the price-sensitivity parameters (slopes) of the two out-of-pocket groups, which can be written as:

$$(11)\ b = \left(\frac{H}{(H+L)}\right)b_H + \left(\frac{L}{(H+L)}\right)b_L = \omega_H b_H + \omega_L b_L$$

where the shares of *H* and *L* as proportions of all out-of-pocket consumers, ω_H and ω_L, sum to 1.

Using (10) and (4), equilibrium market prices for brands 1 and 2 can be expressed as functions of exogenous terms:

$$(12a)\ P_1^* = \frac{(ba_1 + sa_2)}{(M+1)(b^2 - s^2)} + \frac{M}{M+1}c_1 + \delta\frac{[b(\theta_1 + h) + s(\theta_2 - h)]vz}{(M+1)(b^2 - s^2)}w$$

$$(12b)\ P_2^* = \frac{(ba_2 + sa_1)}{(M+1)(b^2 - s^2)} + \frac{M}{M+1}c_2 + \delta\frac{[b(\theta_2 - h) + s(\theta_1 + h)]vz}{(M+1)(b^2 - s^2)}w$$

The assumption that *b*, the weighted average of the own-price terms, exceeds *s*, the cross-price term, ensures that the denominators in (12) are positive, which means prices for the contract and noncontract brands are positive (given typical assumptions about the relative sizes of demand parameters and marginal cost).

Results of the WIC Model

An examination of (9), (10), and (12) shows whether equilibrium levels of a chain's quantities, the market quantities, and prices respond positively or negatively to a change in any one factor, holding other factors constant. This chapter focuses on price effects, although brief attention is given to quantity effects. It is important to distinguish which price effects are due to WIC *per se* as a government-funded formula-subsidizing program, which are due to WIC's rebate program, and which are due to sole-source procurement.

The chapter begins by discussing price effects associated with changes in marginal cost, price-independent brand preferences, and population. The chapter continues with a discussion of price effects under two scenarios:

- the presence of the WIC program (without rebates) relative to the absence of the WIC program;
- an increase in the relative size of WIC (without rebates).

The remainder of the chapter then considers each of the following WIC-related factors in turn:

- an increase in the relative size of WIC if WIC has rebates generated by open market contracts;
- the use of open market contracts relative to the absence of any rebate contracts;
- an increase in the relative size of WIC if WIC has rebates generated by sole-source contracts;
- the use of sole-source contracts relative to the use of open market contracts;
- the use of sole-source contracts relative to the absence of the WIC program; and
- the use of home delivery or direct distribution for distribution of WIC formula relative to the use of the retail food delivery system.

A central variable of the WIC model is the relative size of WIC, w, measured by the ratio of WIC to non-WIC formula-fed infants. A challenge in reviewing price effects occurs because there is a multiplicative interaction in (12) between w and its coefficient, which contains the parameters θ_1, θ_2, δ, and h. Thus, the price effect due to a marginal increase in w depends on whether WIC has a rebate program, whether the rebate program uses an open market contract or sole-source procurement, and on the distribution system used for WIC formula.[16] In the end, it turns out that price effects are easiest to consider by reviewing them in a particular sequence.

[16] An analogous mathematical structure is found in the familiar Distance-Speed-Time relationship D = ST, where the multiplictative interactions between S and T implies that the Distance effect of a change in Speed depends on the level of T and the Distance effect of a change in Time depends on the level of S.

Effects of Marginal Cost, Brand Preferences, and Population

Marginal Cost. In (12), a brand's price depends positively on the brand's own marginal cost. A second result of (12) is that a brand's price does *not* depend on the marginal cost of the competing brand, e.g., c_2 is not a factor that affects P_1* (hereafter, the asterisk that denotes equilibrium values will be implicit). However, that result depends on particular features of the WIC model: a more general model may find that P_1 is affected by c_2 . A third outcome of (12) is that its price-cost relationship matches precisely the Cournot model's price-cost relationship. Thus, the special features of the WIC model that distinguish it from the Cournot model do not change the role of marginal cost: in both models, a one-unit change in c_k raises P_k by $M/(M+1)$.

Econometric Specification of Wholesale Cost. A brand-specific retail price regression in Oliveira et al. includes the brand's wholesale cost as an independent variable, since wholesale cost is a major determinant of marginal cost. Furthermore, the price regression *excludes* the wholesale costs of other brands. This econometric specification is restrictive in that, as noted above, a more general theoretical model may find that in principle a brand's retail price may be affected by wholesale prices of other brands. The exclusion of wholesale prices of other brands in the regressions is motivated less by the results of the WIC model *per se*—although the WIC model identifies certain conditions under which the specification is a correct one—and more by the very high correlation between the wholesale prices of various manufacturers. Severe multicollinearity problems would be introduced in a retail price regression if all wholesale prices were included in any one brand's regression.

Although the WIC model, like the Cournot model, predicts that a price regression's coefficient on wholesale cost should be a positive fraction equaling $M/(M+1)$, that particular outcome depends strongly on the linear demand specification used by the two models. Alternatively, a constant-elasticity demand formulation cannot be ruled out as a possibility (although it cannot be readily incorporated into the formal WIC or Cournot models), in which case a regression coefficient on wholesale cost would exceed 1. In summary, a price regression's coefficient on wholesale cost is certainly expected to be positive, though not necessarily fractional.

Price-Independent Brand Preferences. Price-independent brand preferences are measured by a_k, the constant term in demand in (1). An increase in a_k results in an increase in the brand's retail price in (12). There is no empirical measure for a_k, and the term is simply absorbed by the constant in a brand's price regression. It is worth identifying a_k as a distinct term in the model even though it is not empirically measured because it is useful to note that observed cross-brand variation in retail prices may be due in part to unobserved cross-brand variation in a_k.

Population Effects. The expressions in (10) and (12) exhibit a fundamental structural difference: the number of non-WIC households, Y, is a component of Q_k but not of P_k. These results imply that the "scale" of demand—

whether a market area's demand is "big" or "small" on account of population size—affects only Q_k but not P_k. In other words, if the numbers of H, L, and W households were to each increase proportionately, either over time or relative to another market area, then Q_k would increase by that same proportion but P_k would remain unchanged. Given that infant formula can be sold at a constant marginal cost (by assumption), variation in the size of a market area does not affect equilibrium prices.

Econometric Specification for Population. If a market area's population were to be included in a brand's price regression, the coefficient is expected to be statistically insignificantly different from zero. The sign of the variable's coefficient may be either positive or negative due to randomness in the data, but no systematic (statistically significant) relationship is predicted between price and population.

Effects of Relative Size of WIC, Without Rebate Contracts

Two Price-Increasing Effects. In this section, let $\theta_k = a_k/(a_1 + a_2)$, $\delta = 1$, and $h = 0$. Two scenarios will be considered to examine price effects due to WIC: $w > 0$ vs. $w = 0$, which compares the presence of WIC with the absence of WIC; and a marginal increase in w.

To keep the sequential discussion of the effects of WIC and the rebate program organized, we temporarily assume that WIC does not have a rebate program. This assumption is referred to as *counterfactual* since WIC currently does have a rebate program; the assumption could just as well be called an *historical* assumption since it describes WIC prior to the implementation of the rebate program. Examination of the counterfactual facilitates considering the effects of WIC, as a government-funded formula-subsidizing program, prior to and separately from considering the effects of WIC's rebate program. In the absence of the infant formula rebate program, it is supposed that all WIC formula is distributed using the retail food delivery system, making $\delta = 1$ in (12).

Under the counterfactual, WIC households themselves choose whether to redeem vouchers for brand 1 or for brand 2. As a result, θ_k in (12) is positive for both brands, equaling the value of $a_k/(a_1 + a_2)$ as noted earlier in the section "Demand of WIC Households". There is no tag-along effect under the counterfactual, so $h = 0$ in (12).

It is accurate to say that WIC "adds" to the overall market demands for infant formula. After all, WIC provides vouchers to (low-income) households which those households use to obtain more formula than they would have paid for if they were not WIC participants. However, given the assumption of constant marginal cost, the price effect of WIC can not be attributed to its role in increasing demand—whether the "scale" of demand is small or large affects only Q_k—but instead to WIC's effect on the *price sensitivity* of demand. Specifically, WIC decreases the price sensitivity of demand in the overall infant formula market, which in turn increases the P_k established by profit-maximizing supermarket chains.

This effect can be separated conceptually into two aspects. One aspect was identified in an analysis of WIC and the formula market by Salant (2003), while another was identified by Post and Wubbenhorst (1989).

Salant considered the behavior of a monopolistic infant formula manufacturer and examined major manufacturers' wholesale price series. Based on a "reservation price" monopoly model, Salant argued:

> . . . by removing the portion of the population with the lowest reservation price for infant formula from the general market, the WIC program inevitably raised the profit-maximizing monopoly price . . . What previously restrained [the monopolist] was the recognition that a price increase would drive away the poorer customers; but once the WIC program absorbs these customers, the monopolist has nothing further to lose if he raises the price . . . As more infants are added to the WIC program, the model predicts that the [monopolist] will continue to raise the price to non-WIC customers.

The pricing behavior identified by Salant does not require that the firm be a monopolist or a manufacturer: his economic reasoning also applies to the WIC model in which multiple supermarket chains engage in (imperfect) competition in the establishment of a retail price.

Salant's argument that WIC "removes" from the general market the (low-income) households with the *lowest reservation price* is recast by the WIC model as the argument that WIC "removes" from the general market the (low-income) households that are relatively *more price sensitive* ($b_L > b_H$).[17] Formally, let the numerical values of *W*, *L*, and *H* in the *absence* of the WIC program (the counterfactual) be represented by *W'*, *L'*, and *H'*, where $W' = 0$, $L' = L + W$ (the WIC households all fall below the model's income cutoff that demarcates low- from high-income households; see the section "Demands of Out-of-Pocket Households"), and $H' = H$ (the number of high-income households is the same with or without WIC). The overall price sensitivity of the out-of-pocket households is *always* a weighted average of b_L and b_H, but the numerical *value* of that weighted average depends critically on whether or not WIC is present. In the *presence* of WIC, the numerical value of that weighted average is given by (11). Let b_0 designate the value of the weighted average in the *absence* of WIC, where

$$(13)\ b_0 = \left(\frac{H}{H+(L+W)}\right)b_H + \left(\frac{(L+W)}{H+(L+W)}\right)b_L$$

Comparison of (13) and (11) shows that $b_0 > b$. As WIC "removes" some low-income households from the out-of-pocket segment of the market, the mix of out-of-pocket households that remain is less price sensitive: the weights on b_L and b_H are shifted more towards towards b_H, lowering the weighted average below b_0. A decrease in the price sensitivity of out-of-pocket households raises P_k in (12)—a result that will be established formally below. Thus, holding other factors constant, each of the *M* supermarket chains will find it profit-maximizing to increase the retail price of infant formula in the presence (versus the absence) of WIC.

[17] The WIC model, like Salant, does not consider how in the absence of WIC some of the low-income households may choose breastfeeding rather than purchase formula out of pocket.

We call this the *out-of-pocket composition effect* because the effect depends on whether out-of-pocket demand is composed of relatively few or many low-income households. Salant himself noted that this effect is analogous to pricing effects that seem to be found in the markets for certain pharmaceutical products. Prior to the introduction of generic pharmaceutical products that are substitutes for brand-name products, it might have been predicted that the entry of generic products would (as substitutes) lower the price of the brand-name product due to the increase in "competition." However, it was observed that in some instances the price of the brand-name drug *increased* after generic drugs entered the market. One explanation is that those consumers who were most price sensitive switched to the generic drug, leaving the less price sensitive (or so-called "brand-loyal") customers in the market for the brand-name product. In response to the decrease in elasticity in demand facing its product, a profit-maximizing pharmaceutical company will raise the price on its brand-name drug.

Another mechanism by which WIC decreases the price sensitivity of demand was identified by Post and Wubbenhorst. They argued that by providing WIC households with vouchers, the WIC program produces a "customer that is essentially unconcerned with the price she or he is paying." The WIC model calls this mechanism the *voucher effect*. In (12) the voucher effect is present given that $\delta = 1$, in which case price is affected by w through a mechanism other than the price-sensitivity term b. As w increases from zero (in the absence of WIC) to a positive value (in the presence of WIC), the mix of demands in total market demand is changed, with relatively fewer *price-sensitive* out-of-pocket households and relatively more *price-insensitive* WIC households resulting in a decrease in overall price sensitivity.[18] The profit-maximizing supermarket chains respond to the reduction in price sensitivity by raising the equilibrium retail prices of infant formula when WIC is present.

[18] The voucher effect is also a particular type of "composition" effect, involving the composition of overall market demand and the relative numbers of WIC and non-WIC households.

Although the out-of-pocket composition effect and the voucher effect both affect the mix of households in the infant formula market, the two are different: the former changes the mix *within* the group of out-of-pocket households while the latter changes the mix *between* the out-of-pocket households and the WIC households.

The voucher effect reflects the WIC model's general principle that the scale of demand is unimportant. A change in the *absolute* size of WIC—whether WIC is "big" or "small" as measured by W—does not necessarily change price: if a change in W is accompanied by a proportionate change in Y, then w is unchanged and price is unaffected. In contrast, a change in the *relative* size of WIC, as measured by w, does affect price even if overall population is fixed.

While WIC does "remove" a set of low-income households from the out-of-pocket segment of the retail food system—as Salant emphasized—WIC also provides vouchers that make WIC households price insensitive—as Post and Wubbenhorst emphasized—which "adds" those *same* households *back into* the retail food system. A way of describing both effects at once is to state that WIC *converts* out-of-pocket low income households (whose price sensitivity is *greater* than for high-income households) into WIC households (whose price sensitivity—zero—is *smaller* than for high-income households).[19]

[19] The concept of *converting* low-income households from non-WIC to WIC participation helps clarify how there are two answers to the seemingly simple question: "Are WIC households more or less sensitive to price than high-income households?" The answer depends on whether the price sensitivity of WIC households is considered *ex ante* or *ex post* to their participation in WIC.

The discussion has introduced the out-of-pocket composition effect and the voucher effect while considering the presence vs. the absence of WIC. Similarly, an expansion of WIC—represented by a marginal increase in *w*—would also increase price as a result of the same two mechanisms.

Effects of Relative Size of WIC, Formal Derivation. The formal derivation of the price effects of changes in *w* focuses on P_1 in (12a) and, for generality, does not here set zero values for particular parameters such as δ or *h*. The total effect on price due to a change in *w* is given by:

$$(14)\quad \frac{dP_1\left(w, b(w)\right)}{dw} = \left[\frac{\partial P_1}{\partial w}\right] + \left[\frac{\partial P_1}{\partial b}\right]\left[\frac{db}{dw}\right]$$

As discussed earlier, the relative size of WIC affects prices through two mechanisms. These two mechanisms correspond to the voucher effect and the out-of-pocket composition effect, respectively, which are represented by the first term on the right in (14) and by the product of the final pair of terms.

The voucher effect is given by the partial effect of *w* on price, which is non-negative:

$$(15)\quad \frac{\partial P_1}{\partial w} = \delta \frac{\left[b\theta_1 + s\theta_2\right]vz}{(M+1)\left(b^2 - s^2\right)} \geq 0$$

The voucher effect is strictly positive if δ = 1, i.e., if WIC formula is distributed using the retail food delivery system.

Examination of the out-of-pocket composition effect begins by identifying the relationship between *b* and *w*, which can be expressed as

$$(16)\quad b(w) = b_0 - \left(\frac{H}{N}\right)\left(b_L - b_H\right)w$$

where b_0 is the weighted average price sensitivity in the absence of any WIC program from (13). Recalling that price sensitivity is relatively large for low-income households (making $b_L > b_H$), an increase in *w* reduces *b*, i.e., db/dw < 0.

The remaining term in (14) represents the partial effect of *b* on price:

$$(17)\quad \left[\frac{\partial P_1}{\partial b}\right] = -\left[\frac{\left(b^2 + s^2\right)\left(a_1 + \delta\theta_1 vzw\right) + 2bs\left(a_2 + \delta\theta_1 vzw\right) + \delta(b-s)^2 hvzw}{(M+1)\left(b^2 - s^2\right)^2}\right] < 0$$

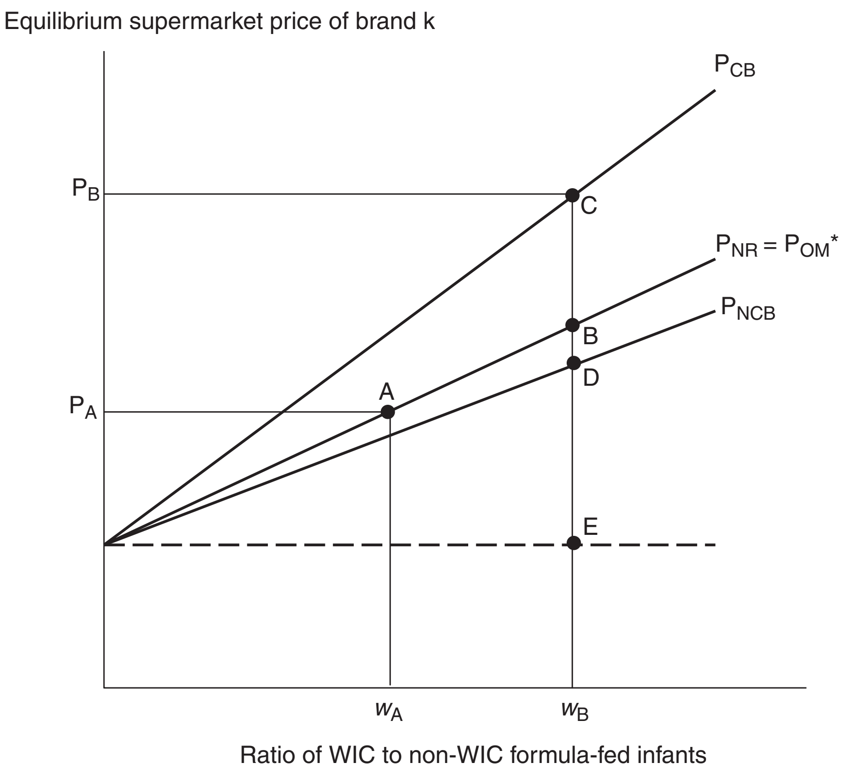
The value of the expression is negative whether δ equals 1 or zero and *h* is zero or positive. Because *db/dw* < 0 and the partial effect of *b* on P_1 is also negative, the out-of-pocket composition effect is positive. If δ = 1 the voucher effect and the out-of-pocket composition effect both work in the same direction, making the total effect of *w* on P_1 unambiguously positive.

If δ = 0, the effect of *w* on P_1 remains positive due to the out-of-pocket composition effect alone.

Evaluation of the second derivative (not shown) demonstrates that P_1 is convex in *w*. For some analyses, such as behavior towards risk, the curvature properties of a relationship between two variables is central. However, in the graphical analysis below, the major results of the WIC model can be portrayed most easily by treating the relationship between P_1 and *w* as approximately linear.

Graphical Illustration. Figure 1 illustrates the relationship between the equilibrium price and *w* on the graphical line labeled P_{NR} for "no rebate." When considering P_{NR}, the variable P_k on the vertical axis can be thought of simply as the equilibrium price of *either* brand in (12); the interpretations of other graphical curves in Figure 1 are considered below.

Figure 1
Retail prices vs. relative size of WIC under various contract systems



*One relationship between price and *w* is labeled both P_{NR} and P_{OM}, signifying that the same relationship exists whether no rebates are in effect or an open market contract is in effect (given that marginal cost of infant formula to supermarkets is held constant).

Source: Economic Research Service/USDA.

Along P_{NR} all other price-determining factors besides *w* are held constant. The slope of P_{NR} measures the price effect on P_k due to a marginal change in *w*. In general, the value of this price effect does depend on which brand is considered (inasmuch as θ_k in (12) can be brand specific).

The figure illustrates the price effects due to:

- the presence of the WIC program (under the counterfactual assumption of no rebates) relative to the absence of the WIC program;
- an increase in the size of WIC (under the counterfactual);

When considering the *presence* versus the absence of WIC, the relevant change is from a zero value of w to a positive value, say w_A. When considering an *expansion* of WIC, the relevant change is an increase in the value of w, say from w_A to w_B. In either case, the change in w results in a retail price increase. Of course, the magnitudes can differ, with a movement from the intercept to point A in the former case and from point A to point B in the latter case. However, the qualitative results—the direction of price effects—are the same for both cases.

Econometric Specification. The price regressions in the companion volume contain three independent variables of particular interest:

- median household income (I), as a measure of central tendency of the income distribution
- the poverty rate (R)
- the ratio of WIC to non-WIC formula-fed infants (w).[20]

The regression includes I and R to capture the effects of differences across out-of-pocket households of (income-dependent) price sensitivities and the relative frequencies of out-of-pocket households at various income levels.

As R increases, it is likely that the share of L out of all out-of-pocket households increases as well, increasing b in (11) and decreasing P_k. Although the income cutoff for R is (by definition) the poverty line and the income cutoff between the WIC model's low- and high-income populations is set above the income threshold at which a household qualifies for WIC (185 percent of the poverty line), R is used in the companion volume as a rough proxy for the overall shape of the income distribution within a market area.[21] The predicted sign for the regression coefficient on R is negative.

The inclusion of I in the price regression introduces an empirical element that the WIC model has not fully considered. As a simplified theoretical model, the WIC model sets but *two* values for price sensitivities, given by b_H and b_L , and focuses on the mix of L and H households as the varying determinant of the overall price sensitivity of the out-of-pocket households (in (11)).[22] However, in actual market areas, each household's level of income can vary, and each level of income may be associated with a particular value of price sensitivity: instead of just two price-sensitivity values of b_H and b_L there may instead be a range of many (unobserved) income-dependent values. Thus, the many possible levels of household incomes and price sensitivities and the frequency distribution of households together determine b, a market area's overall price sensitivity for out-of-pocket households.

The variables R and I together capture, as effectively as can be done with available data, the factors that influence b and the out-of-pocket composi-

[20]The same symbol w is used to designate both this ratio (for the regression analysis) and the WIC model's ratio of WIC to non-WIC formula-buying households. Strictly speaking, the two ratios do differ slightly to the extent that a household may have more than one formula-fed infant.

[21]Although R and I are likely to be (negatively) correlated, the inclusion of R in the regression does not capture how an area's low *median* household income results in a low price: R can only capture the role of income *distribution* inasmuch as the regression also contains I. If I were omitted, then the coefficient on R would measure the combined effects of low median income and of income distribution.

[22]These two values are set for any given value of D, the ratio of discount stores to population. As discussed, a change in D does change the price sensitivities to a new pair of values.

tion effect. If R and I were not included in the regression, the coefficient on w would measure a combination of the voucher effect and the out-of-pocket composition effect. Because R and I are included in the regression, the remaining role for w is to capture the voucher effect alone.

Effects of Relative Size of WIC, With Open Market Contract

In this section, let $\theta_k = a_k/(a_1 + a_2)$, $\delta = 1$, and $h = 0$. A marginal increase in w is considered given that manufacturers pay rebates under an open market contract.

The open market contract, even when it was in use, was never as predominant as the sole-source contract. Nevertheless, an open market contract is considered prior to the sole-source contract in order to separate as fully as possible the price effects of a *rebate system* from the price effects of a *sole-source contract*. A key feature that distinguishes a rebate system under an open market contract from a rebate system under a sole-source contract is that the open market contracts generate rebates *without* affecting the relative demands for different brands, while sole-source contracts channel all WIC demand to a single contract brand.

Under the open market contract, just as under the no-rebates counterfactual already considered, WIC households choose whether to redeem vouchers for either brand 1 or brand 2. Under the open market contract, θ_k in (12) are positive for both brands, equaling the same values of $a_k/(a_1 + a_2)$ introduced for the counterfactual. Because there is no single contract brand, the tag-along effect remains zero ($h = 0$). Given these common specifications for the values of θ_k and h, the value of the coefficient of w under the open market contract *matches* the value of the coefficient under the counterfactual, given by (14). Thus, the effect of a change in the relative size of WIC is the same regardless of whether WIC has no rebate program or WIC has a rebate program that uses open market contracts.

Effects of Open Market Contracts. In this section, let $\theta_k = a_k/(a_1 + a_2)$, $\delta = 1$, and $h = 0$. The effect of open market contracts *per se* is considered.

It is important to distinguish between two different questions:

- What is the price effect of a change in the relative size of WIC if there is an open market contract?
- What is the price effect of an open market contract (versus no open market contract)?

The first question has already been answered, and the answer involves the value of the *slope* of the relationship between P_k and w; the slope of the relationship happens to be the same with or without an open market contract. However, just because the slope is unaffected by the open market contract does not mean that *price* is unaffected. Price can be affected by the open market contract due to a change in:

- w, which changes the location of equilibrium price on a given curve; and

- marginal cost c, which changes the curve's location.

Thus, even though the same terms appear in (12) whether the counterfactual or open market contracts are considered, the values of two of the terms (w and c) may depend on which of the two scenarios is considered. Initially, marginal cost will be held constant, in which case any change in retail price due to the open market contract occurs along the same P_{NR} line associated with the no-rebate counterfactual. It is for this case that Figure 1 relabels P_{NR} as P_{OM} for "open market" contract.

Under the counterfactual no-rebate assumption, WIC is financed by Congressional appropriations alone. Suppose in this case that the relative size of WIC is w_A in Figure 1, with an equilibrium price of P_A on the line P_{OM}. Once rebates are received, suppose that Congress maintains the amount of appropriations steady—so that rebates fully supplement those appropriations—or that Congress lowers appropriations, but by less than the amount of the rebates. Either way, total WIC funding grows and the WIC program supports more participants.[23] To the extent that more infants participate in WIC as a result of the rebates, w increases (say to w_B) and retail price increases from P_A to P_B on P_{OM}, holding other factors (such as marginal cost) constant.

In this scenario, when WIC receives rebates from open market contracts, the relative size of WIC increases and price increases. Some analysts may therefore attribute the price increase to the rebates, concluding that the rebates "caused" a retail price increase. However, other analysts might attribute the price increase not to the rebate program *per se* but instead to the increase in the relative size of WIC. This alternative way of describing the price increase and its "cause" is based on the view that Congress can support any particular size of WIC it chooses—be it w_A or w_B—either by appropriations alone or by some mix of appropriations and rebates. In this view, Congress can achieve any particular w with or without rebates, making the relative size of WIC the only critical factor in determining retail prices. This view considers the method of financing—the mix between appropriations and rebates—to be important for *budgetary* considerations, but secondary (actually, ineffectual) in determining retail price at any *given* value for w.

Throughout the rest of this report the WIC model treats wholesale prices as exogenous, but here a relaxation of that assumption is considered. The graphical curve P_{OM} depends in part on marginal cost, which in turn depends on manufacturers' wholesale price. If manufacturers increase wholesale prices in response to the payment of rebates or to the relative size of the WIC program (which itself can depend on rebates, as just noted), then retailers' marginal costs rise, which would increase retail prices. Noting that marginal cost in (12) is a component of the intercept of P_{OM} in Figure 1, an increase in marginal cost would shift P_{OM} parallel upwards (not shown). In this case the lines P_{OM} and P_{NR} would differ, and retail price would be affected not only by any increase in w associated with rebates but also by the upward shift in P_{OM}. Having identified this possible repercussion from the rebate program on wholesale price, the remainder of this report returns to concentrating on retailer behavior and again treats wholesale prices as exogenous.

[23]An implicit assumption is that there had been eligible households with infants who are not participating in WIC that would participate if additional funding were available, so that an increase in total WIC funding is indeed associated with an increase in w.

Effects of Relative Size of WIC, With Sole-Source Contract

In this section, $\theta_1 = 1$, $\theta_2 = 0$, $\delta = 1$ and $h = 0$. Even though this section examines sole-source contracts, which means there is a single contract brand, the tag-along effect will be still be treated as zero; the tag-along effect is examined separately below.

There are four questions (each involving two prices) that will be answered in this section and the following two sections:

- What are the effects on contract and noncontract brand prices due to an increase in the relative size of WIC, given that a sole-source contract is in effect?
- What are the effects on the prices of a national brand serving as either the contract or noncontract brand as a result of changing from an open market contract to a sole-source contract, at a given *w*?
- What are the effects on a national brand's prices as it changes in contract brand status?
- What are the effects on the prices of a national brand serving as either the contract or noncontract brand as a result of changing from the absence of WIC (and its rebate program) to the presence of WIC and a sole-source contract?

Under the sole-source contract, the contract brand receives all of the WIC demand, making $\theta_1 = 1$, while the noncontract brand receives none of the WIC demand, making $\theta_2 = 0$. Given that $\delta = 1$ and $h = 0$, (12) becomes:

$$(18a)\ P_1^* = \frac{(ba_1 + sa_2)}{(M+1)(b^2 - s^2)} + \frac{M}{(M+1)}c_1 + \frac{bvz}{(M+1)(b^2 - s^2)}w$$

$$(18b)\ P_2^* = \frac{(ba_2 + sa_1)}{(M+1)(b^2 - s^2)} + \frac{M}{(M+1)}c_2 + \frac{svz}{(M+1)(b^2 - s^2)}w$$

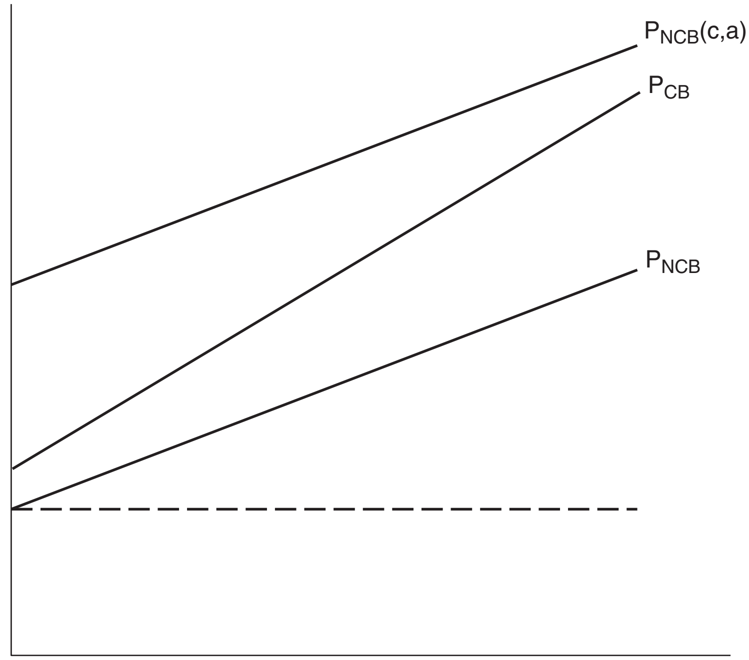
Figure 2 makes a comparison of price curves for two *different* national brands: the P_{CB} and P_{NCB} curves refer, respectively, to the curves for the contract brand (e.g., Mead-Johnson) and the noncontract brand (e.g., Carnation). The figure shows that the intercept of P_{CB} is above the intercept of P_{NCB}; the reverse is true for the intercept of the curve $P_{NCB}(c,a)$, which will be considered below. Difference in intercepts could be due to a difference in non-price brand preferences, as measured by a_1 and a_2, to a difference in the marginal costs of the two brands, or both.

In Figure 2, P_{CB} has a positive slope, which reflects the coefficient on *w* in (18a). Given that brand 1 receives all WIC demand, it is intuitive that an increase in *w* results in an increase in P_1.

One might at first expect that an increase in the size of WIC will have *no* effect on the price of the noncontract brand, which receives none of the

Figure 2
Retail prices vs. relative size of WIC for two national brands

Equilibrium supermarket price of Brand K



Ratio of WIC to non-WIC formula-fed infants

Source: Economic Research Service/USDA.

WIC demand (either before or after the increase in the relative size of WIC). If there is no WIC-related price effect on the noncontract brand, its price curve would be the (unlabelled) horizontal dashed line. What is perhaps unexpected is that the price curve for the noncontract brand is given by P_{NCB}, which lies above the horizontal line. According to (18b) and its graphical illustration as P_{NCB}, an increase in the relative size of WIC results in an increase in the price of the noncontract brand P_2.

The mechanism by which w affects the price of the noncontract brand is through the demand substitution behavior of the *non-WIC* households. An increase in w results in profit-maximizing supermarket chains establishing a higher P_1 along P_{CB}, and (at least some) non-WIC households respond to this increase in the price of brand 1 by switching demand to brand 2 (strictly speaking, the price sensitivity of demand for brand 2 must be affected, not merely the scale or size of demand). Supermarket chains respond to the change in the demand for brand 2—which was caused by their very own increase P_1 in the first place—by increasing P_2.[24]

As mentioned previously, one of the powerful features of the WIC model is that it permits (but does not require) substitution behavior between brands. In (2), the parameter that captures the extent to which non-WIC households substitute between brands within the supermarket sector is s, which appears in the numerator in (18b). If non-WIC households do not substitute at all between the brands, then $s = 0$ in (18b) and the price curve for the noncon-

[24]If a *nonequilibrium* situation were being examined, the increase in the price of brand 2 would result in (at least some) non-WIC consumers switching to brand 1, resulting in nudge up in the price of brand 1 and a nudge down in the price of brand 2, which would result in a further chain of effects between the prices of the two brands (with each link in the chain growing progressively smaller). However, an advantage of the formal mathematical approach used by the WIC model is that it examines the equilibrium outcome of that entire process (through the *simultanteous* determination of the prices of the two brands), so that the entire sequence or chain of interactions between the two brands results in a final outcome that is portrayed in (14) and Figure 2. The changes in the equilibrium prices P_1 and P_2 already take into account all the interactions.

tract brand would be represented by the dashed horizontal line. The P_{NCB} curve in Figure 2 assumes that $s > 0$. This report adopts that assumption hereafter. The econometric analysis in Oliveira et al. subjects this assumption to a statistical test.

There is a difference between the positive slopes of P_{CB} and P_{NCB} because b appears in (18a) and s appears in (18b). The closer s is to b—the better brand 2 can substitute for brand 1—the closer P_{NCB} comes to being parallel to P_{CB}, making the price effect of w on the contract and noncontract brands more similar. The WIC model stipulated that $b > s$, making P_{CB} steeper than P_{NCB}.

Figure 2 illustrates one additional curve labeled $P_{NCB}(c,a)$, where the notation emphasizes how marginal cost and non-price brand preferences affect the location of the price curve. In contrast to P_{NCB}, $P_{NCB}(c,a)$ is located above rather than below P_{CB}. As price curves for a noncontract brand, $P_{NCB}(c,a)$ and P_{NCB} share a common slope (which is exceeded by the slope of P_{CB}). Figure 2 shows the price effect due to a change in w is greater for the contract brand than for the noncontract brand regardless of whether the contract brand's retail price is high or low relative to the noncontract brand's retail price (i.e., regardless of whether the noncontract brand's price lies on $P_{NCB}(c,a)$ or P_{NCB}).

Oliveira et al. found that, within market areas, there is not a clear and consistent relationship between a formula's being the WIC contract brand and that formula being sold at the highest average retail price. However, comparing the retail prices of contract and noncontract brands of formula does not necessarily identify WIC-related price effects since *other factors may affect retail prices*. Retail prices of two national brands do reflect the relative size of WIC and which of the two national brands holds the rebate contract. But retail prices also reflect non-price brand preferences and marginal cost. While non-price brand preferences are not measured empirically, differences across national brands in wholesale prices are measurable. A comparison of P_{CB} and P_{NCB} shows how a particular national brand can be the contract brand in a market area and have a higher retail price than a noncontract brand due to a relatively high wholesale price for the contract brand. In contrast, the expectation that the contract brand has the highest retail price would not be met if P_{CB} is compared with $P_{NCB}(c,a)$. Due to a relatively low wholesale price, a national brand associated with P_{CB} has a retail price below the noncontract brand price on $P_{NCB}(c,a)$. The empirical analysis in Oliveira et al. is designed to separate the retail price effects due to contract brand status from the effects due to wholesale prices.

Contract Systems, Contract Brand Effects, and Distribution Systems

Effects of Sole-Source Contracts Compared With Open Market Contracts. In this section, $\delta = 1$ and $h = 0$ and a comparison is made between $(\theta_1, \theta_2) = (1, 0)$ and $\theta_k = a_k/(a_1 + a_2)$.

This section begins with a comparison of retail prices under a sole-source contract with retail prices under an open market contract. A key difference between the two types of contracts is whether WIC households can select between brands 1 and 2 or if WIC households must purchase a single contract brand.[25] Then the section examines how retail prices compare between a sole-source contract and the absence of the WIC program.

Returning to Figure 1, the curves P_{CB} and P_{NCB} straddle the curve P_{OM}, radiating from the same intercept. Now the interpretation of Figure 1 is that it applies to any single national brand under varying conditions. Under an open market contract, the retail price of the national brand is at point B, given w_B. Suppose that a sole-source contract is adopted instead of an open market contract, and the national brand is awarded the rebate contract. The price effect of a sole-source contract for the contract brand, relative to an open market contract, is to increase retail price from point B to point C. The reason for this price increase is *not* due to a "rebate system" per se: the open market contract also generates rebates. Instead, the movement from point B to point C is because the share of WIC demand received by the given national brand increases from a fraction, given by $a_k/(a_1 + a_2)$ under the open market contract, to 100 percent.

Suppose instead that a sole-source contract is adopted instead of an open market contract, and the national brand is not awarded the rebate contract, becoming the noncontract brand. The price effect of a sole-source contract for the noncontract brand, relative to an open market contract, is to decrease the retail price from point B to point D. The reason for this price decrease for the noncontract brand is that its share of WIC demand drops from a fraction (under the open market contract) to 0 percent. Even though the national brand loses its fractional share of WIC demand, its retail price does not drop from point B to the dashed horizontal line at point E. The demand substitution from the contract brand to the noncontract brand exhibited by non-WIC households helps sustain the retail price of the noncontract brand, making the decrease in its retail price smaller than would be the case if there were no substitution behavior.

Effects of Contract Brand Status. In this section, $\delta = 1$ and $h = 0$ and a comparison is made between $\theta_k = 0$ and $\theta_k = 1$ for a given manufacturer's brand.

Given that a sole-source contract is in effect, the price effect for a national brand changing status from noncontract to contract is represented by a move from point D to point B; alternatively, the move from point B to point D represents the price effect of changing status from contract to noncontract. These changes are the price effect of a change in *contract brand status*. The price effect of contract brand status depends on the relative size of WIC. If w is small, the contract brand status makes little difference in a national brand's retail price, whereas if w is large, the change from contract to noncontract status—from having all of the WIC demand to having none of the WIC demand—results in a large price effect.

[25]A second difference between open market and sole-source contracts can be important in practice. Although both types of contracts generate rebates, historically the amount of rebates obtained from a sole-source contract is larger than the amount from an open market contract. This difference in turn could affect w and therefore retail prices. However, since the theoretical effects of rebates were already identified in the discussion of the open market contracts, it will be assumed hereafter that the rebate levels of the open market and sole-source contracts are the same. This assumption is adopted to concentrate on the effect that results from channeling all WIC demand to a single contract brand, holding other factors constant. The size of the differences in rebates may be of great importance in a practical comparison between the two types of contracts.

Effects of Sole-Source Contract Compared With the Absence of WIC. In this section, let $(\theta_1, \theta_2) = (1, 0)$, $\delta = 1$, and $h = 0$.

The answer to a simple question such as "What are the price effects of sole-source contracts?" depends on what conditions are being compared with the sole-source contracts. One alternative condition to a sole-source contract, considered above, is an open market contract. This section examines a condition in which WIC and its rebate program are absent.

Figure 1 shows that in the absence of WIC w is 0, resulting in a retail price of the national brand at the intercept or, equivalently, at point E. If the WIC program is adopted and a sole-source contract is used, the effect on the retail price of the national brand depends of course on whether the national brand is awarded the WIC contract or not. Retail price increases from E to C for the contract brand, while retail price increases only from E to D for the noncontract brand.

In this section, the price effect of a sole-source contract—compared with the absence of WIC—is to increase the retail price of formula for *both* the contract (E to C) and noncontract brands (E to D). As previously noted, the price effect of a sole-source contract—compared with an open market contract—is to increase the retail price of the contract brand (B to C) and *decrease* the retail price of the noncontract brand (B to D). The seemingly simple question "What are the price effects of using a sole-source contract?" results in two answers that have different magnitudes and even different signs. This is but an example of the general principle that it is important to identify the alternative condition when investing the theoretical or empirical effect of a change in policy, economic, or demographic variables.

Tag-Along Effect. In this section, let $(\theta_1, \theta_2) = (1, 0)$ and $\delta = 1$. A comparison is made between $h = 0$ and $h > 0$.

The tag-along effect, the composite of the medical promotion effect and the shelf-space effect, represents certain demand-shifting behaviors that favor the contract brand at the expense of the noncontract brand. Reintroducing a positive h shows that the tag-along effect *enhances* the positive effect w has on the contract brand's P_1, entering the numerator of (18a) positively, but (partially) *offsets* the positive effect w has on the noncontract brand's price P_2, entering the numerator of (18b) negatively.

Qualitatively, Figure 1 is not affected the tag-along effect. If the tag-along effect is present, the price effect of a change in w is greater for the contract brand and smaller for the noncontract brand, creating a gap in Figure 1 between the P_{CB} and P_{NCB} curves that widens more quickly.

The price regressions in Oliveira et al. have no separate measure for the tag-along effect, which is simply treated as a fixed parameter and absorbed into the regression coefficients on w.

Alternative Distribution Systems. In this section, a comparison is made between $\delta = 0$ and $\delta = 1$, given that $\theta_1 = 1$ and $\theta_2 = 0$.

If a WIC State agency does not use the retail food delivery system to distribute WIC formula, WIC consumers obtain formula either by the direct distribution system (as in Mississippi) or the home distribution system (as in Vermont). Alternative distribution systems involve contracts between State WIC agencies and manufacturers but the contracts do not, strictly speaking, involve rebates from manufacturers. Instead, State WIC agencies purchase directly from the manufacturer. Nevertheless, direct distribution and home distribution strongly resemble a rebate system in that they are all designed for cost-containment.

Under direct distribution or home distribution, a marginal change in the relative size of WIC (or the presence of WIC vs. the absence of WIC) increases retail prices due to the out-of-pocket composition effect alone, which operates through changes in b. WIC "removes" low-income households from the general market, but the voucher effect is absent because WIC does not "add" these same WIC households back into the retail food delivery system. In this case, $\delta = 0$ in (12), canceling the term that contains w explicitly, and setting the partial derivative in (15) to 0. The out-of-pocket composition effect is still positive, but because the voucher effect does not augment it, the retail price is lower than it would be if the retail food delivery system were used, holding other factors constant.[26]

[26]While it might be thought that a lower retail price is desirable (from a consumers' perspective), a State that uses direct distribution or home distribution bears the administration costs of operating the State's formula distribution system, and such costs must be funded somehow. An assessment of the many pros and cons of adopting alternative distribution systems is beyond the scope of this report.

The empirical analysis in Oliveira et al. focuses on price data from market areas in which the retail food delivery system is used.

Effect of Market Structure Conditions

Discount Stores. Another factor that affects retail price is a household's ability to buy formula at discount stores. It was discussed earlier how an increase in D, the ratio of the number of discount stores to total population, can be expected to increase the price sensitivity of demand for supermarket formula, as measured by b. An increase in b, in turn, decreases P_k. In addition, an increase in D and the convenience of discount stores to WIC households may lower v, the fraction of formula WIC households receive in supermarkets, thus decreasing P_k further.

Concentration (M). An increase in M, the number of (equally sized) firms, lowers *concentration* whether concentration is measured by the Herfindahl-Hirschman Index, the four-firm concentration ratio, or any other measure of concentration. As in the Cournot model, if $M = 1$, the result in the WIC model is a monopoly outcome (although here it is an outcome associated with *one* monopoly supermarket chain pricing *two* interdependent brands). As M increases without limit, concentration falls, market output and price approach the outcome of a perfectly competitive market in which price equals marginal cost (for each brand). Thus, in the WIC model an increase in M is associated with a decrease in price (for each brand), just as in the Cournot model.

Oliveira et al. considers how an increase in concentration may be associated with a decrease (rather than an increase) in the retail price of infant formula, but that discussion lies outside the scope of this report.

Summary of Econometric Specification

An econometric specification that is consistent with the WIC model is given by:

$$(19)\ P_{i,t}^{k} = \beta_0 + \beta_1\left(CB_{i,t}^{k}\right)*\left(w_{i,t}\right) + \beta_2(1 - CB_{i,t}^{k})*\left(w_{i,t}\right) + \beta_3\left(WC_t^{k}\right)$$
$$+ \beta_4\left(D_{i,t}\right) + \beta_5\left(HHI_i\right) + \beta_6\left(I_{i,t}\right) + \beta_7\left(R_{i,t}\right) + \varepsilon_{i,t}$$

where

- $P^{k}_{i,t}$ represents the retail price of brand *k* formula in market area *i* in time period *t*;
- $CB^{k}_{i,t}$ represents a dummy variable that equals 1 if brand *k* is the contract brand in market area *i* in time period *t* and equals zero otherwise;
- $w_{i,t}$ represents the ratio of WIC to non-WIC formula-fed infants in market area *i* in time period *t*;
- WC^{k}_{t} represents the wholesale cost for brand *k* in time period *t*;
- $D_{i,t}$ represents the number of discount stores relative to population in market area *i* in time period *t*;
- HHI_i represents the *M*-firm Herfindahl-Hirschman Index for market area *i* in 2000;
- $I_{i,t}$ represents median household income in market area *i* in time period *t*;
- $R_{i,t}$ represents the poverty rate for market area *i* in time period *t*;
- $\varepsilon_{i,t}$ represents an error term

It is expected that $\beta_1 > 0$, measuring the price effect on the contract brand of a change in *w*, and that $\beta_2 > 0$, measuring the price effect on the noncontract brand of a change in *w*. It is also expected that $\beta_3 > 0$, $\beta_4 < 0$, $\beta_5 > 0$ (based on the WIC and Cournot models), $\beta_6 > 0$, and $\beta_7 < 0$.

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Appendix: WIC Model Symbols

M the number of supermarket chains in a local market area

c_k marginal cost to the supermarket chain for formula brand *k* (*k* = 1, 2)

$C_{k,i}$ total cost of brand *k* (*k* = 1, 2) for chain *i* (*i* = 1,...,M)

$q_{k,i}$ quantity of brand *k* formula sold by chain *i* (*i* = 1, ..., M)

N the number of households in a local market area that use formula

H high-income households, used to represent both their number and their type

L low-income households, used to represent both their number and their type

$q_{k,j}$ quantity demanded for brand *k* formula (*k* = 1, 2) by type j households (*j* = *L, H*)

P_k supermarket price for brand *k* formula (*k* = 1, 2)

a_k price-independent demand parameter (intercept) for brand *k* formula

u demand parameter that measures the tag-along effect

b_j own-price demand parameter (slope) for type j households (*j* = *L, H*)

s cross-price demand parameter

z a household's saturation level of formula (and the WIC allocation)

$q_{k,W}$ quantity demanded for brand *k* formula (*k* = 1, 2) by WIC households

v the fraction of vouchers that a representative WIC household redeems in supermarkets

θ_k the share of supermarket formula demand by a representative WIC household that is provided by brand *k* formula (*k* = 1, 2)

δ dummy variable that equals 1 if WIC formula is distributed through the food delivery distribution system and zero otherwise

Q_k Market demand for the supermarket sector for brand *k* formula (*k* = 1, 2)

A_k market-level term equaling $(H + L)a_k$

U market-level term equaling (H + L)u

B market-level term equaling $Hb_H + Lb_L$

S market-level term equaling (H + L)s

Q_W market-level WIC demand for all formula

D the ratio of the number of discount stores to total population

h a constant of proportionality relating U to Q_W

α a derived parameter

β a derived parameter

γ derived parameter

Y the number of non-WIC households

w the ratio of WIC to non-WIC households that buy formula

b the group-weighted average of price sensitivity terms b_H and b_L, if WIC is present

b_0 the group-weighted average of price sensitivity terms b_H and b_L, if WIC is absent