Impact of the WIC Program on the Infant Formula Market

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Abstract

Since 1972, the Special Supplemental Nutrition Program for Women, Infants, and Children (WIC) has provided free infant formula to low-income families. Today, infant formula purchases through the WIC program account for roughly half of all infant formula purchased in the United States. Beginning in the late 1980s, WIC agencies, in an effort to contain rising program costs, secured rebates from formula manufacturers through sole-source contracts for the infant formula they purchase. During 1980-2002, infant formula did not substantively change but real wholesale prices nearly doubled. This research examines the impact of providing free formula through the WIC program and its use of sole-source contracts to control program costs on the wholesale price of infant formula. The findings show that providing free formula to low-income families is the primary factor in the growth in real wholesale prices of formula and that sole-source contracts not only have reduced the cost of formula to the Government but also have retarded wholesale price growth.

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Executive Summary

From 1980 to 2000, the real wholesale price of infant formula almost doubled even though the formula being marketed remained substantially the same during this period. The consequences of these events had significant impacts on the budgets of families with infants as well as the federal government's efforts to provide formula to low-income mothers through the Special Supplemental Nutrition Program for Women, Infants, and Children (WIC). In 1990 and again in 1991, the Senate committee on Antitrust held hearings on the rising cost of infant formula. Senator Metzenbaum asked what he felt all parents were asking, "why is the price of formula so high?" This research attempts to determine what factors have lead to the escalation of the wholesale price of formula.

As Senator Metzenbaum noted in the 1990 hearing, the infant formula market is oligopolistic. During the 1980s and 90s, formula was produced and marketed by three and, for a limited time, four firms. Existing formula manufacturers were able to compete for market share on factors other than price. While a lack of competition may justify high prices, they do not explain the increase in the real price of formula over this period. As the senator noted, the real cost of the primary input of formula did not change over the 1980s, nor were there any significant changes in the number of firms. While manufacturers did market new formulas for niche markets, the predominant infant formula remained unchanged during this period. Consequently, changes in the demand must have taken place to explain the increasing real price of formula. In 1980, roughly one out of five mothers participated in the WIC program and would receive their infant formula free of charge. By 2002, roughly one out of two mothers participated in the WIC program. The expansion of the WIC program has fundamentally altered the demand for infant formula by both increasing the demand for formula and making the demand less sensitive to changes in prices. In the presence of a lack of price competition, manufacturers have been able to translate these changes in demand for their product into higher prices.

In 1972 the WIC program was implemented and through outreach efforts participation in the program has steadily grown until 1999 when it reached a plateau of serving one out of two infants. The steady growth in program participation compounded with rising formula prices created fiscal pressures on WIC agencies to contain the costs of the infant formula portion of the WIC program. The most successful efforts found by state agencies were to secure rebates from infant formula manufacturers through sole source contracts. The formula manufacturer offering the lowest net formula price (wholesale price minus a rebate) would be awarded a contract to be the sole brand for all of the WIC recipients in the state. The sole source contracting procedure was first used by several states in 1986 and was later mandated to be used by all states in 1989. But it was not until 1994 that all states had adopted the sole source contract.

In the Senate hearings, concern was raised that rebate program may contribute to even higher formula prices as the manufacturers attempt to recoup the cost of the rebates. In the two-year period of 1989 and 1990, formula manufactures increased formula prices in percentage terms twice as fast as in the prior two-year period. Given that this was the time period when the federal government had mandated the use of sole source contracts by state agencies, suspicion was raised that families not participating in the WIC program were subsidizing the rebate program. Although a 1998 GAO report failed to conclude that there was sufficient evidence to draw any conclusions, suspicion remained that the rebate program, while successfully reducing the cost of the WIC program, had an adverse effect on higher income families not being served by WIC.

To examine the separate impact of providing free formula to low-income families and the use of the sole source rebate program to contain program costs, we employ both theoretical and empirical approaches. The theoretical model assumes the formula manufacturer has a significant degree of market power that is the result of both barriers to entry to the market and the demand faced by the firms. We posit that mothers will be sensitive to the price of formula when deciding the extent to which they will bottle feed their infants. However, we will assume that mothers decide which brand of formula to use based upon factors other than price of formula such as advice that they receive from friends, family and health care professionals.

Finally, the model assumes, in the absence of the WIC program, the demand for the firm's product is composed of two types of mothers. One type of potential infant formula consumer represents low-income mothers whose demand for formula will be more sensitive to the price than high-income mothers. When the WIC program is implemented, low-income mothers will be eligible to participate and receive vouchers redeemable at retail stores for infant formula. As more low-income mothers participate in the WIC program, the overall price elasticity of demand for infant formula should fall allowing firms to charge higher prices for their product. Consequently, in the absence of the rebate program, the rise in the wholesale price of formula is a reflection of a steadily declining price sensitivity of demand for formula created by the rise in participation of the low-income mothers in the WIC program.

With the advent of the sole source rebate program, formula manufacturers faced a new set of market conditions in which, if they were to continue to sell to mothers participating in the WIC program, they would have to compete directly on price for the WIC market. The theoretical model assumes that the existing firms set their wholesale price and their rebate bid in the sole source auctions to maximize their expected profits where each firm is assumed to be able to form a subjective probability of winning the contract that is inversely related to the net price (wholesale price minus the rebate) they bid. Winning the contract results in expanding their sales of formula to WIC mothers, however, at a smaller net average revenue for the sales to WIC mothers. Win or lose the contract, the firm will hold onto their sales to mothers who pay for their formula (non-WIC mothers and mothers who are eligible for WIC but have chosen not to participate in WIC).

The theoretical model predicts that, compared to a situation where the WIC program exists but it has not implemented a rebate program, the implementation of a sole source rebate program will induce the firm to lower its wholesale price. The explanation for this result is the following. The rebate program creates the opportunity and necessity for the firm to recognize that it is selling its product to two distinct populations: those mothers who are paying for the formula and those mothers for whom the government is paying for the formula. Given, that the sole source contract is given to the firm who bids the lowest net price, not the greatest rebate, the firm has an incentive to set the wholesale price at a level that maximizes the profits from the group of mothers that pay for their formula and offer a rebate that will maximize the expected profits from WIC mothers. The model shows these decisions are separable. The demand from those mothers not participating in WIC will be more price sensitive than the demand the firm would have faced in the absence of the rebate program (combined demand from WIC and non-WIC mothers). Consequently, we would expect the wholesale price with the rebate program to be lower than what it would be in the absence of the rebate program. However, the wholesale price with the rebate program exceeds what it would be if the WIC program did not exist and all mothers had to pay for their formula.

In bidding for the WIC contract, the firm offers a rebate that reflects a balance between the marginal change in the expected profits due to an increased probability of winning the contract and the marginal change in the expected profits due to lower average profit margin from offering a larger rebate. From a theoretical perspective, the pricing of formula sold through the WIC contract follows an inverse elasticity relationship just as did the rule that governed the setting of the wholesale price of formula. Traditional theory predicts that a firm with market power will set the price so that the potential profit margin (price minus marginal production costs) as a percentage of the price of the good is equal to one over the price elasticity of demand of its customers. When determining its rebate for the WIC contract, the firm will set the net price so that the profit margin (price minus rebate and marginal production costs) as a percentage of the net price (price minus rebate) will equal one over the elasticity of the probability of winning the contract with respect to the net price. The elasticity of the probability with respect to the net price bid by the firm should reflect the competitiveness of the bidding process where more competitive bidding would be reflected in a higher elasticity and consequently a lower profit margin.

The theoretical model provides insights about the relationship between the size of the rebate offered by the firm and other variables of interest. As we have previously noted, the firm determines the level of rebate to reflect a desired net formula price (wholesale price minus the rebate) that will be chosen independent of its wholesale price. Consequently, if the firm increases its wholesale price, then we would expect to raise its offered rebate by equal amount.

Smaller states have felt that they had not been able to acquire the same level of rebates that large states could in their sole source contracts. The theoretical model suggests that the size of the WIC contract will have no effect on the size of the rebate offered by the firm. This implication is the result of assuming that the probability of winning the contract is independent of the size of the contract. If a larger WIC contract induces more firms to bid and consequently lowers the probability of the firm's chances of winning the contract, holding the net price constant, the firm will be induced to raise its rebate offer.

Our empirical examination of the role the role WIC plays in the infant formula market utilizes two sets of data. To examine the impact of WIC on wholesale prices, we analyzed the wholesale prices of Mead Johnson and Ross Labs for milk-based infant formula in both concentrated and powdered formulations during the period of 1981 through 2002. The second data set used in the study is composed of the bids by these two companies from all of the sole source contract competitions held during the period. We chose to focus upon Mead Johnson and Ross Labs because their combined sales represents roughly 85 percent of all formula sales. We conclude our analysis with data from 2002, the year that enhanced formula arrived in the market, to maintain a homogenous product for comparison.

The empirical examination of the impact of the WIC program on wholesale formula prices benefits from the existence of four periods differentiated by stages of the implementation of the WIC program over this twenty-two-year period. From 1980 to 1987, the sole source rebate program didn't exist but there was steady growth in the proportion of infants participating in the WIC program. From 1987 to 1994, the growth in WIC participation continued with the gradual implementation of the sole source rebate program. By 1994, all states had implemented the sole source rebate program but growth in participation continued. By 1999, participation had reached a plateau and both aspects of the WIC program found a steady state in terms of their implementation. To parameterize the extent to which WIC provides free formula to mothers, we utilized a variable reflecting the percentage of all infants participating in the WIC program. The rebate program was captured by a time-varying variable reflecting the percentage of WIC infants whose formula was purchased by a sole source contract. The empirical analysis of the time series of wholesale prices also controlled for the number of infants, breastfeeding rates, price of milk, and the composition of other competing formula manufacturers.

As our theoretical model predicted, increasing the proportion of low-income infants participating in the WIC program in the absence of the rebate program should allow formula manufacturers to charge higher prices for their product. The empirical results suggest that, for every percentage point increase in the participation rate of infants in WIC, the real wholesale price increases by 2.5 percent. The theoretical negative impact of the rebate program on prices was found in our empirical analysis of wholesale prices. The estimated effect was that, for a percentage point increase in the number of WIC infants covered by a sole source contract was associated with a .22 percent point reduction in the real wholesale infant price. In 2002, the rebate program covered 92 percent of WIC infants. Consequently, our model predicts that if the sole source rebate had never been implemented, the real wholesale price would be 20.4 percent higher.

Today, 47.6 percent of all infants participate in the WIC program. To estimate the impact of the WIC program's provision of free formula, we would want to know what would be the wholesale price today if in 1972 we had not implemented a WIC program. If there was not a WIC program, it is doubtful that the government could have implemented a rebate program. Our empirical estimates suggest that real formula prices have doubled (100-percent increase) over what they would have been in the absence of the program. If the government had not implemented the rebate program, the real price of formula would have been 120 percent higher than in the absence of WIC.

Using the estimates from the empirical model, the predicted real wholesale price of formula rose by 60.2 percent over the twenty-one-year period. In 1981, 16.8 percent of all infants participated in the WIC program and the rebate program was not in existence. If the WIC program had not expanded (participation rate remained at 16.8 percent) and the rebate program had not been implemented, then the real prices of formula would have increased by 5.3 percent, accounting for all changes in all other factors (number of infants, breastfeeding rates, price of milk, and competition in the industry). Consequently, the WIC program accounts for 91 percent of the increase in the growth of real formula prices during this period.

The second data set examined was the bids by Mead Johnson and Ross Labs on the 117 sole source contracts during the period studied. The important implication of the theoretical model was that the firm's decision to set the wholesale price and rebate offers in the sole source solicitations were separable. If the firm chose to raise its wholesale price by $1 it would raise its rebate offers by $1 in order to keep the net price to the government unchanged. Based upon the bids made by Mead Johnson and Ross Labs during this period, we found statistically significant confirmation of the theoretical model's implications of the relationship between wholesale prices and rebates.

While we found that the patterns of rebates offered in initial solicitations differed from subsequent solicitations of rebates, the rebates proposed by Mead Johnson did not differ from Ross Labs' rebates. In addition to controlling for the real wholesale price, in our analysis, we controlled for the size of the contract, the number and composition of bidders, and in the case of subsequent solicitations, the firm who held the current contract.

Small states have been concerned that they have been unable to receive similar sized rebates that larger states were receiving. While we found statistical evidence confirming their concern, the elasticity of the rebates offered by Mead Johnson and Ross is quite inelastic – a ten-percent increase in the size of the contract produces a less than one-percent increase in the size of the rebate. We found that states that banded together to request a single solicitation received rebates that were statistically equivalent to rebates received by a single similarly sized state.

When examining the rebate bid in subsequent solicitations, we found that who holds the current contract is an important determinate of the rebates offered by Mead Johnson and Ross Labs. When firms with a minority market share (Wyeth and Nestle) held the current contract, Mead Johnson and Ross Labs aggressively bid for the contract by offering rebates that were 3.3 percent higher than what they would have bid if one of them had held the current contract. If one of the firms with a dominant market share held the contract, then the 'Big Two' firm not holding the contract would offer a rebate that was 2.7 percent lower than it would have bid if it had held the contract. This behavior can be interpreted as either bidding to hold on to a contract you have or being differential to the other major market player.

Our examination of the impact of the number and composition of bidders produced mixed results. If only the major market firms bid on a contract, there is only a statistically insignificant increase in the rebate than if both firms bid instead of only one of them. While this result is not surprising, the participation of the minority market share firms created a rather puzzling result. In the initial solicitations, as more of the minority firms participated, the rebates offered by Mead Johnson and Ross Labs fell. In subsequent solicitations, if either Wyeth or Nestle participated, the bids from the 'Big Two' fell. But if both Wyeth and Nestle participated, then the bids of Mead Johnson and Ross Labs were not statistically different from what would have been bid if neither Wyeth nor Nestle had bid. The puzzling effect of the smaller market share firms on the bids of Mead Johnson and Ross Labs remains a result that requires explanation.

"We want to know what many American mothers and fathers undoubtedly want to know. Why are infant formula prices so high?"

Senator Howard Metzenbaum (1990)

Introduction

In 1990 and again in 1991, the Senate Subcommittee on Antitrust, Monopolies and Business Rights of the Judiciary Committee held hearings investigating the pricing policy of companies marketing infant formula. The Senators as well as witnesses expressed concern with the impact of the rising formula prices was having on the budgets of families with infants. Concern was expressed over the increased cost of Special Supplemental Nutrition Program for Women, Infants and Children (hereafter referred to as the WIC program). Senator Metzenbaum noted that wholesale prices over the 1980s had risen by more than 150 percent far outstripping the increases in other consumer goods including food but more importantly in his mind, the prices of inputs such as milk. Over the same time period, the Senator noted that the price of milk had only risen by 36 percent.

In the Senator's mind, the reason for the rising real price of infant formula was clear – a lack of true competition in this sector of the economy. To substantiate their views, the critics of the industry noted that two firms, Ross Labs[1] and Mead Johnson both subsidiaries of pharmaceutical companies, sold over 85 percent of all infant formula. The remaining share of the market was sold by Wyeth a subsidiary of American Home Products. This highly concentrated industry was accused of 'cozy' pricing where no one firm attempted to raise its market share by lowering its price but was characterized

[1] Ross Labs is now called Abbott Nutrition but for this report we used the time appropriate name of Ross Labs.

by one firm taking the lead in raising prices and other firms joining in lock step. Senator Metzenbaum noted 'if this isn't oligopolistic pricing, then this Senator has never seen it.'

Noncompetitive behavior was also seen by the Senator in the response of the formula manufactures to cost containment initiatives in the WIC program. Beginning in 1986, state agencies implemented competitive bidding procedures for those companies wishing to supply formula to families participating in the program. During this time, companies offering the largest rebate on formula would be awarded the contract to supply all of the formula to the state's participants. In 1989, the average rebates were roughly $1.50 per can of 13 ounce of liquid concentrate. In March of 1990, Mead Johnson announced that it would not bid more than 75¢ per can. In the subsequent state competitions, rebates of 75¢ per can become the standard bid for all firms.

While the Senate hearings provide the most public documentation of the concern with the lack of competition in the infant formula market, the Federal Trade Commission (FTC) and nineteen States Attorney Generals sued the formula manufacturers during the period of 1990 through 1996. After the Senate hearings in December 1990, the FTC subpoenaed the records of three major formula firms: Ross Labs, Mead Johnson and Wyeth. Although the FTC did not charge the firms of engaging in price fixing, in January of 1992 Mead Johnson entered a consent agreement where they pledged to refrain from pre bid communications, direct advertisement of their product and to provide the USDA with 3.1 million pounds of powdered formula for distribution in the US or in humanitarian efforts abroad.

Simultaneously, states began to bring suits alleging that price fixing and the marketing strategies of the firms were driving up the cost of WIC program. The

Florida States Attorney General based their case on the companies' marketing scheme of paying doctors and hospitals to endorse their formula to their patients. In January 1993, Mead Johnson agreed to pay $4 million and Wyeth $1 million to settle the suit without admitting to any wrongdoing. In other civil cases, the plaintiffs alleged that the companies conspired to fix prices by forming the Infant Formula Council in order to share pricing and marketing information and to limit competition by agreeing to market their product only directly to doctors and hospitals. This period of civil litigation ended in 1996 with Ross Labs agreeing to pay seventeen states a total of $32.5 million while not having to admit to any wrongdoing.

Regardless the cause, the rising real price of formula was having an effect on the household budgets of young families whose mothers who were returning to work and relied upon formula as a substitute for breastfeeding. The government and taxpayers were also feeling the effect of rising formula prices. The WIC program that provides formula to low-income infants whose mothers do not exclusively breastfeed was especially feeling the pinch of the rising prices. While infants represent roughly one quarter of the participants of the program, the supplements given to them represent over 50 percent of the total costs of the program. The rapid rise in formula prices during the 1980s forced Congress with the dilemma of restricting the number of women, infants and children being served by WIC or raising the budget to pass on the rising costs of the program to the taxpayers.

The primary question we will focus upon is the question that Senator Metzenbaum asked – why are formula prices so high? After an examination of the evidence, we will conclude that real formula prices have increased as the result of the government's policy of providing formula to low-income families through the WIC program. Today, the government pays for over 50 percent of the formula consumed in the United States by families whose demand for formula in the absence of this program would be the most sensitive to the formula price. When the government provides formula to these families, the effect is to increase the total demand for formula and create a total demand for formula that is less sensitive to price. Consequently allowing firms with market power to charge a higher price for infant formula.

We will also examine whether the cost containment activities of the government instituted through a competitive bidding process contributed to rising wholesale prices as was proposed in the Senate hearings. We will find there is theoretical reason and some empirical evidence to believe the rebate program decreased and not increased real wholesale formula prices.

The bidding process of the infant formula firms in the rebate program represents the second empirical focus of this paper. Using data from over 100 solicitations for competitive bids covering the period from 1986 to 2002, we will examine the bids made by the two major firms in the infant formula industry, Mead Johnson and Ross Labs. Based upon our analysis, we find that the two firm's bidding behavior is statistically similar. Perhaps unsurprising we find that bids for initial solicitations for a sole source contract are different than those from subsequent rounds of bidding. The size of the contract – the number of infants covered by the contract – induces firms to offer larger rebates and consequently lower net prices for formula. Finally we find some evidence although not conclusive that when Mead Johnson and Ross Labs both bid on an initial contract, the rebates are higher but in subsequent solicitations they don't aggressively compete for contracts the other company has won. However, they tend to bid more aggressively against firms with smaller market shares, Wyeth and Nestle.

The remainder of the paper is organized in the following manner. In the next section, we document the historical trend in infant formula prices. We begin in 1981 and track the change in the real wholesale price of formula for a twenty-one year period. The broad based picture that is formed by this examination is that real wholesale formula prices have doubled over this period. However most of the growth in the real price of formula occurred prior to roughly 1996 and since that time the rate of growth in prices has significantly declined.

The following two sections of the paper provide background information about the structure of the infant formula industry and the federal government's program that provides free formula to low-income mothers. Over the past twenty-five years, there have never been more than four infant formula manufactures selling formula under their own brands. The limited number of competitors in the market is likely the result of the nature of the product. For many infants, formula is the primary source of nutrition during the first year of their life. Consequently, both parents and the public have an interest that this product be both safe and promote healthy infant development. This concern has led to the regulation of the production of infant formula by the FDA.

Parents wanting what is best for their infant's development will turn to sources they can trust will provide advice on which formula to use. While other parents and relatives may provide this advice, it is reasonable to expect that many parents will also turn to their health care professionals. Manufacturers of infant formula seeking to influence the choice of parents turn to medical detailing of their product to influence health care professionals to recommend their brands over their competitors. Finally, if their child is digesting their current brand of formula and their development appears to be normal, parents would not be likely to change brands even if the cost savings could be achieved.

These market conditions suggest that companies associated with pharmaceutical drug companies would have a comparative advantage over other manufacturers and would dominate this industry. Additionally, we would expect mothers to be quite insensitive to the relative prices of different brands of formula. But given that formula feeding of infants is perceived to be less desirable for infant development compared to breastfeeding, we would expect the mothers to sensitive to the real price of formula relative to other goods.

In 1974, the federal government implemented a permanent program to provide formula free of charge to low-income mothers. This program is known as the WIC program and is the focus of the third section of paper. The description of the WIC program begins with a brief historical overview of the program and a description of the eligibility criterion for participation in the WIC program. The single most important fact revealed in this section is currently the federal government pays for more than one half of all formula purchased in the US. The section concludes with an overview of the government's efforts to use its market power to contain the program's cost of infant formula with the implementation of a sole source rebate program.

The fourth section of the paper develops a theoretical model of how a firm with a degree of market power will price its formula in response to the WIC program's purchase of formula on behalf of low-income mothers as well as its offer of a rebate to secure a sole source contract to provide formula to mothers participating in the WIC program. The primary implication of the model is that the price of formula set by the firm will be independent of the rebate amount that the firm would offer to win the sole source contract but the size of the rebate will depend upon the price of formula.

Firms with market power will set the price of formula to reflect the price elasticity of its customers that will face that price – the less price elastic the demand for the product, the higher the price will be charged by the firm. As the WIC program is implemented without a rebate program, low-income, relatively price sensitive mothers will participate in the WIC program. If we assume the government's demand for formula is price inelastic then the price elasticity of the firm's overall demand will become more inelastic allowing the firm to set higher prices. When the government uses its market power as the single largest purchaser of formula by forcing firms to compete for a sole source contract to provide formula to WIC mothers, the price elasticity of customers who will face this 'full' price will increase as the government negotiates a different price through the rebate program. The consequence is that firms will lower the formula price compared to the situation when the rebate program had not been implemented.

The next two sections reflect the empirical examination of the framework developed in the paper. The fifth section reports upon an analysis of real wholesale prices over the period of 1981 through 2002. This analysis provides evidence that confirms the predictions of the theoretical model. The sixth section reports upon a preliminary analysis of the bids offered by Ross Labs and Mead Johnson for over 100 sole source contract competitions held between 1986 and 2002. The paper concludes with a summary of findings and a discussion of potential avenues for future research in this area.

1. Relative Infant Formula Prices – 1981 through 2002

Stroll down the infant and baby food aisles of any grocery story and one is confronted a wide assortment of infant formulas. To compare alternative brands and formulations of infant formula, we have normalized the wholesale price of any product to the cost of using the product to make a 2 ounce serving of formula. This normalization will account for changes in the packaging of the product over time and across brands as well as differences in the formulation of the product (powder or liquid concentrate).

We have limited our time frame to the period from 1981 through 2002 for two reasons. The starting point was determined by the availability of data on wholesale formula prices quoted by the firms. The end point of the analysis was chosen to represent the emergence of a new enhanced formula being massed marketed employing DHA/ARA[2]. Martek Biosciences Corporation's proprietary blend of DHA and ARA is used exclusively by United States infant formula manufactures. These two fatty acids that are found in mother's milk are believed to play a key role in an infant's mental and visual development.[3] These enhanced formulas sell at a premium compared to the previous formulas. Consequently to insure that we are examining a fairly homogeneous product, we decided to conclude our analysis with the advent of these enriched formulas.

A central focus of the 1990 and 1991 Senate hearings was the rising price of infant formula over the 1980s. While the testimony recognized that rising formula prices could be a reflection of rising input prices, the details of both the charts and discussion focused upon the changes of the nominal price of formula.

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[2] DHA/ARA refers to the active ingredients in this formula – docosahexaenoic acid (DHA) and arachidonic acid (ARA).

[3] See Chea (2002).

However, the real price (price of formula relative to the price of other consumer goods) is the more relevant comparison. In Figure 1 we have plotted the real wholesale price of a 2 ounce serving of infant formula based upon liquid concentrated milk based infant formula from November 1981 through December 2002 (monthly calculations) for the four major formula manufactures during the time period. The red line represents Ross Labs; the blue is Mead Johnson; the green (concluding in 1996) is Wyeth; the lower gold line represents Nestle.

The 'saw tooth' nature of each trend is the result of setting a nominal price and then letting inflation of the prices of other goods erode the real price of formula. The subsequent peak represents the real wholesale price after the firm has implement a new nominal price.

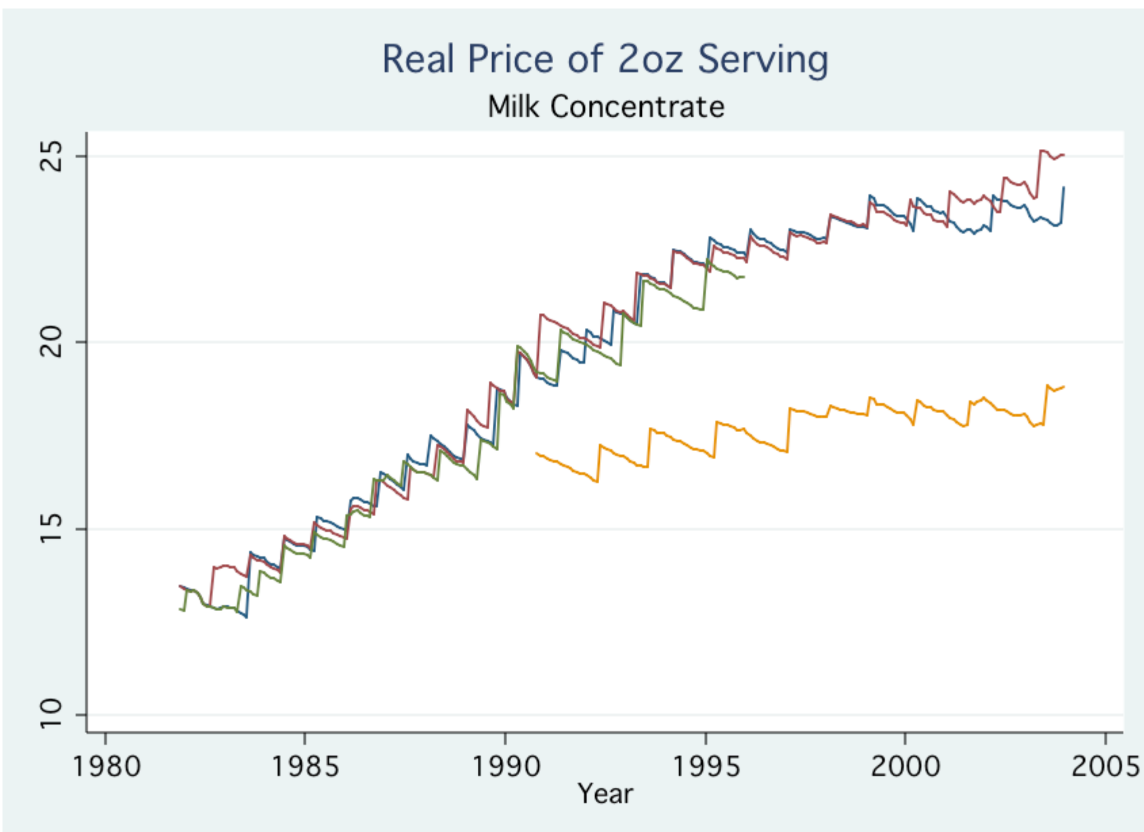

Figure 1

The concerns being expressed in the Senate hearings are reflected in Figure 1. Over the 1980s, the real price of formula continually rose and the existing three companies appeared to adjust their prices in lock step. The three formula manufacturers who are associated with pharmaceutical companies (Ross Labs, Mead Johnson and Wyeth) have a similar path of real prices over the time period that all three firms marketed formula. The increases in real prices did not abate after the Senate hearings but continued in much the same as manner as they did prior to the hearings. It was not until Wyeth left the market in 1996 that there appears to be slowing in the price inflation of infant formula. It was not until the late 1990s that the real price of formula appears to have stabilized at a level that is roughly twice the real price of formula in 1981.

Nestle entered the US market in 1989. Nestle has priced its formula at a considerable discount compared to the 'Big Two' firms, Mead Johnson and Ross Labs. Nestle has chosen to maintain a constant real price for its product compared to the other two firms.

The real price of formula (the relative price of formula relative to all other goods) is not the only relative price that could be analyzed. There exists alternative formulas that differ in terms of their source of protein (milk versus soy based) and different formulations (liquid concentrate versus powder) in addition to the companies that manufacture the formula. In Appendix A, we document that the relative price of milk relative to soy based formula has not varied significantly over the time period of interest. Consequently we have chosen to focus exclusively upon the real price of milk-based formulations marketed by 'Big Two' firms in our analysis.

2. The Structure of the Infant Formula Industry

History of Infant Formula[4]

Before the use of substitutes for breast milk became popular in the 19th century, mothers who could not, or did not choose to breastfeed their infants would use a wet nurse. Wet nurses would either come to a family's home, or the infant could be sent to live with the wet nurse until it was weaned. Wet nursing was so popular in the 18th century that governments in Europe created bureau's to regulate the practice.

In the 19th century, animal milk became a popular substitute for mother's milk, with cow's milk being the most commonly used. Donkey's milk, however, was preferred, as it looked more similar to breast milk.

Infants fed cow's milk had a higher mortality rate than infants breastfed. In 1838, the German scientist Johann Franz Simon published the first chemical analysis of breast milk and cow's milk. His and other studies showed that cow's milk was more prone to curding than breast milk, and was harder for infants to digest. Cow's milk had a higher protein and a lower carbohydrate content than breast milk. Physicians began to recommend that water, sugar, and cream be added to cow's milk to make it more similar to breast milk.

Around 1860, a German chemist, Justus von Leibig, created the first commercial product. It was a powder containing wheat flour, cow's milk, malt flour, and potassium bicarbonate that was added to heated cow's milk prior to being served. Marketed as Leibig's Soluble Infant Food, it soon became popular in Europe, and was the first commercial baby food to be sold in the United States at $1 a bottle in 1869.

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[4] The historical overview of infant formula and the industry was adapted from Schuman (2003)

In the 1870's, Nestle introduced it's own infant formula in the US, Nestlé's Infant Food. It was mixed only with water, and did not require cow's milk, making it the first completely artificial formula in the US. It sold for 50 cents a bottle.

By the late 19th century, more than 8 different brands of formula were available in the US. Because of their cost, however, and concerns about their nutritional value by doctors, most women still breastfed their infants.

From 1890 through 1915, the percentage method developed by Thomas Morgan Rotch, was the most popular alternative to breastfeeding. It involved diluting cows milk so that the percentage of Casein, the protein that causes cows milk to curdle, became equivalent to that of breast milk. Sugar and cream were then added to make up for the dilution of sugar and protein. This method was very complicated and labor intensive, however, and fell out of favor by 1920.

The pasteurization of milk in the late 19^{th} century had a nutritional impact on infants fed with cow's milk. Because the pasteurization process depletes milk of vitamins C and D, infants had to be fed orange juice and cod liver oil to make up for the deficiency.

In the early 20^{th} century, the focus switched from modifying the protein content of cows milk to trying to make the milk more closely resemble the carbohydrate and fat content of human milk. In 1912, E. Mead Johnson introduced a cow's milk additive called Dextri-Maltrose to supplement the carbohydrate content of cow's milk. This additive was sold only through physicians to mothers.

In 1919, a new formula was introduced called SMA, simulated milk adapted, which contained a combination of animal and plant fats to more closely resemble breast milk. During the 1920's, other infant formula manufacturers introduced their own breast milk imitating formulas to compete with SMA.

In 1924, the Moores and Ross Milk Company introduced a new formula designed to mimic breast milk. It was named Similac because it was "similar to lactation." In the late 1920's, Mead Johnson introduced Sobee, the first soy-based infant formula. In 1941, Nutramigen, the first protein hydrolysate infant formula was introduced. In 1951, Ross' Similac became available in concentrate form. In 1959, Mead Johnson introduced Enfamil, and that same year, Ross introduced Iron-Fortified Similac.

Despite the advancement in artificial formulas, evaporated milk remained the most popular choice for non-breastfeeding mothers. In 1883, John B. Myenberg had developed a process for creating unsweetened evaporated milk. The evaporation process chemically altered the cow's milk, making it easier for babies to digest. By the 1940's, a combination of unsweetened evaporated milk and sugar had become the predominant alternative to breastfeeding in the US. In 1960, an estimated 80% of bottle fed infants received condensed milk formula instead of a commercial formula because of its affordability and ease of preparation.

During the 1960's, commercial formulas began to grow in popularity, and by the mid 70's, had almost entirely replaced evaporated milk formula and breastfeeding. Breastfeeding rates reached an all time low, 25%, in the mid 70's because of the ease and affordability of commercial formulas. A major factor in the growing popularity of infant formula was its usage in hospitals for newborns. The infant formula manufacturers encouraged this practice by providing free formula to the hospitals.

In 1980, the Infant Formula Act was passed, which set strict standards for the nutritional content of infant formula, and set manufacturing and testing standards. Since then, infant formula manufacturers have continued to modify their formulas to more closely resemble mother's milk. The manufacturers have also developed a number of specialty formulas for pre-term infants, and infants with special dietary needs and medical conditions.

Most of the developments in infant formula since 1980 have been in niche formulas: special therapeutic formulas designed for infants with particular medical conditions. After the period considered in this study, in 2002 a major change was introduced in the standard infant formulas used by WIC. Mead Johnson, Ross, and Nestle all began to market formulas "enriched" with DHA/ARA, a nutrient that is reported to help in the child's brain development. These enriched formulas sell at a premium to the standard formulas.

Current Market Structure

Today's infant formula industry is essentially an oligopoly consisting of two large pharmaceutical companies that price their formula at a premium and market primarily to healthcare professionals. Bristol-Myers Squibb owns Mead Johnson, the leading brand, while the number-two brand Ross is a division of Abbott Laboratories. The industry at times has had two smaller competitors, Wyeth and Nestle.[5]

Since 1980 there have only been two major changes in the US formula industry, the first being the entrance of Nestle in 1989, and the second being Wyeth's switch from marketing formula under its own name to being a

[5] As will be explained later, Wyeth currently does not market formula under its own name but supplies formula to retail outlet such as Target and Walmart to market under the store's brand names.

manufacturer of store brand formula (for example, Target) in 1996-1997. In that time, no other major competitors have attempted to enter the market[6], and Mead Johnson and Ross have managed to maintain a firm grip on their dominant market positions.

Until 1996, Wyeth, also a pharmaceutical company, sold a premium brand formula in the US, and was a major competitor to Ross Labs and Mead Johnson. Wyeth was unable to profitably participate in the WIC program decided to discontinue selling its premium formulas in the US to focus on its international operations. In 1997, Wyeth reentered the US market, but as a producer of infant formula for PBM Products, Inc., which markets most of the generic-branded infant formula in the US and holds about a 1% market share. This generic formula is usually sold at a discount compared to Mead Johnson and Ross formulas.

Nestle entered the US market through its purchase of Carnation, and has been struggling to build market share. Worldwide, Nestle is the leading brand of infant formula. The unique nature of the US market, however, has kept Nestle's marketing and pricing strategies from being effective in the US. Though considered a premium brand, Nestle formulas are typically also priced at a discount to Mead Johnson and Ross formulas. Nestle currently has somewhere between 10% and 15% of the market. The rest of the market is divided fairly evenly between Mead Johnson and Ross, with Mead Johnson having a slightly larger market share.

While the 'Big Two' formula manufacturers, Ross Labs and Mead Johnson, have historically held 85 percent of the formula market, their relative importance has shifted over time. Prior to 1994, Ross Labs brands represented

[6] Mead Johnson introduced a discount brand marketed under the Gerber name in 1989, but discontinued it in 1997.

roughly one half of the market with Mead Johnson holding one third of the market. By 2000, the relative market shares have been reversed with Mead Johnson holding more than one half of all formula sales leaving Ross Labs with one third of the market. The reason for this shift in market shares is not clear. Executives at Mead Johnson attribute their increased market share to a direct mailing campaign aimed at expectant and new mothers. The mailing informed them both about the benefits of breastfeeding and provided samples of the company's product. However, this claim does not coincide with the fact that Ross's decline in market share appears to have begun two years before the institution of Mead Johnson's direct mailings in 1996. Additionally, Ross Labs has for decades had surveyed mothers about their breastfeeding practices and also provided mothers with coupons for Ross's products.

An industry dominated by a small number of manufacturers will create conditions where firms will be able to price their products above the marginal cost of producing the good. Firms will set their prices low enough so as to remain competitive, but high enough so as to not risk causing its competitors to lower their prices. Because of the small number of competitors in an oligopoly, firms are either able to collude with each other to agree on mutually beneficial market prices, or in a non-collusive market, simply anticipate the pricing strategies of their competitors through experience, and set prices accordingly. In this way, the firms in an oligopoly manage prices to achieve supernormal returns.

The fact that the infant formula industry is an oligopoly does not explain why real prices have increased. Wyeth's withdrawal from the industry in 1996 could have strengthened the market power of Mead Johnson and Ross, allowing them to raise prices with greater ease. However, Nestle's entrance to the market as a low-price competitor in 1989 and the emergence of generic infant formulas in 1997 (manufactured by Wyeth and marketed by PBM), have increased competition for Mead Johnson and Ross, creating pressure for lower formula prices. It is doubtful that story about declining competition in the industry can explain rising real prices of formula.

Marketing of Infant Formula

One of the most distinguishing features of the infant formula market is the unique manner in which formula is marketed. Infant formulas especially the premium brands are very similar to pharmaceutical products in how they are perceived by consumers. Though this trend is slowly changing in the US, consumers typically rely on the recommendations of healthcare professionals in choosing pharmaceutical products. With respect to products they only plan to use for a limited period of time, most consumers are less concerned with price as they are with a product's functionality. Rarely will a consumer switch from using a pharmaceutical product that is working well to a less expensive product that may or may not work as well, provided that the consumer will not be using the product indefinitely.

Similarly, parents often rely on the recommendations of pediatricians or other healthcare workers in choosing a formula. A recommendation can be explicit, or tacit as when a hospital provides a newborn a particular brand of formula. Once parents have made the decision to formula feed their child, whatever brand they first give the infant will likely be the brand that they use throughout infancy, provided that their brand is digestible for their infants.[7] Parents are typically unwilling to risk changing to a less expensive infant

[7] Occasionally, a child's body chemistry will cause it to react negatively to a particular brand of formula, in which case parents will switch brands.

formula if their child has responded positively to whatever formula it was first given.

Thus the key for infant formula manufacturers is to be the first formula a mother gives her infant. To the extent mothers are influenced by their physician or the hospital where the child is born, gaining favor of these two groups is important to the marketing of formula. Ross, Mead Johnson and Wyeth (when they were marketing their own formula) rely upon medical detailing of their products to doctors and hospitals to promote their products. Pursuing this strategy for these firms was cost effective because they could piggyback upon their parent pharmaceutical companies marketing efforts. This has allowed Mead Johnson and Ross to keep such a dominant hold on their market shares over the years, while keeping Nestle from getting a strong foothold in the US.

Nestle, on the other hand, is an international food and beverage manufacturer, without any ties to a pharmaceutical company. It has attempted to gain market share in the US by beating its competitors' prices, and marketing its formula as it would any other nutritional product. So far, Nestle has been unsuccessful, and Mead Johnson and Ross have been able hold onto their market shares.[8]

The costs of medical detailing could be prohibitively high for a non-pharmaceutical company. This may have served as a deterrent for any smaller firms considering entering the US market. Adding to the high cost of marketing is the expense of meeting the nutritional standards and performing the testing of formula required by the FDA. These costs present a formidable barrier to

[8] It should also be noted that in 1989, the year Nestle entered the US market, Mead Johnson entered into an agreement with Gerber to produce formula under the Gerber name. The Gerber formula was apparently set up as a direct competitor to Nestle: it was priced at a discount to other Mead Johnson formulas, and like Nestle formulas, it was marketed directly to consumers. After several years it became obvious that Nestle and Gerber were failing to gain market share, and that pharmaceutical marketing and premium pricing really did work best in the US market. Thus, Mead Johnson discontinued the Gerber brand formula in 1997.

entry, sufficient to discourage the emergence of any small or regional competitors.

Marketing of infant formula has been problematic for the industry. Direct marketing to mothers has been criticized for promoting mothers to abandon breastfeeding in favor of the bottle. During the 1970s, Nestle was singled out for its aggressive marketing of formula in the third world. In the US, the Academy of Pediatricians has actively campaigned against direct advertising to mothers. Yet the original FTC complaint singled out the absence of direct advertising as evidence of the noncompetitive behavior within the industry.

The marketing of formula to doctors has not been without controversy. In 1998, Mead Johnson brought suit against Ross Labs for their claim that Similac was the 'first choice of doctors.' In 2001, a federal judge ordered Mead Johnson to stop distributing inaccurate and misleading information about generic formula brands (PBM manufactured by Wyeth) to doctors.

3. The WIC Program

After a slow beginning as a pilot program in 1972, WIC became a permanent program in fiscal year 1974. The number of women, infants, and young infants served per month increased from 205 thousand in FY1974, to 3.6 million in FY1988, to 7.2 million in FY2000. WIC provides three types of benefits: supplemental food, usually in the form of vouchers or checks that can be exchanged for specific foods from participating retail grocers; nutrition education; and referrals to health care and other social services.

The federal government gives grants to states and Indian tribes to provide the supplemental food, nutrition education, and health and social service referrals, and to administer the program. State grant allocations are based on the amount the state received in the previous year and the estimated number of eligible persons for that state. States then fund local agencies that provide the services to participants. Since WIC is not an entitlement program, allocated amounts of funding may not be sufficient to serve all the eligible persons who wish to participate. If local agencies do not receive enough funds to serve all eligible applicants, they establish a prioritized waiting list. Federal regulations specify a seven-point priority system (7CFR 246.7(e)4) in which priority is based on the type of nutritional risk and the eligibility category. The last year a state had to implement a priority waiting list was 1999. States that have experienced shortages of funds to serve all eligible applicants usually have obtained supplemental funding from the federal government.

WIC Eligibility Criteria

To receive WIC benefits, an applicant and their child must be categorically eligible, residentially eligible, income eligible, and nutritionally at risk. The WIC program is intended to provide supplemental nutritious foods to all pregnant, post-partum women, breastfeeding women, infants (birth to age one) and children less than 5 years old. The primary demographic group for this study is infants whose mothers will receive vouchers for infant formula if they have ceased or reduced breastfeeding.

To be income eligible, an applicant's family income must be less than 185 percent of the U.S. poverty income guidelines. Those who are enrolled in the federal Medicaid, Food Stamp, or Temporary Assistance for Needy Families (TANF) programs are adjunctively eligible for WIC even if their income exceeds 185 percent of poverty. States also may use enrollment in other means-tested programs, such as the National School Lunch Program or the Supplemental Security Income (SSI) program, to qualify an applicant as automatically income eligible for WIC.

To be certified as nutritionally at risk, an applicant must meet at least one of the many approved nutritional risk criteria. These risk criteria fall under five broad categories: anthropometric risk (e.g., underweight, obesity); biochemical risk (e.g., low hematocrit); medical risk (e.g., diabetes mellitus); dietary risk (e.g., inappropriate dietary patterns); and predisposing factors (e.g., homelessness).

Once the infant has been certified to receive benefits from WIC, States may choose to allow the participant to receive benefits without further eligilbility until their first birthday, provided the quality and accessibility of health care services are not diminished.

Size of WIC Program

Since 1974 when the WIC program was implemented, the percentage of infants who participated in the program has increased until roughly 1998 when one out of two infants participated in the WIC program (see Figure 2). Since 1998, the percentage of infants participating in the WIC program has decline but is still 47 percent of all infants. Even if WIC mothers breastfed their infants at the same rate as mothers not participating in WIC, the government today would be paying for roughly one half of all infant formula purchased on market. But as many surveys have documented, the breastfeeding rate for WIC mothers is lower than for non-WIC mothers and hence it is reasonable to claim that the government pays for more than one half of all formula purchased in the US.

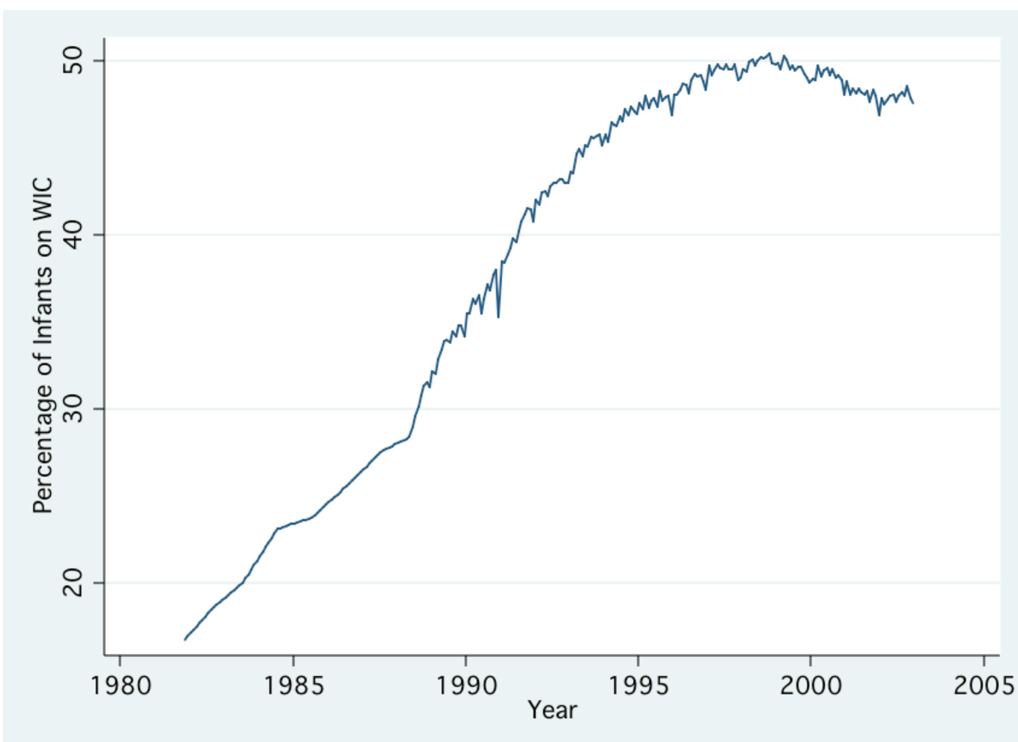


Figure 2

The Sole Source Rebate Program

Beginning in 1986, states experimented with cost containment. Since states were the single largest purchaser of formula, they believed they should be able to acquire a discount or rebate based upon the volume of purchases made through the WIC program. The methods the states chose to obtain these rebates varied. The sole source competitive bid contract is the prevalent approach adopted by states. This type of cost containment effort requires companies to submit a rebate offer on a per can basis. The company who offers the state the lowest net price of formula (wholesale price minus rebate) is awarded the right to supply of the formula to WIC mothers within the State. The States reserve the right to authorize infant formula from other manufacturers.

The cost savings are then used to fund expanded coverage of all WIC eligible individuals, infants, children, pregnant and post-partum women. We should note that the difference between the net price of formula (wholesale price minus the rebate) and the net cost of a can of formula is the retail store markup. In this study we have not examined how the WIC program's provision of free formula and its rebate program has affected this potentially important component – the retail markup -- of the full cost of formula to the government.

The rebate program has become a significant source of funds for the WIC program (see Figure 3). When the rebate program first began on a national basis, the rebates represented 13 percent of WIC outlays. As the rebate program matured, this percentage roughly doubled to 25 percent.

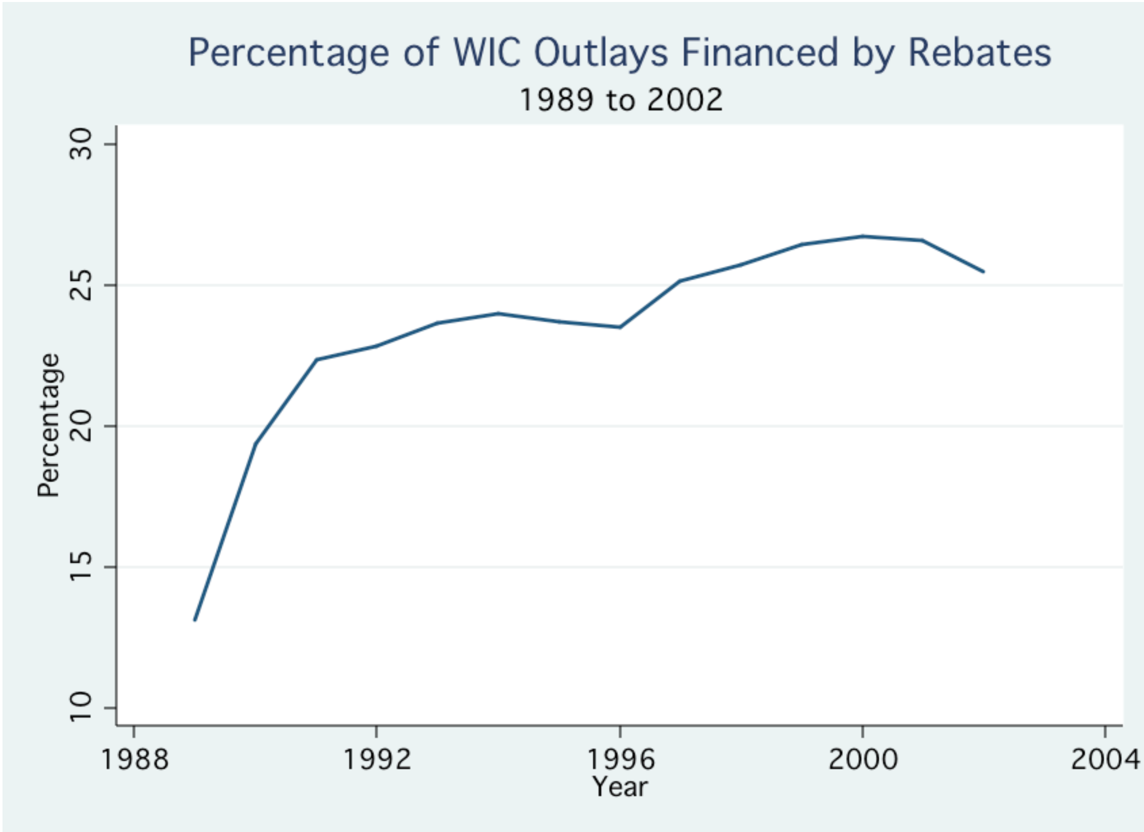


Figure 3

The aggregate dollar amount of rebates grew from $.3 billion in 1989 to $1.5 billion dollars in 2002. These nominal amounts would tend to overstate the growth of the program in real terms. Figure 4 depicts both the trend in the aggregate rebate amounts from 1989 to 2002 in nominal and real terms (constant $2002 dollars). While the trend in nominal terms shows consistent growth, in real terms the aggregate amount of rebates appear to have reached a plateau in 1998 and has remained stable over the remaining period.

Another factor determining the aggregate rebate is the number of WIC infants receiving benefits. To normalize for changes in the infant caseload, we assumed that each infant enrolled in WIC received the same amount of formula and consequently we multiplied the real aggregate rebate amount by the ratio of the infant caseload in 2002 to the infant caseload in the respective year. This normalized trend is presented in Figure 4. The growth in WIC infant recipients began to decline around 1996, consequently prior to this time the growth in the rebate program was overestimated but does not alter our impression that the growth in the aggregate dollar amount of rebates has come to an end.

Even though all states were mandated to institute competitive sole source contracts in 1988, it is not until late 1993 that all states had complied with public law. Figure 5 presents the percentage of WIC infants who were covered by a sole source rebate contract and reside in a state that provide vouchers redeemable at retail outlets. Mississippi and Vermont operate direct distribution systems that dispense formula to WIC participants and are not included in these totals.

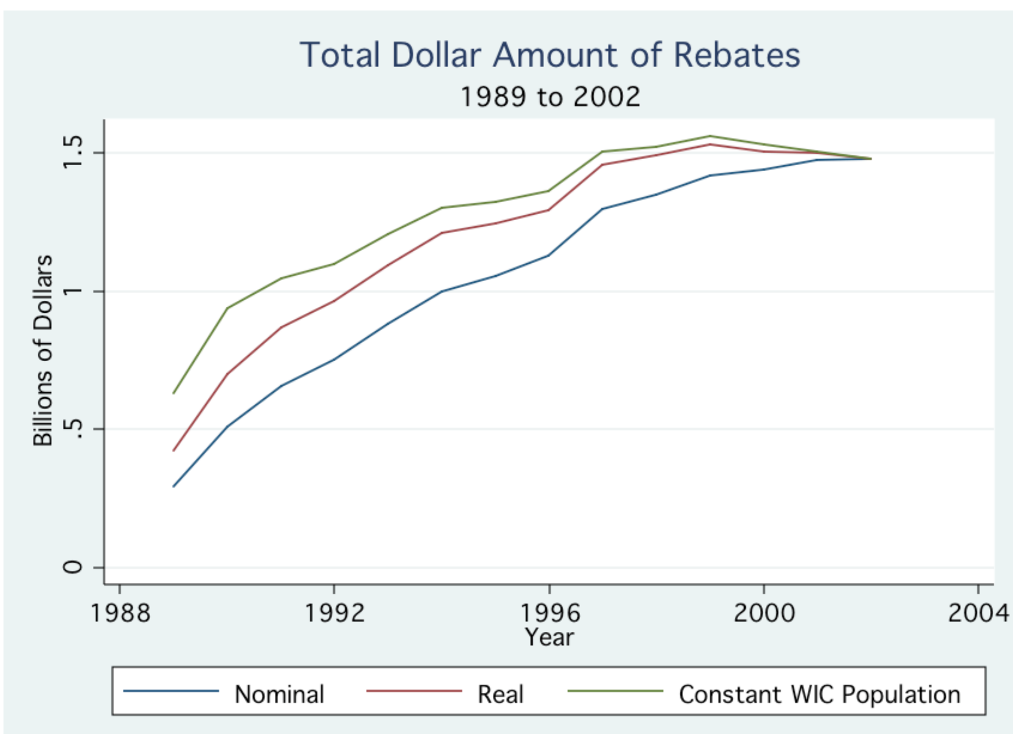


Figure 4

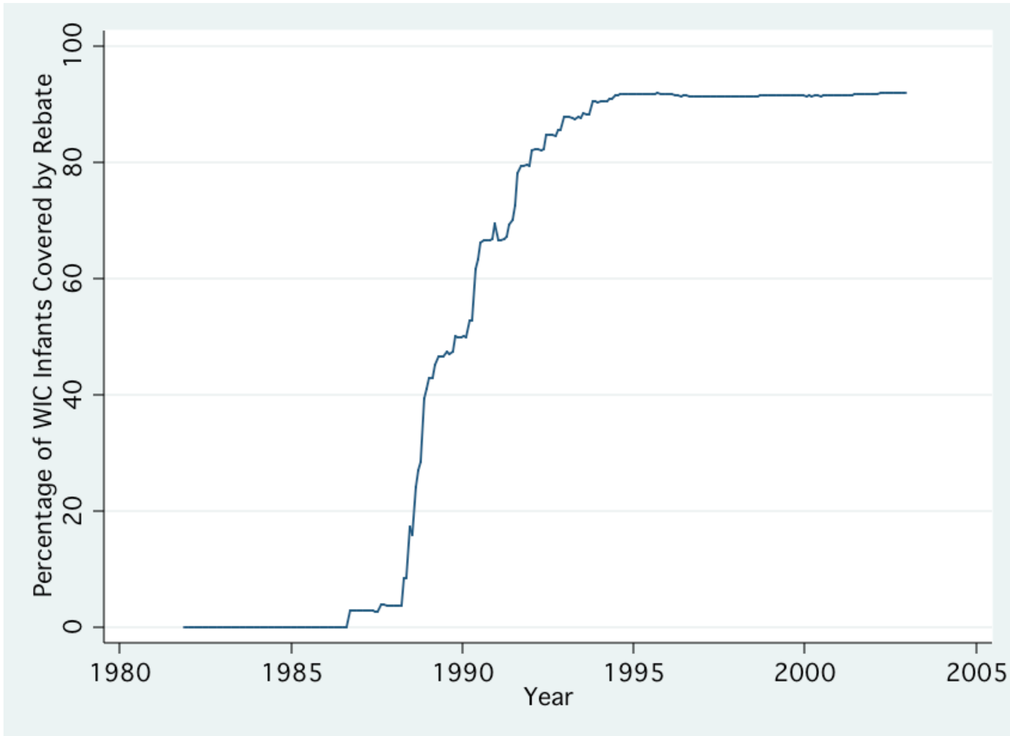


Figure 5

Stagnation in the rebate program has become a source of concern for WIC officials. Over are the days of easy infusion of funds to maintain or expand the program's reach to low-income families. We turn to a short history of the rebate program. From this history, it is clear that formula manufactures have been and most likely will continue to be resistant to the sole source rebate program.

History of the Rebate Program

In 1985, Tennessee, Oregon and South Carolina in an effort to reduce the cost of their WIC programs announced they would implement a competitive bidding procedure that would award to a single company the right to be the primary supplier of infant formula to the WIC program in their respective states. The reaction of the infant formula manufactures was swift and sure. Formula manufacturers were opposed to this plan and saw no reason to depart from the current procurement methods that they believed well served the WIC clientele over the years.

Apart for the obvious reason this method of cost containment would erode their profits, the companies argued the strategy was ill conceived. The reasons they put forward were

- The plan was anticompetitive;
- The plan undermined the right of mothers to choose which formula to feed their infants;
- The plan would undermine the relationship between mothers and their doctors; and
- The plan would not guarantee cost savings.

They threatened the state and federal governments with legal action but in the end they found their best strategy was not to cooperate. In 1986, Tennessee opened the seal bids to find that no one had bid on the state's contract. Only later when Tennessee reopened the auction did Wyeth break rank and submit bids to both Tennessee and Oregon's competitive sole source solicitations.

During this period, the 'Big Two' – Mead Johnson and Ross Labs – proposed an alternative cost containment strategy to the states. They would provide rebates that would equal the difference between the future and current wholesale price of formula if the states would continue to provide vouchers for the infant formula chosen by the mother with their doctor's advice. While this proposal would limit increases in the cost of formula resulting from rising future wholesale prices, compared to the sole-source contract this proposal did little to reduce the overall cost of the program that the states sought.

In 1987, the states of the Florida, Wyoming and Michigan sought rebates in what was called the Open Market strategy. In this type of contract, the WIC clientele would continue to choose the brand of formula and the states would receive the rebate proposed by the company for the number of cans purchased by WIC mothers. When these 'competitions' were held, the states received considerably less in rebates than the states who had held sole source auctions. In their competitive sole source solicitations, Tennessee and Oregon had received bids of 40¢ and 60¢ per can respectively from Wyeth while the states that held the Open Market bids received on average of 20¢ per can. Interestingly, while Wyeth was a consistent bidder in the sole source auctions they rarely would participate in an Open Market bid. This pattern may reflect the low market share of Wyeth's hope that it could increase its market share if the 'Big Two' continued not to bid in the sole source auctions.

In 1988, Texas became a battleground. The 'Big Two' wanted the state to adopt the Open Market approach. The state officials rejected their suggestion, pointing to the low savings of this approach compared to the sole source approach. When the bids were opened, Mead Johnson broke down and offered the winning bid of 92.5¢ per can almost five times the size of the rebates they have offered in previous Open Market solicitations. The size of the Texas market was too large for Mead Johnson not to bid. Yet Ross continued to boycott the sole source solicitation.

On the heels of Texas, Florida decided to rebid their contract and adopted a hybrid approach asking for both a rebate under the Open Market approach but also a rebate if the contract was made as a sole source contract. The state would pick the approach and company that provided the greater cost savings to the state. Now all three companies proposed rebates with Mead Johnson offering a rebate of 87.7¢ per can for both types of contracts and Ross Labs offering $1.05 per can rebates under the sole source arrangement and 63¢ per can under the Open Market approach. Wyeth's bid of $1.085 was the winning bid under the sole source but did not provide a rebate under the Open Market approach. Immediately after winning the contract, Wyeth increased its wholesale price making the effective rebate equal to $1.01 per can, less than what had been offered by Ross Labs. Based upon this experience in Florida and other states, future contracts would contain a clause stating that if the company increased its wholesale price during the contract then the rebate would increase by the same amount.

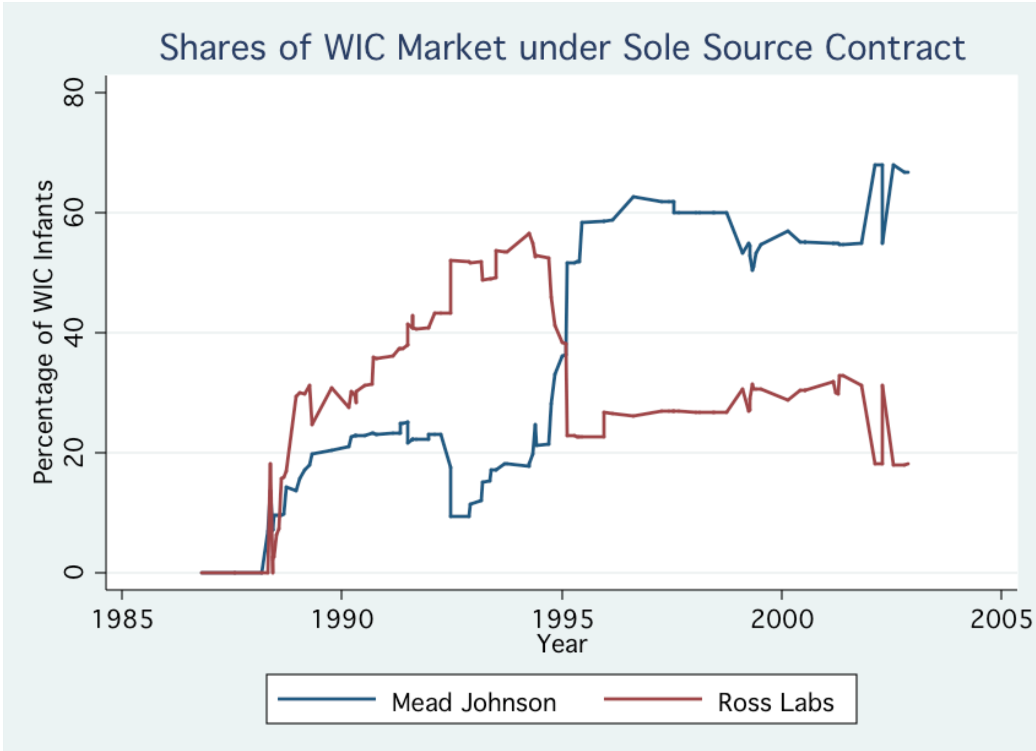
After the Texas battle, Ross Labs began submitting bids to competitive sole source auctions. In what could be one last attempt to convince states that an Open Market approach could provide significant savings to states while maintaining choice for WIC clientele, Ross Labs and Mead Johnson began to offer larger rebates to Open Market solicitations. The rebates offered by both companies were consistently 93¢ per can during 1989 considerably higher than the offers made in the previous year. Their efforts were paying off. By the end of 1989, 25 states had signed Open Market contracts with the 'Big Two' although Wyeth stubbornly chose not to participate in the Open Market approach. Of the twenty Open Market agreements signed in 1989, Wyeth participated in only two – Kentucky and Washington. In both cases, offering 10¢ and 20¢ less per can than the 'Big Two'.

In the same year, 1989, the federal government implemented two important pieces of legislation affecting the rebate program. The FY 1989 appropriation act required that all states to engage in some form of cost containment. The WIC reauthorization legislation enacted in November of 1989 required that when states' current contracts with formula manufactures ended, the new cost containment activities must be a competitive sole source solicitation unless they could show at least as large of savings from their desired approach. What the companies had won at the state level was now being lost at the hands of the federal government.

In late 1989, Ross Labs submitted a 75¢ offer to Hawaii's Open Market request. In March of the next year, Connecticut opened the seal bids for a competitive sole source contract. Ross Labs submitted a 75¢ bid. In both cases, Ross's bids were significant lower than either Mead Johnson or Wyeth. Six days after the opening of the Connecticut bids, Mead Johnson sent a open letter to four states holding competitive bids in the coming months that they would be submitting a bid of 75¢. True to their word, they did. Only in the Texas solicitation did Mead Johnson bid $1.25 to retain their existing contract.

It was this series of events that provoked the Senate Hearings in 1990 and 1991 but also precipitated the FTC investigation of Mead Johnson. While Mead Johnson did not initiate what many felt was bid rigging, they were held accountable for the open letter. The consequence was for the federal government to legislate against the practice of announcing bids prior to the opening of a seal bid WIC auction.

By 1991, the 'Big Two' appeared to have come to terms with the presence of the sole source solicitation of rebates. While initially ceding the WIC contracts to Wyeth, the 'Big Two' began to participate in the states solicitation for competitive bids. Figure 6 presents Mead Johnson and Ross's share of the WIC market during the period of 1986 through 2002. While Ross Labs was initially much more successful than Mead Johnson in securing sole source contracts, there was a dramatic reversal of fate in 1995. The reversal also coincides with the departure of Wyeth from the market and the seemingly acceptance of the sole source contracts by the remaining firms.



Shares of WIC Market under Sole Source Contract
Percentage of WIC Infants
0
20
40
60
80
1985
1990
1995
2000
2005
Year
Mead Johnson
Ross Labs

Figure 6

4. Modeling the Desired Price of Infant Formula

In this section, we first examine a model that describes how a firm with a degree of market power will price its infant formula when the government purchases formula on behalf of a subset of mothers who use formula to feed their infants. We will assume that the government pays the same price for formula that any mother who purchases formula for their infant. The primary implication of the model is when the government provides formula vouchers to mothers who would have been the most sensitive to the price of formula, formula manufacturers will raise their formula prices in response to the increased demand (the government purchases more formula than the mothers would have if they had to pay for the product) and the reduction in the overall price sensitivity of demand. This framework used to explain the impact of providing free formula on formula prices in the absence of sole source contracts has become to be known as the Varian model that appeared in an online supplement to his undergraduate microeconomic textbook. [9]

The Varian model will then be modified to explain how firms would respond to the government's attempt to lower the cost of their formula purchases through competitive bidding for a sole source contract to provide formula to the mothers served by the program – the rebate program.[10] We will demonstrate that if the government awards the sole source contract to the firm offering the lowest net price (the difference between the current formula price and the

[9] See Salant (2003) for an analysis of the WIC program attributed to Hal Varian.

[10] We will not explain to impact of an open market rebate program used by states during the late 1980s and early 1990s to contain costs of the WIC program.

rebate offered by the firm) then the firm's formula pricing decision will be completely separable from its decision of how much to bid on the sole source contract. Prior to when the competitive bidding process is implemented (in the Varian model), the firm bases its formula price on the aggregate price elasticity reflecting both the price elasticity of mothers who pay for their formula and the price inelastic demand of the government who is paying for the formula acquired by mothers participating in the WIC program. Once the competitive bid process is implemented, the firm's market is effectively divided into two segments – one segment where mothers purchase formula using their own monies and the other segment representing the WIC program. Firms will set the price of their formula to reflect the price elasticity of their customers who will be paying that price for their purchases. They will set the net price (price minus rebate) by offering a rebate that will maximize their expected profits from bidding on the contract. The competitive bidding process can then be expected to depress formula prices as the firm now prices its product to reflect the price elasticity of its self-paying customers not the combined price elasticity of both market segments.

A word of caution should be offered. The reader may be tempted to interpret the previous explanation as a story based upon traditional market segmentation theory that serves to explain how a firm with market power can increase its profits by differentiating its price across segments of its market. The sole source competitive bidding process while effectively allowing the firm to segment its market will not lead to increased profits. In fact the purpose of the rebate program created by the government will lead to lower profits for formula manufactures and lower cost for the WIC program.

Traditional market segmentation theory suggests the firm would set prices to the various market segments inversely related to their price elasticities. In the current context, this implies that the government would be charged a higher not a lower price than what is being charged to the self-paying mothers. The sole purpose of the rebate program is for the government to use its market power to secure a lower price. The model suggests that the firm will set its effective price (net price) to the government to reflect the probability of winning the sole source contract and not on the government's price elasticity of demand. Since the price elasticity of self-paying mothers will be higher than the aggregate market price elasticity (self-paying mothers and government demand), the price that they will face should be lower than they would have faced had the sole source competitive bidding process had not been implemented.

The two-part development of the theoretical framework serves to distinguish two distinct aspects of the WIC program – the distribution of free formula to low income mothers and the partial financing of the program through price reductions resulting from the government exercising its market power. Drawing these distinctions are important because as we have suggested in this introduction, the provision of free formula to mothers whose demand is quite sensitive to the price is expected to increase the price of formula while the sole source competitive bidding process is expected to have the oppose effect on prices.

We will be focusing upon how the WIC program and its rebate program affect the wholesale price of infant formula and hence the price, P, we will be modeling is the wholesale price. But clearly, mothers can't purchase formula at wholesale prices but at retail prices. We will assume that retail stores adopt a constant mark up to the wholesale price that is not affected by the WIC program or the rebate program.[11]

Assumption about Competition in Infant Formula Market

To develop a tractable model, we will adopt some simplifying assumptions about the nature of competition existing in the infant formula market. As we have previously observed, infant formula is supplied by a limited number of firms who have been predominately subsidiaries of pharmaceutical drug companies. The sole exception is Nestle – the worldwide leading producer of infant formula. It is our contention these facts reflect barriers to entry into the infant formula market created by the FDA's regulation of manufacturing of infant formula. While drug companies may face lower marginal cost of regulation because of their existing relationship with the FDA, a more significant competitive advantage may be found in the manner by which formula is indirectly marketed to mothers through hospitals and physicians. Formula manufacturers who are subsidiaries of drug companies should experience a competitive cost advantage in marketing their products to hospitals and physicians over other firms.

While the number of infant formula manufacturers is limited, we would still expect the existing firms to compete between themselves for customers. In this preliminary version of the model, we will abstract from potential competition between firms providing formula by assuming that the demand for each firm's formula is unaffected by the price of other firms producing formula. Consequently, as the real price of formula (the nominal price of formula relative to the price of all other non-formula consumption) increases mothers buy less

[11] For an empirical examination of the rebate program on retail mark ups of formula, see Oliveria, Prell, Frazao, and Smallwood (2001).

formula from the firm and do not increase their consumption of formula produced by other firms but increase their use of non-formula means to feed their infants.

Characterizing the Demand for Infant Formula

The impact of WIC program on the firm will be characterized by its effect on the demand for infant formula. Following Varian (Salant, 2003), we will assume there are two types of mothers, WIC eligible low-income mothers and higher income mothers who are not eligible for WIC. We will assume the number of mothers in each group may differ but remain constant during the time period being considered by the firm.

For simplicity, we will assume that each type of mother's demand for the firm's formula depends upon the real price of formula, *P*, which we will assume will be the price charged to all purchasers of formula. The subscript '*W*' will be used to denote the WIC eligible mothers and '*NW*' to denote the high-income mothers who are not eligible for WIC. Each group of mothers' aggregate demand for infant formula can be expressed as $Q_W(P)$ and $Q_{NW}(P)$ respectively. To simplify the model, we assume that the aggregate demand from both groups reflect a constant price elasticity that differs between the two groups. Given WIC eligible mothers are low income and consequently compared to the higher income mothers are likely to be more sensitive to changes in the price of formula. In particular, we will assume the price elasticity of WIC mothers is larger than mothers not eligible for WIC

$$|\eta_W| > |\eta_{NW}|$$

where η denotes the price elasticity of demand.

If all WIC eligible mothers participate in the program, the aggregate amount of formula that would be provided by the WIC program would be equal to B (equal to $Q_W(P=0)$) which is assumed to exceed $Q_W(P)$. To reflect the fact that not all WIC eligible mothers will participate in the program, let τ denote the percentage of low-income mothers enrolled and participating in the WIC program. This rate will be denoted as the 'take up' rate of the program. We will assume that enrolling in WIC does not affect the mother's choice of formula in the absence of a sole source contract and she is free to choose her preferred brand of formula. Consequently the firm's demand given the price P is

$$Q_T(P) = Q_{NW}(P) + (1-\tau)\, Q_W(P) + \tau\, B \tag{1}$$

In the initial version of the model, we will assume that τ doesn't depend upon the price paid by mothers. However, the assumption that the 'take up' rate of the WIC program is unaffected by the price of formula is dubious. The firm's total sales volume could rise by increasing the formula price as long as the increase of sales to WIC eligible mothers exceeded the loss in sales to non-WIC mothers. The firm could raise their volume of formula sold if at the current price

$$\frac{\tau\left(B - Q_W(P)\right)}{Q_T} \times \left[\frac{P}{\tau}\frac{\partial \tau}{\partial P}\right] > \rho\left|(1-\omega)\eta_{NW} + \omega\eta_W\right| \tag{2}$$

where

$\rho = \dfrac{Q_{NW} + (1-\tau)Q_W}{Q_T}$ = the proportion of total volume sales made to self-paying mothers, and

$$\omega = \frac{Q_W}{Q_{NW} + (1-\tau)Q_W}$$ = the proportion of volume sales to self-paying mothers who were eligible for WIC.

While the 'take up' rate may be determined by the formula price, it is also influenced by the outreach efforts of the WIC agencies to inform mothers about the WIC program and its benefits as well as by the decisions of individual mothers who may or may not view the program as beneficial to their family. To the extent to which the 'take up' rate is determined by actions outside the firm's control, the more faith we can place in the assumption that the 'take up' rate is exogenous to the firm.

Given the assumption that the 'take rate' is independent of the formula price, the price elasticity of demand for the firm's product equals

$$\eta_T = \rho\left[(1-\omega)\eta_{NW} + \omega\eta_W\right] = \rho\eta_{SP} \qquad (3)$$

where the subscript *SP* denotes the group of self-paying mothers and *T* denotes the total or overall sales to all customers – self-paying mothers and the WIC participating mothers paid by the government. As 'take up' in the WIC program increases (τ), the price elasticity of demand for formula will fall for two reasons: the portion of paying customers (ρ) will decrease and the proportion of paying customers who are low-income and more price sensitive (ω) will also decline. Mathematically, the change in the price elasticity with respect to τ is equal to

$$\frac{\partial \eta_T}{\partial \tau} = \eta_P \frac{\partial \rho}{\partial \tau} + \rho\left(\eta_{NW} - \eta_W\right)\frac{\partial \omega}{\partial \tau} > 0 \ . \qquad (4)$$

The Varian Model

In the absence of the rebate program, the firm will be assumed to price its product so as to maximize its profits

$$P\,Q_T(P) - C(Q_T(P)) \qquad (5)$$

where $C(Q)$ denotes the total cost of producing Q units of formula. The first order conditions for maximizing the firm's profits is

$$\left[Q_T + P\frac{\partial Q_T}{\partial P}\right] - \frac{\partial C}{\partial Q} \times \frac{\partial Q_T}{\partial P} = 0$$

or

$$MR\big(Q(P)\big) = P\left[1 + \frac{1}{\eta_T}\right] = P\left[1 + \frac{1}{\rho\eta_{SP}}\right] = \frac{\partial C}{\partial Q} = MC. \qquad (6)$$

The first order condition implies the firm would set the formula price so that the marginal revenue is equal to the marginal cost of producing the last unit of formula. To simplify the discussion, we will assume the marginal cost (MC) is independent of the scale of operation of the firm.

The primary conclusion of the Varian analysis is that the WIC program (provision of free formula to low-income mothers) would result in an increase in the price of formula. If the WIC program didn't exist then all mothers would have to pay for the formula (ρ=1.0) and the 'take up' rate would be zero. Consequently the price elasticity of demand for formula (η_o) would equal

$$\eta_O = \frac{Q_{NW}}{Q_{NW} + Q_W}\eta_{NW} + \frac{Q_W}{Q_{NW} + Q_W}\eta_W \qquad (7)$$

that would be greater (in absolute) value than the price elasticity of demand if the WIC program is implemented with a take up rate of τ

$$\left|\eta_O\right| > \left|\eta_T\right| = \left|\rho\eta_{SP}\right|. \tag{8}$$

Note this is a restatement of equation (4) where we showed that price elasticity of demand and the 'take up' rate for the WIC Program were positively related. Consequently as the WIC program expands, the demand for formula will increase (see equation (1)) and the price elasticity of demand will decline in absolute value (equation (8)).

Let P_o denote the formula price in the absence of the WIC program. This price must satisfy equation (6) when ρ equals 1.0 and τ is equal to zero

$$P_O\left[1 + \frac{1}{\eta_O}\right] = MC. \tag{9}$$

As the WIC program is implemented and expands, the firm faces a less elastic demand for its product because of two factors – less of its product is paid for by mothers who will be responsive to the price and the government is paying for formula who would have been the most sensitive to the price. The consequence of the lower price elasticity of demand is the bracketed term on the left hand side of equation (9) becomes smaller – the marginal revenue at P_o declines. For the firm again to maximize its profits (satisfy equation (6)) it will raise its price.

This presentation may be a little confusing because typically the presentation of firm behavior is told in terms of the quantity supplied not the price it charges customers. Since the quantity of formula produced and sold will be negatively related to the price the firm can charge, the relationship between the marginal revenue and the price will be opposite of the relationship between the marginal revenue and output of the firm. As the firm raises its formula price, the quantity demanded will fall and consequently the marginal revenue for the firm will rise. Hence if we have a change of variable – quantity output to price – the graph of the relationship between the price and marginal revenue would be upward sloping holding all of the other parameters of the model constant. The marginal cost as a function of the formula price will be a constant because as price increases, output will fall but by assumption this will not affect the marginal cost of producing formula. If the marginal cost of producing formula rose with output then as a function of the price of the good, the marginal cost relationship would be decline with increases in the price. The relationships between marginal revenue, marginal cost and the formula price are depicted in Figure 7 for two different 'take up' rates of the WIC program. If the 'take up' rate of the WIC program is τ_1 the firm would maximize its profits by adopting the price P_1. If the 'take up' rate rose to τ_2, the marginal revenue at every price would fall reflecting the decline in the price elasticity of demand and consequently the firm would raise its price to P_2 to once again maximize its profits (satisfy equation (6)).

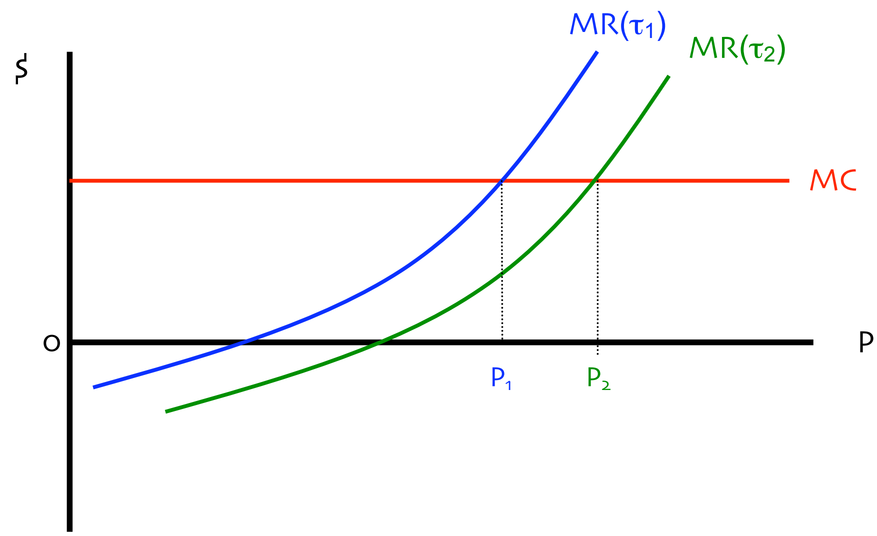


Figure 7: Formula Price Increases with Rising Take Up Rate (τ)

While the 'take up' rate of the WIC program will become the primary factor that emerges from the empirical work, the model proposes three other avenues by which changes in other factors could affect the price of formula – the aggregate quantity purchased by non-WIC eligible mothers (Q_{NW}); the aggregate quantity purchased by WIC mothers but with their own money under the assumption that no WIC eligible participated in the program (Q_W); and the amount purchased by the government for WIC mothers if all WIC eligible mothers participated in the program (B). While the first quantities are envisioned to be determined by the price of formula, other factors such as income, breastfeeding rates and population trends will also play an important role.

If breastfeeding rates among high-income mothers declined, we would expect a shift in the demand for formula from this group of mothers. When Q_{NW} increases holding everything else constant, the marginal revenue at any given price will be affected in two opposing directions. As Q_{NW} increases the proportion of self-paying mothers (ρ) would increase resulting in an increase in the marginal revenue and providing an incentive for the firm to lower prices. However when Q_{NW} increases, the proportion of self-paying mothers who are WIC eligible (ω) declines resulting a decline in the average price sensitivity of those mothers who pay for formula (η_{SP}). This latter effect results in a decline in the marginal revenue (holding the price constant) leading to an increase in the price of formula. The net impact on formula prices is ambiguous.

Changes in the quantity of formula purchased by the WIC eligible population are a little more difficult to characterize because in most scenarios a change in Q_W will also be reflected with a change in B. For example, an increase in the number of mothers eligible for WIC should increase both Q_w and B. In general, B will be a constant multiple of Q_W ($B = \lambda Q_W$ where $\lambda > 1.0$), consequently a change in Q_W (holding τ -- the 'take up' rate -- constant) will produce a decline in the price of formula while the change in B will cause the price to rise. When Q_W increases, both ρ and ω will increased due to a more price elastic demand for the firm's product. With the upward shift in the marginal revenue, the firm will lower its price to sell more formula. If B also rises then the overall price elasticity (η_T) will decline because the proportion of sales to non-governmental customers will decline. This will result in a decline in the firm's marginal revenue inducing them to raise prices. When both Q_W and B change in the same direction, their impact on formula prices is ambiguous.

Finally if Q_{NW}, Q_W and B change by the same proportionate factor (α), the firm's desired price is predicted by the model to remain unchanged. Changes in aggregate quantities will leave the parameters (ρ and ω) unchanged and consequently the total price elasticity (η_T) remains unchanged. This conclusion of the model underscores how the Varian model relies upon relative price elasticities as opposed to a scale effect to explain the impact of WIC on the price of formula.

Modeling the Rebate Program

In 1989, the federal government required all WIC agencies to implement a competitive bidding process for a sole source contract. In these procurement auctions, manufacturers submitted a proposed rebate. The firm who offerred the lowest net price (wholesale price minus rebate) was awarded the contract to provide all of the formula for the WIC mothers in the jurisdiction of the WIC agency. By 1993, all WIC agencies had implemented the rebate program. The question that we will now turn is how will the firm bid on a sole source contract and how will this cost containment procedure affect the wholesale price of formula.

The modeling strategy has been to assume the price charged by the firm's competitors had no impact on the firm's demand. This assumption is reasonable if mothers primarily rely upon non-price related information to decide which brand of formula to purchase. Given that mothers may be reluctant to change brands solely in response to prices, competition on the basis of price for self-paying customers may not be high. However, when the government places the formula consumed by WIC mothers for competitive bids based upon price, the firm's behavior may become more competitive. Consequently to talk about one firm in isolation from the other firms may create some confusion for the reader.

Let us assume there are only two firms (X and Y). We will also assume that the government has already implemented a program to provide formula free to low-income mothers but pays the same price for formula as non-WIC mothers pay for their formula. For all practical purposes, this describes the WIC program prior to the institution of the rebate program. We will assume that the infant formula market can be divided into four distinct types of sales: Firm X's sales to WIC mothers; Firm Y's sales to WIC mothers; Firm X's to mothers who pay for their formula; and Firm Y's sales to mothers who pay for their formula.

With the rebate program, the government submits for a competitive bid the total purchases of formula intended for all WIC mothers. If the firm loses the competitive bid, it will be assumed that they will be able to maintain the sales they had made to the self-paying mothers prior but will lose the sales they had made to WIC mothers. For the firm who wins the contract, their total sales will increase because they now will be providing formula to all of the WIC mothers as well as the sales to the self-paying mothers who had purchased their brand prior to the institution of the rebate program.

It has been suggested that the winner of a sole source contract wins more than the sales to the WIC mothers who would have bought a different brand if they had the choice. Some observers have proposed a 'shelf space effect' on sales of the winning brand. Because the WIC program represents a majority of volume sales in a state, winning the sole source contract will most likely result in an increase in the shelf space retailers will provide to the winning brand. If self-paying mothers use the increased shelf space as an implicit endorsement of the winning brand and begin purchasing the winning brand then it is possible that the winning firm could win more by capturing other firms' sales from the self-paying mothers. While this effect is possible, in this version of the model we ignore this additional benefit to the firm of winning the sole source contract.

With the rebate program, winning the sole source contract means not only the firm will 'keep' the WIC eligible mothers on WIC who would have bought their formula in the absence of WIC but also the other WIC mothers who would have bought other brands. Hence if the firm wins the contract, their total sales will be

$$Q_C = (1+\sigma)\,\tau\, B \tag{10}$$

where σ represents the purchases of WIC mothers who would have bought other brands expressed as a percentage of the firm's WIC sales in the absence of the rebate program. Note the firm's share of the WIC market in the absence of the sole source rebate program is $1/(1+\sigma)$.

We will assume that the firm is risk neutral and chooses the formula price and rebate amount prior to knowing whether or not they have 'won' the contract. In particular they will choose the price (*P*) and the per unit rebate (*R*) to maximize their expected profits. The winning firm will be the firm that offers the lowest net price (*NP=P-R*) and consequently the firm's probability of winning the contract will increases as the net price falls. Let $\pi(NP)$ denoted the probability of winning the contract and consequently the expected profits would be equal to

$$(1-\pi)\left[PQ_{Lose} - C(Q_{Lose})\right] + \pi\left[PQ_{Win} - C(Q_{Win}) - RQ_C\right]$$

$$PQ_{Lose} - C\left(Q_{Lose}\right) + \pi\,\Gamma Q_C \tag{11}$$

where

$$\Gamma Q_C = (P-R)Q_C - \left(C\left(Q_{Win}\right) - C\left(Q_{Lose}\right)\right) = (P-R-MC)Q_C$$

$$\Gamma = P - R - MC = NP - MC$$

$$Q_{Lose} = Q_{NW} + (1-\tau)Q_W$$

$$Q_{Win} = Q_{Lose} + Q_C \quad \text{and}$$

$$\pi' = \frac{\partial \pi}{\partial NP} < 0 \; .$$

The term, ΓQ_C, represents the firm's gain in profits if it wins the competitive bid – the net price (*P-R*) times the quantity of sales to WIC (Q_C) reflects the total net revenues while the difference $C(Q_{Win}))-C(Q_{Lose}))$ represents the total cost of supplying the formula for the sole source contract. Given our assumption of constant marginal costs of production, the change in total costs equals MC Q_C.

The first order conditions for the firm's profit maximizing choice of price and rebate are

$$Q_{Lose} + P\frac{\partial Q_{Lose}}{\partial P} + \pi Q_C = \frac{\partial C(Q_{Lose})}{\partial Q}\frac{\partial Q_{Lose}}{\partial P} - \pi' \Gamma Q_C \quad (12)$$

$$-\pi' \Gamma Q_C = \pi Q_C \quad (13)$$

The left hand side of equation (12) represents the impact of a marginal change in the price of formula on expected revenues of the firm. As the firm raises its price the firm's revenues from selling formula to the self-paying mothers will change by the amount

$$Q_{Lose} + P\frac{\partial Q_{Lose}}{\partial P} .$$

As the firm changes the price then the total revenues from sales made through the sole source contract will also change by the amount of the quantity purchased through the contract, Q_C. Consequently the firm's expected revenues from the sole source contract will increase by πQ_C.

The right hand side of equation (12) represents the cost to the firm of changing the price of formula. The first term represents effect of a marginal change in price on the production cost of the firm. The second term of the right hand side reflects the impact of a change in price on the probability of winning the contract. If the firm raises the price holding the amount of the rebate constant then the probability of winning falls by $-\pi'$ and consequently the firm's expected loss of profits is $-\pi'\Gamma Q_C$.

Equation (13) represents the condition for the profit maximizing choice of a rebate amount. The benefit to the firm of a larger rebate is the increased probability of winning the contract and the profits associated with winning. Consequently the expected profits from a marginally larger rebate is $-\pi'\Gamma$. However increasing the rebate amount lowers profits if the firm wins the sole source contract. This loss in profits represents the expected cost of a higher rebate (πQ_C) – the right hand side of equation (13). Note that given our assumption of constant marginal production costs, the first order constraint for the rebate is independent of the scale of operation of firm and the size of the sole source contract. Consequently equation (13) can be rewritten as

$$-\pi'\Gamma = \pi \tag{13'}$$

For the firm to maximize its expected profit from selling formula it will select values for P and R in a manner that two conditions expressed in equations (12) and (13) are both met. Given that the net price reflects the average revenue from the sales from winning the contract and determines the probability of winning the sole source contract, the marginal impact of a change in the price of formula on the expected profits from the sole source contract will equal and opposite in sign to the impact of a marginal change in the size of the rebate. Consequently if the firm is to maximize its profits it will set a value of R given P

so that it meets the condition expressed in equation (13) and consequently the condition expressed in equation (12) can be simplified to

$$Q_{Lose} + P\frac{\partial Q_{Lose}}{\partial P} = MC\,\frac{\partial Q_{Lose}}{\partial P}$$

or

$$P\left[1 + \frac{1}{\eta_{SP}}\right] = MC \qquad (12')$$

Examining equation (12′), the rebate amount (*R*) is absent. Consequently, the choice of the formula price is independent of the rebate the firm chooses to bid. Specifically, the firm will price its formula to reflect the price elasticity of the customers who will be facing the 'full' formula price – the self paying mothers who are not participating in the WIC program. The government will be paying a different price, the net price, which can always be determined independent of the price through an adjustment of the rebate amount.

In the absence of the rebate program when the government paid the identical price that self-paying mothers paid, the price elasticity of its paying customers (government and self-paying mothers) would be lower than just the price sensitivity of its self-paying mothers. Consequently, we would expect the firm to set a lower price compared to what it would charge in the absence of the rebate program.

While it simplifies our thinking about the impact of the rebate program if the choice of the formula price is independent of the choice of rebate amount, it is the result of the simplifying assumptions we have made. Earlier in this section, we discussed the potential 'shelf space' effect on the demand of self-paying mothers. To the extent this effect is present, we would expect winning the contract would reduce the price elasticity of the demand for formula of the self-paying mothers. Consequently, the firm's decision to set the price P will be influenced by the probability of winning and hence the rebate amount.

Even in the absence of the 'shelf space' effect on demand of self-paying mothers, the assumption of constant marginal costs is also important to this result. If the marginal production cost (MC) was a function of the scale of operation then equation (12′) would equal

$$P\left[1+\frac{1}{\eta_{SP}}\right]=(1-\pi)MC_{Lose}+\pi MC_{Win} \qquad (12'')$$

where MC_{Lose} and MC_{Win} reflect the marginal cost at the scale of operation losing and winning the contract respectively. Given the probability of winning the contract depends upon the net price, the firm's decision of formula price will be determined simultaneously with the rebate amount (equation (13)).

The choice of criterion for winning the sole source contract plays an important role in creating the separability between the decision of price and rebate. As we noted in the previous section of the paper, the first competitive bids were based upon which firm would offer the largest rebate even though the net price of formula from the winning firm could be higher than the losing firm. If π is a function of the rebate amount, R, and not the net price, the corresponding condition to equation 12′ equals

$$P\left[1+\frac{1}{\eta_{SP}}+\frac{\pi}{\eta_{SP}}\frac{Q_C}{Q_{Lose}}\right]=MC \qquad (12''')$$

Consequently the rebate amount appears in this condition and the firm will have to simultaneously determine the formula price and the rebate amount.

Each of these three alternative scenarios not only make the discussion of the model less transparent but undermine the primary insight – the implementation of a sole source contract system of bidding will lower the formula price not raise it. Under each of these three scenarios, the definite conclusion of the model becomes ambiguous and we can't determine a priori the impact of the rebate program on wholesale prices. Since the criterion for winning the sole source contract is the net price and not the size of the rebate, the third situation is not troublesome. The assumption of constant marginal costs is also not too troubling as long as firms do not bump into capacity constraints. This leaves the 'shelf space' effect as a potential source of concern for this modeling effort.

Let us now turn to the factors determining the size of the rebate. The firm will offer a rebate (participate in the competitive bid) only if it can make a profit on sales to the WIC participating mothers. Given our assumption of constant marginal costs of producing formula, the firm will offer a bid as long as the net price exceeds the marginal costs of producing a unit of formula

$$P - R - MC > 0.$$

If the firm can make a profit from winning the WIC contract then the profit maximizing rebate offer must satisfy

$$-\pi' \Gamma = \pi \tag{13'}$$

where the left hand side represents the marginal benefit to the firm of a higher rebate offer while the right hand side reflects its marginal cost. The firm will offer a rebate as long as the marginal benefit exceeds the marginal cost when the firm's rebate is zero,

$$-\pi'(P)(P - MC) > \pi(P) \tag{14}$$

If the condition expressed in equation (14) is met, the firm will compete for the sole source contract. The amount it bids will be determined by the marginal cost and benefits expressed in equation (13′). The marginal cost of the rebate (π) will rise with larger rebate amounts because our assumption that larger net prices offered by the firm will lower its probability of winning the contract,

$$\frac{\partial \pi}{\partial R} = -\pi' > 0 \tag{15}$$

The marginal benefit ($-\pi' \Gamma$) can't be expected to have a monotonic relationship with rebate amount,

$$\frac{\partial\left(-\pi'\Gamma\right)}{\partial R} = \pi''\Gamma - \pi' \frac{\partial \Gamma}{\partial R} = \pi''\Gamma + \pi' \tag{16}$$

While we have assumed π' to be negative for all net prices (rebate amounts), we have not made any assumptions pertaining to the second derivative of the probability of winning with respect to the net price (π''). At low level of rebates, we would expect the probability of winning to be rising at a increasing rate (π'' > 0). Consequently the marginal benefit of larger rebate amounts should initially be rising as long as

$$\pi''\left[P - R - MC\right] > -\pi'. \tag{17}$$

As the rebate continues to increase diminishing returns to set in and the rate of increase in the probability of winning the contract should decline. The marginal benefit should continue to decline until the rebate is equal to P-MC when the marginal benefit to further increases in the rebate are zero. Figure 8 reflects the marginal benefit and marginal cost at different rebate offers where R* reflects the profit maximizing level of rebate.

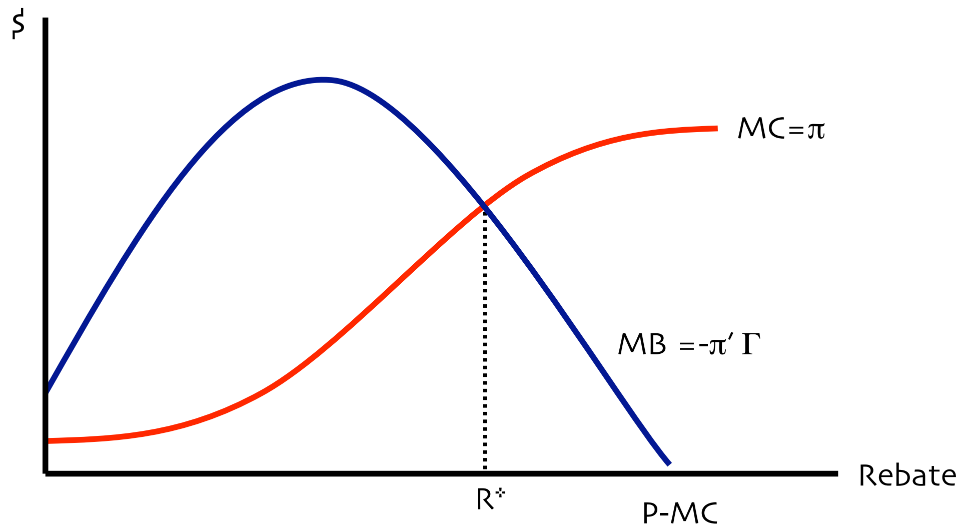


Figure 8 – Marginal Benefit and Cost of Alternative Rebate Offers

When the firm sets the wholesale price, equation (12′) indicates that the mark up of the price over the marginal cost (P-MC) relative to the price will be equal to the inverse of the price elasticity of demand of the self-paying customers. This suggests that the firm will be operating in the elastic portion of the demand of their self-paying mothers. A similar inverse elasticity rule is implicit in the firm's decision of setting its rebate or net price of formula to the government. Equation (13′) can be written as

$$\frac{NP - MC}{NP} = \frac{1}{\eta_C} \qquad (13'')$$

where η_C is the elasticity of the probability of winning the sole source contract with respect to the net price offered by the firm

$$\eta_C = -\frac{NP}{\pi}\pi'.$$

Given the left hand side of equation (13″) must be less than one, the firm will offer a net price to the government that is in the elastic proportion of the probability of winning the contract. The function determining the probability of winning the sole source contract, π, plays the same role in guiding the firm where to set its net price for the WIC contract that the demand function plays in its decision to set its wholesale price.

Assuming the firm has chosen the profit maximizing wholesale price and rebate to bid ($NP^{*}=P^{*}-R^{*}$), the choices must meet the first order conditions (equations (12′) and (13′)) but at the optimal choices, the second order condition with respect to the choice of rebate must also be met

$$\pi''(NP^{*})\left[NP^{*}-MC\right]+2\pi'(NP^{*})<0 \tag{18}$$

This condition will be met if the firm's marginal benefit exceeds the marginal cost of the rebate amount when the rebate amount is zero and the probability of winning the sole source contract declines with increases in the net price.

Let us assume that the firm has chosen the profit maximizing price and rebate (P* and R*). If the firm adopts a higher real wholesale price for formula due to changes in other factors then the marginal benefit ($-\pi'\Gamma$) of the rebate offer increases at initial profit maximizing choices,

$$\frac{\partial(-\pi'\Gamma)}{\partial P}=-\pi''\Gamma-\pi'>0 \tag{19}$$

while lowering the marginal cost of the rebate,

$$\frac{\partial(\pi)}{\partial P}=\pi'<0. \tag{20}$$

Consequently, the firm will increase its rebate offer in response to an increase in the price of formula. But we can be more specific with regards to the magnitude of the change in rebate offer with respect to a change in the price. Since the pricing decision is separable from the choice of rebate, an increase in the wholesale price will be met with an equal increase in the rebate amount to keep the net price constant.

In the model we have specified, the size of the contract (Q_C) does not affect the size of the rebate. This result is a consequence of our assumption of constant marginal production costs that renders the first order constraint guiding the firm's choice of rebate (equation (13')) independent of the size of the contract. However, a slight modification of the model will allow for the size of the contract to have an effect on the rebate.

We will assume that the probability of winning depends not only upon the net price offered by the firm but the size of the contract and the number of firms bidding on the contract,

$$\pi\left(NP, Q_C, N\right)$$

We will further assume that a larger contract as well as more number of firms bidding on a contract will reduce the firm's probability of winning at every net price,

$$\frac{\partial \pi}{\partial Q_C} < 0 \quad and \quad \frac{\partial \pi}{\partial N} < 0.$$

These assumptions appear reasonable since a larger contract may produce more 'competitive' bids from all companies and more firms bidding should also increase the competitiveness of the bids.

Consequently, increases in either the size of the contract or the number of firms bidding will lower the marginal cost of the rebate. If this effect was the only consequence of a more competitive bidding process, the firm would be induced to raise its own rebate offer. However, the impact of either of these variables on the marginal benefit of the rebate ($-\pi'\Gamma$) is ambiguous. The increased competition in the bidding for the sole source contract will most likely also reduce the marginal benefit of the profit-maximizing rebate given the less competitive environment. But as long as the marginal benefit falls by a smaller amount than the reduction in marginal cost,

$$\frac{\partial \pi}{\partial Q_C} < -\frac{\partial \pi'}{\partial Q_C}\Gamma < 0 \quad or \quad \frac{\partial \pi}{\partial N} < -\frac{\partial \pi'}{\partial N}\Gamma < 0$$

the firm will increase its rebate offer.

Discussion

During the 1992 Senate Hearings, the rebate program was held responsible for the significant increases in the wholesale price of infant formula. It was believed that companies were attempting to recoup the lost profits due to the rebate program by raising the wholesale price. This model questions that logic and suggests that profit maximization would lead to the opposite conclusion – the rebate program would induce the firm to lower its wholesale price. In the absence of the rebate program, the firm will price its formula to reflect combined price elasticity of non-WIC mothers and the assumed inelastic demand of WIC mothers. But with the rebate program, the firm has the opportunity to charge different formula prices to both self-paying mothers and the government who is purchasing the formula on behalf of WIC mothers. The firm sets a wholesale price that maximizes its profits of selling formula to non-WIC mothers ignoring the size of the rebate and offers a rebate that maximizes its expected profits of selling formula to the WIC population that effectively sets the price to WIC mothers at the wholesale price minus the rebate.

While there are similarities of the current model to a story of market segmentation, the analogy is not complete. Let us assume that the firm could segment its clientele into two markets and for simplicity we will denote them as the WIC and non-WIC markets. The theory of market segmentation suggests that the firm would want to charge different prices to both markets based upon the price elasticity present in the separate markets – charging higher prices in the market with the more price inelastic demand. Compared to the situation where the firm could not segment the market, individuals that are more sensitive to the price would face lower prices when the market was segmented and consequently benefit from segmentation.

As we have argued, in the absence of the WIC program, WIC mothers will be more price sensitive than non-WIC mothers. But the WIC program 'transforms' these mothers into perfectly inelastic consumers. In the absence of the rebate program, the WIC program lowers the market price elasticity of the demand for formula that allows the firm to raise the price of formula to both non-WIC mothers and the government who is purchasing the formula for the WIC mothers. With the rebate program, the firm can effectively charge different prices to non-WIC and WIC mothers. Market segmentation theory would predict that when the market are segmented the price to non-WIC mothers will fall since the price elasticity of their demand is greater than the total market when the WIC program is instituted. We should also note that the price the firm would charge to non-WIC mothers with the rebate program would be higher than the price they would charge these mothers in the absence of the WIC program. The reason being that if WIC mothers did have to pay for their formula then they would be more price elastic than the non-WIC mothers and hence in the absence of the WIC program, the price elasticity of the total market demand would be more price elastic than of the non-WIC mothers.

While there is a great deal of similarity between the present model and the market segmentation story for non-WIC mothers, the analogy breaks down for WIC mothers. In the absence of the rebate program, firms can't distinguish between types of customers but the rebate program creates a mechanism that allows them to do so. When the market is segmented in the rebate program, the price of elasticity of the WIC mothers is no longer relevant. If it were then the net price to WIC mothers should rise not fall. What is missing is the reality that when rebate program is implemented, the government can also exercise its market power by demanding a lower price for the formula it is purchasing. The market segmentation model assumes that the presence of market power only on the seller's side of the market.

Why do Firms Bid on Sole Source Contracts?

For infant formula manufacturers, the rebate program has eroded the profitability of the market. Prior to the implementation of the sole source contracts, firms were enjoying rising profits as real formula prices steadily rose even though the cost of their inputs didn't. The government was a passive 'customer' who paid for the decisions being made by WIC mothers. The rebate program spelled an end to this relationship as government demanded and was able to acquire discounts for their purchases.

As we retold in the previous section of the paper, the manufacturers were not happy with this arrangement and actively attempted to undermine the rebate program. Faced with the sole source contract, what could the firms do? Their only option was to refuse to bid on the contracts. This was exactly what they attempted to do. But this option would only work if the demand from WIC mothers would have gone unmet. If the firms could enter into a binding cooperative agreement not to bid then the government could have been forced into abandoning its rebate program. But in the absence of such agreement, each firm had an short-term incentive of greater profits by submitting a bid. We believe that Wyeth was just such actor in the story. Here was a company who held a relatively small market share and was being offered an opportunity to greatly expand their volume of sales if they bid on these contracts. Once Wyeth began bidding and winning contracts, it was only a matter of time before the others would begin to participate. In many respects, this situation mirrors the prisoner's dilemma problem. While it is in the interests of all infant formula manufacturers not to bid, each firm has incentive to do so as long as the others don't.

The model developed in this section also sheds light on the 'Big Two's' offer of the Open Market rebate alternative to the sole source contract as well as Wyeth's reluctance to endorse this alternative approach. By allowing WIC mothers to continue to determine which brand they would utilize, the manufacturers would continue to face a rather price inelastic demand for their product and consequently they would able to maintain their real prices for formula. While they would have to surrender some of their profits to the government, they were betting that the level of profits they would enjoy under the Open Market approach would be higher than they would receive from the sole source contract when they truly would have to compete for sales for WIC mothers. Wyeth on the other hand realized that they stood to potentially gain a larger market share from the sole source contracts than to continue with the current situation where WIC mothers choose their brand of formula.

5. Empirical Model of Real Wholesale Price Determination

Econometric Specification

In Appendix B, we specify a statistical model of how the firm would decide to adjust its nominal price as the price as the price of other goods changed. The proposed adjustment process suggests that any point in time, the firm has previously set a nominal price that it now can change or allow to remain in effect. To determine whether the firm will change its nominal price, the firm examines whether the current nominal price adjusted for changes in the price of other goods (P^C) is sufficiently below (λ) the firm's desired real price (P^*). If it is not then the firm does not change its nominal price. If it is then the firm changes its nominal price to reflect the firm's current desired price plus a 'mark up' (μ). This relationship is summarized in equation (21),

$$\ln(P_t) = \begin{cases} \ln(P_t^*) + \mu & if\ \ln(P_t^c) \leq \ln(P_t^*) - \lambda \\ \ln(P_t^c) & if\ \ln(P_t^c) > \ln(P_t^*) - \lambda \end{cases} . \tag{21}$$

The theoretical model developed in the previous section explains how the firm would determine its desired price in the presence of the WIC program providing formula free of charge to low-income mothers and a cost containment effort patterned after a competitive sole source rebate program. We hypothesized that the desired price would be affected by market conditions such as the number of infants who would be formula fed and the number of competitors in the market as well as the cost factors such as the price of inputs (milk). Let us represent all of these factors with the vector X and assume that the firm's desired price would be a linear combination of these factors

$$\ln(P_t^*) = \alpha + \beta' X_t + \varepsilon_t \ . \qquad (22)$$

If we assume that ε is independently and normally distributed with mean zero and standard deviation σ and Δ represents the set of all t where a nominal price change occurred, the log likelihood function would equal

$$\sum_{t \in \Delta} \ln\left(f\left[\frac{\ln(P_t) - (\alpha + \mu) - \beta' X_t}{\sigma} \right] \right) + \sum_{t \notin \Delta} \ln\left(F\left[\frac{\ln(P_t^C) - (\alpha - \lambda) - \beta' X_t}{\sigma} \right] \right) \qquad (23)$$

where f() and F() are the standard normal density and cumulative functions respectively.

Given values for μ and λ, equation (23) represents the likelihood function for the censored normal regression model, a generalization of the Tobit model. Unfortunately, all three parameters can't be identified by the available data. In Appendix B, we show that the sum of μ and λ will equal the desired growth in the real price plus the anticipated inflation. Consequently at the time of a contemplated price change, λ will be a linear function of μ and can't be estimated separately by the model. In practical terms this implies that any combination of μ and λ that yields the same sum will produce the same set of estimates of the model.

It was hoped that at a minimum, we could estimate α and the sum of the other two parameters, $(\mu+\lambda)$. Unfortunately, when we tried to estimate this specification, the model could not be identified. Hence to estimate our model, additional information about (μ+λ) or α is needed.

The data on price changes by the firms was examined to glean a reasonable guess about the sum of real price growth and anticipated inflation. By comparing the real price established at the time of subsequent prices changes, we approximated the desired growth in real prices and the amount of inflation experienced.

Given we know the prices of both Mead Johnson and Ross Labs have been similar, it is not too unsurprising that these calculations suggest the average of (μ+λ) is similar across both firms and product formulations. The average sum for Mead Johnson was 5.2% for milk based liquid concentrate and 5.1% for milk based powder. For Ross Labs, the averages were 5.4% for both formulations.

Given these calculations, one estimation approach is to adjust the formula prices when the firm changes prices by subtracting .051 for Mead Johnson milk based liquid concentrate brands; .052 for Mead Johnson milk based powder; and .054 for all of Ross Labs brands. This is equivalent to constraining λ to be zero and assuming μ to have the above values (recall the any combination of the parameters producing the same sum will yield the same model estimates).

One would expect the sum of μ and λ to vary over the time. Figures 9 and 10 display the calculated sum of (μ+λ) (marked by the Total line with triangles), growth in real prices (line with circle) and experienced inflation between price changes (line with no symbols). The first figure is for Mead Johnson's milk based liquid concentrate while the second is for Ross Labs. The data for the two companies' powder formulations are similar and not presented.

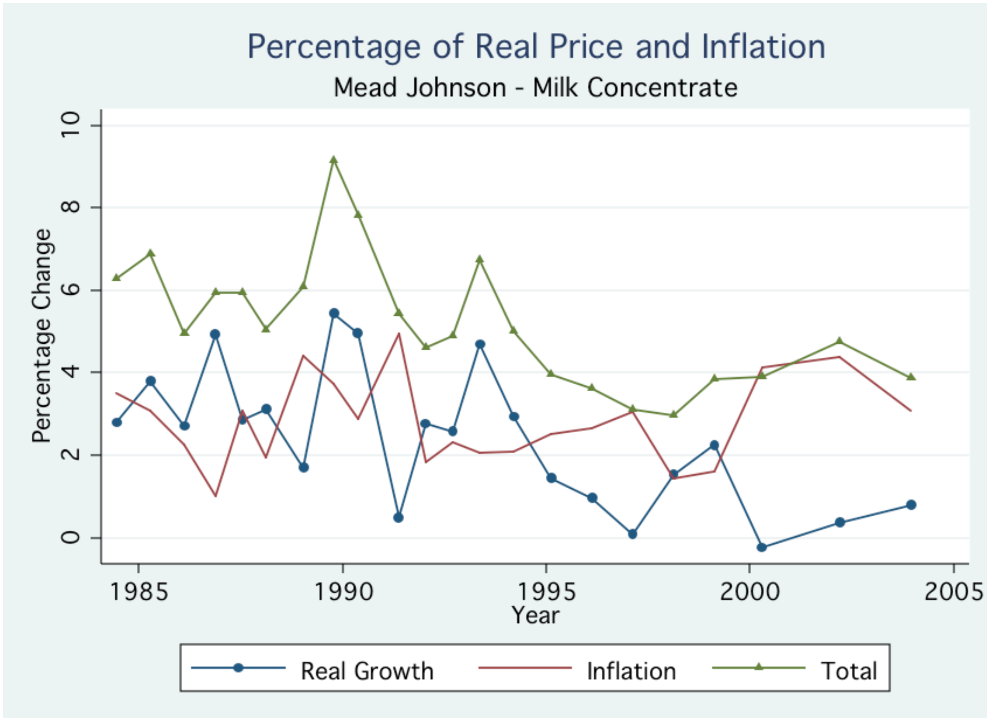


Figure 9

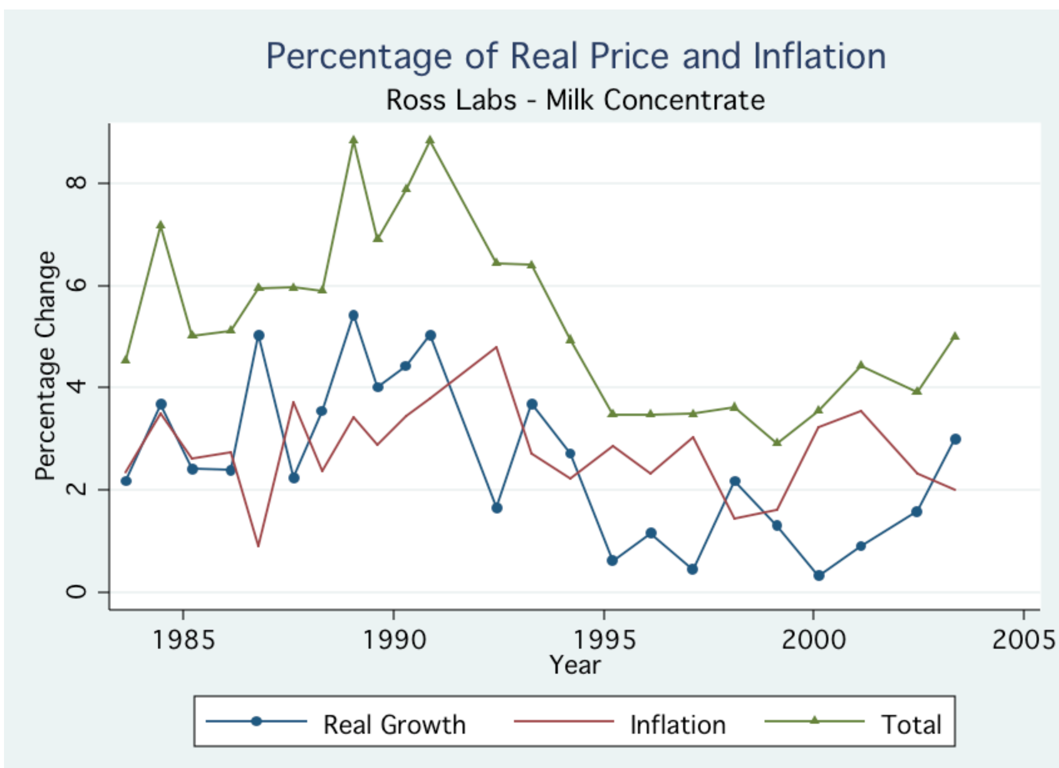


Figure 10

Over the period of our study, increases in the nominal prices (the sum of ($\mu+\lambda$)) have been created equally by increases in growth in real prices and inflation. The patterns between the two companies is similar until 2000 when Ross Labs appears to be engaging in a policy to raise the real price of its product compared to the modest increases implemented by Mead Johnson.

The second approach to estimation is to allow the variation in the sum of ($\mu+\lambda$) to be reflected in the estimation by adjusting the price by the estimated sum ($\mu+\lambda$) at the time of the price change instead of a constant adjustment done in the first approach.

Factors Affecting the Desired Price

Based upon the theoretical model, we hypothesize that increases in the size of the WIC program should have induce firms to increase the wholesale price of their formula in response the increasing price elasticity of demand for their product as well as increased sales. The variable we have chosen to capture the size of the WIC program is the percentage of infants who are WIC (onWIC). As we documented in that chapter, outreach of state agencies has over the time period of our analysis increased the percentage of infants participating in WIC from about 20 to 50 percent.

The model also suggests that the rebate program would lead to lower real wholesale prices for formula. To account for the time lag in the states adopting these cost containment we constructed a variable, Rebate, that represents the percentage of all WIC infants covered by a sole source contract in the state they resided.

Over the time period covered by this study (1981 through 2002), the potential size of the infant formula market has undergone some significant changes due to changes in fertility and breastfeeding rates. Figure 11 presents the time trends in both the number of infants and breastfeeding rates during this period.

Since 1981, the total number of infants (aged from birth to 1 year old) has ranged from 3.6 million to slightly over 4.1 million. The 1980s witnessed a steady increase of roughly 10 percent in the number of infants in the United States. Since 1991, the number of infants initially fell and then recovered after 1996 to the point where in 2003 there are slightly over 4 million infants.

Breastfeeding rates have fluctuated over this period. During the 1980s as the number of infants rose, breastfeeding rates decline from 29 percent to 21 percent – roughly a 27 percent decline[12]. Since 1990, the breastfeeding rate of mothers has increased from the low of roughly 21 percent to the average rate of breastfeeding of 38 percent.

Consequently, the size of potential market for the formula companies has been altered by these two trends. Shown in Figure 12, the number of infants who would have been potentially fed with formula rose over the 1980s but since 1990, the number of infants fed with formula has steadily decline.

We chose to capture these trends by allowing for separate effects for the number of infants and changes in breastfeeding rates over time by including the log of the number of infants (expressed in millions) denoted by the variable **LnInfants** and by the log of percentage of the infants not breastfeeding (100 – breastfeeding rate) denoted by the variable **LnFFRate**.

[12] The breastfeeding rates used in this study reflect the average rates over the first year of the child's life. See Appendix C for the description of how this breastfeeding rate was constructed.

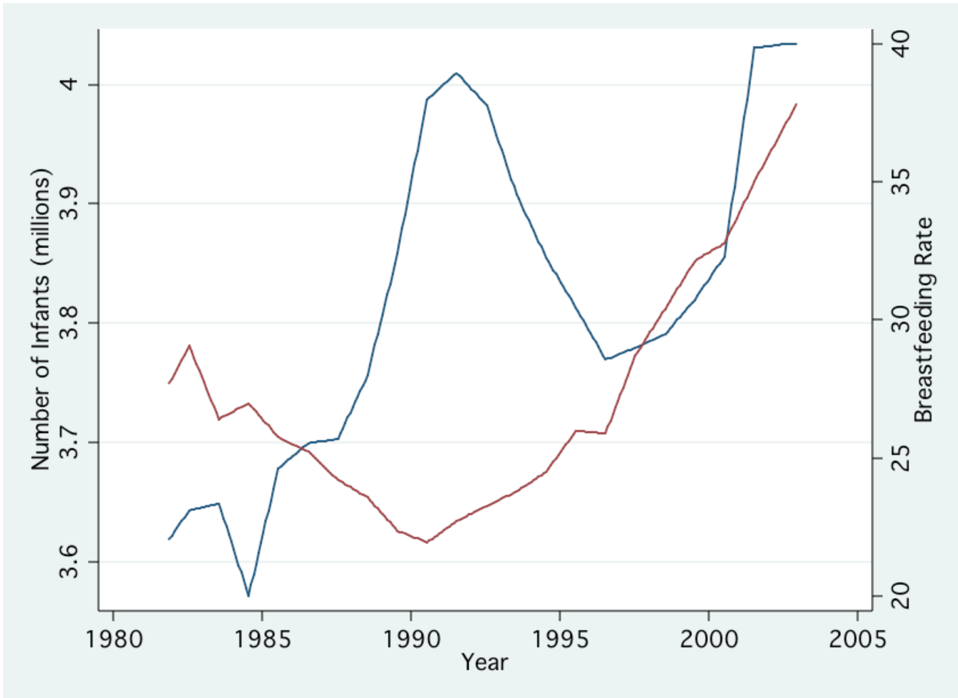


Figure 11
Number of Infants and Breastfeeding Rates: 1980 to 2002

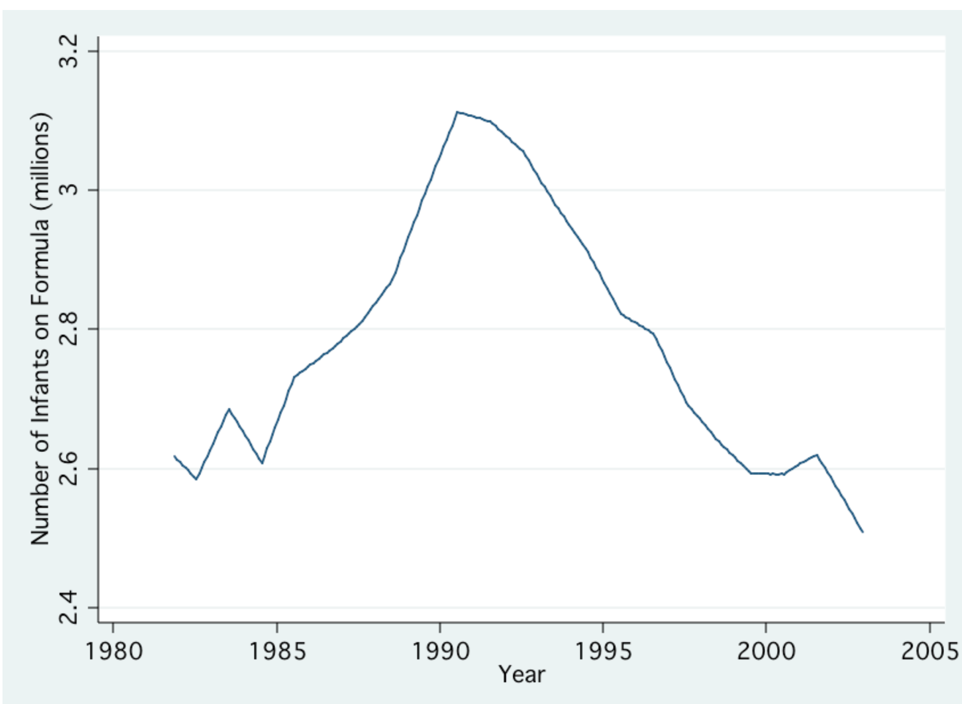


Figure 12
Estimated Number of Infants Using Formula

Increases in the cost of inputs should have a positive effect on prices. The only input price that we could obtain was for the primary component of formula, milk or soy. In a previous section we documented that over the period of this study, the real price of both milk and soybeans have been declining. Since we will be focusing solely on milk-based products, we constructed a variable reflecting the log of the real price of milk, LnRPMilk.

While the 'Big Two' firms – Mead Johnson and Ross Labs – have continuously marketed formula over this time period, they have faced competition from different firms. Wyeth marketed formula under their name but ceased in 1996. Nestle with its acquisition of Carnation began marketing its Good Start brands in 1990. To capture the changed nature of the competition for the Mead Johnson and Ross Labs, we constructed two dummy variables reflecting these different time periods. Comp4 is a dummy variable equal to one for the time period when there were four firms marketing (1990 through 1996) and zero otherwise. NestleOnly is a dummy variable equal to one for the time period when Nestle was the only competition (after 1996) and zero otherwise. The coefficients on these variables would reflect the differential effect of these competitive situation compared to the level of competition when only Wyeth was the sole competitor. Given that Nestle has been adopted a different marketing strategy compared to the other three firms based upon price, we would expect that both of these variables would have a negative effect on the real wholesale price.

Empirical Results

We have chosen to focus solely upon the determination of the real price of milk based infant formula (both liquid concentrate and powder formulations) marketed by Mead Johnson and Ross Labs. We have limited our attention to the milk based products primarily because they represent the vast majority of WIC purchases. As we have noted previously, the data covers the period from November 1981 through December 2002.

For each of the four types of milk-based formula (liquid concentrate and powder formulation for both Mead Johnson and Ross Labs), there were 254 monthly observations. After completing separate analysis of each formula type, we conclude that we could statistically combine the data into one analysis sample of 1,016 observations[13]. We did account for differences between with four different types of formula with series of dummy variables.

In our analysis, we controlled for the following variables that varied by month:

OnWIC	Percentage of infants participating in WIC (0 to 100)
WICRebate	Percentage of WIC infants covered by a rebate Contract (0 to 100)
LnInfants	Log of the number of infants (in millions)
LnFFRate	Log of the proportion of infants NOT breastfed (0 to 1)
LnRPMilk	Log of the real price of wholesale milk
Comp4	Four (Mead Johnson, Ross, Wyeth and Nestle) Firms are marketing formula
NestleOnly	Three firms ((Mead Johnson, Ross and Nestle) are marketing formula
	Omitted Category: Three Firms (Mead Johnson, Ross and Wyeth) are marketing formula
RossMC	Ross Labs' liquid concentrate
MJPowder	Mead Johnson's powder formulation
RossPowder	Ross Lab's powder formulation
	Omitted Category: Mead Johnson's liquid concentration

[13] Although we will treat the observations as independent, the 1,016 observations represent 4 observations per time period (two companies and two product types) and 254 time periods. The observations are most likely correlated both at a point in time and across time. To account for these correlations is beyond the scope of this project.

Censored Normal Regression Results

We employed two approaches to solve the problem of under identification of the model. One approach was to assume a constant value for the sum of the adjustment factors (μ+λ) that reflected the anticipated growth in real prices and inflation for each of the two types of formula produced by the two firms. The second approach was to allow the sum to vary over time by using the percentage change in nominal price computed at a subsequent price change as the estimate of (μ+λ). The maximum likelihood estimates of the desired real wholesale price model based upon these two approaches are found on the next page. For comparison purposes, we report OLS estimates of the wholesale price model in Appendix D. If the censored normal model is correct then we would expect the OLS estimates of coefficients to be attenuated and the standard errors to be understated. Both of these expectations were present when the OLS is compared to the maximum likelihood.

Comparing the results from the two approaches, there are only minor differences between the magnitudes of the estimates and estimates of the standard errors. Consequently for the remainder of the paper, we will focus upon the first approach of a constant value for (μ+λ).

Censored Normal Regression

Approach One: Constant Value for ($\mu+\lambda$)

ALnPrice	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
OnWIC	.0253026	.0009166	27.61	0.000	.023504	.0271013
WICRebate	-.0022243	.0002594	-8.58	0.000	-.0027333	-.0017154
LnInfants	.8326889	.0777006	10.72	0.000	.6802152	.9851627
LnFFRate	-.0814404	.0545312	-1.49	0.136	-.1884484	.0255676
LnRPMilk	.0200853	.0190793	1.05	0.293	-.0173544	.057525
Comp4	-.0181004	.0088623	-2.04	0.041	-.0354911	-.0007097
NestleOnly	-.0399155	.0135846	-2.94	0.003	-.0665728	-.0132581
RossMC	.0072932	.0043994	1.66	0.098	-.00134	.0159263
MJPowder	-.0387837	.0043568	-8.90	0.000	-.0473332	-.0302342
RossPowder	-.0211428	.0044166	-4.79	0.000	-.0298096	-.012476
_cons	.8809812	.1351697	6.52	0.000	.6157345	1.146228
/sigma	.0225118	.0014785			.0196104	.0254131

Censored Normal Regression

Approach Two: Time Varying Value for ($\mu+\lambda$)

CALnPrice	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
OnWIC	.0251905	.0008892	28.33	0.000	.0234457	.0269353
WICRebate	-.0021955	.0002516	-8.73	0.000	-.0026892	-.0017018
LnInfants	.8389881	.0756771	11.09	0.000	.690485	.9874912
LnFFRate	-.0808874	.0532011	-1.52	0.129	-.1852852	.0235104
LnRPMilk	.021432	.0185491	1.16	0.248	-.0149675	.0578314
Comp4	-.0183913	.0085675	-2.15	0.032	-.0352035	-.001579
NestleOnly	-.0389689	.0132262	-2.95	0.003	-.064923	-.0130148
RossMC	.0086673	.0042939	2.02	0.044	.0002413	.0170934
MJPowder	-.0383046	.0042653	-8.98	0.000	-.0466745	-.0299348
RossPowder	-.0198801	.0043084	-4.61	0.000	-.0283346	-.0114256
_cons	.8706964	.1313244	6.63	0.000	.6129952	1.128398
/sigma	.0215048	.0014006			.0187565	.0242532

The estimated effect of the expansion of the WIC program conforms to our theoretical predictions that providing more infants with free formula would lead to increases in the wholesale price. For every percentage point increase in the take up rate, the wholesale price is estimated to rise by 2.5 percent. The sole source rebate program is estimated to have depressed wholesale prices. Today, the rebate program covers roughly 92 percent of WIC infants consequently the estimates indicate it has resulted in 20.4% lower real wholesale prices for infant formula.

We anticipated that both the number of infants and rate that infants are not breastfed would have a positive effect on prices by increasing the size of market for all manufacturers. While the number of infants has the predicted sign, the estimated coefficient of the formula feeding rate (LNFFRate) is negative. This negative coefficient implies that if the number of infants remains the same and the breastfeeding rate decreases (increases) then wholesale price will decrease (increase). This result remains somewhat of a mystery but when estimated a slightly different specification where a single variable (LNFFInfants = LNInfants+LNFFRate) reflecting the number of infants estimated to be using formula, the estimated positive relationship reflects our prior expectations.

Our control for the price of production inputs (LNRPMilk) has the expected effect. Increases in the price of milk are associated with a increases in the price of formula although the statistical significance of the estimate is not high.

The effect of competition from other firms was expected to depress the price of formula prices of the 'Big Two' – Mead Johnson and Ross Labs. The estimated coefficients confirm our expectations. When both Wyeth and Nestle represented the competition to the 'Big Two', wholesales were on average 1.8 percent lower. After Wyeth exited from the market, the competitive pricing practices of Nestle had even a larger impact on the 'Big Two' depressing real wholesale prices by 4 percent.

Brand and formulation of the type of formula have an effect on the price of formula. Ross Lab's liquid concentrate after controlling for other factors is .7 percent more expensive compared to Mead Johnson's liquid concentrate over this time period. Powder from both firms is less expensive than Mead Johnson's liquid concentrate. Mead Johnson's powder is 3.8 percent lower while Ross Lab's powder is 2 percent lower than Mead Johnson's concentrated formulation.

Estimated Impact of Free Formula and the Rebate Program

One of the central goals of this research project has been to determine the extent to which the provision of free formula to low-income families and the sole source rebate program have affected the wholesale price of infant formula. We have specified a theoretical model that predicts that providing infant formula to low-income mothers whose demand would be extremely price elastic would reduce the overall price elasticity of the demand for infant formula allowing firms with market power to raise the real price of formula.

In the absence of a sole source rebate program, the government acts as a passive buyer of formula even though they are accounting for roughly half of all formula sales. With the implementation of the sole source rebate program, the government is exercising its power in the market. With the rebate program, the firms must compete for the WIC market. Under the assumption of risk neutrality, the profit maximizing firm will set the wholesale price to reflect the willingness of self-paying mothers to pay for formula that presumably will be less than if the market was the combined purchases of all mothers.

Consequently we would expect the wholesale price to be less than it would be in the absence of the rebate program.

These predicted effects of WIC and the rebate program were found in our analysis of the time series (1981 through 2002) of milk-based infant formula of the largest two manufactures of infant formula – Mead Johnson and Ross Labs – that account for roughly 85 percent of all sales of formula. The coefficient on the percentage of all infants participating in WIC (OnWIC) of .0253 implies that for every percentage point increase in the participation rate of infants in WIC, the real wholesale price would increase by 2.5 percent. The coefficient on the percentage of WIC infants covered by a rebate contract (WICRebate) was a negative .00222 implying that as more states implemented a rebate program the real wholesale price would be lower than previously. That is not to imply that companies actually lowered their prices but increased their wholesale prices by a lesser amount than they would have had if the sole source rebate program was not in effect. Today, state rebate program covers 92 percent of WIC infants (it is not 100 percent in our data because we didn't have rebate information for two states, Mississippi and Vermont, and Indian tribal agencies). This implies that if the sole source rebate program had never been implemented, real wholesale prices would be 20.4 percent higher than are today.

Today, 47.6 percent of all infants participate in the WIC program. To estimate the impact of the WIC program's provision of free formula, we would want to know what would be wholesale price today if in 1972 we had not implemented a WIC program. Of course if there was not a WIC program, it is doubtful if the government could have implemented a rebate program. Consequently, the total effect of the current WIC program on real wholesale prices is .0253(-47.6) - .00222(-92) or real formula prices have doubled (100 percent increase) over what they would have been in the absence of the program. If the government had not implemented the rebate program, real price would have been 20 percent higher still or 120 percent higher than in the absence of WIC.

The consequences of WIC on formula prices for non-WIC mothers can't be understated. Doubling of the price of formula for those mothers who must pay from their own pockets can be a financial burden that can be avoided only if one chooses methods other than formula to feed their infants. The ideal alternative would be breastfeeding and perhaps the most significant promotion of breastfeeding that WIC has had on non-WIC mothers is through its effect on formula prices. While it is not a focus of this project, an interesting project would be to examine the differences in breastfeeding rates between WIC and non-WIC mothers over time. If rising formula prices are affecting breastfeeding rates then we should expect to see breastfeeding rates to increase faster for non-WIC mothers than for WIC mothers.

The potential costs of WIC mothers using infant formula instead of breastfeeding must be balanced against the financial benefits derived from participating in the WIC program. However from the perspective of the WIC mothers, the rebate program is inconsequential. Since infants have high priority in WIC funding, rising formula prices are unlikely to limit their access to the program. However, other WIC eligible families who might not be served if overall funding is limited would be affected by the absence of the rebate program. But if Congress continues its pledge to fully fund WIC then taxpayers will bear the burden of the higher prices. In the absence of the rebate program, taxpayers and non-WIC mothers would be paying $2.20 for formula that in the absence of the program would cost only $1.00. If the real costs of formula manufacturing have remained constant then producing formula has been extremely more profitable with the implementation of the WIC program.

The rebate program based upon sole source competitive bidding was aimed at reducing the cost to the taxpayers at the expense of the formula companies. Our estimates suggest that with the rebate program the real price of formula would be $2.00 for what would have cost $1.00 in the absence of the program – saving non-WIC mothers 20¢ but even more for taxpayers. Historically, the rebates have been on average 85% of the wholesale price. This implies that the net price to the taxpayer would be 30¢ implying a much lower profit margin on formula sold to the WIC program.

Compared to the world without WIC, the current WIC program creates a situation where the firms can increase their profit margins on volume sold to non-WIC mothers but at the expense of lower profit margins for formula sold to WIC. Overall profits of the firms will depend upon the volumes of formula sold to the two groups. As the firm raises the prices to the non-WIC mothers, the volume of sales can be expected to fall but we would not expect them to raise prices so that total profits to this group would be less than under the old price of $1.00. But the profits would not be as great as in the absence of the rebate program – they would fall by 20 percent. Profits with the rebate program should still exceed the profits the firm would make on the non-WIC mothers if there hadn't been a WIC program providing free formula. The comparison of profits with and without the WIC program for sales to WIC mothers is less clear. When the rebate program is implemented, the profit margin per unit should fall but it should expect to continue to make a profit otherwise the firm would not offer a rebate or bid. Consequently, the firm's profits from sales to WIC mothers will be less with the rebate program unless increased volume of sales to the WIC is substantially higher.

This argument about the impact of the rebate program on profits compared to the situation without a WIC program (also no rebate program) may explain the exit of Wyeth from the infant formula market. Given its relative low volume of sales, it found that its total profitability under the WIC rebate program was less than it was when there was no WIC program. It could effectively capture the old days of the absence of the WIC program by stop marketing its own brand, stop participating in the WIC program, and become in essence a low price brand sold directly to retail outlets for their marketing to non-WIC mothers.

The above comparisons examine the total impact of the WIC program on wholesale prices but we can also examine the contribution of the WIC program to the growth in the prices over the two decade period. Instead of calculating the percentage change based upon actual prices, we examined the predicted desired real prices derived from the censored normal regression model. Over the twenty year period, the predicted real wholesale price of formula rose by 60.2%. In 1981, 16.8 percent of all infants participated in the WIC program and the rebate program was not in existence. If the WIC program had not expanded (participation rate remained at 16.8) and the rebate program had not been implemented then the real prices of formula would have increased by 5.3 percent accounting for all changes in all other factors (number of infants, breastfeeding rates, price of milk, and competition in the industry). Consequently the WIC program accounts for 91 percent of the increase in the growth of real formula prices during this period.

While we are convinced by the evidence that the expansion of the WIC program's provision of free formula is largely responsible for the dramatic increases in the price of infant formula, some additional analysis could provide even more convincing evidence. If we could obtain data covering a time period starting prior the implementation of WIC (for example starting in the late 1960s), we could have some direct evidence on the pattern of prices without the

WIC program. Unfortunately, we were unable to obtain the wholesale price data from the companies.

6. Time Pattern of Bids in the Rebate Program

For the time period of this study (1986 through 2002), 117 competitive sole source solicitations were held. In only three of these competitions, Mead Johnson and Ross Labs both chose not to offer a bid. Two of these bids were early in the rebate program where Wyeth was the only bidder. In fourteen other competitions, one of the 'Big Two' chose not to bid – in nine occasions Ross Labs was the sole representative of the 'Big Two' to bid. In the remaining 100 contracts, both Mead Johnson and Ross Labs submitted bids.

When Mead Johnson or Ross Labs were the sole representatives of the 'Big Two', they were very successful in obtaining the contract against Wyeth or Nestle. When Mead Johnson submitted a rebate bid and Ross Labs didn't, Mead Johnson won each of the five contracts. Ross Lab's success wasn't perfect but they did win eight of the nine contracts where they chose to submit a bid and Mead Johnson didn't. When both of the 'Big Two' submitted rebates bids, Mead Johnson was successful in winning 44 percent of the contracts and Ross Labs in 35 percent of the time.

Given the dominance of Mead Johnson and Ross Labs both in the overall market and in securing sole source contracts, we decided to focus our analysis on the bidding practices of the these two companies. Consequently, our analysis will be limited to the 105 bids of Mead Johnson and 109 bids of Ross Labs submitted to competitive bids prior to 2003 when the enriched formulas containing DHA/ARA began to enter the market in significant quantities.

The winner of a competitive bid is determined by which company that offers the lowest net price for the various formulations and bases stipulated in the call for bids provided by the state. For example, the state proposes to pay for W cans of milk based concentrated formula; X cans of milk based powder; Y cans of soy base concentrate; and Z cans of soy base powder. The companies are required to provide rebates for each base and formulation of infant formula. Then using the firm's wholesale price, the net price of each type of formula is computed. Finally a weighted net price is calculated based upon the relative amounts of formula called for in the bid announcement. The winner of the bid process is the company offering the lowest weighted net price.

This procedure does allow for companies to offer lower rebates on the types of formula that are not highly weighted (utilized) by the state. Unfortunately, we were not able to acquire the bids on all of the various types of formula requested by the state but had access to only the rebates and net prices offered on milk based concentrate. Consequently the analysis will be limited to this type of infant formula. While in the early years of the rebate program milk based concentrate was the dominant formula requested by states, over time milk based powder has become the most requested type of formula. We will not able to estimate how the trend from concentrate to powder formulation has affected the rebates offered by manufactures.

While the net price is the most relevant perspective to examine the effectiveness of the rebate program on containing costs, the size of the rebate has also historically been of interest. To account for changes in the wholesale price over time, we computed the rebate amount offered by the firms expressed as a percentage of the wholesale price. Figure 13 presents the offered rebates of Mead Johnson and Ross Labs over the time period of our study.

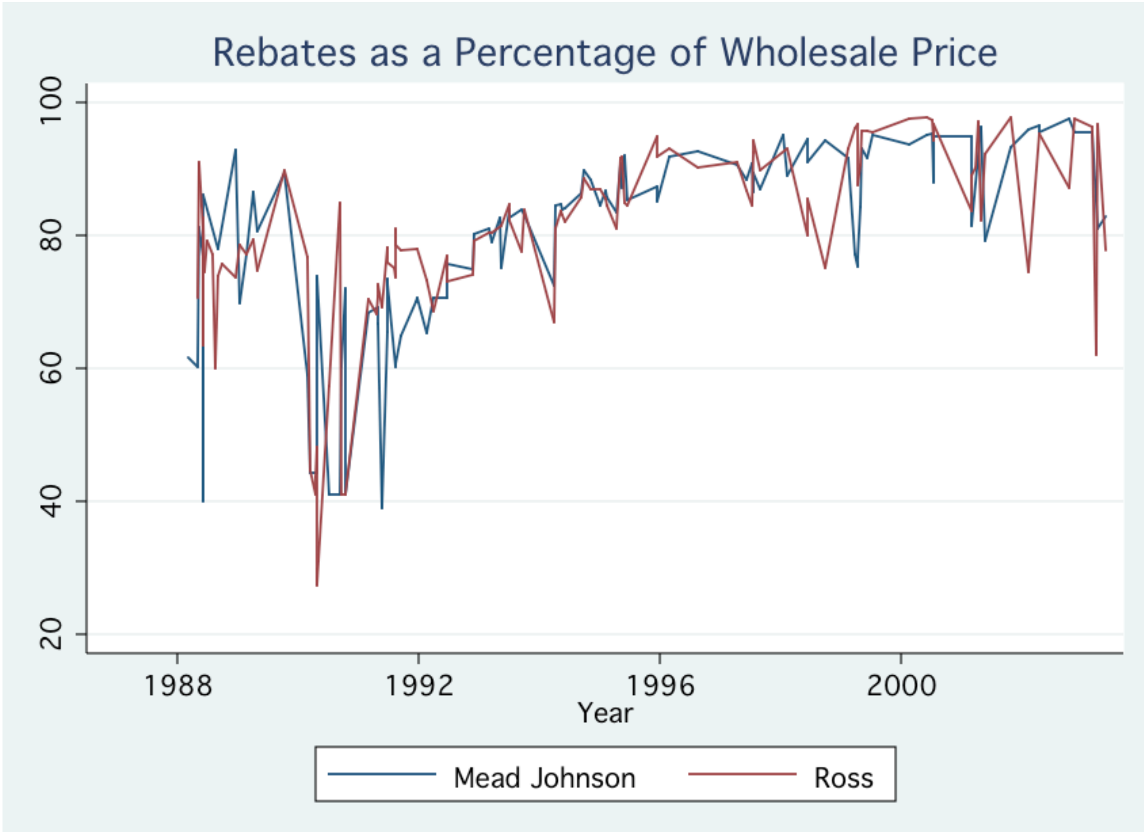


Figure 13

Examining the bids by the 'Big Two', there appears to be three distinct periods. The period covering 1988 through 1991 represents the initial rebate solicitations from states. During this time period there was the infamous series of bids where first Ross Labs and then Mead Johnson tried to establish a baseline rebate of 75¢ per can that accounts for rebates bids in the 40 percent range. Over the time period, the average rebate as a percentage of the wholesale price was 65% for Mead Johnson and 69% for Ross Labs. Yet there was significant variation in the bids – the standard deviation for both companies' bids was 15 percentage points. When both companies bid on a contract, the difference between their bids was substantial. The average difference during this period was 12 percentage points.

The second time period runs from 1992 through 1997 when the solicitations were primarily for subsequent contracts. The average rebate was 84 percent of the wholesale price while the variability of offers for each company substantially fell – the standard deviation of the bids of Mead Johnson and Ross Labs was 7 percentage points. When both companies bid the average difference between their bids fell to 3 percentage points. This period could be characterized as when the companies were finally accepting the reality of the rebate program and began to finally adjust. The bidding was competitive and the result was welcomed by the states as the size of the rebates steadily grew over the period.

The final time period running from 1998 through 2002 can be characterized as when rebate program had matured. During this period, the average rebates of both companies averaged 91 percent of the wholesale price. The variability of the submitted rebate bids remained at the same level as in the previous period (7 percentage points). The one distinctive feature of this period was the increase in the average difference between the two companies – increasing from 3 to 8 percentage points.

Two hypotheses emerge from this examination of the data. First as one might expect, the initial solicitation for rebates for a geographic area differs from the subsequent bids. Second, the firms did in fact take a good deal of time to adapt the sole source auctions. It was not 'overnight' and the transition period may have lasted five years (1992 through 1997).

Prior to moving to a discussion of our empirical model, a few comments are required on the geographic area covered in the rebate contract. In most instances, the geographic area being bid in a competitive contract is a state. Of the 114 contracts where either Mead Johnson or Ross Labs submitted a bid, 94 bids were for a single state. However, groups of states have formed to collectively solicit rebate bids. In the remaining 20 requests for bids, the number of states included in the contracted ranged from 2 to 10 states. In the following empirical analysis, all variables used in the analysis were constructed to reflect the characteristics of the geographic area covered by the contract whether it was a single state or a group of states.

Specification of an Empirical Model

This section provides the details of the empirical model that we will employ to examine the bidding behavior of the two major firms in the infant formula industry, Mead Johnson and Ross Labs. We chose to focus upon the bidding behavior of these two firms because since 1996 they have held WIC sole source contracts that cover 85 percent of all WIC infants – a percentage that mirrors the estimates of their combined market shares of all infant formula sales. After an early attempt to resist the states' efforts to employ competitive sole source bids, beginning in 1991 the 'Big Two' adopted bidding strategies that has steadily increased the share of WIC infants using their brands. A second reason for focusing upon these two firms is that the major participant and winner of numerous contracts during the early years of bidding, Wyeth, no longer markets formula under its own name and consequently doesn't participate in the competitive bids. Its replacement, Nestle, participated in a limited number of bids during the time period ending in 2002. Consequently it was felt that there was insufficient data to produce an explicit comparison to the strategies of the 'Big Two' firms.

Our theoretical model suggests that three factors can influence the rebate offers made in a competitive contract: the wholesale price of formula, the size of the contract, and subjective probability of winning the contract. In this section, we will discuss the variables we have constructed to reflect these theoretical constructs.

Dependent Variable: Rebate for a Can of Milk Based Concentrate

While the bids are judged upon the basis of which firm's bid offers the state the lowest net price (wholesale price minus the rebate amount), the theoretical model focused upon the factors that determined the rebate the firm would choose to bid in order to maximize their expected profits. While the model viewed the decision making process as simultaneously determining both the wholesale price and the rebate, we believe that a more realistic perspective is to assume that the firm sets its wholesale price based upon expectations about its potential success in winning the sole source contracts and then determines its bidding strategy based upon the previously sent wholesale price. If this perspective is correct then an empirical modeling of the rebate offer should mirror the estimates of an empirical modeling of the net price submitted by the firm.

In this report, we will provide estimates of an empirical model where the dependent variable is the log of the real (in $2002 dollars) rebate (**lnRebate**) that the firm submitted to a competitive sole source bid held from 1986 through December of 2002. In Appendix E, we report estimates of the empirical model explaining the net prices offered by the two companies.

Independent Variable: Wholesale Price of a Can of Milk Based Concentrate

Based upon our theoretical model, we would predict that if the wholesale price rises then the firm would increase its rebate offer by an identical amount resulting no change in the net price of formula to the government. Based upon the date when the bids for a contract were due, we computed the log of the real (constant dollar) value of the firm's current wholesale price. Given concerns with the possible endogenity of the wholesale price, we chose to employ an instrument for the wholesale price. We constructed this instrument from the fitted values from a regression based upon the model we estimated in the previous section of the paper. Separate regressions for Mead Johnson and Ross Labs were estimated using the same monthly data (1981 through 2002) employed in the previous analysis but where the dependent variable was the log of the real wholesale price of a can of milk based concentrate. The variables controlled for in the OLS regression were the percentage of infants participating in the WIC program (OnWIC), the log of the number of infants in the US (LnInfants), the log of the rate that infants are fed with formula (LnFFRate), the log of the real price of milk (lnRPMilk), a dummy variable indicating whether four firms marketed formula (Comp4), and a dummy variable indicating whether Nestle was the only competitor to the 'Big Two' (NestleOnly). The variable indicating the proportion of WIC infants covered by a competitive sole source contract (WICRebate) was not included in this regression. The predicted variables from this regression (fitlnRWP) were then matched to the data based upon the date when the bids for the contract were due.

As we have already noted, the theoretical model predicts that a dollar change in the wholesale price should be reflected with a dollar increase in the rebate bid by the firm. Since the empirical model seeks to explain changes in the log of the rebates with changes in the log of prices, the coefficient on the price variable reflects the elasticity of the rebate with respect to the wholesale price. Consequently the theoretical model predicts the coefficient on the price variable will equal P/R. For example, if the rebate as a proportion of the wholesale price was .75 then we would expect the coefficient to be 1.33.

Independent Variable: Size of the Contract

WIC agencies have speculated that the rebate they receive from the formula manufactures is determined by the size of their state or the contract group they have joined. Small states feel that they are at a disadvantage relative to larger states in their efforts to contain the cost of their programs through the rebate program. The constant marginal cost assumptions of theoretical model led us to conclude that the size of contract should not have an effect on the firm's bid. However, if the size of the contract increases the competitive bidding for the contract and reduces the probability the firm would win the sole source contract then we would expect the larger contract to be associated with higher bids by the firm. We experimented with several different measures to proxy for the size of the contract but chose to employ a rather simple variable – the log of the ratio of the average of the number of infants in the geographic area covered by the contract relative to the number of infants participating nationally in WIC over the six months prior to the time when the bids were due. This variable is denoted as **lnCSize** whose coefficient is hypothesized to be positive.

Independent Variable: Probability of Winning a Contract

While it is impossible to obtain direct measures reflecting the firm's chances of winning a contract, the number and composition of the firms submitting bids might serve as an indirect indication of the chances of any firm winning. We are hypothesizing that as the number of firms submitting bids increases, the probability of any firm winning should fall. A lower probability of winning the contract, should induce the firm to bid a higher rebate. We included three dummy variables in our analysis to reflect the number and composition of the bidders. The dummy variable, CB_BigTwo is set equal to one if the other member of the 'Big Two' also bids on the current contract and consequently the omitted category is when only one of the dominant firms bids. Holding the number of bidders from the firms representing a minority share of the market (Wyeth and Nestle), we would expect having both dominant firms bidding would increase the size of the rebate.

The number of minor market share firms, Wyeth and Nestle, participating in the solicitation should affect the bidding of the dominant firms. Again we would be believe that if these firms bid, their presence would reduce the probability of the dominant firms winning the bidding and consequently induce the dominant firms to raise their rebate offers. We created two dummy variables to capture the number of these minor market share firms participating in the current solicitation. CB_Minor1 equals one if there was only one minor market share firm participating and CB_Minor2 equals one if both participated. The omitted category was when neither Wyeth nor Nestle participated. It was our expectation that both of these variables would have a positive impact on the size of the rebate with CB_Minor2 having a greater positive effect on rebates than CB_Minor1.

Other Factors

Contracts covering larger proportions of WIC infants can be the result of large states or several states banding together for the purpose of a single competition. While the formation of a group may lead to larger rebates for the states, the companies may incur higher costs in dealing with numerous state agencies compared to a single state with comparable numbers of infants. Consequently, the firms may value the large contracts from groups compared to contracts from single states and bid a smaller rebate even holding the size of the contract constant. We included a dummy variable, **Group**, to indicate whether the contract up for bid was from a group of two or more states. The omitted category represents when the contract is solicited by a single state. The hypothesis coefficient on this variable is negative.

During the time period of the analysis, contracts have been both initially awarded and then reopened for new bids. We hypothesized that the initial solicitation of a sole source contract would differ from later solicitations when a 'benchmark' would have been established by the previously winning rebate as well as the knowledge of what the other firms bid. While we didn't have a specific hypothesis how the bids would differ, we decided to estimate separate models for initial and subsequent solicitations.

For the subsequent contracts, we wanted to examine whether firms tend to bid aggressively with firms who currently hold the contract by offering larger rebates or tend to bid in a way to let the current holder of the contract to keep the contract. Our initial hypothesis was that the 'Big Two' firms would tend to try to outbid competitors who were less dominant in the market (from the 'Big Two's' perspective this would be Wyeth and Nestle) and be differential to a fellow member of the 'Big Two.' We constructed two dummy variables to reflect who currently holds the contract. One dummy variable, **CC_Minor** was constructed to equal one if either Wyeth or Nestle currently holds the contract. The second dummy variable, **CC_BigTwo** was set to one if the <u>other</u> firm in the 'Big Two' currently holds the contract.

It is reasonable to expect the firms would require time to adjust to bidding for the sole source contracts. As our short history of the rebate indicated, the 'Big Two' firms actively tried to undermine the sole source competitive contracts. Most notable was the period when Mead Johnson tried to signal to other firms their intention of setting a baseline rebate of 75¢ per can. After some empirical testing, we determined that Mead Johnson and Ross Labs bidding behavior during this period was significant different than other periods. For that reason, we have eliminated the bids for Mead Johnson and Ross Labs from 15 competitions during the period running from February 1990 through April 1991.

After eliminating these solicitations, the remaining solicitations were effectively divided into two time periods. The first time period (from 1986 to 1990) was composed of initial solicitations while the second was composed of subsequent solicitations. Given we had already decided to estimate the model separately for the initial and subsequent solicitations, we decided to construct separate proxies for the adjustment process as the time that had passed from the beginning of the respective time periods. For the initial solicitations, **Time0** was constructed as the number of years (months divided by 12) that had passed from the first solicitation in 1986 to the current bid. For subsequent solicitations, **Time1** was constructed to reflect the number of years that had passed since April 1991 – the end of the 75¢ rebate era.

Model Estimates and Discussion

We began our analysis of the bidding data by testing whether there was a statistically significant difference of the model specification for bids of Mead Johnson and Ross Labs. For the initial and subsequent solicitations, we separately estimated the empirical specification on Mead Johnson and Ross Labs bids and tested the null hypothesis of equality of the coefficients across firms. The statistical tests based upon the data for the initial solicitations indicated that there was no statistical difference (the p value .582). However, for the subsequent solicitations we found that the sole exception of the effect of the size of the contract, there also was not a significant difference between the bids of the two firms. Consequently we will report estimates based upon the combined data from both manufactures while including a dummy variable, **Ross**, that will equal one if the bid is for Ross Labs and zero otherwise. When analyzing the data for subsequent solicitations, we will include an additional variable that is an interaction between the firm and the size of the contract (**Ross*lnCS**). The coefficient on this variable will reflect the difference between how Ross Labs and Mead Johnson react to different contract sizes.

Our cursory examination of the bid data suggested that the first bids on a state's (or group) contract might differ from subsequent bids. To test that hypothesis, we analyzed separately the bid data by whether the data was a first bid or a subsequent bid. We tested the null hypothesis that the variables common across the two specifications were equal for the two samples. We were able to reject this hypothesis at the 1% level and consequently we will report estimates of the bidding models estimated separately for the initial solicitation of a contract and subsequent bids. Estimates of the bidding model where the log of the real value of the rebate amount.

OLS Model Estimates of Rebate Amount: Initial Solicitations

Source	SS	df	MS
Model	.848139092	7	.121162727
Residual	.643146638	39	.016490939
Total	1.49128573	46	.032419255

Number of obs	47
F(7, 39)	7.35
Prob > F	0.0000
R-squared	0.5687
Adj R-squared	0.4913
Root MSE	.12842

lnRebate	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
fitlnRWP	1.293455	.2090545	6.19	0.000	.8706023	1.716308
lnCSize	.0783273	.0229918	3.41	0.002	.031822	.1248325
CB_BigTwo	.0508939	.0563347	0.90	0.372	-.0630538	.1648416
CB_Minor1	-.1226476	.0818704	-1.50	0.142	-.2882461	.042951
CB_Minor2	-.2769715	.1187182	-2.33	0.025	-.5171016	-.0368414
Group	.0372369	.0758257	0.49	0.626	-.1161351	.1906089
Ross	.0388875	.0382133	1.02	0.315	-.0384063	.1161813
_cons	-.5294064	.1814657	-2.92	0.006	-.8964555	-.1623573

OLS Model Estimates of Rebate Amount: Subsequent Solicitations

Source	SS	df	MS
Model	2.41378667	11	.219435152
Residual	.779260774	126	.006184609
Total	3.19304745	137	.023306916

Number of obs	138
F(11, 126)	35.48
Prob > F	0.0000
R-squared	0.7560
Adj R-squared	0.7346
Root MSE	.07864

lnRebate	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
fitlnRWP	1.095137	.2060902	5.31	0.000	.6872905	1.502983
lnCSize	.023043	.0113405	2.03	0.044	.0006005	.0454855
Ross*lnCS	-.029655	.0150482	-1.97	0.051	-.0594348	.0001249
CB_BigTwo	.0054869	.0341322	0.16	0.873	-.0620598	.0730336
CB_Minor1	-.0314488	.0167184	-1.88	0.062	-.0645341	.0016365
CB_Minor2	.0175777	.0267609	0.66	0.512	-.0353813	.0705366
Group	-.0035263	.0166099	-0.21	0.832	-.0363968	.0293442
CC_minor	.0325019	.0180698	1.80	0.074	-.0032577	.0682614
CC_bigtwo	-.026714	.015551	-1.72	0.088	-.0574889	.004061
Time1	.0184442	.003924	4.70	0.000	.0106786	.0262097
Ross	.0410169	.0189025	2.17	0.032	.0036093	.0784244
_cons	-.3713409	.2085925	-1.78	0.077	-.7841393	.0414576

First Solicitations of Contracts

Estimates of the size of the rebate offered by a firm to an initial contract solicitation suggest that the wholesale price is positively related to the size of the rebate. As we have noted, the theoretical model predicts that every dollar increase in the price of formula would be met with a dollar increase in the rebate amount and consequently there would not be a change in the net price. In terms of elasticities, the theoretical model predicts the elasticity of the rebate should be equal to the ratio of the wholesale price to rebate (P/R). During this period of time, the average ratio of rebate to wholesale price was .76 implying the theoretical model would predict the coefficient on the price variable in the rebate equation to be 1.32. We can't reject the null hypothesis that the coefficient on fitlnRWP is equal to 1.32 (p value equals .900).

The size of the contract has a statistically significant effect on the size of the rebate offered by the firms. Contracts covering a larger portion of the WIC population estimated to lead to larger rebates but the relationship is quite inelastic. For a ten percent in the size of the contract, the rebate is expected to increase by .7 percent.

We hypothesized that as other firms bid on any given contract, the firm might be led to believe that their chances of winning were lower and consequently offer higher rebates. If both of the dominant firms bid on the solicitation, the average rebate is 5 percent higher than if only one of the 'Big Two' offered a rebate. While the estimated effect is in the hypothesis direction, the effect is not significantly different from zero. When at least one minor market share firm bids, the expected rebate of the 'Big Two' declines by an estimated 12 percent. If both Wyeth and Nestle bid then the expected rebates of Ross Labs and Mead Johnson decline by 28 percent compared to the situation when both would had not bid. The estimated effect of participation of Wyeth or Nestle wasn't consistent with our prior expectation.

When a group of states solicit a bid on a contract, the firms are estimated to provide higher rebate amounts and lower net prices compared to when a single state had solicited the bid. The estimated effect is exactly opposite to the direction we hypothesized, however, the estimated effect isn't significantly different from zero (p value equals .626). The final control variable included was a dummy variable indicating whether the data was for Ross or Mead Johnson. While the coefficient suggests that holding all other factors constant, Ross Labs offered rebates that were on average 4 percent higher than Mead Johnson, this relationship is not significantly different than zero (p value .315).

Subsequent Bids of a Contract

After the initial award of a sole source contract in a state, firms should have more information of what is necessary to win the contract and could adjust their bidding strategy accordingly. The lower unexplained variance of the rebates offered by Mead Johnson and Ross Labs strongly suggests this to be the case.

The estimates of the impact of wholesale prices reflect a less elastic response to the changes in wholesale prices than compared what was found in the initial solicitations. One factor leading to the less elastic response of the rebates to changes in wholesale prices is the increase in the ratio of rebates relative to wholesale price that occurs as the subsequent bids are solicited. The average ratio of rebates to wholesale price rose from .76 to .86 during this period. If the theoretical model is correct then the coefficient on the log of real wholesale prices should decline from 1.32 to 1.16. The estimated coefficient of 1.095 is not significantly different from 1.16 (p value equals .754).

In subsequent solicitations, the impact of the size of the contract plays a less important role than it did in the initial bids. The effect of contract size on the rebate for Mead Johnson's bids suggests that large states continue to benefit from being large although the effect is considerably smaller (1/3 of the effect in initial solicitations). However, Ross Labs bids are not affected by the size of the contract (p value for the effect of contract size on Ross Labs' bids is .537). When states band together for a solicitation, the bids made by Ross Labs and Mead Johnson are not significantly negatively affected as being estimated by the coefficient on the variable **Group**.

The impact of having both members of the 'Big Two' bidding on a contract continues to the have the hypothesized sign but the estimated coefficient is statistically insignificant. The participation of Wyeth and Nestle in the solicitations results in smaller rebate offers of the dominant firms if only one of the minority market share firms participate. But if they both participate then rebate offers from the 'Big Two' are statistically identical to the offers they would have made if neither Wyeth nor Nestle had submitted bids. While the estimates of the impact of the number of firms competing are still puzzling they are less puzzling than the estimates from the initial solicitations. With the sole exception of having only one of the minority market share firms participating, the evidence suggests that the number and composition of firms participating in a solicitation has no effect on the size of rebate offered by the 'Big Two.'

In subsequent bids for an existing contract, we tested whether or not firms bid more aggressive when other firms hold the existing contract as opposed to when they hold the contract. We constructed two dummy variables to capture this effect – **CC_Minor** is set to one when either Wyeth or Nestle holds the existing contract and **CC_BigTwo** is set one when the other member of the 'Big Two' holds the existing contract. The omitted category and consequently the comparison group is when the firm making the bid holds the contract. For example, let us assume that the firm making the bid is Mead Johnson then the coefficient on **CC_Minor** tells us the difference between the bid when either Wyeth or Nestle holds the existing contract and when Mead Johnson holds the existing contract. The coefficient on **CC_BigTwo** reflects the difference in the bid when Ross Labs holds the existing contract and when Mead Johnson holds the contract. A positive coefficient on either variable in the rebate specification indicates that Mead Johnson bids aggressively against these competitors compared to when they hold the contract. A negative coefficient implies a differential stance toward these competitors.

The estimated coefficients on **CC_Minor** and **CC_BigTwo** are statistically significant at 10% level of confidence and tell an interesting story. Compared to when the firm bidding holds the existing contract, a member of the 'Big Two' will be bid more aggressively against Wyeth or Nestle than when they hold the contract. They will offer a rebate that is 3.3 percent higher than what they would have offered if they had the contract. But the firm is deferential to the other member of the 'Big Two' holds the contract. They will bid a rebate that is 2.7 percent lower when the other member of the 'Big Two' holds the contract. An equally valid interpretation of this coefficient is that when a member of the 'Big Two' holds a contract (CC_BigTwo = 0) they will bid aggressively to hold onto the contract compared to the situation when the other 'Big Two' firm holds the contract. However, they will bid less aggressively compared to the situation when either Wyeth or Nestle holds the current contract.

While there was not a significant time trend in the initial bids, we found a significant growth in rebates associated with the elapsed time since the end of the 75¢ rebate debacle that we placed in April of 1991. Over the time period, the real rebates holding all other factors constant grew at annual rate of 1.84

percent. If we don't control for all of the other variables contained in the model, the average growth rate of the real rebates is 3.62 percent. This implies that one half of the growth in the rebates can be attributed to changes in other factors mostly increases in the real wholesale prices.

The final variable included in the model is the dummy variable indicating whether the bid was from Mead Johnson or Ross Labs. The estimated coefficient indicates that holding everything else constant Ross Labs offered rebates were 4.1 percent higher than Mead Johnson. But this is somewhat misleading because holding everything else constant doesn't account for the differences between Ross Labs and Mead Johnson's reactions to different contract sizes. For median size contracts during this period (covering 2.1 percent of all WIC infants) there is no statistically significant difference between Mead Johnson and Ross bids even though the point estimate of the difference would be 1.9 percent. For the largest contract during this period (covering 14.9 percent of WIC infants), Ross is estimated to underbid Mead Johnson by 3.9 percent but this point estimate is not statistically significant different from zero. For smaller than median contracts, Ross is statistical significantly estimated to over bid Mead Johnson. For example, if the contract covers 1.6 percent of all WIC infants the point estimate of the difference between Ross Labs and Mead Johnson is 2.7 percent whose p value equals .070.

Appendix E contains the estimates of bidding functions when the independent variable is the net price. The model estimates for the net price are opposite in sign from the estimates based upon the rebate amount discussed above. The only exception is the hypothesized coefficient on the real wholesale price should be zero instead of P/R when the rebate is employed as the dependent variable. We find that the coefficient on wholesale prices is not statistically different from zero as hypothesized in the theoretical model. A final observation is that the overall fit of the model employing the net price is less and consequently the mean squared error is higher resulting lower significance of the estimated coefficients. However, using the net the price instead of the rebate amount doesn't substantially alters any conclusion about the statistical significance of estimated relationships.

Conclusions

In this study, we have examined the relationship between two features of the WIC program – the provision of free infant formula to low income mothers and the sole source contracting procedure implemented to contain the program's cost – with the setting of wholesale prices in the industry and the amount of rebates secured by sole source rebate program. We first examined the impact of both features of the WIC program on wholesale prices. Based upon our analysis of the data from 1981 to 2002, we arrived at the following conclusions. The increasing participation of infants in the WIC program has resulted in a less price sensitive demand for formula and consequently formula manufactures have able to increase the real wholesale price. The effort to contain the formula costs of the WIC program through the implementation of a contracting process where firms had to competitively bid for the exclusive right to supply formula to WIC infants within a geographic area (sole source contracts) has resulted in lower wholesale prices not higher wholesale prices as was expected by policymakers in the early 1990s. The impact of the rebate should be welcomed news not only by taxpayers but also by those eligible for WIC whose participation is made possible by the savings in formula cost from the rebates but also by parents who pay for formula out of their own pocket.

The second part of the paper focused upon the bidding behavior of Mead Johnson and Ross Labs from the start of the sole source competitive contracts in 1986 through 2002 – a period when the type of formulas were similar in content but potentially significantly different from the enriched (DHA/ARA) formulas not being marketed by manufactures. Some tentative conclusions do emerge from the data. First, the bidding behavior of Mead Johnson and Ross during this period does not significantly differ. Secondly, we found confirmation of an important finding of theoretical model that the firm's wholesale pricing decision wouldn't affect the net price (wholesale price minus rebate) of formula to the government. Thirdly, we found evidence to support the hypothesis that bids to an initial solicitation do differ (initial solicitations led to lower rebate amounts) from those bids made to subsequent solicitations. Perhaps this result reflects the fact the theoretical model is a static representation of the bidding process. But in subsequent bids the model does not account for the dynamic nature of the bidding process where the firm has already acquired some WIC contracts. In future versions of the modeling effort, accounting for the dynamic and sequential nature of the bidding process should be a priority.

The size of the contract – the number of infants covered by a contract – has been shown to affect the rebates and consequently net prices faced by the government. A larger contract will result in larger rebates and lower net prices.

While the empirical findings conformed quite well with the predictions of the theoretical model, the impact of having more firms bid on the solicitation remains a puzzle. In the initial solicitations when more of the minority market share firms bid on a contract, the rebate offers of Ross Labs and Mead Johnson fell. In subsequent solicitations, a similar result was found if only one firm joined in the bidding but if a second minority firm bid the rebate offer was not significantly different from when none of the minority firms bid. These findings remain a puzzle to explain.

Our examination of the bids from subsequent solicitations provided some evidence of Mead Johnson and Ross Labs defending the contracts they hold but not going after contracts by the other. They were more likely to pursue new contracts by bidding more aggressively against the firms with smaller market shares – Wyeth and Nestle.

Currently there is concern that the aggregate level of rebates has peaked and with the advent of the enriched formulas the aggregate level of real savings in the WIC program may begin to decline. Given we have not examined any of the more recent solicitations that have begun to included the enriched formulas or solicitations when this new formulation had begun to become the predominate choice of mothers, what follows should be viewed as speculation based upon what we have learned from this study.

Assuming the cost of producing the enriched formula is higher than the formula it is replacing, it is difficult to believe that the net price to WIC of the enriched formula will ever be less than or let alone equal to the net prices WIC was paying for non-enhanced formula in 2002. If the net price of formula to the WIC program is going to be higher, the question is going to be how much higher? In the near future, it is plausible that mothers paying for their formula out of their own pockets may become more insensitive to the price allowing formula manufacturers greater profit margins as well as higher real wholesale prices on the enriched formula. To the extent this is true, one could envision a scenario where in efforts to continue their WIC contracts, the firms would offer higher rebates. Depending upon the extent of the cost increases caused by the use of DHA/ARA in formula, it is quite possible that over time the ratio of rebates to wholesale prices would move back to levels close to the level we are experiencing today.

The optimism in our prediction is based upon history and a belief in the effect that competition for WIC contracts will have on rebate offered by firms. During the 1990 and 1991 Senate hearings, a similar concern was raised about a potential decline in the aggregate savings in the rebate program. Yet over time, the rebate as a percentage of the wholesale price rose steadily over the next five year until it stabilized to a level roughly where we were in 2002. Competition often takes time but in the end it will lead to larger rebates even though there is a limited number of firms in this market. Unless the firms have entered into an implicit agreement undermine the rebate program, the cost savings should be restored to the WIC program.

We will conclude with a suggestion for future research that has not been mentioned prior to this point in the paper but it is probably so obvious that it does not need mentioning. Central to the framework that has been developed to understand how the WIC program affects the price of formula is how mothers decide upon the extent to which they will rely upon formula to feed their infants and how they make their decisions of which brand of formula to purchase. Of particular interest is how the price of formula enters the decision to how to feed their infants (breastfeeding or formula) and if they choose to utilize formula the decision of which brand to use.

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Appendix A

Time Trends in Relative Formula Prices

In this appendix, we will examine the time trends of the relative prices of alternative infant formula all normalized to reflect the cost of a two-ounce serving of formula. Beside the company producing the formula, formula can differ by its source of protein (milk versus soy based) and formulation (liquid concentrate versus powder). The purpose of this appendix to examine the question whether the price (cost) of alternative formula differ more over time than does the cost of formula relative to the price of other consumption goods. To the extent that the relative price of alternative types of formulas do not vary, it provides a justification to focus upon only type of formula.

Milk versus Soy

While the majority of infants are fed with milk-based infant formula, companies market alternative formulas such as soy-based, low iron, or more recently the 'enhanced' formulations containing DHA/ARA. During the time period of interest of this study, the only alternative formulation with sufficient market share is the soy-based formula. The decision to use a soy-based alternative formula is most likely reflective of the inability of the infant to tolerate a milk-based formula. This decision could also reflect the food predilections or nutritional concerns of the parents. However, for other parents the decision of which formula base to use could be determined by the relative price of the soy versus milk based products.

Figures A.1 (for Mead Johnson) and A.2 (for Ross Labs) depict the relative price of soy based formula relative milk based formula. In each figure, the line with the 'X' denotes the relative price for powder formulation while the line with without a mark reflects the concentrated formulation. Since the late 1980s, the price of soy-based formula has been higher than the price of milk based formula. For both brands, there has been upward trend in the relative price of soy-based formula.

The trend of the relative price of soy-based formula could be reflecting the rising cost of the soybeans relative to the price of milk. To examine this potential explanation, we computed the relative price of a bushel of soybeans to the wholesale price of Grade A milk during the period of 1981 through 2002. The data was acquired from the National Agricultural Statistics Service Web site. As Figure A.3 shows the relative price of soybeans to milk has displayed considerable variability over this twenty-two year period, however, the data reflects a downward trend in the relative price of soybeans (linear time trend shown in figure). Figure A.4 documents separately the real price of milk (solid line) and soybeans (line marked with 'X') over the time period. As shown in the figure, the real price of both inputs has been falling. Consequently the rising relative price of soy-based formula could be the result of smaller scales of operation coupled with an increasing consumer base that is relatively insensitive to the relative price of soy to milk.

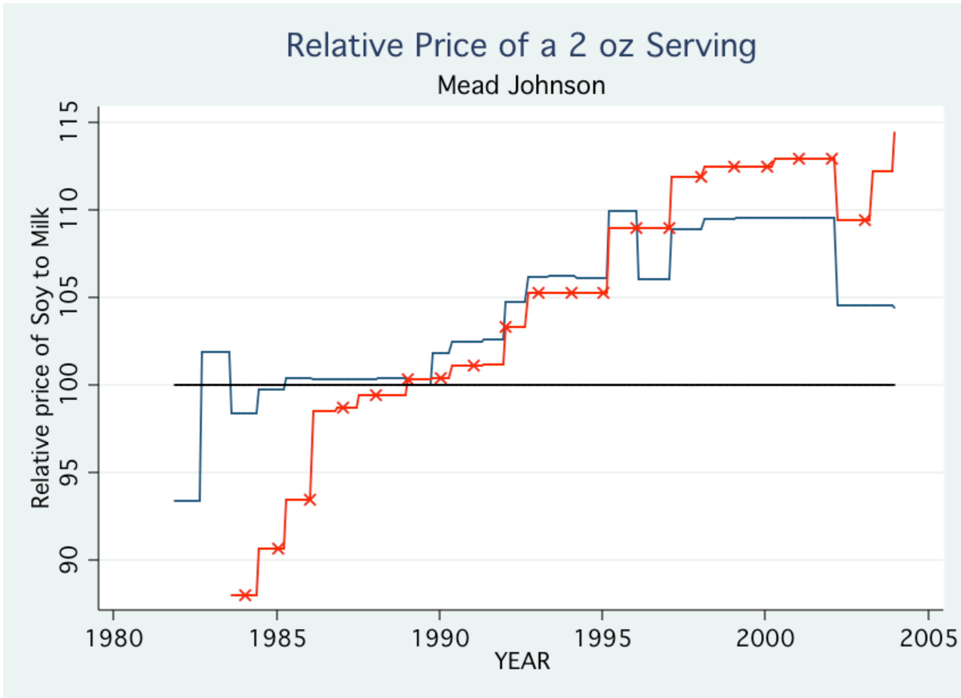


Figure A.1

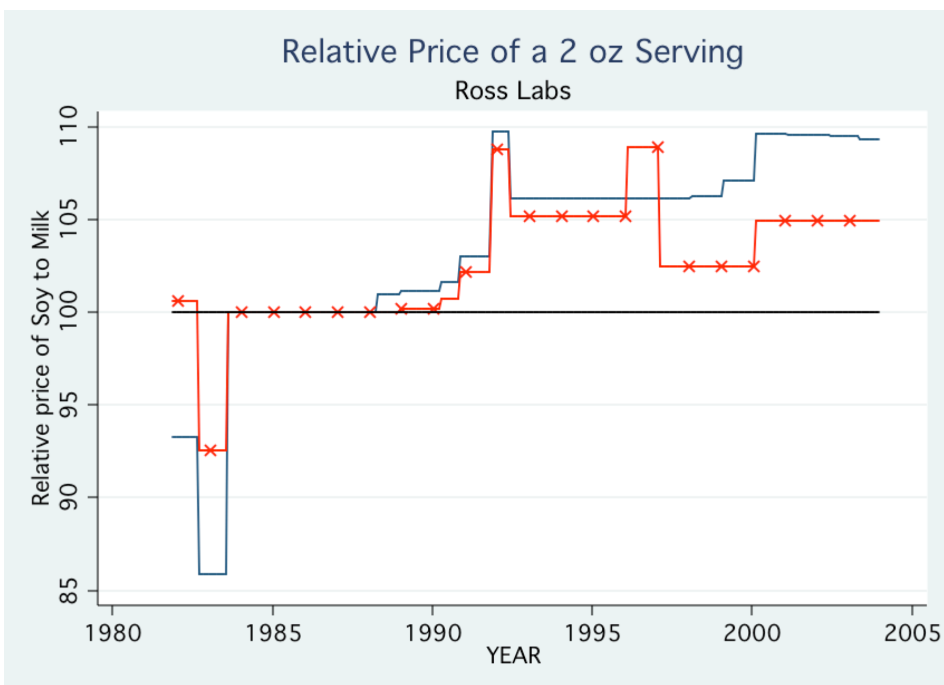


Figure A.2

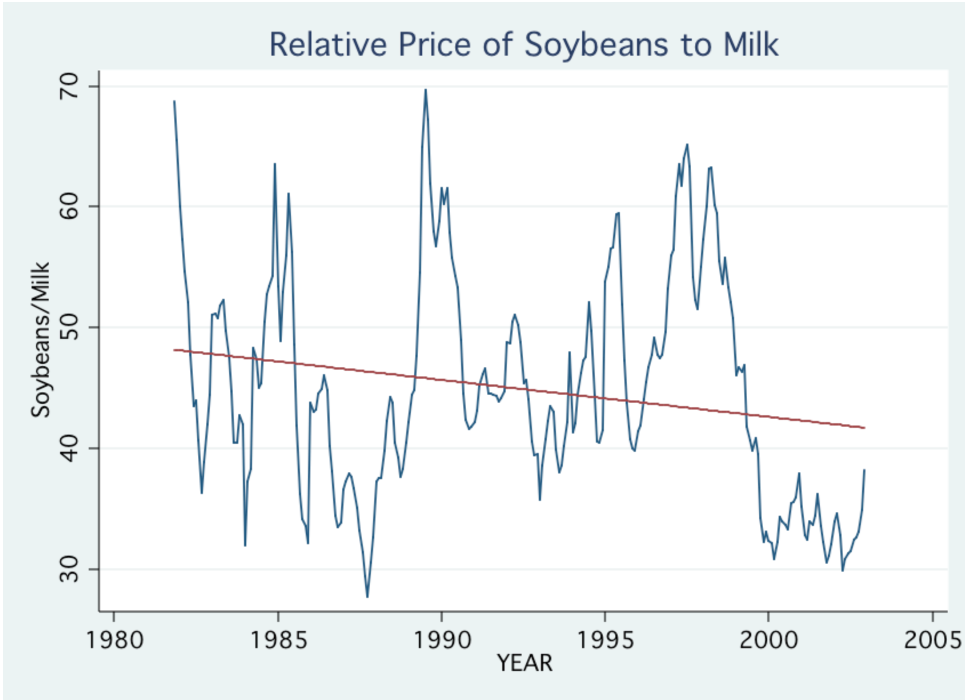


Figure A.3

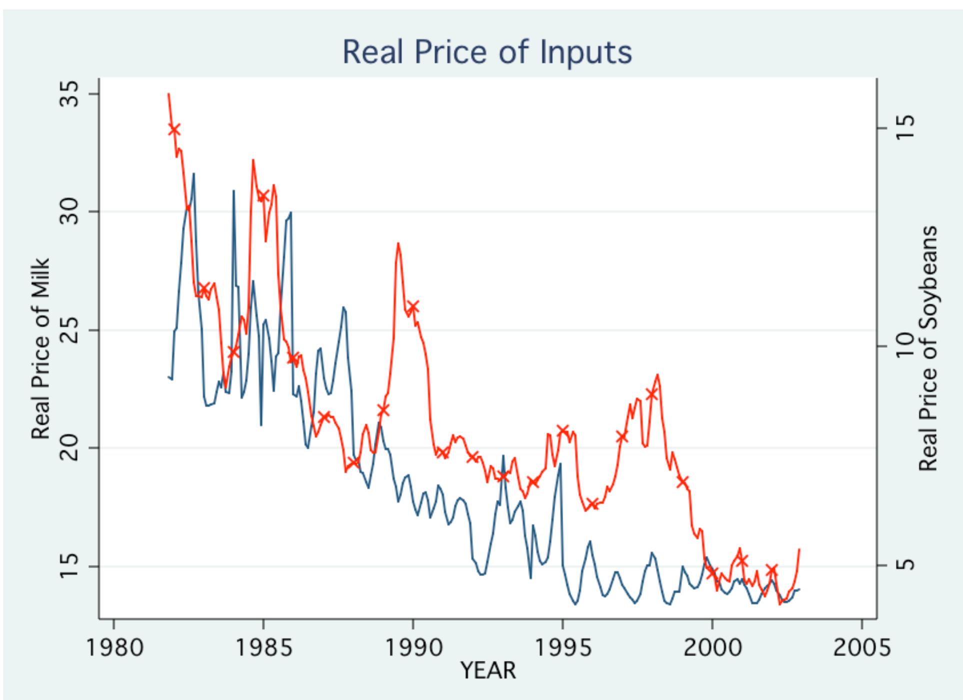


Figure A.4

Liquid Concentrate versus Powdered Formulations

Both milk and soy formulas are provided to consumers in three formulations: ready to use, liquid concentration, and powdered form. While this study does not examine the ready to use formulation, this formulation clearly provides the greatest convenience of use for the parents. The other two formulations do require mixing of the formula with water. Figures A.5 (Mead Johnson) and A.6 (Ross Labs) display the relative price of the powder versus liquid concentrated formulations for the two major companies' milk and soy based (line marked with 'X') formulas.

For milk-based products, both Ross and Mead Johnson have historically priced their powder formulations roughly four percent lower than their liquid concentrated formulations. Since the relative costs of producing and distributing formula in these two forms is not known, the lower cost of powder may reflect either lower costs to the producer or 'compensation' to the consumer to use the more inconvenient formula.

For soy-based formula, the relative price of powder to liquid concentrate display clear trends that are opposite for the two companies. Mead Johnson over this time period has steadily increased of the price of formula in powder form relative to liquid concentrate. Ross Labs on the other hand has done exactly the opposite. Today, Ross Labs offers a larger discount on their soy powder than they do on the milk-based products. Mead Johnson provides no discount for the purchase of powder soy-based formula compared to the mid 1980s when the discount was roughly 14 percent.

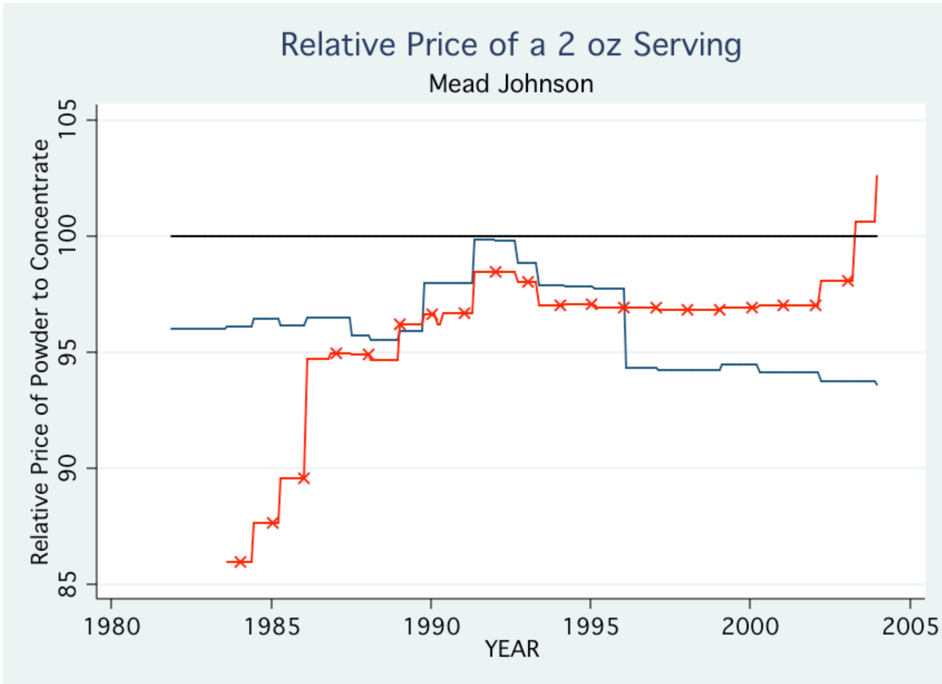


Figure A.5

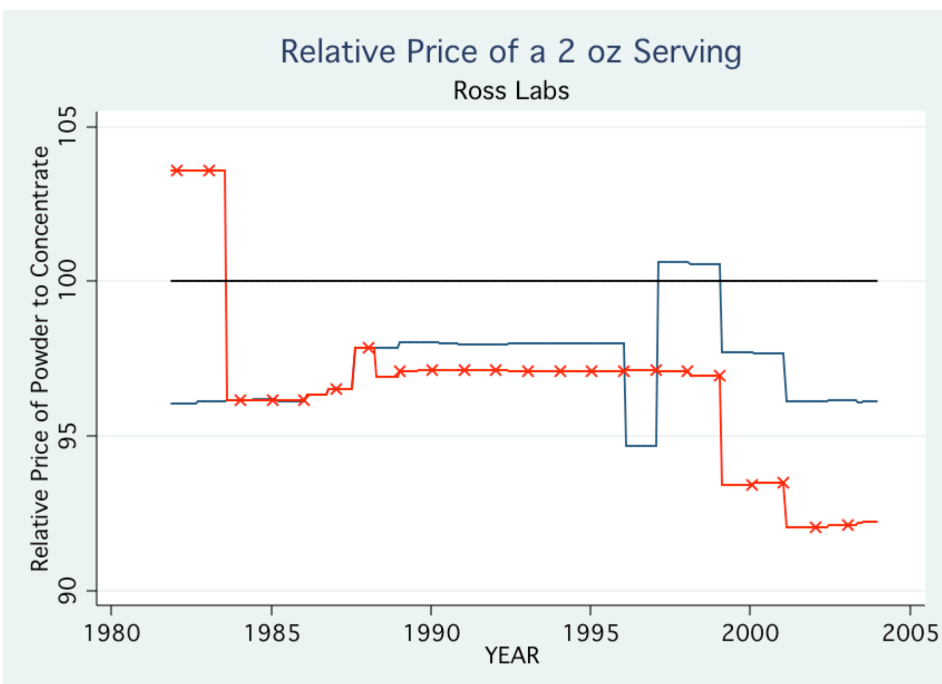


Figure A.6

Mead Johnson versus Ross Labs

The final comparison between the two brands provides the clearest and cleanest comparisons between potentially homogeneous products given the regulation of the production of formula by the FDA. The next four figures display the relative price of the Ross Labs product relative to Mead Johnson's price. Figure A.7 is for milk-based liquid concentrate while Figure A.8 is for milk-based powder formulation. Figures A.9 and A.10 present the corresponding data for the soy-based formulas.

These figures reveal more information than which company's price is higher at any point time. Spikes or peaks in the data indicate which company initiated a price increase and the amount of time before the other company responds. For example, in August of 1982, Ross Labs implemented a price change in its products to which Mead Johnson did not respond until September of 1983. In February of 1985, Ross Labs implemented a price change and one month latter Mead Johnson responded. Nine times during this time period, both companies implemented price changes in the same month. The simultaneously implemented price changes are marked with an 'X'.

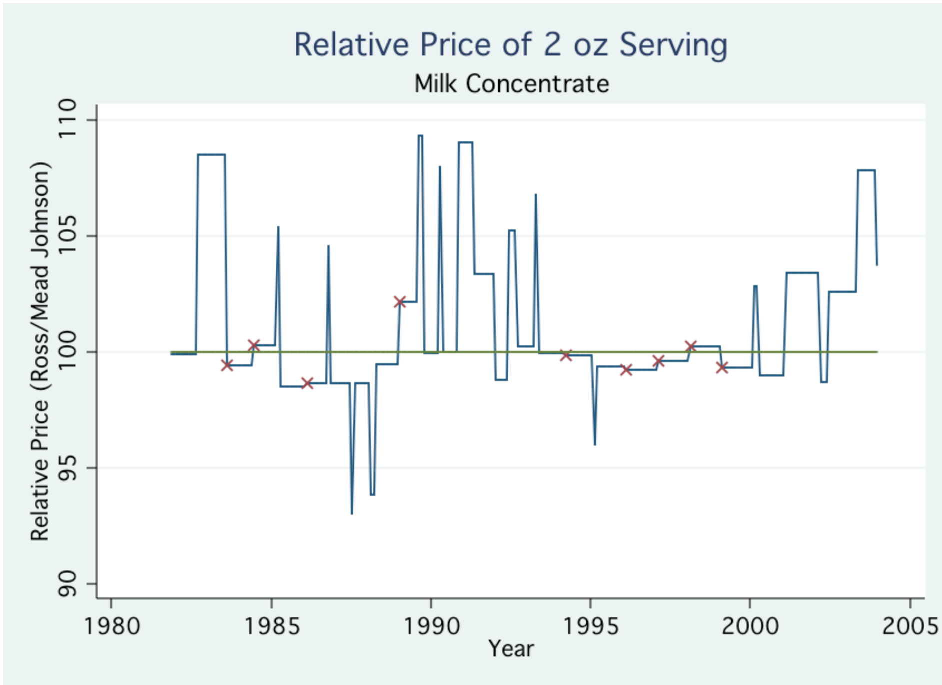


Figure A.7

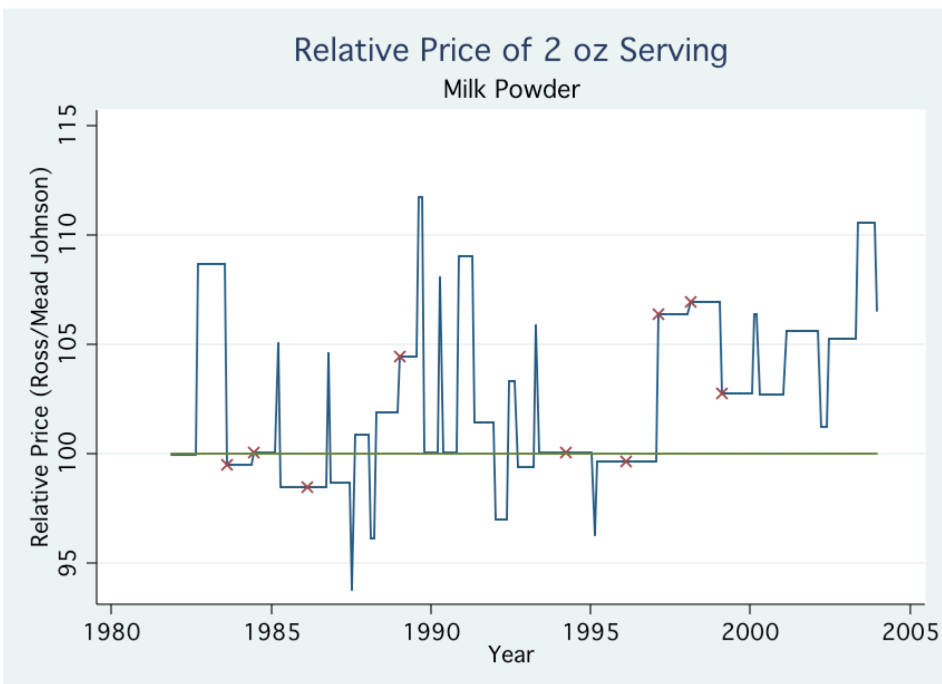


Figure A.8

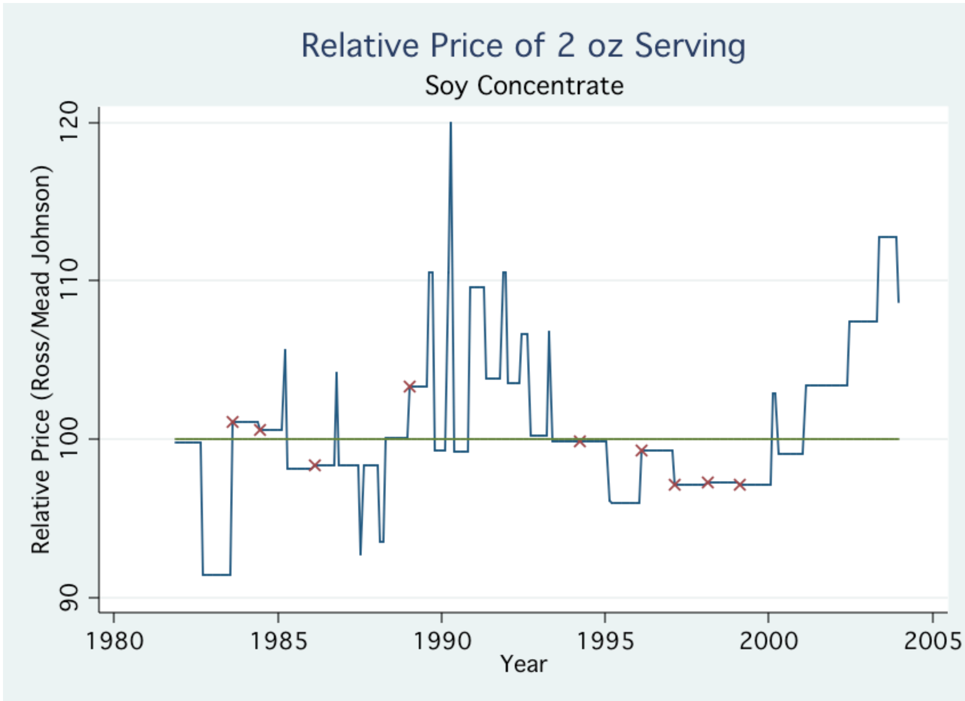


Figure A.9

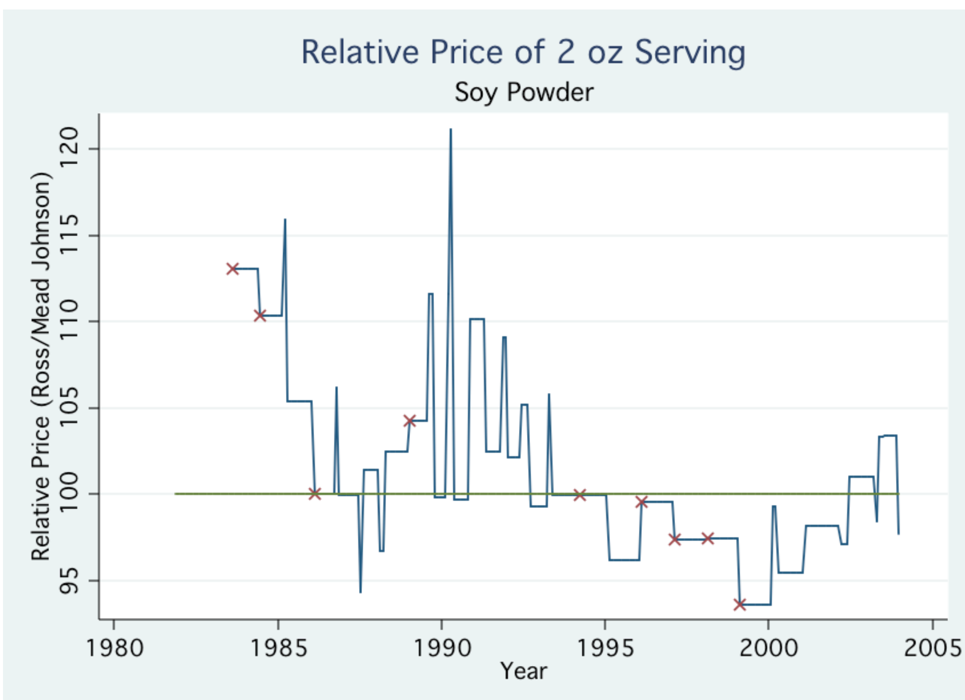


Figure A.10

At any point in time, the relative price of any product across the two companies will not fully reflect the relative cost to the consumer. Since mothers will be reluctant to switch formula as the price changes, the cost relative cost of the two brands will depend upon the time path of price changes. We have constructed an index of the relative cost of using one brand over the other by first computing the average price of each brand over a twelve month period. For example, for May of 1995 we computed the average price of both brands over the period of May of 1995 through April of 1996. From these two averages, we computed the average cost of using Ross products relative to Mead Johnson products for an infant who would have born in May of 1995 and used formula throughout their first year of life. To reflect the fact that in any given month, there are infants born in June of 1994 through May of 1995, we then computed of average of the relative costs from each of cohort born in these months. We will denote this as our index of relative costs of formula to mothers in any given month. These calculations are presented in Figures A.11 (milk-based products) and A.12 (soy-based products) where the line marked with 'X' reflects the values for powder formulation and the unmarked is for liquid concentrates.

For milk based liquid concentrate brands, the two companies have on average priced their products so that the cost formula was almost identical between the brands. Only during the period around 1990 and since 2000, has Ross Labs undertaken price changes to make their liquid concentrate more expensive than Mead Johnson. The pattern of relative costs of powdered milk formula follows the same pattern as liquid concentrate until 1996 when Ross Labs begin to undertake a series of price changes to make powder product more expensive than Mead Johnson.

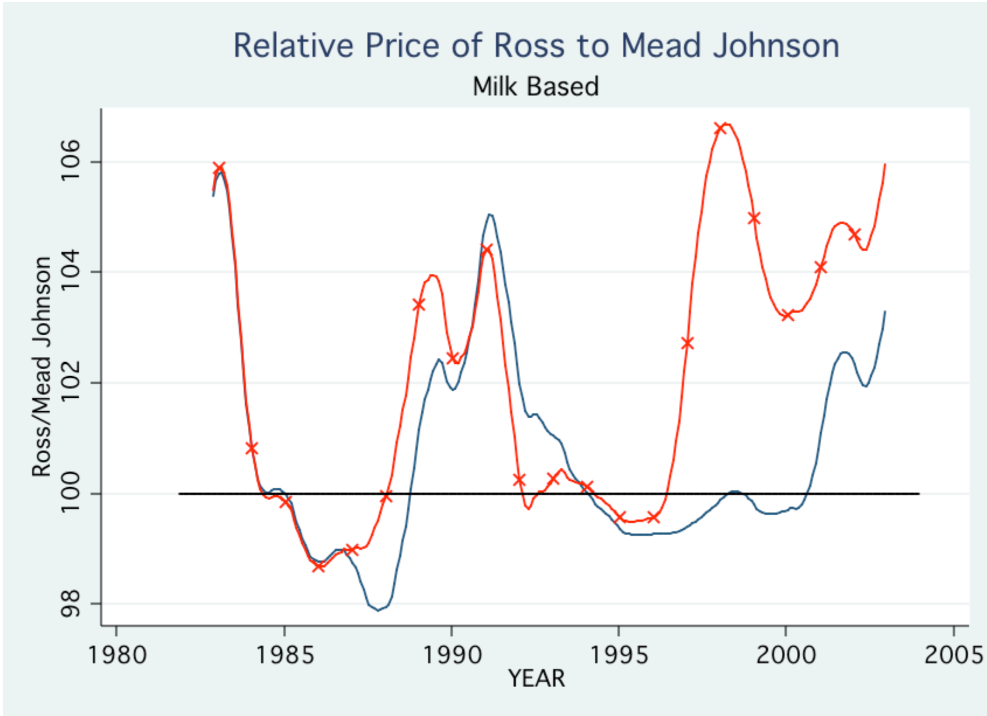


Figure A.11

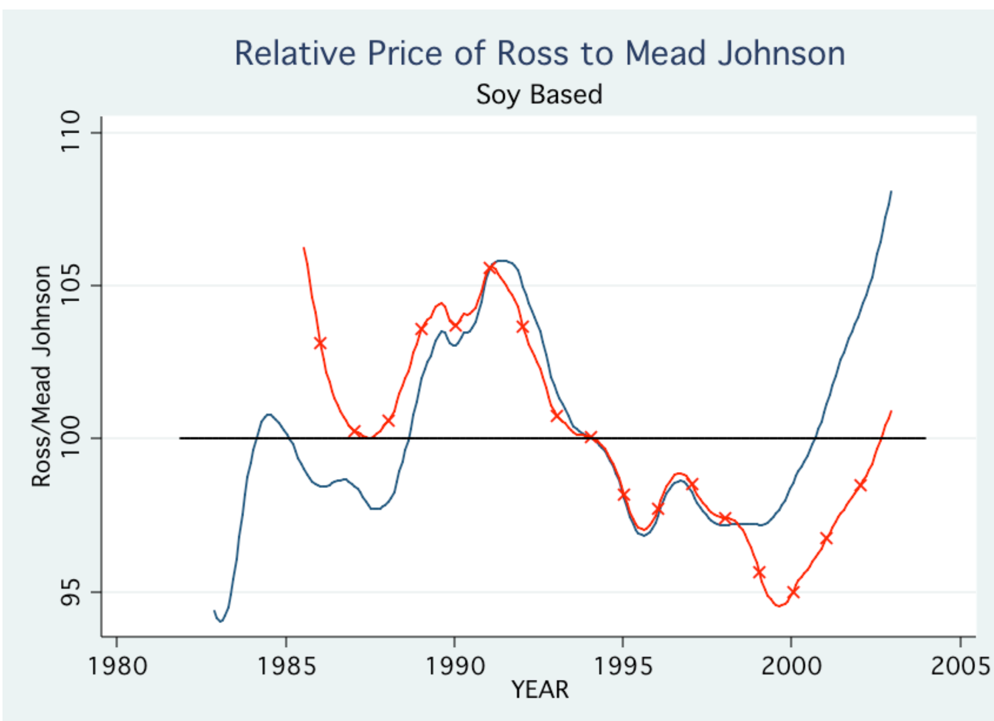


Figure A.12

The relative cost of soy products of Ross Labs versus Mead Johnson display similar time trends as milk based products. During the period around 1990, Ross Labs' products were more expensive than Mead Johnson. At the peak in 1991, they were roughly 5 percent more expensive. However during the period from 1994 through 2001, Mead Johnson's soy products were more expensive. However starting in 2000, Ross Labs undertook a strategy of raising its soy based product prices. By 2004, Ross's soy based powder formula was roughly the same price as Mead Johnson but it had increased its price of liquid concentrate to be 10 percent more expensive than Mead Johnson.

Summary

When examining the set of all relative prices of infant formula, the single clearest difference over this time period has been seen the price of formula relative to the price of all other goods – the real price of formula. While the price of milk and soy based formula have changed over time as well as the relative price of formulation preparation (liquid concentrate versus powder), the variations in these dimensions have been small compared to the increase in the real price of formula for both companies, Mead Johnson and Ross Labs. This result justifies our approach to focus upon the determination of the real prices of milk-based formula.

Appendix B

A Model of Nominal Price Adjustment

To either establish or to maintain a real or relative price for infant formula, manufactures would have to be constantly change the price of their product in response to variation in the prices of other goods (not necessarily inputs to the production of formula). For example, if the price of all other goods rose by 10 percent and the manufacturer maintained the nominal price of formula then not only would have formula become relatively cheaper for consumers of formula but the real value of the firm's revenues have fallen. Consequently even if we ignore the increase in the cost of manufacturing the formula, the real value of profits would have fallen. In response, we would expect the firm to adjust its price (nominal) to maintain the real value of its price.

It has been proposed that it is costly for the firm to continuously change its price. If there is a fixed cost to the firm of adjusting its price, the firm faces a tradeoff between the frequency of adjusting their nominal price and the gap between the current price and their desired price at any given time. While other researchers have examined this problem in a broader context, we will only consider a more simple context where the firm anticipates a given rate of inflation in the prices of other goods (continuous rate of inflation is assumed to be i) and it has chosen to continue charging its current nominal price for a time period of length T. If the fixed costs of changing its price is F dollars per unit of output then for the firm to break even it would chose to set a nominal price above its desired price so over the time period it 'breaks even.' If δ is the percentage growth rate in the real desired price for formula, the firm would initially set the nominal price to be μ percent above the desired price at time 0 so that

$$\int_0^T \left[P_o^* e^{\mu - it} - P_o^* e^{\delta t}\right] dt - F = 0$$

where P_0^* is the desired real price at time 0. Solving the above relationship for μ yields

$$e^{\mu} = \frac{iT}{1 - e^{-tT}}\left[\frac{F}{P_o^* T} + \frac{e^{\delta T} - 1}{\delta T}\right].$$

The above expression can be simplified using the approximation

$$\frac{e^{x} - 1}{x} \approx e^{x/2}$$

consequently

$$\mu \approx \frac{iT}{2} + \ln\left[\frac{F}{P_o^* T} + e^{\delta T/2}\right] = \frac{iT}{2} + \frac{\delta T}{2} + \ln\left[\frac{F e^{-\delta T/2}}{P_o^* T} + 1\right]$$

or

$$\mu \approx \frac{iT}{2} + \frac{\delta T}{2} + D\left(F / P_o^*, \delta, T\right).$$

where *D* is an amount (*D*>0) that will be positively related to the fixed costs relative to the desired price but negatively related to the growth in desired real prices and length of time between price changes.

While we have motivated this price adjustment process were the firm adjusts its price once every T time periods, it can also be interpreted as the firm establishing a threshold so that when the firm's established real price (nominal price deflated by the amount of inflation since the last price rise) falls below this threshold, the firm changes it price. We will express this threshold as being λ

percent below the desired price at time *T*. In terms of the above model, the threshold would equal

$$Threshold = P_o^* e^{\delta T - \lambda}$$

where

$$\lambda = \frac{iT}{2} + \frac{\delta T}{2} - D.$$

Once the real price at any time falls below this threshold amount then the firm will increase its nominal price and consequently the real price to be equal to μ percent above the desired price at that time. Note the percentage increase in the nominal price will equal

$$\mu + \lambda = iT + \delta T$$

the anticipated inflation over the next time period plus the growth in desired prices but does not reflect the fixed costs of the price adjustment.

Over the period the firm maintains its nominal price, the observed real price for the product will be in the interval

$$P_t \in \left[P_o^* e^{\mu}, P_o^* e^{\delta T - \lambda}\right] \quad \forall t \in [0, T]$$

where $\mu > \lambda$. Given this pricing strategy, the firm will anticipate that for more than *T*/2, the real price it charges its consumers will exceed the desired price and the remaining time, the firm's price will be less than its desired price.

The model of price of adjustment we are proposing can be summarized with the following equation defining the real value of the price of formula at time t:

$$\ln(P_t) = \begin{cases} \ln(P_t^*) + \mu & if \ \ln(P_t^c) \le \ln(P_t^*) - \lambda \\ \ln(P_t^c) & if \ \ln(P_t^c) > \ln(P_t^*) - \lambda \end{cases}$$

where P^c_t is the real price of formula at time t based upon the previous nominal price and P_t is the observed real price of formula at time t.

While the parameters, μ and λ, have been characterized to be constants, they are a function of the firm's expected rate of general inflation, the firm's own desired growth in real prices, and the fixed costs of changing prices. Clearly as time progresses, the firm's expectations about inflation and desired growth in the real price of its product will evolve and consequently also will the parameters μ and λ. However, we will assume the firm formulates a pricing strategy (sets μ and λ) for the next T time period based upon the firm's actual experience since the last price change and maintains that strategy until the next price change. This does not imply that firm will change its price every T time periods. For example, consider the situation where the actual rate of inflation exceeds (is less than) the firm's expected rate. In this scenario, the firm will change its price sooner (later) than the anticipated time of T. If conditions change and the firm's desired price deviates from its expected desired price formulated at the last price change, the firm will be assumed to change its timing of its next price change. For example if after the previous price change the firm's desired real price exceeds (is less than) what the firm expected its desired price to be at that time then the firm will be more likely to change its price sooner (later) than time T. Not because the firm has altered the value for λ but because the probability that current real price is less than firm's current actual desired price minus λ has increased (decreased).

Appendix C

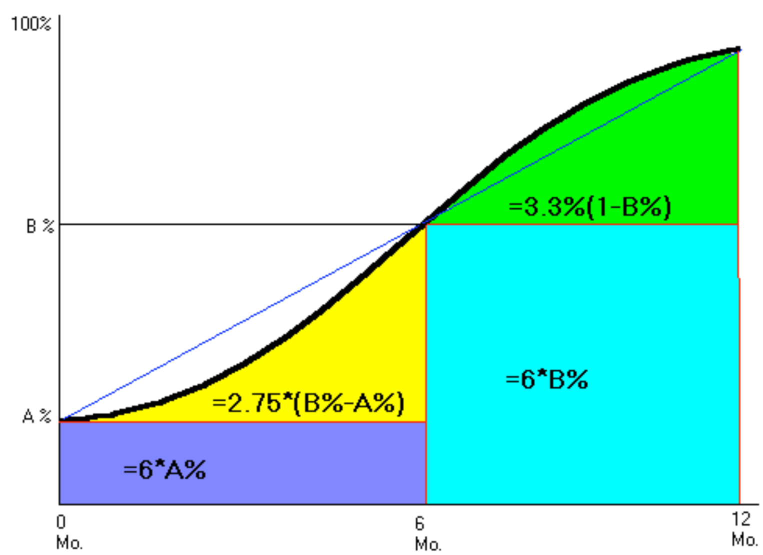
Description of Variables

Size of Infant Population

The population estimates of infants in the US were obtained from the annual report, "Resident Population of States (by single year to 85+ and sex)" published by the Population Distribution Branch and Population Estimates Branch of the U.S. Bureau of the Census. This report contains intercensal estimates of the US population, on July 1, by single year of age in each state. These reports can be obtained on the Census Bureau's web site. The population aged 0 to 1 was chosen to define the US infant population. The data from the Census Bureau reflected the population size in each July. A linear extrapolation was used to estimate the population in months August through June.

Breastfeeding and Formula Feeding Rates

The breastfeeding rates for US infants, when in the hospital and at six months after birth, from 1980 through 2000 were obtained from the Ross Mothers Survey. Ross acquires data for the Mothers Survey by sending questionnaires to all new mothers in the US. To estimate the percentage of infants formula fed in the hospital and at six months, the one minus the breastfeeding rates at those dates were computed. Next, the average annual formula feeding rate was estimated by finding the area under the curve as shown in the firgure below, and dividing that area by twelve. It was assumed that formula-feeding rates increased less rapidly in the first six months after birth, and more rapidly in the following six months. This is why the curve appears to have a logarithmically curved shape.[14] In the figure below, A% is the formula feeding rate in the hospital and B% is the formula feeding rate at six months. The area of the yellow figure calculated at 2.75*(B%-A%) represents approximately 92% the area of the triangle with the hypothesis going from A% at 0 months to B% at 6 months. Similarly, the area of the green figure, calculated at 3.3*(1-B%) represents approximately 110% of the area of the triangle with the hypotenuse connecting B% at 6 months with 100% at 12 months. Thus the total area under the curve is equal to 6*A% + 6* B% + 2.75*(B%-A%) + 3.3*(1-B%), and the average annual formula feeding rate is that area divided by 12.



The average formula feeding rate for each year was assumed to be equal to the July rate for each year. A linear extrapolation was then performed to calculate the rates for August through June of each year. The formula feeding rates for 2001 and 2002 were estimated by projecting out the trend line of the

[14] Note that it was not necessary to make this assumption, and would have been more correct to simply measure the area under two straight lines, from A% to B%, and from B% to C% (C% being measured at 12 months, and just below 100% to account for the small percentage of mothers who continue breastfeeding after one year). Both methods of calculating the average annual formula feeding rate produce similar results; therefore it is irrelevant which method is used.

1980 through 2000 rates two additional years, and estimating the points on that line.

Percentage of infants on WIC

The population of infants on WIC in each state and in the US as a whole was obtained from the Center on Budget and Policy Concerns. For October 1988 through August 2003, monthly counts were available. For 1980 through 1982, only the infant count at September was available, and for 1983 through 1988, only the yearly average was available. Thus, linear extrapolation was used to estimate the monthly population of infants on WIC from September 1980 through October 1988. For each month the total number of infants on WIC was divided by the total infant population in the US to obtain the percentage of infants on WIC.

Percentage of WIC Infants Covered By Rebate Program

A history of all bids for sole source contracts, specifying the net price of the bids and the winning bidder from 1986 through May of 2003, was obtained from the Center on Budget and Policy Concerns. From this was constructed a chart detailing which manufacturers held sole-source contracts in each state from 1986 through 2003. Using the population of infants on WIC for each state, the total number of infants in states for which a manufacturer held a sole source contract was calculated from 1986 through 2002. The number of infants on WIC in sole-source states was divided by the total number of infants on WIC to obtain a monthly percentage of WIC infants in sole-source states.

It was necessary to create this variable because the rebate program was phased in slowly over the years, and thus had different levels of impact at different points in time. This variable will allow the model to take this into account. It should be noted that this variable is still not at 100% because several states have yet to adopt the rebate program.

Real Wholesale Price of Milk and Soy

The plant pay prices of milk, that is the wholesale price that a manufacturer would pay to farmers for Grade A milk, from 1980 through 2002 was obtained directly from the National Agricultural Statistics Service. The per bushel price of soybeans was taken from the same source. These prices were then inflated by the CPI to reflect December 2002 prices.

Appendix D

OLS Estimates of the Wholesale Price Model

For sake of comparison, the following are the estimates of the OLS regression of the log of the real price of a 2 ounce serving of formula (LnPrice) on the control variables reflecting factors believed to determine the desired real wholesale price of formula.

OLS Regression Results

Source	SS	df	MS
Model	40.3370579	10	4.03370579
Residual	.643661383	1005	.000640459
Total	40.9807193	1015	.040375093

Number of obs	= 1016
F(10, 1005)	= 6298.15
Prob > F	= 0.0000
R-squared	= 0.9843
Adj R-squared	= 0.9841
Root MSE	= .02531

LnPrice	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
OnWIC	.0216609	.0004375	49.51	0.000	.0208024	.0225194
WICRebate	-.0017042	.0001343	-12.69	0.000	-.0019679	-.0014406
LnInfants	.7722456	.0392468	19.68	0.000	.6952305	.8492607
LnFFRate	-.0670394	.025707	-2.61	0.009	-.1174849	-.0165938
LnRPMilk	-.02491	.010168	-2.45	0.014	-.0448629	-.0049571
Comp4	.0016767	.0052075	0.32	0.748	-.008542	.0118955
NestleOnly	-.0141302	.0069799	-2.02	0.043	-.027827	-.0004334
RossMC	.00701	.0022457	3.12	0.002	.0026033	.0114167
MJPowder	-.0395161	.0022457	-17.60	0.000	-.0439229	-.0351094
RossPowder	-.019613	.0022457	-8.73	0.000	-.0240197	-.0152063
_cons	1.24529	.0689986	18.05	0.000	1.109893	1.380688

Comparing the estimates from the Censored Normal Regression to the OLS, we see that as we would expect the estimates of the coefficients from the OLS analysis are attenuated toward zero compared to the maximum likelihood estimates. Not only are the magnitudes of the estimated effects of the variables larger, they now have the predicted sign with the sole exception of LnFFRate. The estimate of the effect of the real price of milk (LnRPMilk) is positive while the effect of having four firms (Comp4) is negative. Accounting for the censoring of the errors, lowered the estimated significance levels of the estimated coefficients, however all of the estimated coefficients remain significant at the 5% level with the exception of the estimated effect of LnFFRate, LnRPMilk and RossMC.

Appendix E

Estimates of the Bidding Model: Dependent Variable Net Price

In this appendix, we report the estimates of the bidding model for initial and subsequent solicitations.

OLS Model Estimates of Net Price Amount: Initial Solicitation

Source	SS	df	MS
Model	1.88315638	7	.26902234
Residual	5.8704948	39	.150525508
Total	7.75365117	46	.168557634

Number of obs	47
F(7, 39)	1.79
Prob > F	0.1176
R-squared	0.2429
Adj R-squared	0.1070
Root MSE	.38798

lnRNP	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
fitlnRWP	.405566	.6315997	0.64	0.525	-.871965	1.683097
lnCSize	-.1843887	.0694632	-2.65	0.011	-.3248912	-.0438862
CB_BigTwo	-.2352362	.1701995	-1.38	0.175	-.5794973	.1090248
CB_Minor1	.2424209	.2473485	0.98	0.333	-.2578887	.7427305
CB_Minor2	.6024603	.3586737	1.68	0.101	-.1230256	1.327946
Group	-.1743526	.2290862	-0.76	0.451	-.6377232	.2890181
Ross	-.0672358	.1154509	-0.58	0.564	-.3007573	.1662857
_cons	-.843958	.5482479	-1.54	0.132	-1.952894	.264978

OLS Model Estimates of Net Price: Subsequent Solicitations

Source	SS	df	MS
Model	29.1898766	11	2.65362514
Residual	27.2460678	126	.216238633
Total	56.4359443	137	.4119412

Number of obs	138
F(11, 126)	12.27
Prob > F	0.0000
R-squared	0.5172
Adj R-squared	0.4751
Root MSE	.46501

lnRNP	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
fitlnRWP	.6954429	1.218619	0.57	0.569	-1.716167	3.107053
lnCSize	-.1980596	.0670567	-2.95	0.004	-.3307628	-.0653563
Ross*lnCS	.20259	.0889803	2.28	0.024	.0265007	.3786793
CB_BigTwo	.1172324	.2018252	0.58	0.562	-.2821737	.5166385
CB_Minor1	.1332769	.0988568	1.35	0.180	-.0623577	.3289116
CB_Minor2	.025122	.158238	0.16	0.874	-.2880264	.3382704
Group	.047163	.098215	0.48	0.632	-.1472015	.2415276
CC_Minor	-.180134	.1068472	-1.69	0.094	-.3915815	.0313134
CC_BigTwo	.1137804	.0919535	1.24	0.218	-.0681929	.2957536
Time	-.1317434	.0232028	-5.68	0.000	-.1776611	-.0858257
Ross	-.2804791	.1117712	-2.51	0.013	-.501671	-.0592871
_cons	-1.100936	1.233415	-0.89	0.374	-3.541828	1.339956