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Assignment of New Products Under Classified Pricing: A Conceptual Dynamic Model of Class Assignment Outcomes

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PREFACE

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SUMMARY

The introduction of new milk-based beverages has raised the issue of which class these products should be assigned to under Federal Milk Marketing Orders. The objective of this paper is to explore the dynamics of assigning a new product to a price class under a system of classified pricing that also includes product-pricing formulae. A conceptual simulation model using the system dynamics modeling approach is used to assess how class assignment decisions affect input (producer) prices and revenues. The model includes three products: a storable product (SP), a perishable product (PP), and a "new" product (NP). The SP and PP are assumed to have stable demands for which quantities demanded change only in response to prices. The NP is assumed to have a growing demand over time, but the quantity demanded is also determined by the NP price. The storable product is assumed to be a residual claimant on the input supply, and the market price of the storable product determines the price that the manufacturer of each product must pay for the input.

The model developed in this paper predicts that:

- Assignment of the NP to the higher price class always increases revenues in the short-run (up to one year), but can result in lower prices and revenues in the long run. The initial increase in the input price results in a larger supply of the input, whereas the higher NP price reduces demand for the input. This results in greater SP production and a decrease in the base price used to set minimum prices for all of the input. Under certain conditions, the effect of the lower base price can offset the gains from assigning NP to the higher price class.
- The class assignment that yields a higher blended input price and cumulative producer revenues depends in part on the demand elasticities for the three products. If demand for all three products is inelastic, assigning the new product to the higher class will only increase cumulative producer revenues if the new product has the most inelastic demand; otherwise, producer revenues are increased by assignment to the lower class.

- The relative elasticities of the SP and NP are the most important to understanding whether assignment to the higher price class increases cumulative producer revenues. If demand for the SP is highly elastic, then NP demand can be more elastic and still result in higher cumulative producer revenues when input used in NP manufacturing is assigned to the higher class.
- If the NP product cannibalizes sales of the PP, this can affect whether assignment of the NP to the higher class increases cumulative revenues. If cannibalization is based on an inward shift of the PP demand curves and NP demand grows, the presence of cannibalization does not influence the outcomes of the class assignment decision. If cannibalization is based on actual sales of the NP, then assigning the NP to the higher class can result in larger cumulative producer revenues even when NP demand is the most elastic of the three.
- Cross-price effects can also influence the outcomes of the class assignment decision. If the impact of NP price on PP sales is reasonably large, assigning NP to the higher price class is more likely to increase cumulative producer revenues. However, the impact of cross-price effects depends on how the manufacturer of the NP prices the product and expands production capacity as sales increase.
- The nature of by-products from NP production can influence the outcomes of the class assignment decision. If by-products are a small part of the NP production process and their yield of SP is low, it is likely that assignment of the NP to the lower price class will yield a higher blended input price and cumulative producer revenues. If by-products are a larger proportion of the NP input use and the by-product yields larger quantities of the SP, the blended input price and cumulative input supplier revenues are larger when the NP is assigned to the higher-price class.

Given their dependence on model parameters and assumptions, the outcomes of class assignment decisions for milk-based beverage appear to be empirical questions, rather than deducible based on logic or theory alone. In a more general sense, the dynamic conceptual model illustrates that the existence of "offsetting effects" (unintended consequences) is often a powerful determinant of the dynamic outcomes of policies. Additional empirical (modeling) assessment of the dynamic effects of class assignment decisions for the dairy industry is merited.

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INTRODUCTION

Recently-introduced beverage products such as *Swerve* from the Coca-Cola company and *LeCarb* from Southwest Foods in Texas have raised the issue: to which price class should these products be assigned under Federal Milk Marketing Orders? Current regulations assign the milk used in these products to Class II on the basis of the milk solids content of the final product. Some administrators have argued that legislation indicates that form and use determine class assignment, and therefore because these products are consumed as beverages (i.e., in fluid form) that they should be priced in Class I. Certain dairy producer groups have also argued that these products should be assigned to Class I because they believe that this will enhance producer revenues compared to when they are assigned to Class II.

To the extent that enhancement of producer revenues is an objective of the assignment of products to classes, the conceptual model of a price-discriminating monopolist provides a guideline. Under this conceptual model, there is a single seller of a product who is able to set different prices in two or more markets. Accordingly, producer revenue is increased when markets with more inelastic demand are charged a higher price and those with less inelastic demands a lower price. The model of a price-discriminating monopolist can be used as the basis for a regulatory system with price differentials, but the ultimate market outcomes of this approach differ somewhat from this basic price-discrimination model. In particular, the price received by producers and the quantity produced is higher than in the monopolistic case (and consumers pay lower prices; Stephenson, 2003). A key point is that demand elasticities influence the price to be charged in the different markets, but the seller must be able to exercise some control over supply.

The conceptual model of a price-discriminating monopolist can provide a useful first approximation for the assignment of products to classes when the objective is to maximize producer revenues. However, in the case of a new product it is helpful to consider a conceptual model that includes additional elements relevant to understanding both short-run and long-run outcomes. That is, the dynamics of the introduction of the new product can be important, so a conceptual model that explicitly includes them can provide additional insights. Moreover, the price-discriminating monopolist model in its most basic form does not include a number of characteristics relevant to assessing the impacts of a new product on US dairy markets. These include the use a product-pricing formula based on the market price of a storable product to determine the base milk price for other products, the potential for new products to cannibalize existing (fluid milk) products, cross-price effects between new and existing products, and potential market impacts from by-products resulting from production of the new product.

The objective of this paper is to explore the dynamics of assigning a new product to a price class under a system of classified pricing and product-pricing formulae. A system dynamics model of generic input supply and product markets linked by product-pricing formula is developed to explore the implications of assigning a new product to a higher or lower price class. This model explicitly accounts for the dynamics of the adjustment process in response to the growth of a new product (hence a new demand for the input) and allows testing of the sensitivity of the model outcomes to various parameters. The basic model structure is described briefly, with additional details in Appendix A. Extensions to this model to explore the impacts of cannibalization, cross-price effects and by-products are developed in turn. Throughout the discussion, generic terms such as "input supply" and "perishable product demand" are used rather than "milk" or "fluid products" to emphasize that this is a conceptual model that still does not fully account for the intricacies of US dairy product markets; as is the case for all models, it too is a simplified representation of reality. However, it complements the insights of the basic price-discriminating monopolist model concerning likely effects of a new product introduction in US dairy markets. The model also highlights the information (parameters) needed to both assess the impacts and determine whether assigning the new product to the higher class or the lower class enhances producer revenues. Our purpose is to illuminate the conditions under which assignment of a new product to Class I will likely enhance producer gross revenues. Although the emphasis here is on long-run outcomes, the dynamic pattern of prices and revenues can also be important to different segments of the dairy industry (e.g., dairy producer groups may be willing to accept somewhat lower prices in the long-run if revenues increase in the near term).

MODEL DESCRIPTION

The basic model structure has the following characteristics:

- Three products: a storable (with less inelastic demand and assigned to the lower price class), perishable product (with more inelastic demand and assigned to the higher price class) and "new" product for which demand grows over time and which needs to be assigned to a new class;
- One input is used in the production of each of the three products, with different input requirements for the storable product (10 units input per unit output), perishable (1 unit input per unit output) and new product (2 units input per unit output);
- The storable product is a residual claimant on the input supply, i.e., input demands for the perishable and new product are met first, and the storable product sector must process the remainder of input supplies. As is the case for the other products, all storable product manufactured (whether from "surplus" input supplies or not) becomes a part of inventories, which in turn will influence market prices. That is, there is no continual accumulation or "free disposal" of the storable product made with "surplus" input;
- Initial product demands (sales) are specified so that derived input demands are equal for the storable and perishable products. These two products each demand 1000 units of input initially, so "Class I utilization" is assumed to be 50%;
- Production of the perishable and new products depends on demand, which influences inventory levels (there is a short inventory turnover time for the perishable product), price-setting, and utilization of production capacity. Production of the storable product depends only on the residual input supply and the input requirement per unit output;
- Demand for the new product grows following a sigmoid curve, a common dynamic pattern for new product introductions. Capacity to manufacture the new product is assumed to grow exogenously with expected growth in product sales. The input supply needed to support production at full market potential for the new product is assumed to be 100 units, or 10% of the input needed for the storable product and perishable product. Thus, at full market potential, total demand for the input would increase 5% if input demand for other products remained unchanged;

- Classified pricing based on a product-price formula is included. The storable product price is used in a product-price formula with a processing cost allowance to calculate the price for input used in the storable product. The input price for use in the perishable product adds a fixed differential of $2.50 per unit to the input price applicable to the storable product. No market premiums are included, so these "minimum" prices are also the actual prices;

- The price received by input suppliers is the weighted average (blend) of the two "classified" input prices. The proportions of input use for the three products are the weights.

- Capacity to process each of the products is assumed fixed (although production can and will vary because the percentage utilization of existing capacity will vary in response to profitability), as is the raw input supply capacity (although production will also vary with the blend price). This is analogous to ignoring long-run shifts in the supply curves for the products and the input.

- The model simulates monthly effects for 100 months, using a system dynamics modeling framework. This framework specifies a stock-flow structure and feedback loops that influence the behavior of model variables over time. The model is essentially a system of non-linear differential equations that is simulated through time using the mathematical technique known as numerical integration.

The basic model is depicted graphically in Appendix A, which includes a further discussion of the model structure and assumptions. Appendix B provides illustrative results of how the model can be used to assess the short-run and long-run impacts of a change in the Class I differential. This exercise illustrates how increased input supply and decreased PP demand reduce the SP product price and decrease the base price used for all of the input. As a result, the long-run increase in the "blend price" for the input is much lower than the initial increase. This same type of effect occurs if a new product is moved from a lower price class (like Class II) to a higher price class (like Class I).

IMPACTS OF ASSIGNING A NEW PRODUCT TO A PRICE CLASS

To assess the impact of changing the class to which the New product (NP) is assigned (i.e., whether it must pay the differential or not), we assume that the NP is initially assigned to the lower price class (i.e., manufacturers pay the base price for the input) and simulate the dynamic model for 100 months. This provides a base scenario from which we can examine the growth in sales of the NP, prices of the SP, PP and NP, price of the input, revenues received by input suppliers, and total expenditures by consumers[1]. A second scenario shifts the NP to the higher price class at time T=10 (i.e., after time 10, NP manufacturers pay the base price plus the differential for the input), which is early in the process of growth in NP sales. The difference between these two scenarios suggests something about which class assignment is preferable depending on policy goals (e.g., higher input supplier revenues or lower consumer expenditures). The basic model of the price-discriminating monopolist predicts that because the NP has the most elastic demand (Appendix A, Table A1), charging a higher price for the input should not increase producer revenues in long-run equilibrium.

Under the base scenario in which the NP is assigned to the lower price class, sales of the new product grow over time, to nearly 200 units per month, whereas sales of the SP and PP decrease (Figure 1). The decrease in SP and PP sales occurs because the increased demand for the input has raised input costs and therefore product prices (Figure 2; the difference in units from top to bottom of the Y-axis is the same for each of the products, indicating that the price of SP increased by more than NP or PP). In particular, growth in input supplies lags behind growth in input demand for the NP, so less input is available for the SP sector. Lower than desired inventories of SP lead to the relatively larger increase in SP prices, which also affects the input costs for the PP sector through the product-pricing formula. The base price, the input price paid by PP manufacturers and the weighted average input supply price all increase over time in response to the increased demand for the input arising from the NP (Figure 3)[2].

Under the scenario in which the NP is assigned switched to the higher price class at T=10, the basic patterns of price behavior are similar to when the NP is assigned to the lower price class.

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[1] More traditional economic measures such as producer surplus and consumer surplus are also measured but are not reported here for simplicity.
[2] Recall that this model does not include long-term supply response, which would allow more input to be supplied at the initial "reference price."

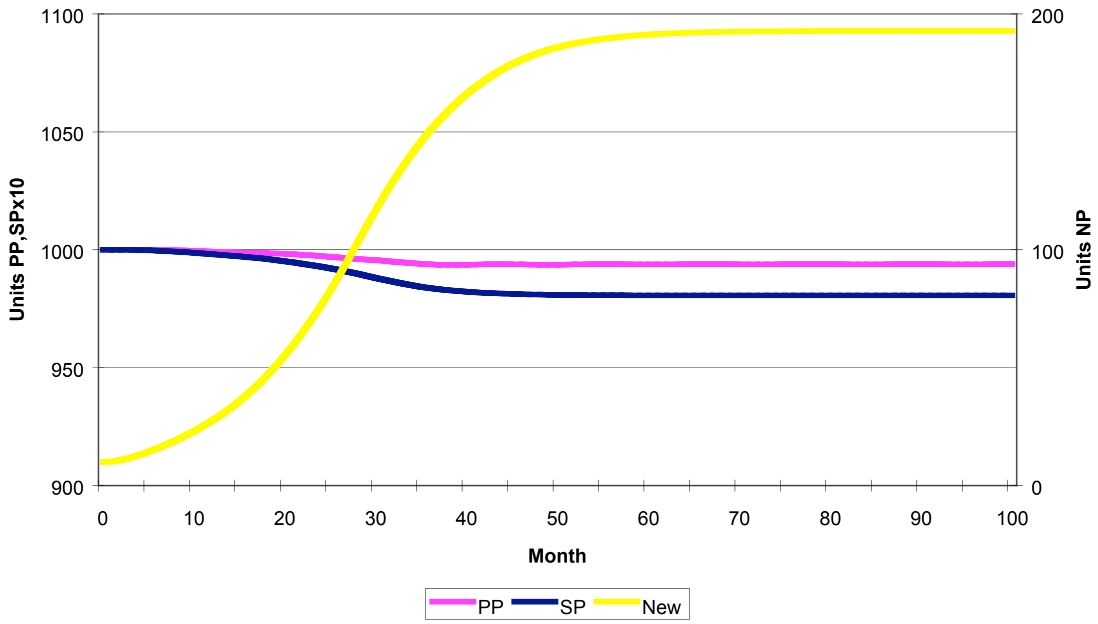

Figure 1. Quantity Demanded of PP, SP and NP, Base Scenario with NP Growth

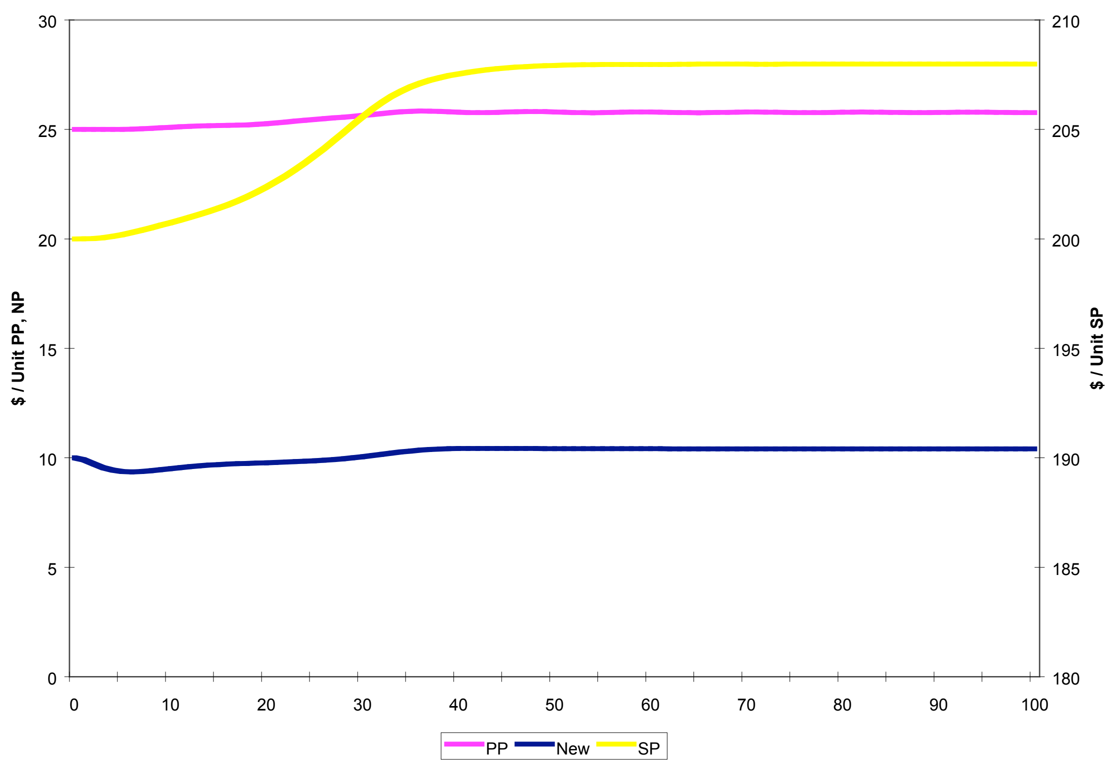

Figure 2. Product Prices for PP, SP and NP, Base Scenario with NP Growth

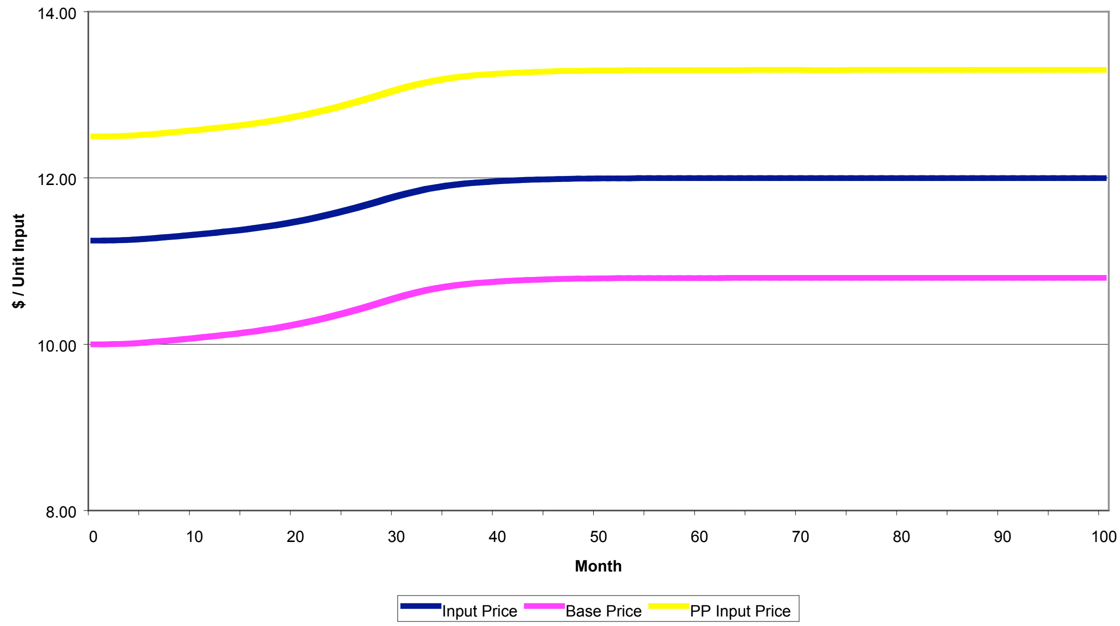

Figure 3. Base Price, PP Input Price, and Blended Input Price, Base Scenario with NP Growth

Growth in demand for the NP increases the derived demand for the input, reduces the amount of input available to the SP sector, the base price increases because SP production decreases, and prices for all products increase over time. Thus, qualitatively the results are similar regardless of the class to which the NP is assigned.

However, there are quantitative differences in the prices, quantities demanded, and the quantity of the input supplied. Assignment of the NP to the higher class reduces the growth in demand for the NP due to higher input costs and higher prices (Figure 4). Sales are reduced roughly 9% after market growth is complete compared to the base case, under the assumptions about NP price elasticity (-0.9) and initial growth rate (10%). The reduction in sales reduces the derived demand for the input, but the additional revenues from NP manufacturers paying the differential increase the weighted average price of the input, and therefore input supplies. Thus, input demands have been reduced but input supplies have been increased. (This is analogous to the effects in the situation where the differential for PP manufacturers is increased.) This increases the amount of input to be processed by the SP sector, which increases SP production and lowers SP price compared to the base case (Figure 5). The reduction in the SP price lowers the base price by about $0.15 (Figure 6) and the input price paid by PP manufacturers, so there is a small

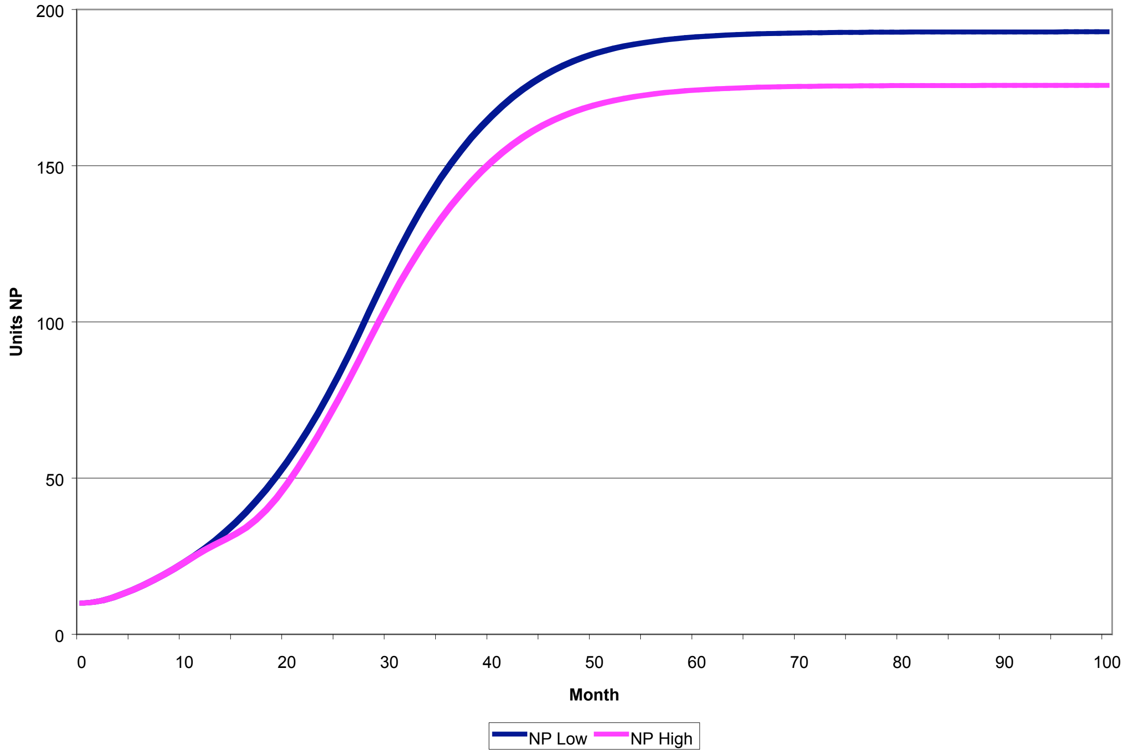

Figure 4. Quantity of NP Demanded, Base (NP Low) and NP High Scenarios

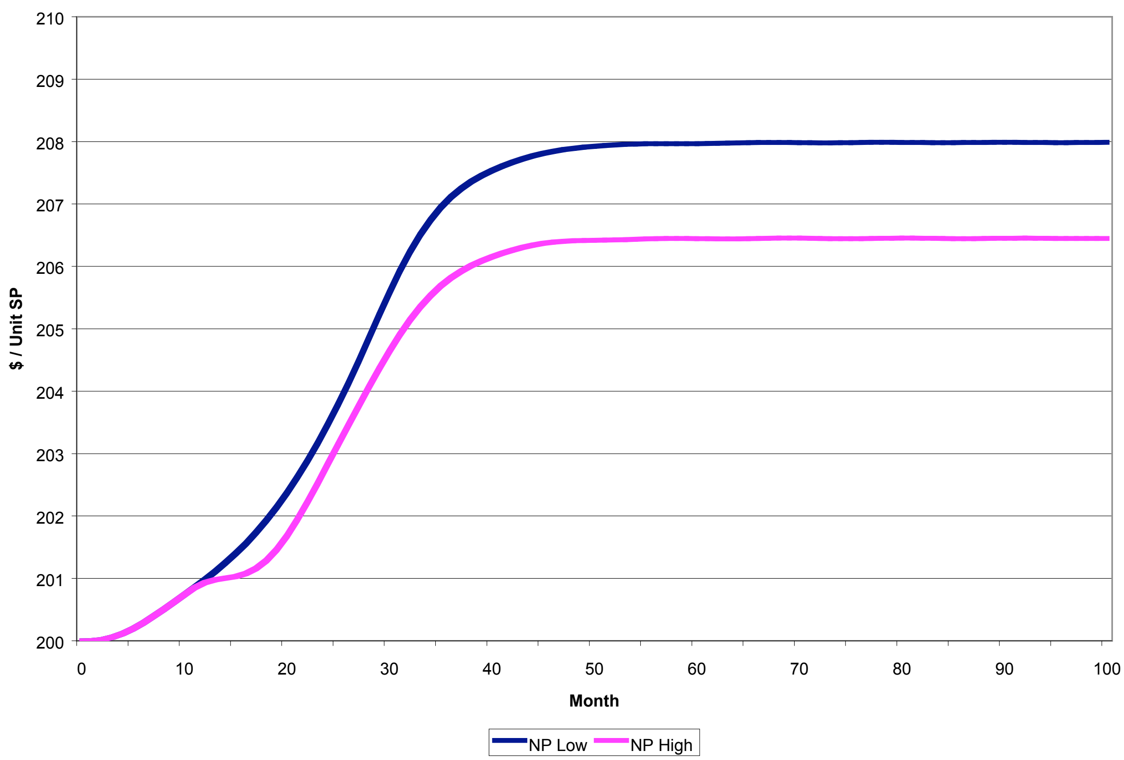

Figure 5. SP Price, Base (NP Low) and NP High Scenarios

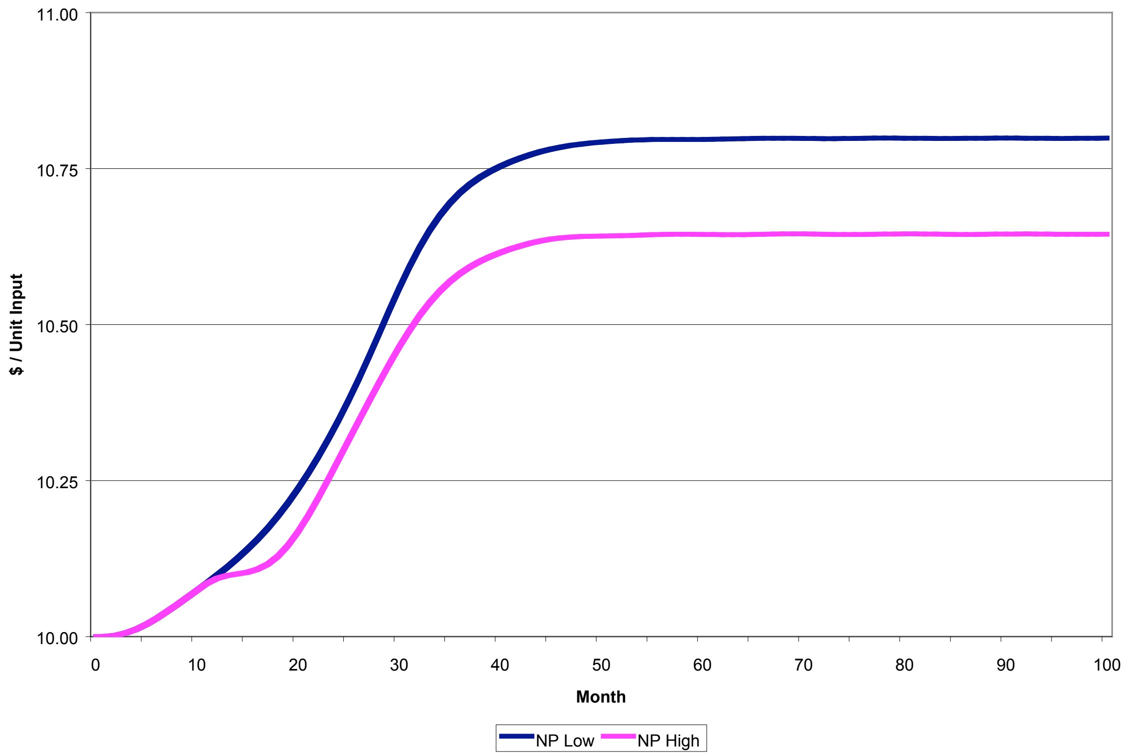

Figure 6. Base Price, Base (NP Low) and NP High Scenarios

increase in input demand for the PP sector. The blended input price received by input suppliers is at first increased by the switch of the NP to the higher class, as additional revenues from the differential contribute to the weighted average price. Over time, however, the reduction in the base price comes to dominate (Figure 7). The weighted average price is $0.04 <u>lower</u> when the NP is switched to the higher class, and cumulative producer revenues are lower at the end of the simulation. The essential logic is that increasing the price for a small share of the input demanded (i.e., input for NP) results in a decrease in the price for a large share (input for both SP and PP). This result arises because of the product-pricing formula that links the base price to the SP price, and because the SP sector is a residual claimant on the input supply. The decrease occurs despite the increase in "Class I" (high class) utilization that occurs with the change in the class assignment of the NP (Figure 8).

The qualitative outcome that assigning the NP to the higher class results in a decrease in input price and input supplier revenues depends to a certain extent on the demand elasticity for the NP. In the extreme case where the price elasticity of demand for NP were zero, then an increase in the price would have no impact on NP demand, no impact on derived demand for the input to

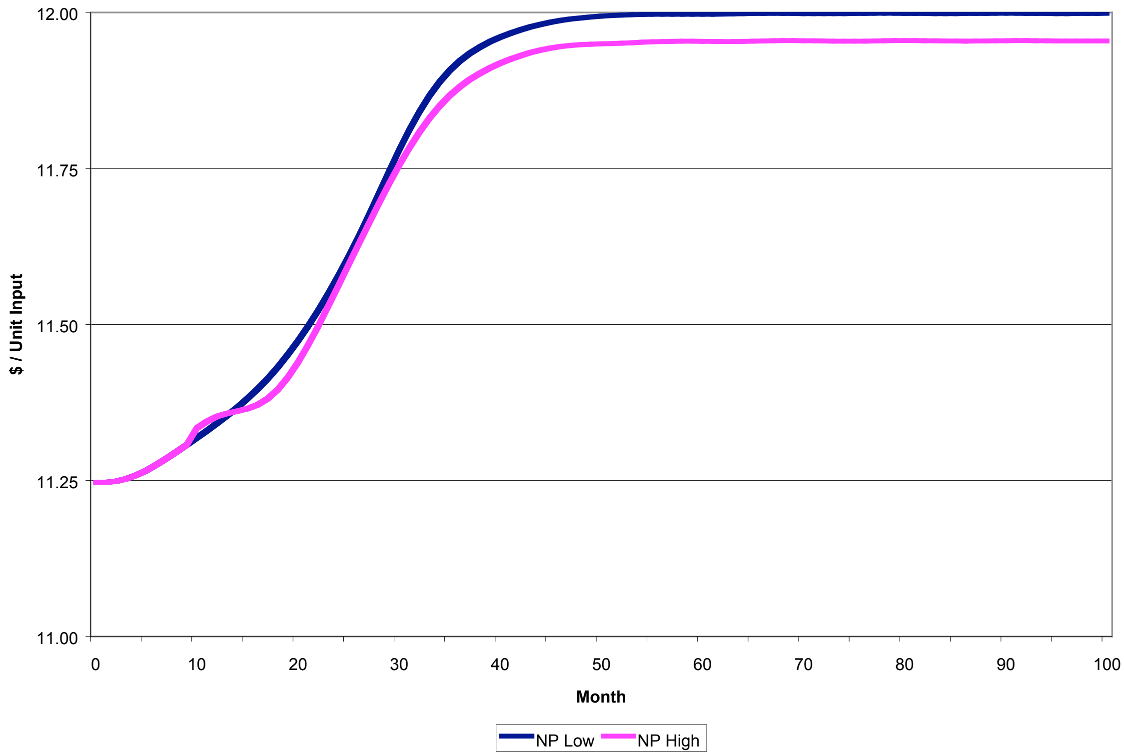

Figure 7. Blended Input Supply Price, Base (NP Low) and NP High Scenarios

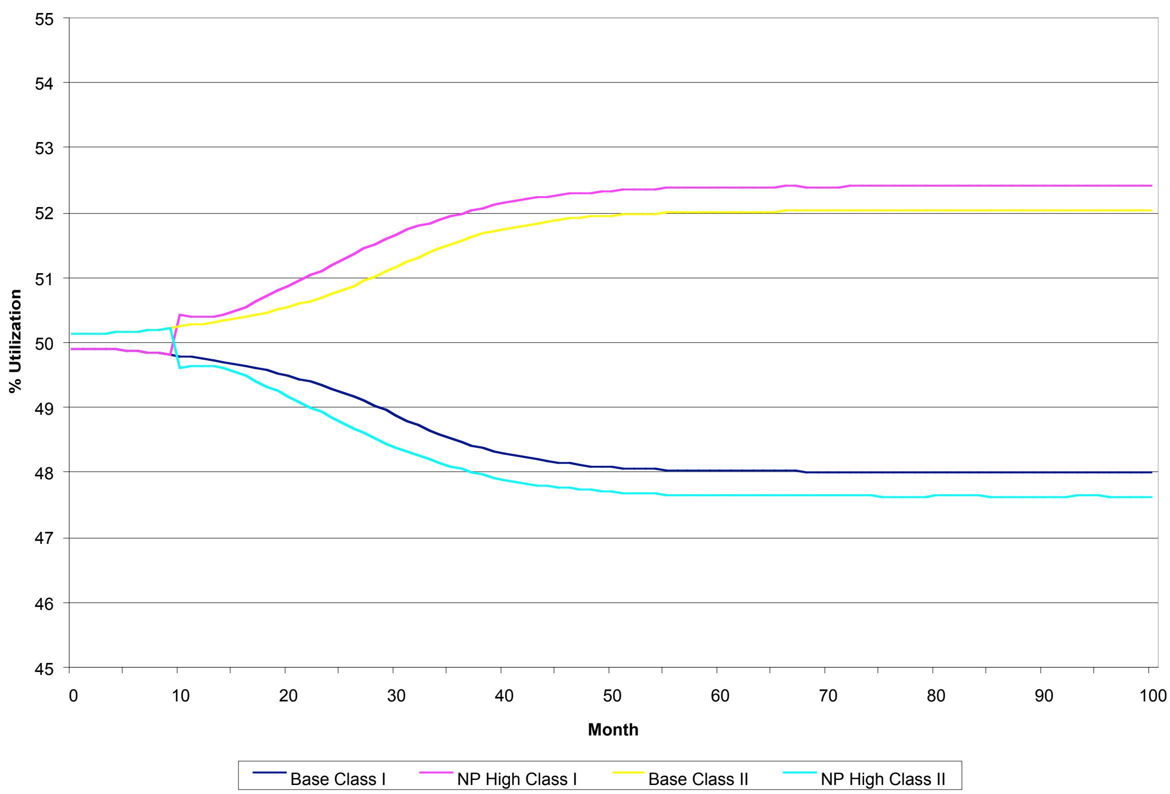

Figure 8. Percentage Class Utilization Base (NP Low) and NP High Scenarios

make NP, and no immediate impact on input used in SP. There would still be a decrease in SP prices and the base price because total input supplies would increase due to the higher price brought about by the shift of NP to the higher class. Thus, there will still be some offsetting negative effect on the pricing for all of the input even if there is no reduction in input demand for NP production. An inelastic demand makes it more likely that there will be an increase in the weighted average input price if the NP is assigned to the higher price class, but does not guarantee it.

To illustrate the impact of the demand elasticity for NP on the outcomes, the two scenarios compared above are simulated with a demand elasticity for NP of –0.1 instead of the –0.9 assumed in the base case (Figures in Appendix C). (Note that the NP demand is now less elastic than the demand for PP.) NP demand is smaller when assigned to the higher price class (Figure C1), but the difference is less than when NP demand is more elastic. Thus, there is a smaller reduction in derived demand for the input compared to the situation in which demand is more elastic. On average, the SP price is lower when the NP is assigned to the higher price class (Figure C2), but the SP price oscillates and is occasionally equal to the price when NP is assigned to the lower price class. The oscillations arise because a more inelastic demand for the NP results in larger price fluctuations for NP and larger variation in input demand for NP manufacturing. This in turn leads to larger variation in the input processed in the SP sector and therefore variation in SP prices (Figure C2). The variation is SP prices results in greater variation in the base price (Figure C3), which then influences input demand for PP manufacturing. Although the price variations are relatively small, the system is less stable when demand for the NP is highly inelastic.

The pattern of the base price when the NP is assigned to the higher price class price mirrors that of the SP price: on average the price is lower and more variable. The blended input supply price oscillates more when the NP is assigned to the higher class, but is on average \$0.01 higher when the NP is assigned to the higher price class. Cumulative input supplier revenues are 0.1% higher for the entire simulation period with NP assigned to the higher price class when NP demand is quite inelastic. Thus, although there is a slight increase in price and producer revenues in this example, it is quite a bit smaller than the \$0.125 per unit that the projected utilization in NP (roughly 5% of input use) times the \$2.50 differential might suggest.

In general, the effect of assigning the NP to the higher price class depends on the demand elasticities of the three products. Sensitivity analyses demonstrate that if the demands for SP and PP are inelastic <u>and</u> that PP is more inelastic than SP, the demand for NP must be more inelastic than PP demand for assignment to the higher class to increase producer revenues. That is, the NP must be the most price inelastic product of the three if assignment to the higher class is to increase the input supply price and producer revenues. This result is consistent with the simpler model of a price-discriminating monopolist. However, if the demand for SP is quite elastic (e.g., -1.5), then assignment of the NP to the higher class can increase input supply price and producer revenues even if NP demand is more elastic than PP demand. For example, if the elasticity of SP is -1.5 and the elasticity of PP demand is the original value of -0.2, any NP demand elasticity greater than -0.8 implies that assignment of the NP to the higher class would benefit producers.

The impacts of the class assignment decision under different assumed price elasticity values for the three products can be summarized graphically using information from a large number of simulations. In particular, the combination of NP and SP price elasticities influences whether assignment of the NP to the higher class increases cumulative producer revenues. To assess how the values of SP and NP elasticities influence the difference in cumulative producer revenues for assignment of NP to the higher or lower price class, 1000 simulations were run using values of the SP elasticity between -0.3 and -1.5 and NP elasticities between -0.1 and -1.5. The percentage difference in cumulative producer revenues for assignment of the NP to the higher class versus the lower class then can be plotted relative to the elasticity values (Figure 9). Numbers within the figure indicate the percentage difference in cumulative producer revenues when the new product is assigned to the high class versus the low class. Negative numbers (to the upper left) indicate that assignment of the new product to the higher class reduces cumulative producer revenues. Positive numbers (to the lower right) indicate that assignment of the new product to the higher class increases producer revenues. The zero line indicates where cumulative producer revenues are equal for the two class assignment choices. The PP demand elasticity was fixed at -0.2 for these simulations, but the results are qualitatively similar when is -0.5.

The figure indicates that whenever the NP elasticity is less than about -0.8 (i.e., -0.8 to -1.5), placing the NP in the higher product class will result in lower cumulative producer revenues regardless of the SP elasticity. In contrast, if the NP demand elasticity is inelastic (e.g., -0.2), pricing the input used in NP production in the higher class will increase cumulative producer

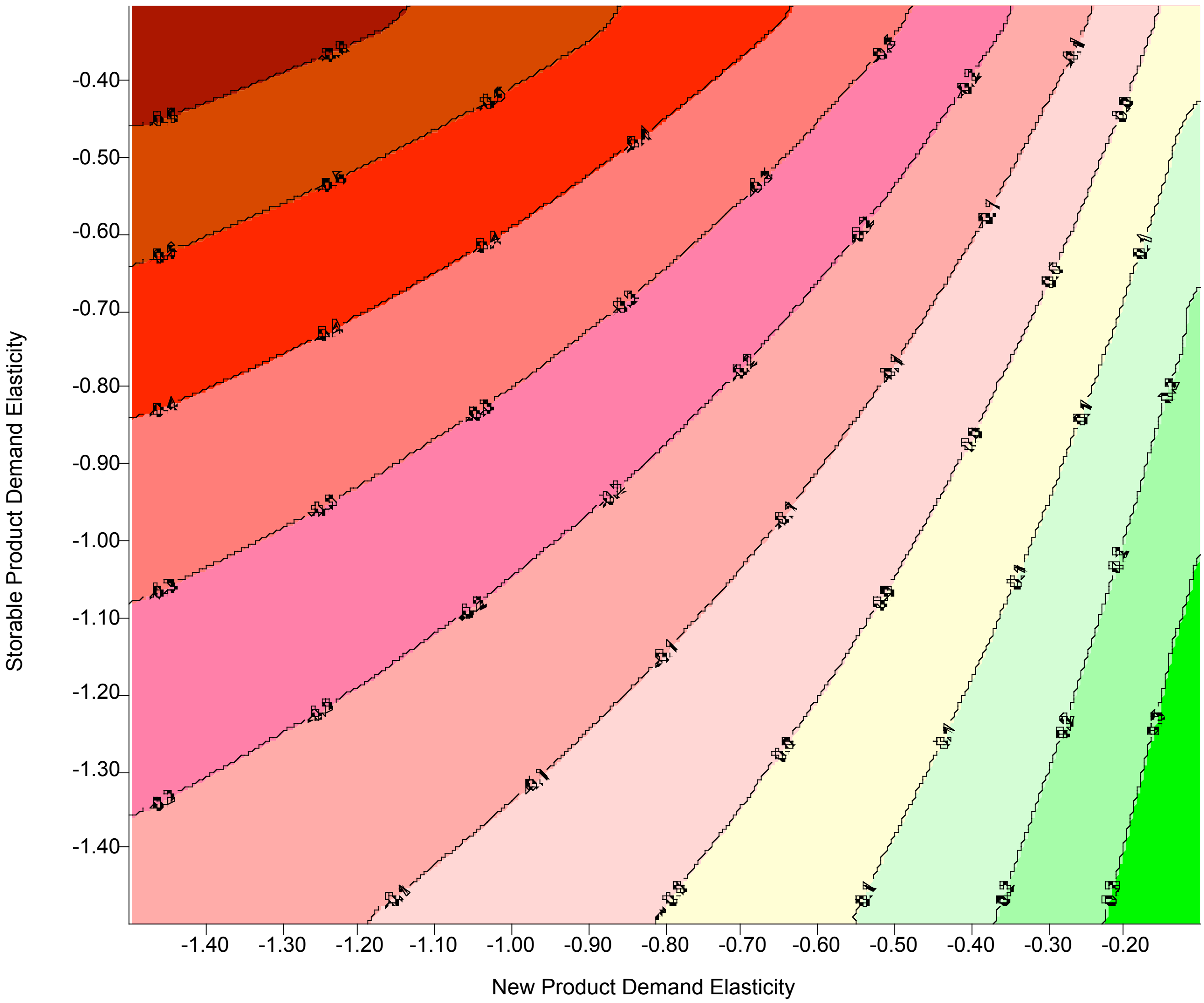

Figure 9. NP and SP Demand Elasticities and Their Impact on the Percentage Difference in Cumulative Producer Revenues

revenues. The zero line indicates that as SP demand becomes more elastic, the NP demand can also be more elastic and still result in an increase in cumulative producer revenues if the NP is priced in the higher class. This occurs because the more elastic is SP demand, the less the SP price needs to fall to bring markets back to equilibrium for a given increase in SP produced. When SP demand is elastic, there can be a larger reduction in NP demand (and therefore and increase in SP production and lower SP price) without fully offsetting the increase in revenues gained from assigning NP to the higher price class. The figure underscores the point that the relative elasticities of SP and NP demand are important determinants of the class assignment outcome, but also that the differences in cumulative producer revenues are small (less than 0.7%) when the NP is assigned to the higher price class.

IMPACTS OF THE NP GROWTH RATE

The growth rate for the NP will influence the levels of product prices. A faster growth rate will increase the demand for the input more rapidly, leading to higher increases in the input price and product prices (Figure C4). As growth in the NP levels off, however, prices will fall somewhat as input supply catches up with input demand. Ultimately, the long-term prices for the products and the input are quite similar regardless of the NP growth rate. When the NP growth rate is larger, the difference between the Blended Input Price when the NP is in the higher class versus the lower class is initially larger than when the growth rate is slower (Figure C5). However, after the initial period were the Blended Input Price is higher when NP is in the higher price class, there is a period of a year where the price difference is more negative (that is, the Blended Input Price is higher when NP is in the lower class) than when the growth rate is slower. In the long term, the growth rate does not change the outcome of the class assignment decision. At these elasticities, assigning NP to the lower class results in higher cumulative revenues for producers after about one year until the end of the simulation.

IMPACTS OF CANNIBALIZATION

The foregoing results provide initial insights about the likely impacts of price elasticities on outcomes for the two class assignment options explored with the model. However, there are other factors that are likely to be important to the dynamic outcomes of a new product introduction. Cannibalization and cross-price effects are two of these. In this paper, cannibalization refers to the idea that some consumers may prefer the NP and therefore reduce their purchases of the PP (for example, consumers preferring *Swerve* to other fluid milk products that they previously purchased). Thus, unlike the situation without cannibalization, the demand for the input will be lessened if cannibalization is a significant factor, and under extreme conditions (where cannibalization is high and the amount of input used in the NP is low compared with the PP) input demand could actually decrease. Cross-price effects reflect the idea that the price of one product can influence sales of another product (often a reasonably close substitute). In this case, the price of the PP influences the sales of the NP and vice versa.

Although cannibalization and cross-price effects are clearly related, here they have been modeled as separate effects.

Cannibalization can be thought of in at least two different ways. One way is that the introduction of the NP shifts the demand curve for the PP inwards regardless of the relative prices, because as consumers become aware of the new product, some of them decide that they prefer the NP characteristics to those of the PP. Alternatively, cannibalization can be thought of as a “point of sale” decision in which consumers who had intended to buy the PP choose instead to buy the NP, so that actual NP sales determine the loss in PP sales. In this model, both types of cannibalization are represented. For the first approach, cannibalization is specified as a constant proportion of NP Reference Demand (that is, not the actual NP demand) independent of relative prices of NP and PP. Cannibalization reduces the Reference PP demand, not the actual PP demand directly. Thus, as the Reference NP Demand increases over time, the Reference PP Demand is reduced by the cannibalization fraction times the Reference NP Demand. Under the second approach to cannibalization, it is specified as a constant proportion of actual NP sales, which directly affect actual PP sales. A cannibalization fraction of 1 is used in the following to illustrate the basic effects of cannibalization in the most extreme case. As would be expected, actual sales of PP are lower under the two alternative formulations with cannibalization than without it (Figure C6). When cannibalization is based on reference demands rather than actual demand, PP sales are lower because the effect of cannibalization is larger. Compared to the situation when cannibalization is zero, the blended input price and producer revenues are markedly reduced, but more so when the reference demands are the basis for cannibalization (Figure C7). The Blended Input Price ends up at about the level it was before the NP introduction, despite that fact that one unit of NP uses only half the input that the PP does. This occurs because the price of the PP falls, which somewhat offset the effect of cannibalization. NP sales are increased somewhat under cannibalization, because the reduction in PP sales reduces the input price relative to what it would have been without cannibalization, thus reducing NP production costs.

What impact does cannibalization have on the class price assignment decision? It turns out that the formulation assumed for the cannibalization effect makes a difference. Results with cannibalization based on the reference demands (that is, which are assumed to shift the demand curves for the two products, rather than based on a framework involving a “point of sale” purchase decision) are qualitatively similar to those without cannibalization given the same own-price elasticities. The difference in Blended Input Price for NP in the high class versus NP in the low class is similar when the cannibalization fraction is 0 or 1 and cannibalization is based on reference demands (Figure 10). Thus, when based on reference demands, the cannibalization fraction does not change the long-term effect of the class assignment decision on the Blended Input Price or cumulative producer revenues—although it has a large impact on their levels. When cannibalization is based on actual sales, assigning the NP to the higher class increases the Blended Input Price and cumulative producer revenues at the assumed own-price elasticity values (Figure 10). This is because assignment to the higher class increases the price of the NP and reduces its sales. The reduction in sales reduces the amount of PP sales cannibalized, which increases the Blended Input Price (Figure C6).

CROSS-PRICE EFFECTS

The cross -price effects are modeled as (Price/Reference Price)$^{\text{Cross-Price Elasticity}}$. These effects are multiplied times the respective PP or NP reference demands and the own-price effects. Positive cross-price elasticities imply that products are substitutes (i.e., and increase in the NP price results in an increase in the PP quantity demanded). Cross-price effects are typically smaller than own-price effects, so the cross-price elasticity of NP on the demand for PP is assumed initially to be 0.1[3]. The NP price effect on PP is initially to decrease demand because the NP price is lower than its reference value (Figure C8). Later in the simulation, the NP price is higher than its reference value, which increases the PP quantity demanded. The blended input price ends up somewhat higher later in the simulation (Figure C9), but is lower during the initial growth phase for NP. Cumulative producer revenues (Figure 11) end up higher with the cross price effect included. The blended input price ultimately is higher because the CPE increases the demand for PP and therefore the input used for PP (thus, utilization in the higher class). In addition to modifying the quantity demanded, the inclusion of the effect of NP price on PP Demand also results in PP demand and price oscillations. The magnitude of the quantity oscillations is small, but the price oscillations are relatively large as a percentage (as would be expected with an inelastic demand). The sustained oscillations appear to arise from the initial

[3] Although it is typical to assume that cross-price effects are equal for two products (called "symmetric"), here they are addressed separately for simplicity. Later discussion shows that the assumption of symmetry does not qualitatively change the outcomes compared to the asymmetric case assumed here.

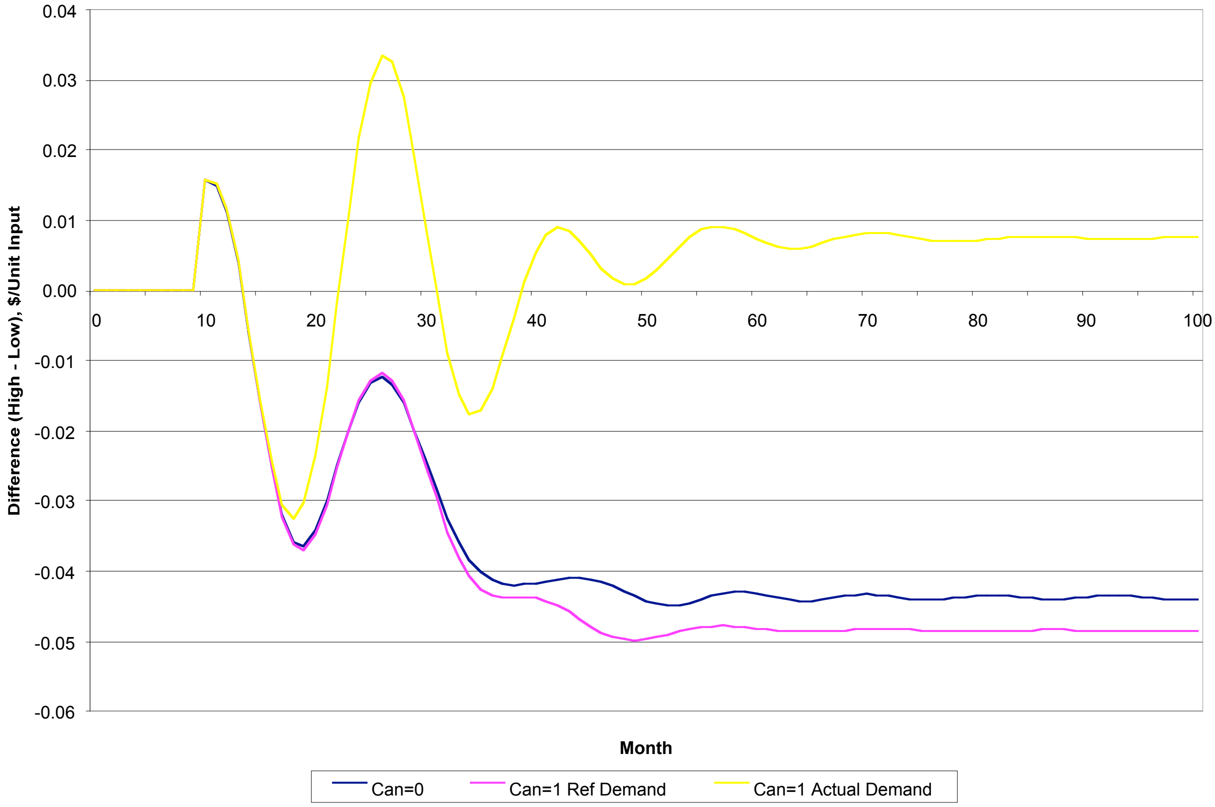

Figure 10. Difference in Blended Input Price, High Minus Low, With Cannibalization Equal to 0 and 1, Alternative Cannibalization Formulations

de-stabilizing impact of the decrease in the NP price, which is then propagated due to 1) the delay in adjustment of actual demand to indicated demand and 2) the relatively high sensitivity of the PP price to PP inventory holdings[4].

The size of the effect of the NP price on PP demand has an impact on which class assignment decision results in higher cumulative producer revenues. When the cross-price elasticity is 0, assignment of the NP to the lower class results in a higher blended input price (Figure C9; again assuming the own price elasticities in Table 1). If the cross price elasticity is 0.1, assignment to the higher class producers a higher long-term blended input price and cumulative producer revenues. This occurs because as the NP price rises above its reference level later in the simulation, this stimulates additional sales of PP, which is contributes to an increase in the blended input price. Because PP is a much larger share of the market than NP, this increase in

[4] If the demand AT and sensitivity are made 0.25 and –0.5, respectively, there are still oscillations but they dampen much more quickly and(or) do not repeat.

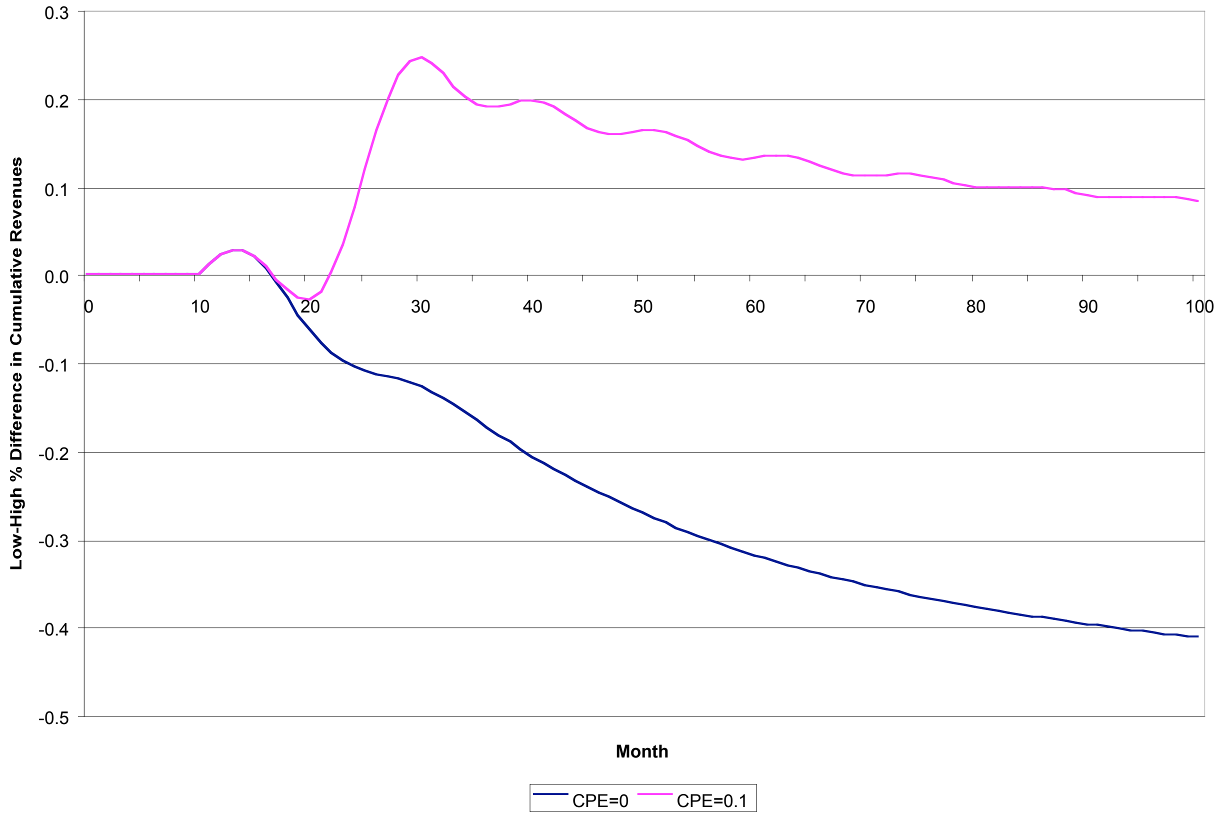

Figure 11. Percentage Difference in Cumulative Producer Revenues between NP High and NP Low Scenarios with With Cross-Price Elasticities Equal to 0 and 0.1

PP sales increases the demand for the input by more than amount of the reduction in input demand for NP because of its higher price. Utilization of the input in the higher price class increases, so the blended input price increases. Initially, however, the blended input price is lower than without the cross-price effect. This arises because the NP price is lower than its reference value, which decreases the demand for the PP, increasing supplies of the input to SP processing and lowering the SP price.

This discussion above raises the basic issue, however, of why the NP price declines initially. This happens because NP inventory coverage becomes higher than the reference level. Inventories grow because production depends on the capacity times the utilization. Capacity growth depends on reference demand, not actual demand, so it grows more quickly than needed. This could be modified in the model to reflect actual demand with some delay, but this may not be a realistic assumption for the development of new capacity. Moreover, it's likely that the capacity expansion and utilization decisions are made differently in the case of a new product introduction (or there is already capacity that can be used to make the NP) than under standard "mature market" operating conditions. If the NP price ends up lower than its reference value, NP sales are increased and PP sales are decreased compared to the situation without cross-price effects. If the NP price ends up higher (as in this simulation), PP sales are increased, which increases the blended input price. Assumptions about NP capacity expansion affect the basic dynamics of the NP introduction and the class assignment decision when the cross-price effects are rather large, as in this case.

In addition, the simulations demonstrate that only the effect of the NP price on PP demand affects the class price decision. When an effect of PP price on NP demand is assumed, the simulation results are nearly identical to those with no cross-price effects. This occurs because the introduction of the NP has relatively limited price impacts on the PP, and the market-wide impacts of the impact of PP price on NP demand are limited because NP is a much smaller segment of the overall demand for the input. Thus, the simulation model suggests that the effect of the NP price on PP demand is the key cross-price effect upon which to concentrate to assess class assignment outcomes.

CLASS ASSIGNMENT OUTCOMES WITH BY-PRODUCTS

The model can also be used to examine the impact of class assignment when there is a by-product from the NP production process. For the purposes of this analysis, it is assumed that production of both the PP and the NP generate by-products that are processed into SP. Two key characteristics of the by-product are 1) its production as a proportion of total raw input and 2) the yield of SP per unit by-product. For the PP, the amount of the by-product is equal to 10% of the input demanded for the PP production. The yield of SP per unit of by-product from the PP is equal to the yield of SP from the raw input[5], 0.10 units SP per unit PP by-product. The by-product used in SP production is priced at the base input price. The by-product from the NP is handled in the same manner as the PP by-product. For the NP, however, the values of the proportion of by-product produced and the yield of SP from the NP by-product are varied to assess whether these parameters alter the outcomes of the class assignment decision.

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[5] The choice of the values for the proportion of the PP by-product and its SP yield have no impact on the qualitative results discussed subsequently.

The basic patterns of prices in the model with by-products and growth in the quantity of NP demanded are similar to those reported previously, so these are not discussed in detail. Rather, the focus is on differences in the blended price and cumulative producer revenues when the proportion of the NP by-product and its SP yield are changed. Two scenarios are considered. In the "Low By-Product Proportion and SP Yield" scenario, the by-product is 10% of the total input used in NP production, and the yield of SP is the same as the raw input (and the PP by-product), 0.10 units SP per unit NP by-product. For the "High By-Product Proportion and SP Yield" scenario, the by-product is 35% of the total input used in NP production, and the yield of SP is higher, 0.25 units SP per unit NP by-product. In each case, NP by-product used in SP production is priced at the base input price.

The by-product model simulations indicate that the proportion and SP yield of the NP by-product have a impact on the blended input price and cumulative producer revenues (Figures C10 and 12). When the by-product proportion is low and the SP yield per unit by-product is the same as the raw input, assigning the NP to the lower-price class results in a higher blended price (Figure C10). Cumulative revenues are almost 0.2% higher when the NP is assigned to the lower price class (Figure 12). Thus, it is similar to the results reported for the initial model with growth in NP demand discussed above.

However, when the by-product is a larger proportion of the NP input demand and the yield of SP per unit by-product is larger, assignment of the NP to the higher-price class results in a higher blended input price and cumulative revenues (Figures C10 and 12). This outcome arises because the reduction in the quantity of NP demanded due to its higher price reduces both the production of the NP and production of the by-product. Reduction of the NP by-product is large enough that it results in lower SP production, which implies higher SP prices, a higher base input price, and a higher PP input price. Although this basic treatment of by-products does not capture the complexity of by-products and intermediate product use in the dairy industry, it does illustrate the potential for the nature of the by-product from NP production to influence which class assignment generates greater producer revenues.

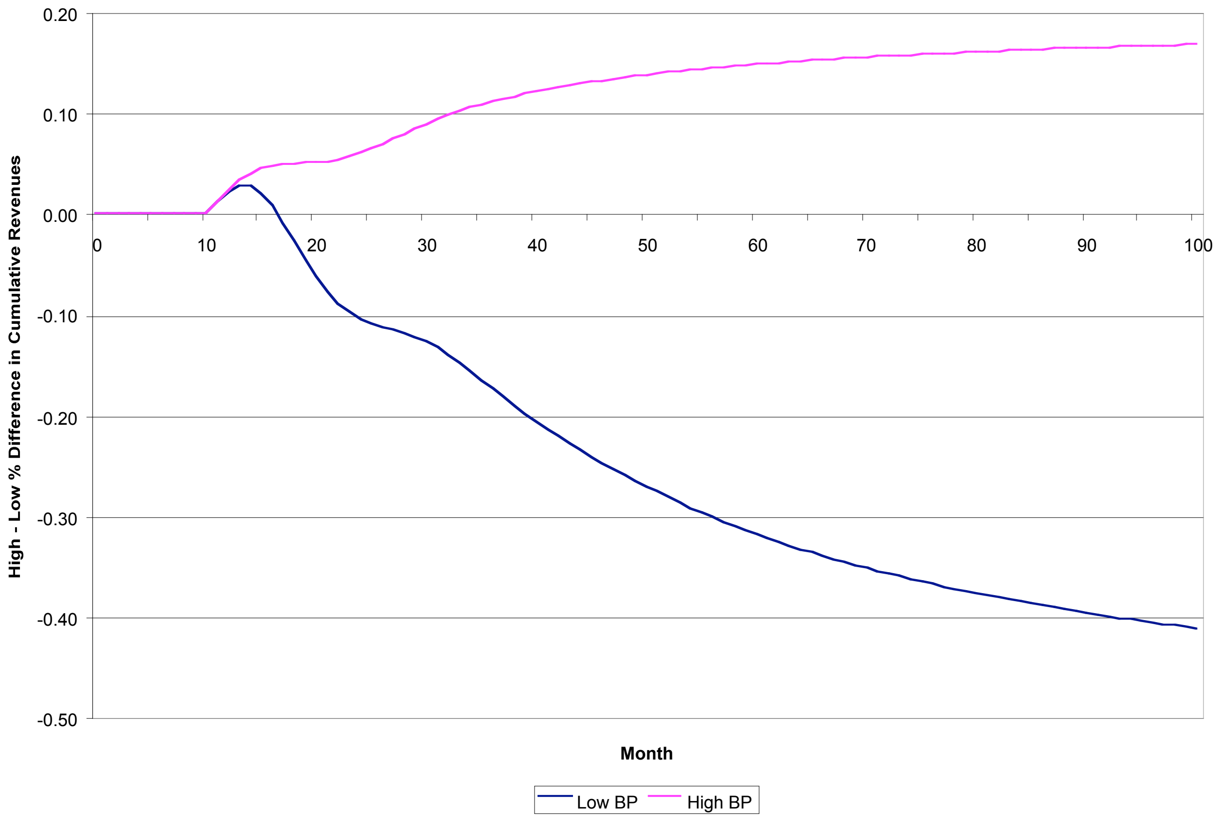

Figure 12. Percentage Difference in Cumulative Producer Revenues between NP High and NP Low Scenarios with Low By-Product Proportion and SP Yield (Low BP) and High By-Product Proportion and SP Yield (High BP)

CONCLUSIONS AND IMPLICATIONS

The conceptual dynamic model developed in this paper predicts certain outcomes that are not inconsistent with the predictions from the model of price-discriminating monopolist, namely that charging a higher price in the market with the most inelastic demand will increase the average producer price and revenues under certain assumptions about the demand elasticities of the other products[6]. The result herein is more subtle in that the input price when the new product is assigned to the higher price class fluctuates above and below the price when the new product is assigned to the lower price class. Even in the case with very inelastic new product demand, the increase in average price and producer revenues from assigning the new product to the higher

[6] Note that higher price and revenues are not shown to be theoretical results valid for all parameters, but empirical ones based on the given parameter values of the model. The appendix explains why simulation of empirical results is necessary for the conceptual dynamic model.

price class may be quite small due the various dynamic effects that work to offset the initial price increase.

Given the parameters of the model, unless demand for the new product is very inelastic—or NP demand is inelastic and SP demand is very elastic—assignment of that product to the higher class is likely to result in lower weighted average input price and producer revenues. This outcome arises because the additional revenues generated by the differential paid on the new product can be more than offset by the decrease in revenues due to a lower base price. The lower base price occurs because of the reduction in input demand for the new product and an overall increase in input supply. Because the storable product sector is a residual claimant on the input supply, this increases storable product inventories and lowers the price, which also lowers base price via the product-pricing formula. In a qualitative sense, the market outcomes of assigning a new product to a class appear robust over a range of parameter values explored with the dynamic model. However, there are quantitative differences in the prices and their variability depending on demand and supply elasticities.

Cannibalization and cross-price effects can also influence the outcomes of the class assignment decision. If PP sales are reduced by increases in NP sales, this results in lower overall input prices and input supplier revenues. However, the assumption about how cannibalization occurs is important to whether assignment of the NP to the higher class increases cumulative producer revenues. If cannibalization is based on reference demands, then the class assignment that maximizes cumulative producer revenues is the same regardless of the degree of cannibalization. If cannibalization is based on actual NP sales, then the stronger the cannibalization effect, the more likely placing the NP in the higher class increases cumulative producer revenues. If the effect of NP price on PP sales is relatively large (e.g., > 0.05) it is more likely that assigning the NP to the higher price class will increase cumulative producer revenues. However, the qualitative impact of cross-price effects depends on the pricing and capacity decisions of the NP manufacturer. If the NP manufacturer attempts to keep prices relatively stable, expands capacity in a manner different than assumed here, or makes capacity utilization decisions based on factors other than price, the class assignment decision that maximizes cumulative producer revenues will be different.

In addition, the nature of by-products from NP production can influence the outcomes of the class assignment decision. If by-products are a small part of the NP production process and their yield of SP is low, it is likely that assignment of the NP to the lower price class will yield a higher blended input price and cumulative producer revenues. If by-products a larger proportion of the NP input use and the by-product yields larger quantities of the SP, the blended input price and cumulative input supplier revenues are larger when the NP is assigned to the higher-price class.

In a more general sense, the dynamic conceptual model illustrates that the existence of "offsetting effects" (unintended consequences) is often a powerful determinant of the dynamic outcomes of policies. This has been demonstrated here for the case of increasing differentials in the absence of new demand for the product and for the case where a new product is assigned to a class under a system of classified pricing. Although the conceptual dynamic model captures many of the important characteristics of a classified pricing system, the reality of the US dairy industry involves a great deal more complexity. The outcomes of class assignment are unlikely to be predicted using logic or basic economic theory alone. Rather, they are essentially empirical questions. Additional empirical (modeling) assessment of the dynamic effects of class assignment decisions for the dairy industry is merited.

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APPENDIX A: DETAILS OF MODEL STRUCTURE

Figure A1 shows the structure for the perishable product (PP) sector. Although the product is perishable, a small amount of inventory is held. Production of the PP product adds to inventories held (in aggregate) by PP manufacturers; shipments of PP product reduce inventories. Inventory coverage (the number of months of inventory typically held by PP manufacturers, or inventory divided by shipments) is equal to one week, and influences price-setting decisions by the manufacturers to their customers. If inventory coverage falls below one week, manufacturers will respond by increasing prices. If inventory coverage increases above one week, manufacturers will lower prices. This effect on prices is modeled through the use of relative inventory coverage (the ratio of actual inventory coverage to the "reference" or typical inventory coverage of one week). This ratio is raised to the power of the sensitivity of the PP price to inventory coverage, which in this case is -1.0. This "effect of inventory coverage on price" is multiplied by a constant "reference price" (initial equilibrium price) to obtain the actual PP market price.

The PP price is used as input to two decision-making processes, one for the PP manufacturer and the other for the customers who buy the PP. For the manufacturer, the PP price determines the short-run expected price, which in turn is used to calculate an expected markup over input costs (i.e., the ratio of the short-run expected price to unit variable costs). Price expectations are adaptive, using a first-order exponential smoothing process[7] over 8 months, although other more complicated expectation formulations could be used. Unit variable costs for PP production depend on the price of the input and the number of units of input needed to produce a unit of output. The price of the input for the PP manufacturers depends on the base input price determined by the product-price formula, which depends on the market price for the storable product (SP) and a fixed differential amount that PP manufacturers pay that SP manufacturers do not.

[7] A first-order exponential smooth in this case specifies that the rate of change in the Expected Price is equal to [Actual Price-Expected Price]/Price Expectation Adjustment Time. Thus, the movement toward a different Expected Price is a constant fraction per time period of the discrepancy between current Actual Price and the current Expected Price. With a first-order exponential smooth, roughly 95% of the total adjustment to a new equilibrium occurs by three adjustment times. Thus, for an expectation adjustment time of eight months, 95% of the total adjustment in Expected Price will have occurred by 24 months after a change in the Actual Price.

The expected markup is used to indicate how much of current production capacity the PP manufacturers wish to use, or "indicated" capacity utilization. The word "indicated" means that this is the capacity that the manufacturer would wish to use based on current price relationships, but because it can take time to modify production schedules, there is a delay between the "indicated" capacity utilization and the actual utilization. The delay between indicated and actual capacity utilization is modeled as a first-order exponential smoothing process[8], with a time adjustment constant of two months. The actual capacity utilization is multiplied by an assumed fixed capacity to calculate production. The amount of input required to achieve this production is calculated using the number of units input required per unit of output (i.e., a fixed-proportions production function). This amount of input supply is assumed to be available to the PP manufacturer, that is, the PP manufacturer has preferential access to input supplies to meet the desired production level.

The connections between the PP inventory, PP price, and PP production form what is called a *negative feedback loop*. This means that if it were possible to exogenously increase PP inventories, there would be a series of responses (lower price, lower markup, lower capacity utilization and lower production) that would tend to bring inventories back down. That is, there would be a dynamic decision-making process that would work to offset the initial increase in inventories (although inventories will not necessarily return to their initial levels). This negative feedback loop can be labeled the "utilization loop", noting the effect of inventory levels on utilization of current capacity and on production.

A second negative feedback loop starts with the PP price and influences the quantity demanded of the PP. Using a standard constant-elasticity of substitution (CES) demand function, an increase in the price decreases the "indicated" industry demand. In this case also, "indicated" implies that it may take current PP buyers some time to adjust their purchases of the PP in response to price increases, perhaps due to the existence of current supply contracts or the need to reformulate a current product mix away from the use of the PP. Again, a first-order exponential smoothing of indicated PP demand is used, with a time adjustment constant of two months. Industry demand is used to calculate shipments from PP manufacturers, subject to the

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[8] A first-order exponential smooth in this case specifies that the rate of change in the Expected Price is equal to [Indicated Capacity Utilization-Capacity Utilization]/Capacity Utilization Adjustment Time. Thus, for an adjustment time of two months, 95% of the total adjustment in Capacity Utilization will have occurred by six months after a change in the Indicated Capacity Utilization.

limitation that the product must actually be available in inventories to be shipped. This is the purpose of the PP max shipment loop shown above the PP inventory box. The “demand substitution” loop is also a negative feedback loop, as can be seen by considering an exogenous increase in the PP price. An increase in PP price leads to a reduction in quantity demanded, which leads to fewer shipments, which leads to more inventory, which leads to greater inventory coverage, which leads to a reduction in price. Again, there is no assurance that the price will return to its initial level, just an indication that an increase in price will be offset to some extent because the quantity demanded will be reduced over time.

The storable product (SP) sector has many elements similar to the PP sector (Figure A2). The demand substitution loop has the same structure (although parameters differ), so that prices influence the quantity demanded, shipments, inventory, inventory coverage, and SP price. The key differences arise with regard to the specification of capacity utilization and the supply of input to the production of SP. Although the SP price and the input costs for SP can be used to calculate an expected markup for SP production, this markup does not influence SP production as it does in the PP sector. Rather, SP production is determined based on the residual input supply. That is, all input that is not used in the PP sector (and subsequently in the “new” product sector also) is assumed to be used in the production of SP. This is equivalent to saying that all input must be processed, as long as it does not exceed the current production capacity of the SP sector. Thus, the capacity utilization feedback loop does not exist in the SP sector. SP manufacturers process all of the residual input into SP, which become part of SP inventories. Because the level of SP inventories relative to some “normal” or desired level will influence prices, the assumption that all residual input must be processed into SP will influence demand for SP as well as other prices in the system. Thus, the assumption of SP being the residual claimant on the input supply <u>does not imply</u> that the SP product manufactured is dumped or otherwise disposed of to bring about a market equilibrium. Rather, all SP production is placed in inventories where it can affect SP prices and, ultimately, other market outcomes.

The SP sector also provides the base price for the classified pricing structure. The SP price is used in a product-price formula with a SP processing cost allowance to determine a formula input supply price. This in turn influences the unit variable cost of SP production, but also is the base price for the use of the input in the manufacture of the PP (i.e., with the added fixed differential). As a result of the product-pricing formula, an exogenous increase in the production of SP will increase SP inventories, decrease the SP price, and decrease the base price and the input price for use in PP production. An exogenous increase in the quantity of input supplied would initially increase the amount of input processed by the SP sector (because derived input demand in the PP sector would be unaffected), so production of SP would increase initially and SP price (and the base and PP input prices) would fall. A key point is that an increase in input allocated to SP reduces the minimum prices for not just the input used in SP production, but also the input price for PP production.

The supply sector for the input (Figure A3) is modeled rather simply, although it has been developed in greater detail specifically for the dairy sector elsewhere (Nicholson and Fiddaman, 2003; Pagel et al., 2002). The input supply price is the weighted average price for the PP and SP sectors. That is, it is a blended price based on the minimum class prices and the amount of input used in each product. This blended input supply price determines the "indicated" input supply quantity, where "indicated" again implies a delay between the amount input suppliers want to produce given currently observed prices and actual production. A first-order smooth with an adjustment time of six months is assumed in the base scenario. The input supply curve is also CES, with the indicated supply quantity equal to a reference (initial) input quantity times the ratio of the current price to a reference (initial) input supply price to the power of the supply elasticity. The initial assumed supply elasticity is 0.5. Thus, when the input supply price increases, input supply will increase over time. For simplicity, there is no long-run supply response (shift of the supply curve) in response to higher prices. This implies that the results will represent something more like "best case" scenarios for producers, because there will be no long-run supply response that will lower input prices. How the input supply is allocated between the SP and PP sectors depends on the relative prices and therefore the derived demand for the input for PP production.

The structure for the "new" product (NP) sector is essentially the same as for the PP sector, although parameters differ (Figure A4). Inventories of the new product influence prices, which influence capacity utilization, production and input demand for NP production. Note that there is no distinction regarding product form (e.g., fluid versus solid) or storability (the product is assumed to be more storable than the PP, but this is not crucial to the dynamic outcomes). Like the PP, demand for the input to make NP demand depends on capacity utilization, and is assumed to be preferentially available to the manufacturers of the NP. The main difference with the PP sector is that the capacity to manufacture the NP is assumed to grow over time to match demand growth. A sigmoid growth model is used to model increases in NP demand over time. This simulates the growth of a market for the NP and shifts in the NP demand curve. Initial demand is 20 units, and an initial fractional growth rate of 10% per month is assumed. With this growth rate, demand for the NP takes roughly four years to reach its full potential, which may be slower than the desired sales penetration of the actual companies introducing new products. (The impact of the rate of growth in sales is discussed subsequently.) Growth in demand slows as the market reaches saturation at close to 200 units. The price of the input for the NP manufacturers is a focal point for assessing the impacts of new product class assignment. It is assumed that the product can either be assigned to the lower price class (with SP) or the higher price class (with PP). The assignment of the NP to the product classes will imply different unit input costs and therefore markup for a given NP price. In the scenarios that follow, it is assumed that the dairy markets initially are in dynamic equilibrium[9] with the NP assigned to the lower price class. The effects of shifting the NP to the high price class are then examined. (The relative effects of changing from one price class to another are the same regardless of the initial class assignment of the NP.) The parameters used in the base scenario for each of the sectors are summarized in Table A1.

Limitations of the Model Structure

Like most models, this one includes a number of simplifications and limitations. First, the dynamics of new product growth are exogenous, which is typically not the case. Companies introducing new products usually develop sophisticated marketing and promotion plans that can be adjusted as market conditions warrant. Despite this, many new products are considered "failures" and are removed from the market if their sales growth lags behind expectations. None of the promotional efforts, or the possibility that the product could be removed from the market if its sales growth lags, are considered in the current model. It could be the case that the class assignment decision would influence whether or not the product is removed from the market, and this possibility is not considered here. A related issue is that this model assumes the NP manufacturer responds to the same types of information as does the PP manufacturers, e.g., inventory levels affect the pricing decision. It is likely that a NP manufacturer will respond

[9] Dynamic equilibrium means that the values for all the variables are non-zero but do not change over time.

somewhat differently to inventory and utilization decisions given that a new product may be promoted or priced differently in order to alter the pattern of growth in sales. It is also assumed that there are no long-term adjustments in manufacturing capacity for the three products. This means that product prices will tend to be lower than if capacity adjustment were allowed.

The model also assumes that the NP manufacturer will alter utilization and pricing decisions in response to even modest changes in input costs, which also depend on the amount of the input used to manufacture the NP. If the NP manufacturer attempts to maintain roughly constant prices over some time horizon during the product's initial growth phase, or if the responsiveness of NP production and prices to an increase in input costs is small, this will limit the reduction in NP demand that results from a higher NP price. However, it seems reasonable to assume that lower profitability will affect utilization of the input, either through reductions in sales or substitutions in the types of inputs used (e.g., soy protein might be substituted for milk protein in the case of *Swerve*). Although the impacts on the NP price and utilization of assignment to the higher class are smaller when the input required per unit NP is small, the overall gains to be had by producers are also smaller when the amount of the input used in NP production is small.

Finally, growth in capacity for the NP is assumed to grow exactly in line with growth in the NP Reference Demand. That is, the model assumes that the NP manufacturer can observe (or estimate) the reference demand and increase NP capacity in a manner perfectly coordinated with it. As a result, capacity grows more quickly than actual NP demand (because NP Reference Demand grows faster than actual NP demand). Because capacity is increasing more quickly than demand, inventories initially increase and NP prices fall until capacity utilization can adjust to a lower level As will be shown below, this pattern of NP prices has implications for assessing the impacts of cross-price elasticities on the decision to assign the NP to the higher or lower price class.

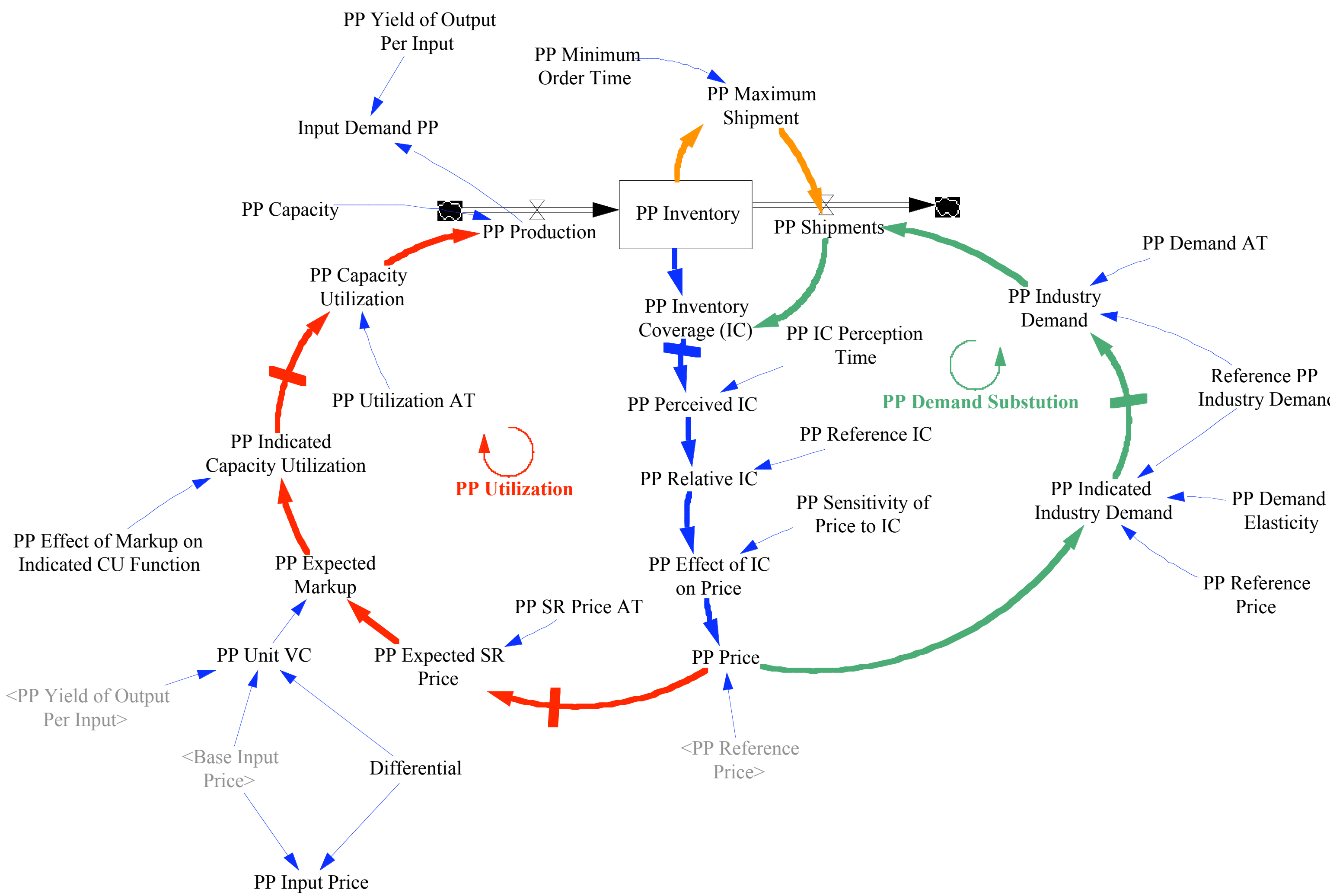

Figure A1. Perishable Product (PP) Sector Stock-Flow Structure

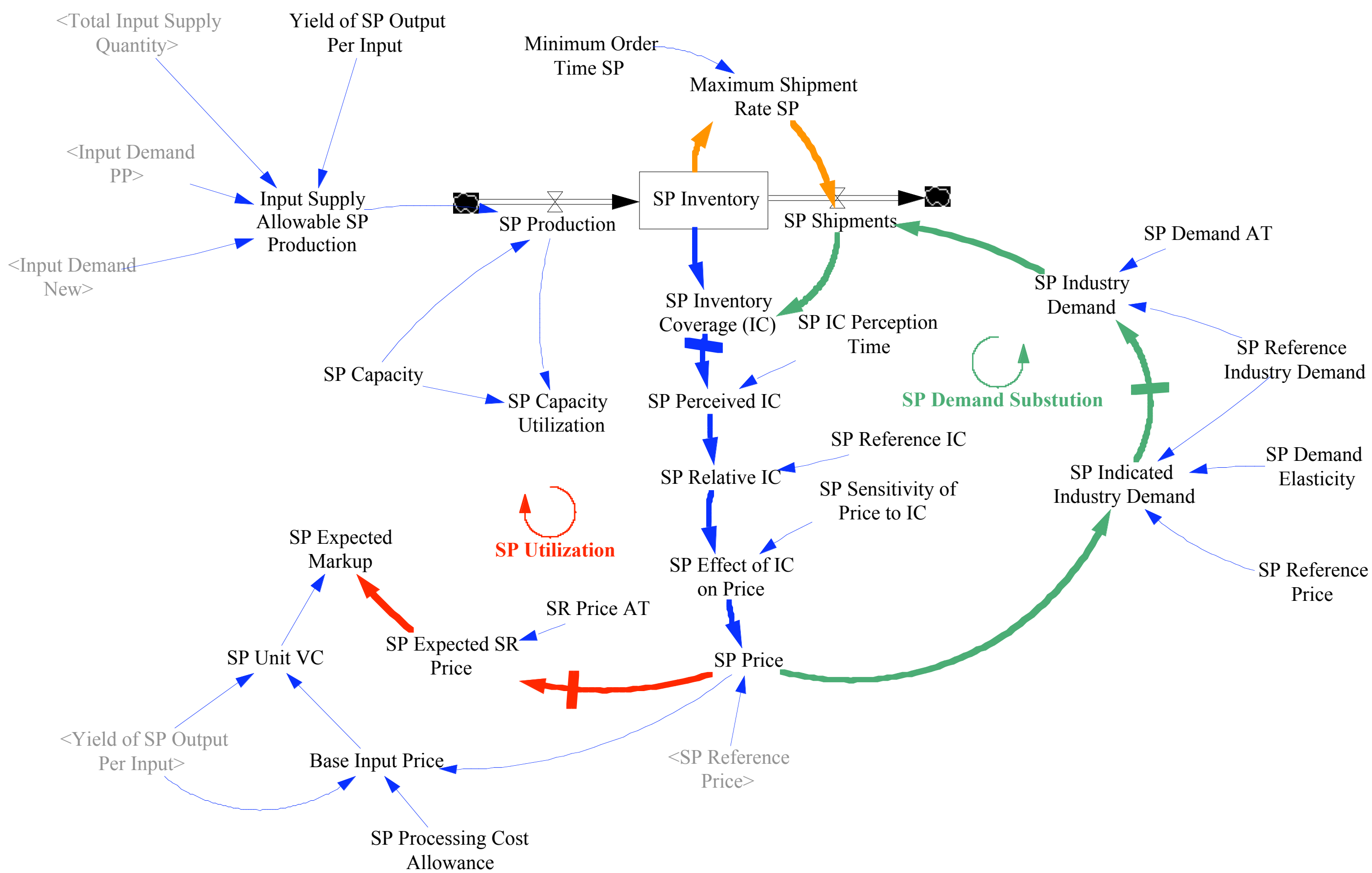

Figure A2. Storable Product (SP) Sector Stock-Flow Structure

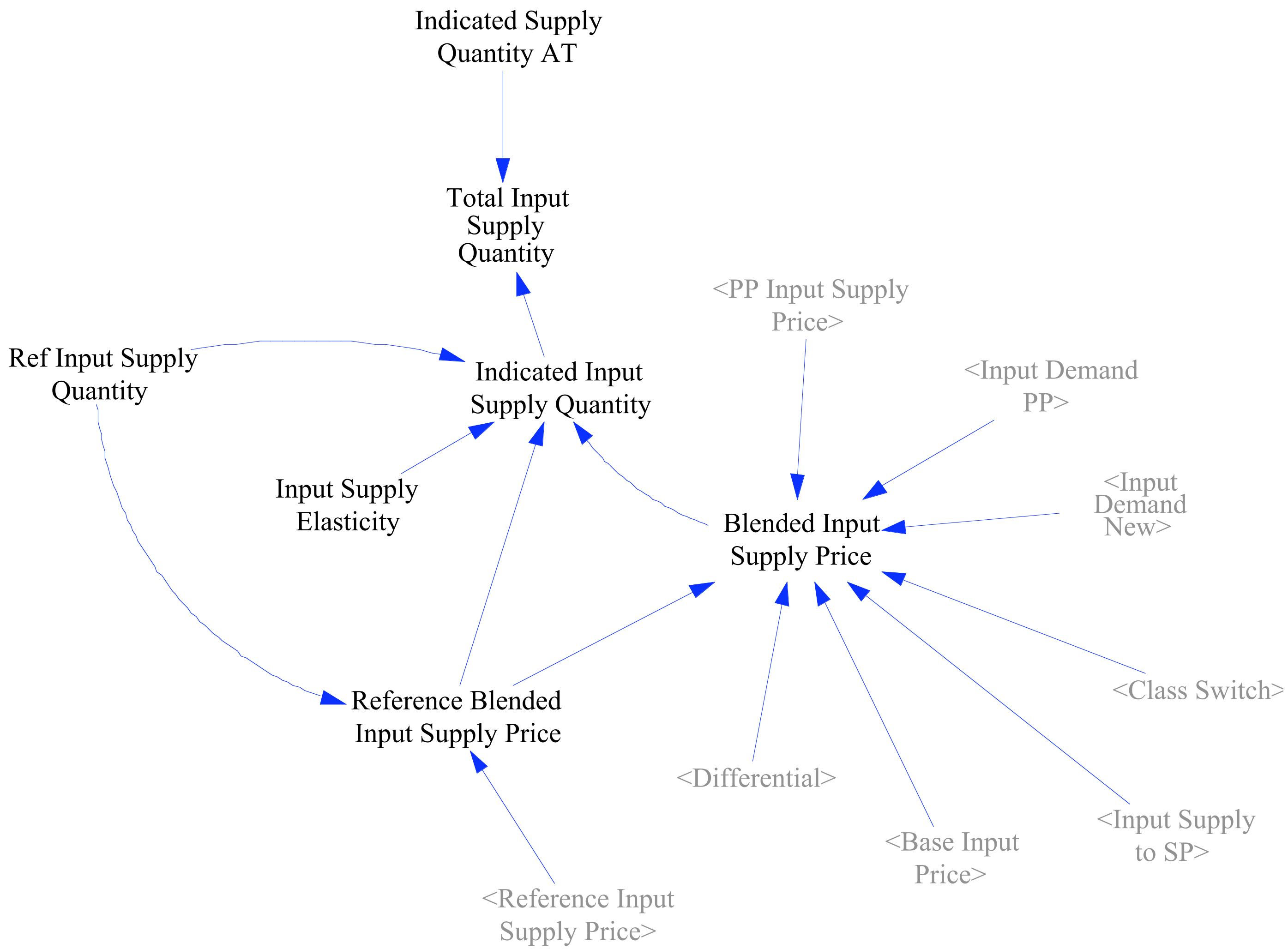

Figure A3. Input Supply Sector Structure

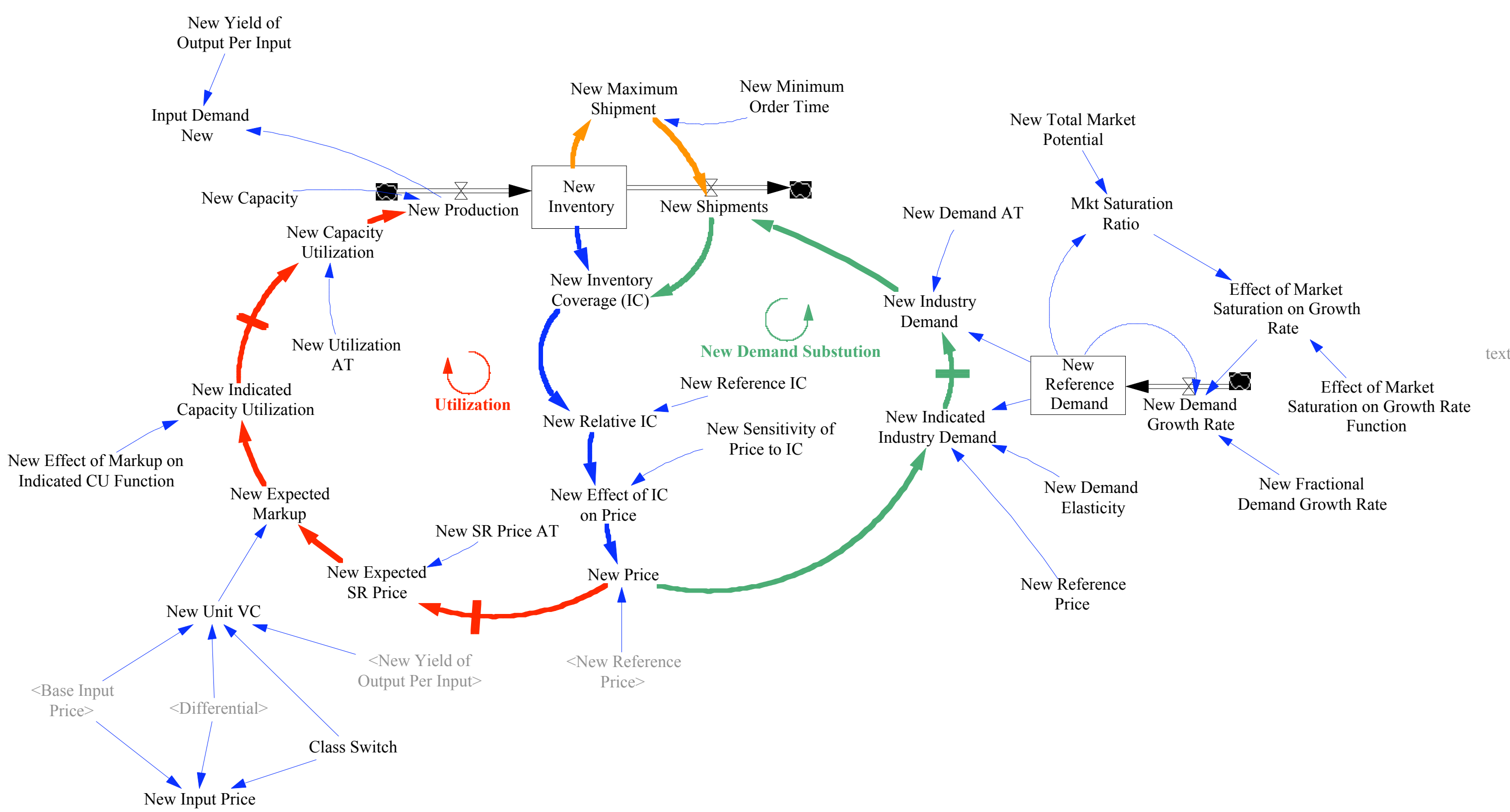

Figure A4. New Product (NP) Stock-Flow Structure

Table A1. Model Parameter Summary by Sector

Paramater	Sector			
	Perishable Product	Storable Product	New Product	Input Supply
Demand Characteristics				
Reference Quantity Demanded	1000	100	Varies[1]	
Demand AT, Months	2	2	2	
Demand Elasticity	-0.2	-0.5	-0.9	
Reference Price, $/Unit Output	25	200	10	
Inventory Characteristics				
Reference Inventory Coverage, Months	0.25	2.00	1.00	
Sensitivity of Price to Inventory Coverage	-1.0	-0.5	-0.5	
Inventory Coverage Perception Time, Months	1	1	1	
Minimum Order Time, Months	0.125	1.000	0.125	
Utilization Characteristics				
Capacity, Units/Month	2000	200	Varies[1]	
Capacity Utilization AT	2	NA	2	
Expected SR Price AT, Months	12	8	8	
Processing Cost Allowance, $/Unit Output	NA	100	NA	
Product Yield Characteristics				
Yield, Unit Output Per Unit Input	1.0	0.1	2.0	
Demand Growth Characteristics				
Market Potential, Units/Month			200	
Fractional Growth Rate, 1/Months			0.1	
Initial New Quantity Demanded, Units/Month			20	
Input Supply Characteristics				
Input Supply Elasticity				0.5
Input Supply AT, Months				6
Reference Input Price, $/Unit Input				11.25

[1] Demand and production capacity for the new product grow over time until market saturation is reached.

MODEL MATHEMATICAL STRUCTURE AND SIMULATION METHOD

The conceptual dynamic model is structured as a system of non-linear differential equations. Unlike simpler static models, there typically is no analytical solution to this non-linear system, so it is not possible to solve for an equilibrium level of individual variables in terms of the underlying parameters of the model. Thus, simulation of the model is necessary. In this case, simulation of the system over time is accomplished using numerical integration. Because the model is a system of non-linear differential equations, key variables such as production and sales are expressed as rates per unit time (e.g., production per month). Variables such as inventories are states (or stocks) that can be calculated through integration over time of the rates variables that affect them, such as production and shipments. The calculations involve the specification of model parameters (like reference prices and elasticities) and a set of starting values for stock variables like inventories. Once these initial values are specified, the other variables in the model—which are functions of the stocks and parameters—can be calculated for the next time step. As an example, production at time t+1 is a function (through prices and utilization) of the level of inventories at time t. Production, however, also contributes to inventories at time t+1. Thus, there is an iterative process of calculating inventories, then production, then inventories, then production. This is sometimes referred to as a "state-rate" formulation because the state (inventories) and rate (production) influence each other in subsequent time steps. Much more detailed discussion of numerical integration can be found in Sterman (2000). The model in this paper was simulated using Vensim® software from Ventana Systems, Inc. (A free functional version of Vensim is available at www.vensim.com.) The model equations are as follows.

PP Sector

PP Inventory = INTEG (PP Production-PP Shipments, PP Initial Inventory)

PP Inventory Coverage (IC) = PP Inventory / PP Shipments

PP Perceived IC = SMOOTH(PP Inventory Coverage (IC), PP IC Perception Time)

PP Relative IC = PP Perceived IC/PP Reference IC

PP Effect of IC on Price = (PP Relative IC)^PP Sensitivity of Price to IC

PP Price = PP Reference Price*PP Effect of IC on Price

PP Indicated Industry Demand = Reference PP Industry Demand*(PP Price/PP Reference Price)^PP Demand Elasticity

PP Industry Demand = SMOOTH(PP Indicated Industry Demand, PP Demand AT)

PP Shipments = MIN(PP Industry Demand ,PP Maximum Shipment)

PP Maximum Shipment = PP Inventory/PP Minimum Order Time

PP Expected SR Price = SMOOTH(PP Price, PP SR Price AT)

PP Input Price = Base Input Price + Differential

PP Expected Markup = PP Expected SR Price / PP Unit VC

PP Unit VC = (Base Input Price + Differential) / PP Yield of Output Per Input

PP Indicated Capacity Utilization = PP Effect of Markup on Indicated CU Function(PP Expected Markup)

PP Capacity Utilization = SMOOTH(PP Indicated Capacity Utilization, PP Utilization AT)

PP Production = PP Capacity*PP Capacity Utilization

Input Demand PP = PP Production / PP Yield of Output Per Input

SP Sector

SP Inventory = INTEG (SP Production-SP Shipments, Initial SP Inventory)

SP Inventory Coverage (IC) = SP Inventory / SP Shipments

SP Perceived IC = SMOOTH(SP Inventory Coverage (IC), SP IC Perception Time)

SP Relative IC = SP Perceived IC/SP Reference IC

SP Effect of IC on Price = SP Relative IC^SP Sensitivity of Price to IC

SP Price = SP Reference Price*SP Effect of IC on Price

SP Indicated Industry Demand = SP Reference Industry Demand*(SP Price / SP Reference Price)^SP Demand Elasticity

SP Industry Demand = SMOOTH(SP Indicated Industry Demand, SP Demand AT)

SP Shipments = MIN(SP Industry Demand, Maximum Shipment Rate SP)

Maximum Shipment Rate SP = SP Inventory / Minimum Order Time SP

SP Expected SR Price = SMOOTH(SP Price, SR Price AT)

SP Unit VC = Base Input Price/Yield of SP Output Per Input

SP Expected Markup = Expected SR Price / SP Unit VC

Input Supply Allowable SP Production = (Total Input Supply Quantity-Input Demand PP-Input Demand New)*Yield of SP Output Per Input

SP Capacity Utilization = SP Production / SP Capacity

Input Supply Sector

Blended Input Price = (Input Supply to SP*Base Input Price + Input Demand PP*PP Input Price + Input Demand New*(Base Input Price + Differential*STEP(Class Switch,10))) /
(Input Supply to SP + Input Demand PP + Input Demand New)

SP Production = MIN(SP Capacity, Input Supply Allowable SP Production)

Base Input Price = (SP Price-SP Processing Cost Allowance)*Yield of SP Output Per Input

Indicated Input Supply Quantity = Ref Input Supply Quantity*(Input Supply Price / Ref Input Supply Price)^Input Supply Elasticity

Total Input Supply Quantity = SMOOTH(Indicated Input Supply Quantity, Indicated Supply Quantity AT)

New Product Sector

New Inventory = INTEG (New Production-New Shipments, New Initial Inventory)

New Inventory Coverage (IC) = New Inventory/New Shipments

New Perceived IC = SMOOTH(New Inventory Coverage (IC), New IC PT)

New Relative IC = New Inventory Coverage (IC)/New Reference IC)

New Effect of IC on Price = (New Relative IC)^New Sensitivity of Price to IC

New Price = New Reference Price*New Effect of IC on Price

Market Saturation Ratio = New Reference Demand / New Total Market Potential

Effect of Market Saturation on Growth Rate = Effect of Market Saturation on Growth Rate Function(Market Saturation Ratio)

New Demand Growth Rate = New Fractional Demand Growth Rate*New Reference Demand*Effect of Market Saturation on Growth Rate

New Indicated Industry Demand = New Reference Demand*(New Price / New Reference Price)^New Demand Elasticity

New Industry Demand = SMOOTH(New Indicated Industry Demand, New Demand AT)

New Reference Demand = INTEG (New Demand Growth Rate)

New Shipments = MIN(New Industry Demand, New Maximum Shipment)

New Maximum Shipment = New Inventory/New Minimum Order Time

New Expected SR Price = SMOOTH(New Price, New SR Price AT)

New Unit VC = Base Input Price + Differential*STEP(Class Switch,10)) / New Yield of Output Per Input

New Input Price = Base Input Price + Differential*STEP(Class Switch,10)

New Expected Markup = New Expected SR Price / New Unit VC

New Indicated Capacity Utilization = New Effect of Markup on Indicated CU Function(New Expected Markup)

New Capacity Utilization = SMOOTH(New Indicated Capacity Utilization)

Reserve Capacity Multiplier = 2

New Capacity = New Reference Demand*Reserve Capacity Multiplier

New Production = New Capacity*New Capacity Utilization

Input Demand New = New Production / New Yield of Output Per Input

Accounting Variables

Total Consumer Expenditures = Consumer Expenditures PP + Consumer Expenditures SP + Consumer Expenditures New

Consumer Expenditures New = New Price*New Industry Demand

Consumer Expenditures PP = PP Industry Demand*PP Price

Consumer Expenditures SP = SP Industry Demand*SP Price

Producer Revenues = Input Supply Price*Total Input Supply Quantity

Abbreviations

INTEG means integration of the variable.

SMOOTH means…<insert mathematical expression here>

STEP (Step Height, 10) means that for time T≥10, the expression takes the value "Step Height." For T<10, the expression equals zero.

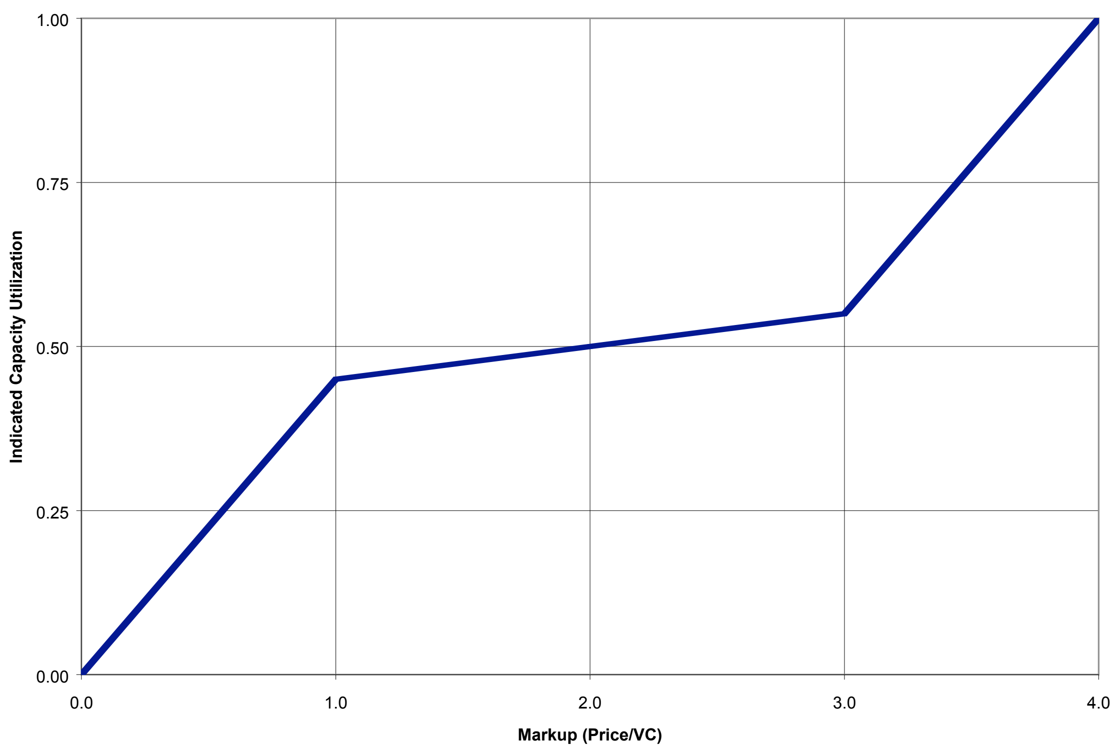

Figure A5. Function for Effect of Markup (Expected SR Price/Variable Cost) on Indicated Capacity Utilization

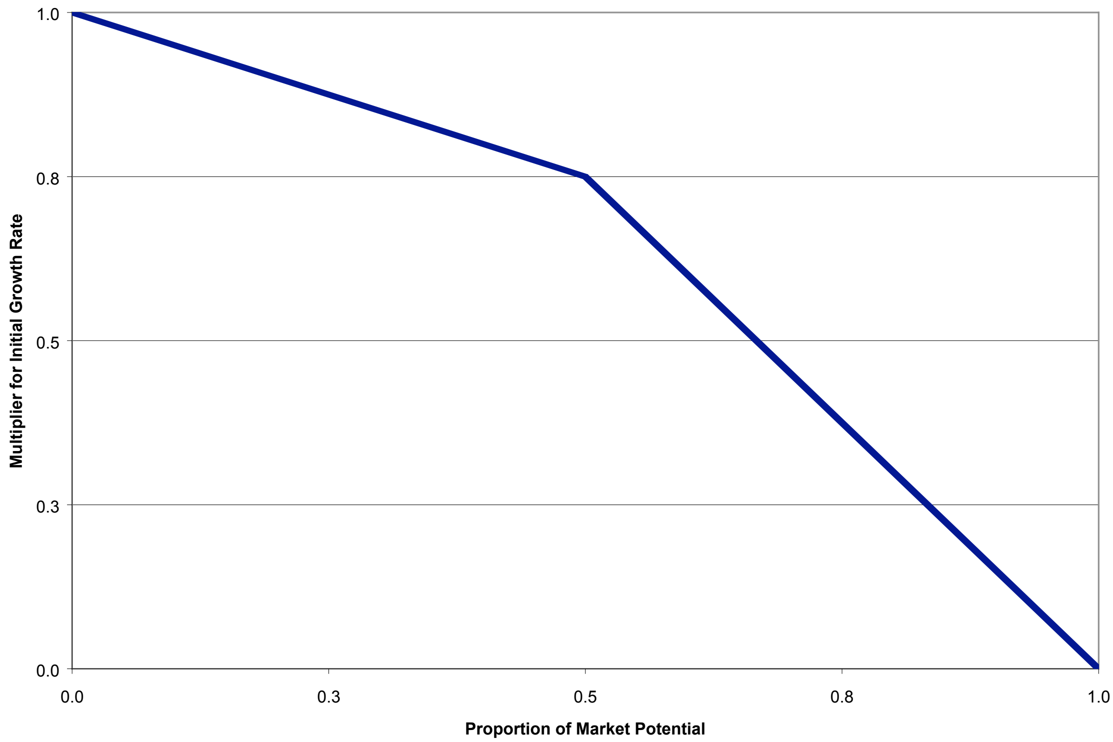

Figure A6. Function for Effect of Market Saturation on New Demand Growth Rate

APPENDIX B: EFFECTS OF INCREASING THE CLASS I DIFFERENTIAL WITH EXISTING PRODUCTS ONLY

To understand the dynamics of assigning a new product to a class, it is useful first to examine the results from simulating an increase in the fixed differential applied to the price of the input used in PP manufacturing in the absence of growth in demand for the new product. The model starts in dynamic equilibrium with a differential of \$2.50 per unit of input, which is increased to \$3.50 per unit of input at time T=10. The increase in the differential immediately increases the PP input supply price by \$1, from \$12.50 to \$13.50 (Figure B1). Thus, the blended input supply price initially increases from \$11.25 to \$11.75. Over time, however, the PP input supply price and the blended input supply price decline because of a decrease in the base price. This decrease comes about because of a reduction in the derived demand for the input for use in PP production (due to a lower quantity demanded) and an overall increase in input supply (due to the higher price). This results in an increase in input processed by the SP sector (Figure B2). Additional input processed by the SP sector results in additional inventories and lower SP prices (Figure B3), which in turn reduces the base price for the entire pricing system. Note also that it takes the SP price about 12 months to get close to the new equilibrium level and that both prices and input allocations oscillate at least until the end of simulation. Thus, given the assumed parameters the system doesn't return quickly to equilibrium[10].

The end result of the increase in the differential is a higher input supply price (and larger input supplies)[11], but the price increase is much lower when the system returns to equilibrium than just after the increase in the differential (\$11.32 per unit compared to \$11.75 per unit). During the first year following the increase in the differential, the increase in cumulative revenues is 1.0%. Cumulative revenues over the entire simulation are 2.0% higher than if the differential had not been changed. Thus, a \$1.00 per unit increase in the differential ultimately results in an increase in the input supplier price of only \$0.07[12]. The presence of negative feedback loops, use of a product-pricing formula involving the SP price, and the fact that the SP sector is a residual

[10] In this case, the oscillations are damped, indicating that the system will return to an equilibrium, which needn't always happen.

[11] Note that higher input prices and an increase in input quantity supplied are the result of a classified pricing system with fixed differentials, as discussed by Stephenson (2003).

[12] Alternatively, this implies that the long-run elasticity of input price with respect to a change in the differential is 0.07 based on the initial reference prices, and the long-run elasticity of revenues with respect to a change in the differential is 0.05 (2% increase in cumulative revenues divided by 40% change in the differential).

claimant on the input supply all contribute to limiting the effectiveness of the increase in the differential as a way to increase the price received by input suppliers. Manufacturers of PP products see higher input costs (and a lower percentage markup) and lower sales, whereas SP manufacturers see lower prices (but higher percentage markup) and increased sales. The larger effects are on sales and prices for SP and PP manufacturers rather than on the price for input suppliers. Although the specific numerical results will differ depending on the parameters assumed, the presence of these offsetting effects (sometimes referred to as the "unintended consequences" of a policy action) is nearly always important for understanding the effects of policies such as changing the differential or assigning a new production to a price class.

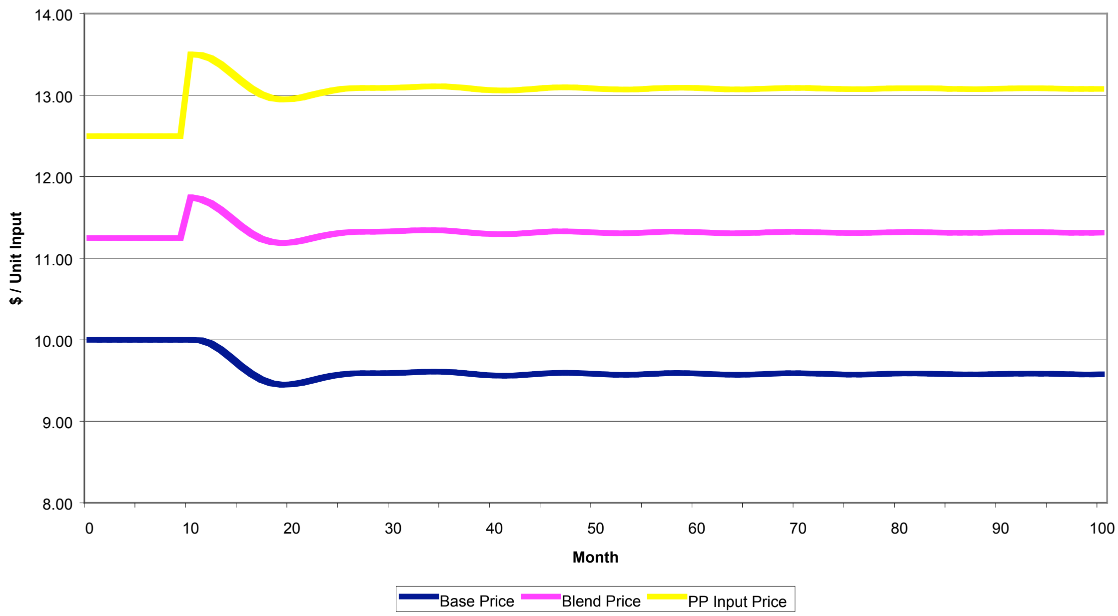

Figure B1. Base, PP and Blend Input Prices, Increase in Differential at T=10

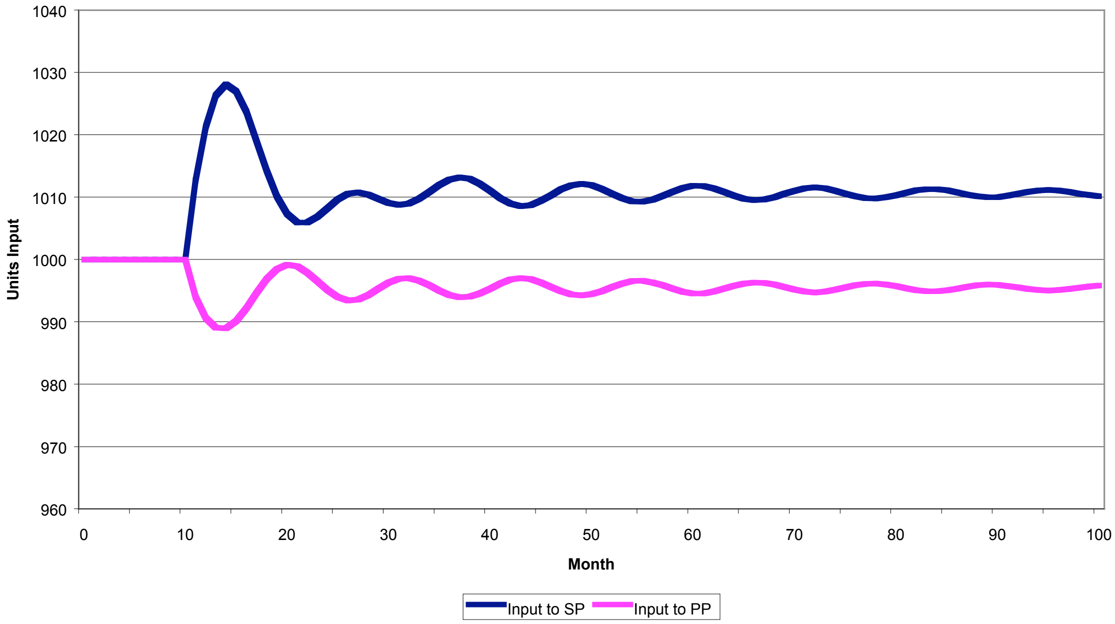

Figure B2. Input Allocation to SP and PP Production, Increase in Differential at T=10

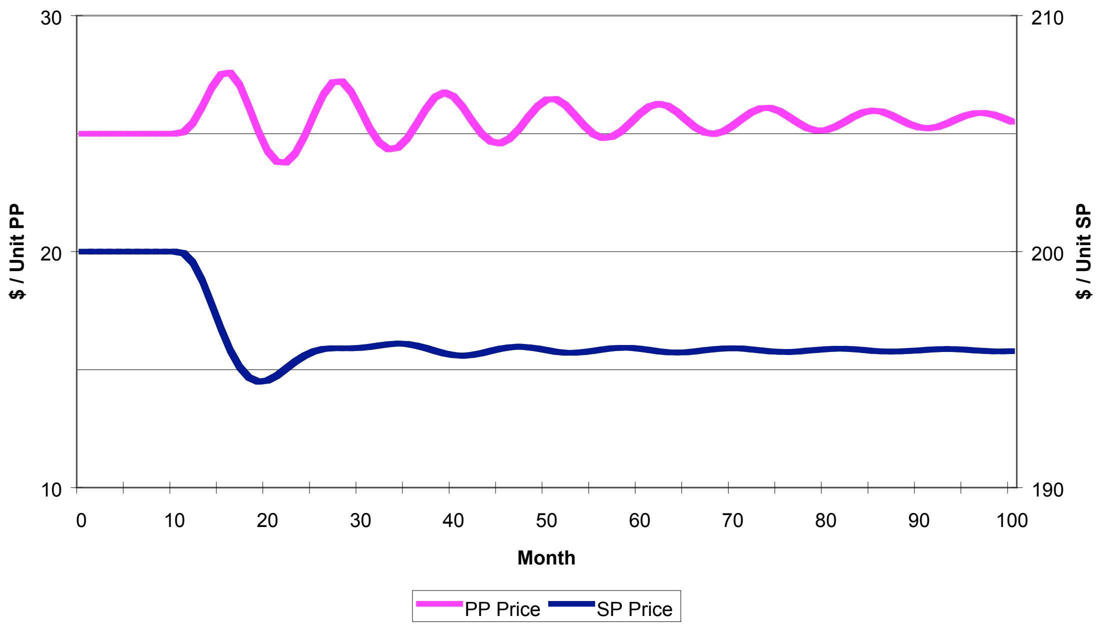

Figure B3. PP and SP Prices, Increase in Differential at T=10

APPENDIX C: ADDITIONAL FIGURES

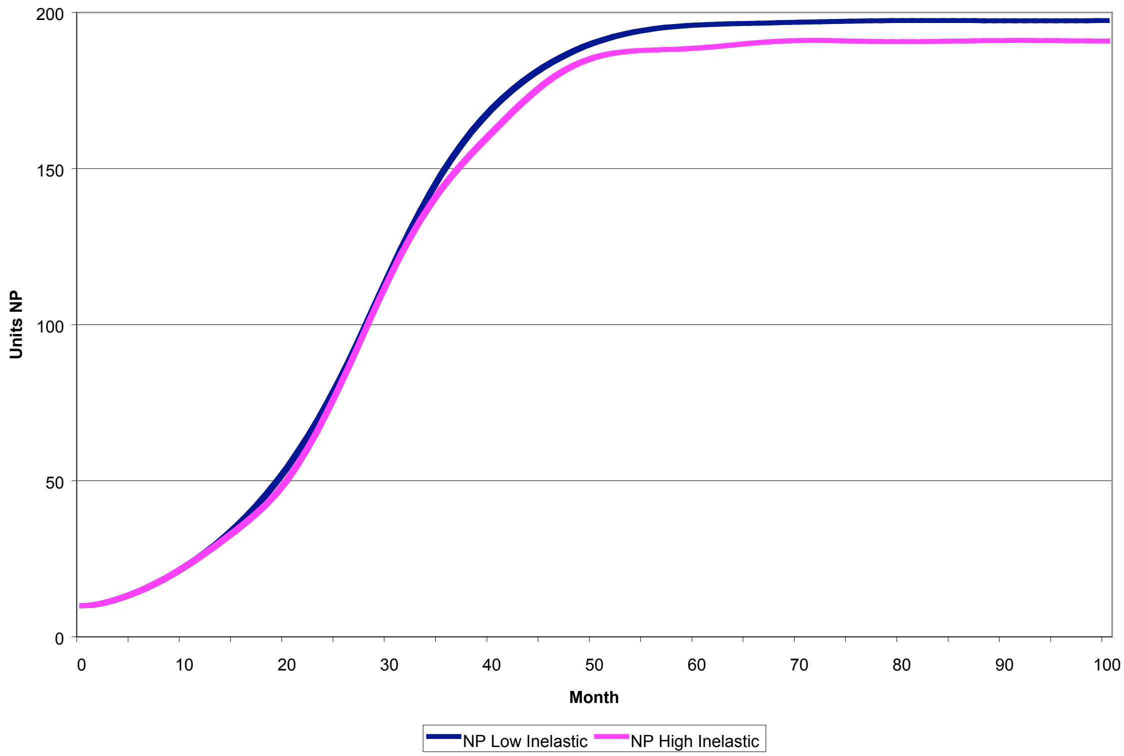

Figure C1. Quantity of NP Demanded, Base (NP Low) and NP High Scenarios, Inelastic NP Demand

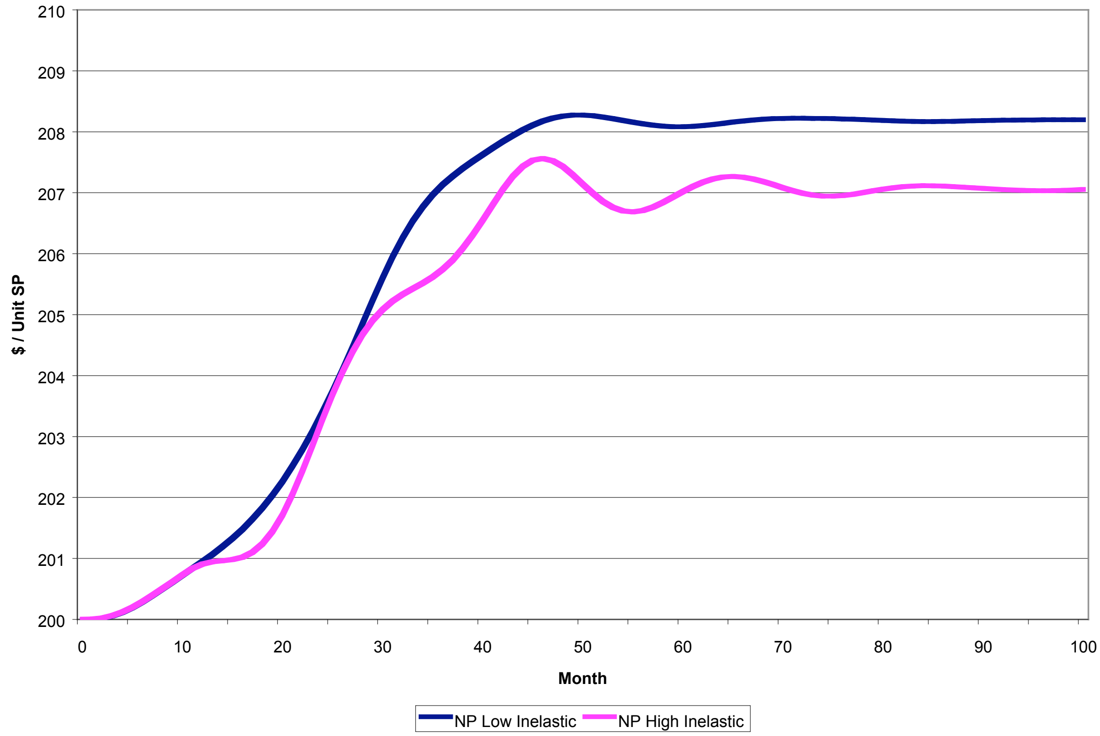

Figure C2. SP Price, Base (NP Low) and NP High Scenarios, Inelastic NP Demand

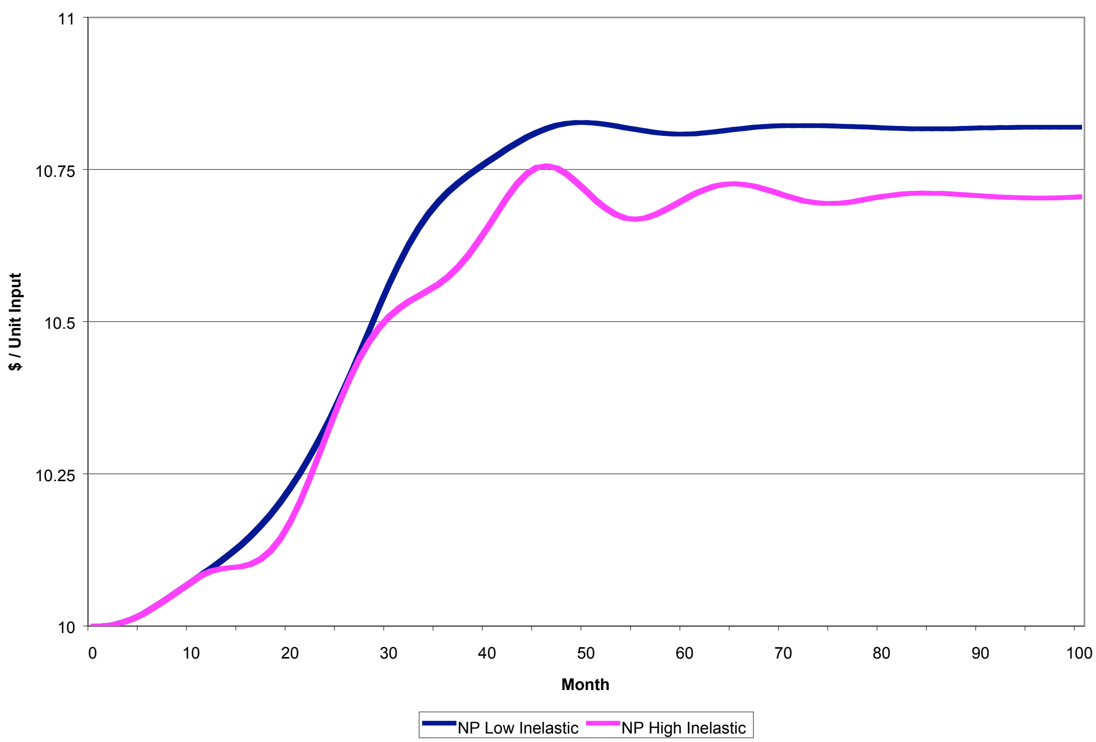

Figure C3. Base Price, Base (NP Low) and NP High Scenarios, Inelastic NP Demand

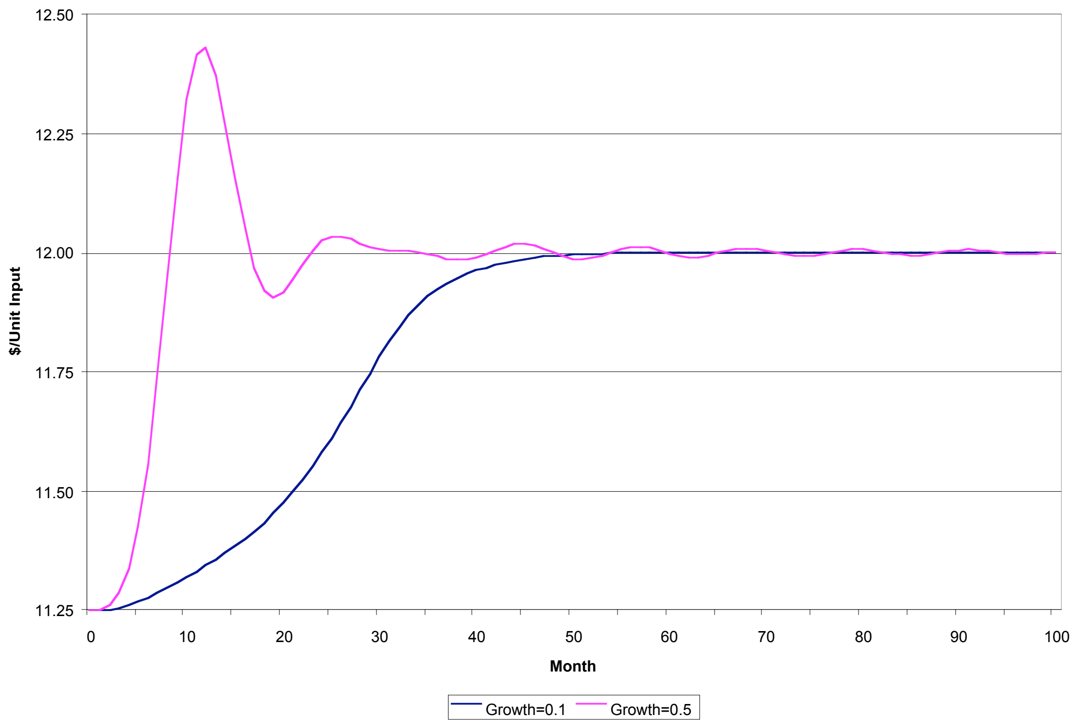

Figure C4. Blended Input Price with Fractional Growth in NP Demand of 0.1 and 0.5 per Month

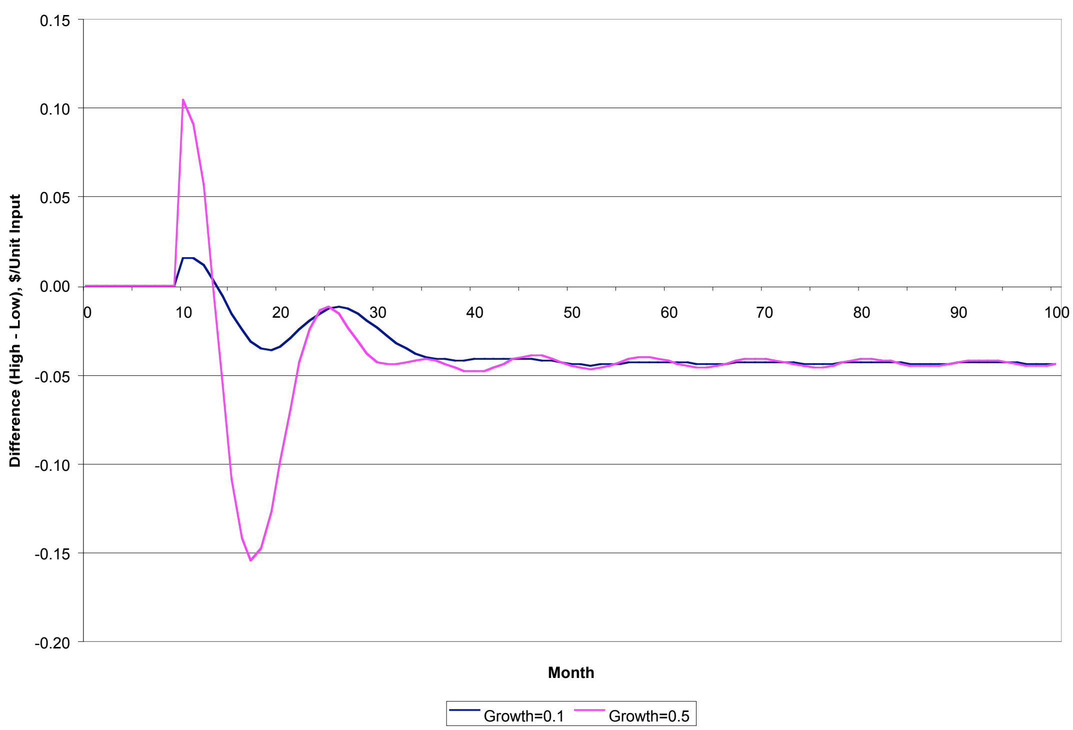

Figure C5. Difference in Blended Input Price, High Minus Low, Fractional Growth Rates of 0.1 and 0.5 per Month

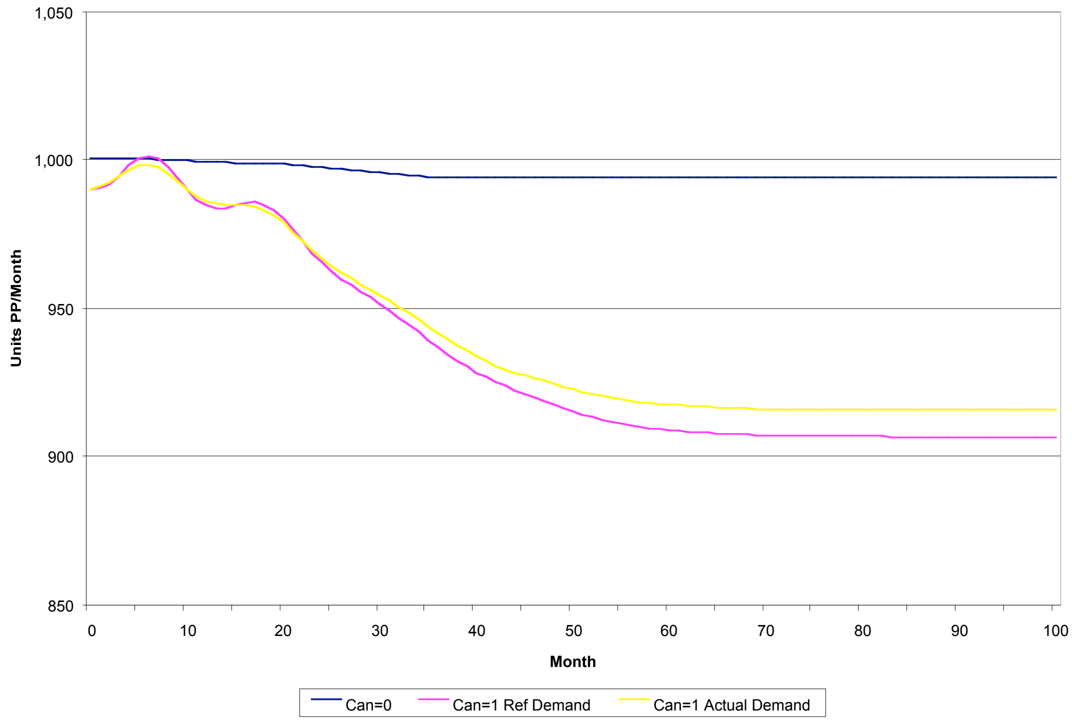

Figure C6. PP Demand with Cannibalization Fraction Equal to 0 and 1, Alternative Cannibalization Formulations

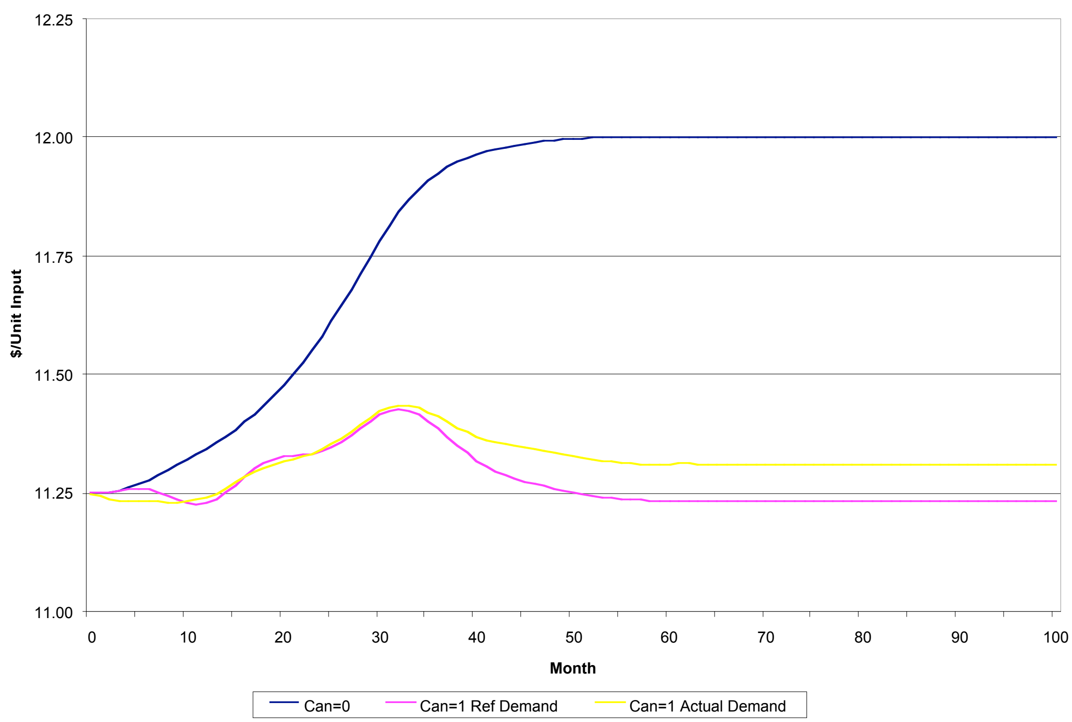

Figure C7. Blended Input Price with Cannibalization Fraction Equal to 0 and 1, Alternative Cannibalization Formulations

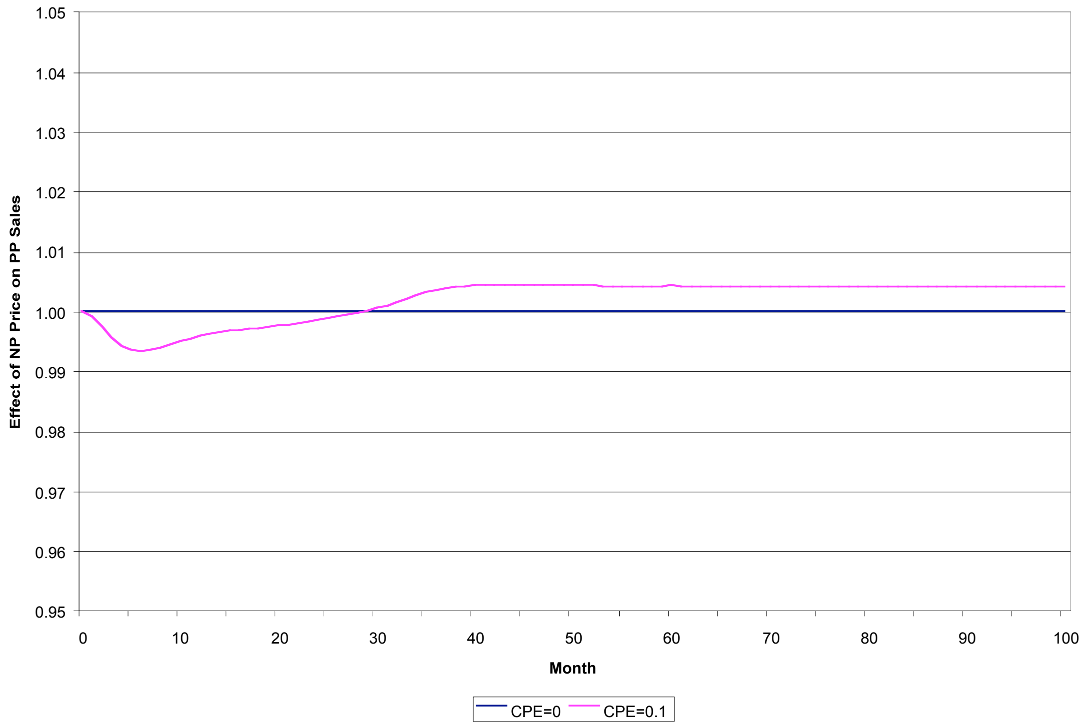

Figure C8. Effect of NP Price on PP Sales with Cross-Price Elasticity Equal to 0 and 0.1

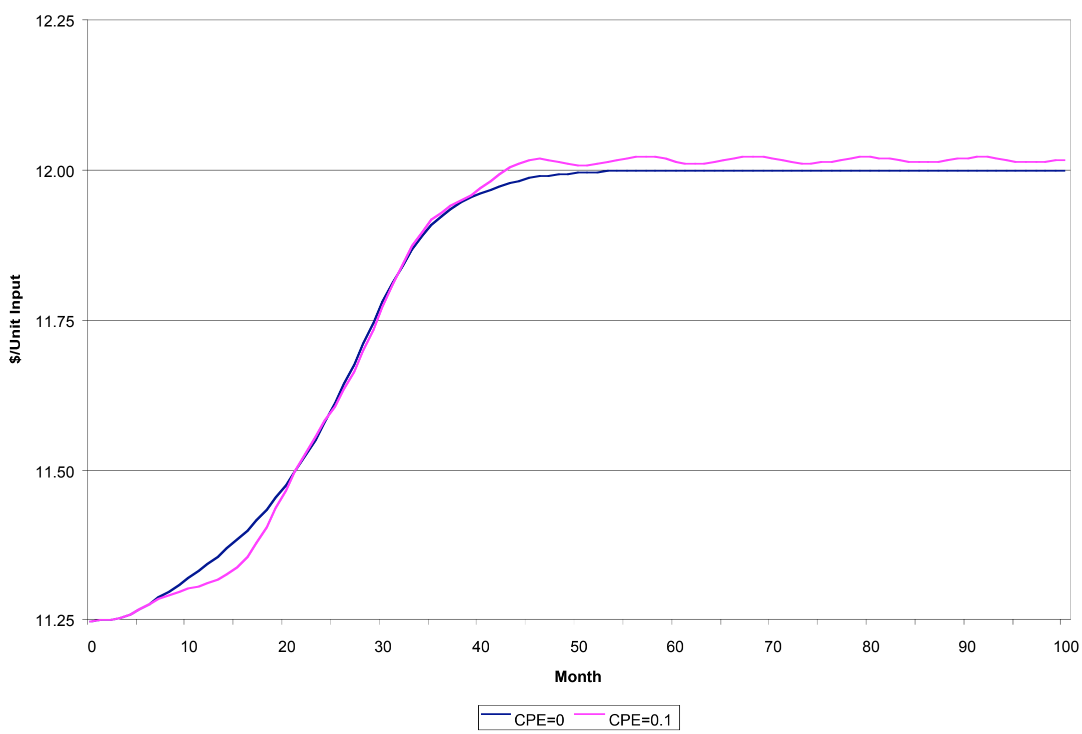

Figure C9. Blended Input Price with Cross-Price Elasticity of NP Price on PP Sales Equal to 0 and 0.1

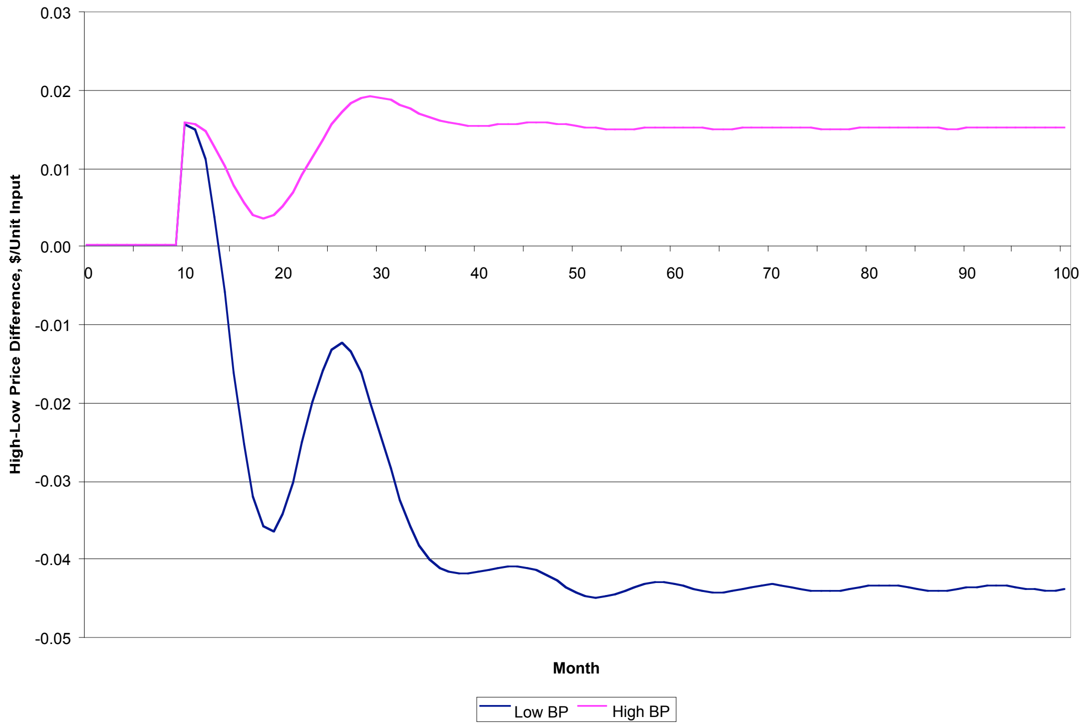

Figure C10. Difference between Blended Input Price in NP High and NP Low Scenarios with Low By-Product Proportion and SP Yield (Low BP) and High By-Product Proportion and SP Yield (High BP)

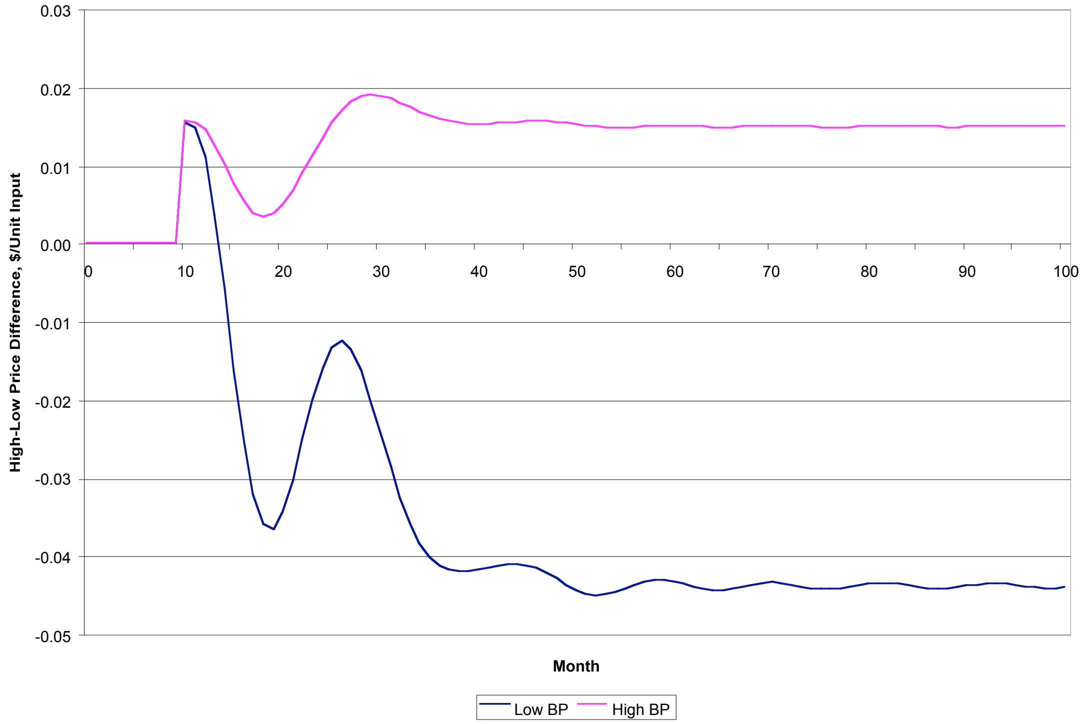

Figure C10. Difference between Blended Input Price in NP High and NP Low Scenarios with Low By-Product Proportion and SP Yield (Low BP) and High By-Product Proportion and SP Yield (High BP)