# Impacts of Retailers' Pricing Strategies for Produce Commodities on Farmer Welfare

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*Abstract*

*The typical model of retail pricing for produce products assumes retailers set price equal to the farm price plus a certain markup. However, observations from scanner data indicate a large degree of price dispersion in the grocery retailing market. In addition to markup pricing behavior, we document three alternative leading pricing patterns: fixed (constant) pricing, periodic sale, and high-low pricing. Retail price variations under these alternative pricing regimes in general have little correlation with the farm price.*

*How do retailers' alternative pricing behaviors affect farmers' welfare? Using markup pricing as the baseline case, we parameterize the model to reflect a prototypical fresh produce market and carry out a series of simulations under different pricing regimes. Our study shows that if harvest cost is sufficiently low, retail prices adjusting only partially, or not at all, to supply shocks tends to diminish farm income and exacerbate farm price volatility relative to the baseline case. However, we also find that if harvest cost is sufficiently large and the harvest-cost constraint places a lower bound on the farm price, increased farm price volatility induced by retailers' alternative pricing strategies may result in higher farm income, compared to markup pricing. Furthermore, taking farmers' risk attitude into account, higher income risk under alternative pricing strategies may offset the higher expected income, resulting in lower expected utility to risk-averse farmers. Our study is the first to evaluate the welfare implications for producers of the diversified pricing strategies that retailers utilize in practice and the resulting attenuation of the relationship between prices at retail and at the farm gate.*

## I. Introduction

The typical model of retail pricing for produce products assumes retailers set price equal to the farm price plus a certain markup (George and King, 1971; Gardner, 1975; Heien, 1980; Wohlgenant and Mullen, 1983; Elitzak, 1996; Wohlgenant, 2001). If markup-pricing behavior holds in the grocery retail sector, we can expect to observe similar retail price variations across chains for a given product sold in the same city, assuming the same supply shocks affect all

competitors. However, observations from a scanner dataset that contains 2 years of weekly retail prices for 6 produce commodities sold at 15 retail chains in 6 major US cities (24,957 observations in total), indicates a large degree of price dispersion in the grocery retailing market. Some stores rarely change the product price, some offer occasional sales, and still others change prices frequently. In addition to markup pricing behavior, we document three alternative leading pricing patterns observed in the data: fixed (constant) pricing, periodic sale, and high-low pricing. Retail price variations under these alternative pricing regimes in general have little correlation with the farm price.

This finding is not consistent with the standard model of retail pricing of farm products, which predicts that retail prices reflect the underlying farm prices and respond to supply shocks efficiently; in practice retailers set prices based on diversified pricing strategies, and the retail price does not reflect developments in the upstream, farm market.

How does this weakened correlation between retail price and farm price affect upstream farmers' welfare? Almost no work to date has addressed this topic. The goal of this paper is to investigate the producer welfare consequences due to alternative pricing strategies employed by retailers, compared to welfare under the benchmark strategy of markup pricing, while holding other factors, such as retailers' exercise of market power, constant. The results provide insight into how the loose connection between retail price and farm price affects farmer welfare.

Our welfare analysis focuses on perishable produce products, such as fresh marketed lettuces and tomatoes. A unique feature of perishable products is that their short-run supply is perfectly inelastic over a range of prices. However, the marginal cost of harvesting establishes a lower bound on the farm price because no product will be harvested at prices below harvest costs (Sexton and Zhang 1996).

To incorporate these market features for perishable produce products into our model, we specify the determinants of weekly farm price under two alternative regimes. When the marginal harvest constraint does not bind, the short-run supply is fixed at the exogenous level of farm production, and farm price depends on the market clearing condition and arbitrage between alternative market outlets. When the marginal harvest cost constraint binds, the farm price equals the level of harvest cost.

Using markup retail pricing regime as the baseline case, we parameterize the model to reflect a prototypical produce market and carry out a series of simulations under different retail pricing regimes to examine how retailers' alternative pricing behaviors affect farmers' welfare. We also simulate the welfare impact under an "aggregate price regime", which accounts for the fact that the different pricing behaviors coexist simultaneously. In addition, through a set of sensitivity analyses, we examine the welfare impact over a range of choices for the key model parameters: unit harvest cost, farm demand price elasticity, and magnitude of supply shocks, which enable us to discern the robustness of our results and to broaden the application of the conclusions.

Our study shows that if harvest cost is sufficiently low, retail prices adjusting only partially, or not at all, to supply shocks tends to diminish farm income relative to the baseline case. In addition, these alternative retail-pricing behaviors exacerbate farm price volatility compared to markup pricing, exposing farmers to greater income risk, which further reduces the welfare of risk-averse farmers. This result remains true under the aggregate price regime that accounts for the coexistence of different pricing strategies across chains.

However, we also find that if harvest cost is sufficiently large and the harvest cost constraint binds frequently, increased farm price volatility induced by retailers' alternative

pricing strategies may result in higher farm income, compared to markup pricing. In essence, the harvest-cost constraint places a lower bound on the farm price, whereas there is no comparable upper bound, meaning that farmers benefit fully from volatility-induced price increases but are protected from the worst price decreases. Whether retailers' alternative pricing strategies causes higher or lower total farmer welfare relative to the benchmark case depends on the values of three key model parameters: the level of unit harvest cost, farm supply volatility, and farm demand elasticity.

In addition, we incorporate farmers' risk preferences into the welfare study. The alternative pricing strategies increase the volatility of farm income. Using a mean-variance utility model to measure farmers' welfare under income risk, riskier incomes are associated with lower utility for risk-averse farmers. Although in certain cases farmers' expected income under retailers' alternative pricing strategies is higher than that of the benchmark case, the presence of greater income risk under these pricing strategies may still reduce farmers' net welfare relative to a mark-up pricing strategy.

This study is the first to evaluate the welfare implications for producers of the diversified pricing strategies that retailers utilize in practice and the resulting attenuation of the relationship between prices at retail and at the farm gate. Various studies have documented the rising consolidation of supermarkets in Latin America, Asia and Africa over the past years, mirroring what happened in the U.S. and more recently in Europe (Reardon, Timmer, Barrett, and Berdegue, 2003; Hu, Reardon, Rozelle, Timmer and Wang, 2004). To the extent that retail chains in developing countries set their prices similarly to what is observed in US retail markets, the welfare implications derived in this paper apply in those settings as well and contribute to the

growing literature on the impacts of food retail consolidation in developing countries on the welfare of smallholder farmers.

The rest of the paper is organized as follows. Section 2 reviews prior literature on related topics. Section 3 describes the data used in this study and provides a brief review of our prior findings about pricing patterns. Section 4 sketches the models. Section 5 carries out welfare simulations under different retail pricing regime as well as the aggregate price regime. Section 6 investigates how harvest cost establishes a lower bound on the farm price and affects the welfare implication. Section 7 provides sensitivity studies on harvest cost, farm supply variation and farm demand elasticity. Section 8 extends the welfare study to incorporate farmers' risk attitude. Conclusions close the paper.

## II. Literature Review

There has been both conspicuous policy concern and economics research debate caused by the rising concentration and consolidation of sales among large supermarket chains in the United States. Two notable questions are: (1) whether retailers have oligopsony power over farmers (Cotterill, 1993; Cotterill and Harper, 1995; Connor, 1999; Cotterill, 1999; Kaufman et al. 2000; MacDonald, 2000; Wright, 2001); and (2) whether farmers experience welfare loss due to the structure changes and the practice of market power in the retail industry (Sexton, Zhang and Chalfant, 2003). The study of market power in the retail industry is difficult because the major market power indicator (the retail markup of a price over its marginal cost) can be affected by many reasons other than market power, especially for multi-product retailers who on average sell 40,000 or more different products in U.S. supermarkets.

Instead of trying to parameterize the structure change of retail industry, this paper focuses on the behavior change of grocery retailers under such transformed market structures. While avoiding the struggle to prove the existence of market power, our simulations provide insight into explaining how retailers' alternative pricing behaviors affect farmers' welfare differently, compared to the baseline markup pricing case.

This section briefly reviews prior research on three areas: (1) marketing margin and markup pricing, (2) retail price dispersion, and (3) welfare implication to farmers induced by alternative retail pricing behavior other than markup pricing. In addition to provide background information on related studies, this review helps to explain why markup pricing is a logical choice as the baseline case to study farmer welfare implication, and how our study is distinguished from prior research.

### *1. Marketing Margin and Markup Pricing*

Markup pricing is a basic assumption on retail pricing practice used widely to estimate marketing margins for food commodities. In such case, the retail price reflects supply shocks efficiently (Thomsen, 1951; Buse and Brandow, 1960; George and King, 1971; Gardner, 1975; Heien, 1980; Fisher, 1981; Wohlgenant and Mullen, 1983; Elitzak, 1996; Wohlgenant, 2001).

The marketing margin, also known as the markup or the farm-to-retail price spread, is the difference between the farm value and retail price, which represents payments for all assembling, processing, transporting, and retailing charges added to farm products (Elitzak, 1996). Prices are determined at the retail level first by what consumers are willing and able to pay for what is marketed, and then farm prices are determined by subtracting all marketing costs from retail prices (Waugh, 1964).

There are varieties of ways to characterize the marketing margin (Gardner, 1975; Fisher, 1981; Wohlgenant, 2001). It can be measured as the difference between retail and farm value of the commodity, by the ratio of retail to farm price, by the farm value share of total retail value ("farmer's share of the retail dollar"), or by the percentage marketing margin (i.e., marketing margin as a percentage of retail or farm price).

### *2. Retail Price Dispersion*

If all retailers adopt mark-up pricing strategy, people would naturally expect similar retail price variation across chains for a product sold in the same city, assuming same supply shocks present in that city. However, observations from scanner data indicate a large degree of price dispersion across chain stores for the same produce products sold at the same market, the prices of some commodities seem never to change, but others vary significantly across time.

The large degree of price dispersion becomes a major characteristic of grocery retail pricing in recent agricultural economics studies (Sexton, Zhang and Chalfant (SZC), 2003; Hosken and Reiffen, 2004). SZC (2003) show that farm-retail price spreads computed at the level of the individual retail chain exhibit wide variability over time, differ widely across chains with respect to mean and variance, and exhibit little correlation across chains. Some studies suggest that retail price variations often reflect changes in retail margins, rather than changes in costs (Conlisk, Gerstner and Sobel, 1984; Pesendorfer, 2002; MacDonald, 2000; Hosken and Reiffen, 2004).

Theories provide different explanations on the motivation of retail price movement. Varian (1980) believes that the motivation of price movement is retail competition, thus a monopoly would not change price. Conlisk, Gerstner and Sobel (1984) argue that even a

monopoly will vary price to discriminate against different consumer groups. Banks and Moorthy (1999) and Pesendorfer (2002) combine both competition and discrimination to explain retail price variation, while Lal and Matutes (1994), Hosken and Reiffen (2001) and Braido (2006) focus on the multi-product characteristics of retailers to explain the interrelated price variation.[1]

### *3. Welfare Implication for Farmers*

No matter what motivations are behind the retail price variation, it is certain that the farm-sector income is affected by the loose connection between retail price and farm-level price for these products. However, few studies have investigated this welfare effect to farmers. Sexton, Zhang and Chalfant (2003) investigate the case in which some final sellers of a commodity adopt a fixed-price strategy, regardless of shifts in supply and/or aggregate demand. They point out that price must fluctuate more widely for all other sellers to make the market clear. As long as marginal revenue is a decreasing function of sales for all market outlets, fixed prices will be harmful to producer welfare. They predict retail prices that respond more quickly and fully to a farm price increase than to a farm price decrease are harmful to producer interests. Also retail prices that adjust only partially, or not at all, to shocks in the farm market are harmful to producers. The presence of imperfect competition in any of the procurement markets does not alter the fundamental conclusion.

The same logic applies also to situations where some sellers only partially transmit farm price changes. A recent study by Li, Sexton, and Xia (2006) focuses on the pricing strategies of holding periodic sales irrespective of conditions in the upstream market. By comparing two

[1] The last class of models, often referred as the "loss-leader" models in the literature, predicts that the multi-product retailers may set prices for some products below marginal costs in order to attract consumers from competing stores.

scenarios: no-sale (i.e., mark-up) strategy to a periodic sale strategy, the authors show that producer revenue with the sale strategy tends to decrease unless the total demand with the sales strategy is sufficiently larger than the total demand with the no-sale strategy.

The above papers on farmers' welfare study inspire the work in this paper. Our paper improves and extends earlier studies by setting up the arbitrage linking between the two market outlets, and including harvest cost into the model. Our findings differ from the earlier works in the sense that although heterogeneous retail pricing behavior tends to increase farm price volatility and reduce farmers' welfare, the existence of harvest cost may indeed alter the undesired welfare impact.

## *III.* The Data and Our Findings about Retail Pricing Patterns

The main dataset used in this study is retailer scanner data on weekly retail prices, volume and dollar sales, provided by Information Resources Inc. (IRI), which covers 15 retail chains in 6 major U.S. cities from January 1998 through December 1999. There are 20 chain-location combinations with 24,957 observations in the full data sample. The market areas include Albany NY (two chains), Atlanta (three chains), Chicago (three chains), Dallas (five chains), Los Angeles (four chains), and Miami (three chains). These markets cover a substantial geographic cross-section of the national market. Six major produce products are included in the study: apples, grapes, grapefruit, iceberg lettuce, oranges, and tomatoes. Each of these products is available in several different varieties. The IRI data are organized by either universal product classification (UPC) codes or price lookup codes (PLU) that specify the variety. Farm-level price data are also available from the USDA Federal-State Market News Service (F-SMNS).

When comparing retail prices across commodities, across locations and across chains, we find differentiated pricing behavior over time at the commodity, location, and chain levels. Comparing across commodities, some chains exhibit strong and uniform chain-level strategic pricing behavior at a given location across all commodities. Comparing across locations, a retail chain may exhibit different pricing patterns for different commodities across cities, even after controlling for the differences in the farm-level price. Comparing across chains at the same location, where we can reasonably assume farm price for a given commodity to be identical, we still observe systematic differences for pricing behavior across chains. These trends indicate the existence of different pricing strategies adopted by different chains.

The four leading pricing patterns we documented are:

a) Mark-up pricing: Retailers who utilize mark-up pricing set the markup fixed or fixed proportional to the acquisition costs. Retail price movement efficiently reflects the changes of supply and price at the farm level.

b) Fixed pricing: The retail price is fixed at a certain level regardless the fluctuation of farm price. One widely adopted marketing practice, known as every day low price (EDLP), is an example of fixed pricing. Under EDLP prices are fixed for extended periods of time and the frequency of promotional sales or discounts is low. At least 3 chains, out of the 15 chains included in our dataset, never changed their retail prices for iceberg lettuce and tomatoes during the 104 week periods.

c) Periodic sale: The retail price stays at a certain level for extended periods, interrupted by temporary price discounts, after which the price returns to its original level. In this case, a single "regular" price or several mass point prices exist. The "weekly special" pricing practices seen in some retail market may exhibit the main characteristics of periodic sale.

It is important to note that although retailers put some basket of products on sale every week, the choice of sale commodities can vary from week to week.

d) High-low pricing: Price fluctuates frequently among different high and low levels. The mean of the prices may be relatively higher than fixed price, but the actual price varies constantly.

Fixed price normally has lower mean than other price categories. The difference between high-low pricing and mark-up pricing is that the price variation of the former shows no close correlation with the farm price variation, but the later does. The difference between high-low pricing and periodic sale is that the former has relatively more frequent price variation.

These pricing strategies (except mark-up pricing) show that retailers fully or partially ignore supply shocks for that product. In some cases, the price falls below marginal cost. Yet considering modern groceries sell a vast number of different products, retailers may well be acting rationally in using these stylized retail price behaviors as marketing strategies to attract and retain customers, in order to maximize their total profit.

Some of the commodities in our dataset, including fresh lettuce and tomatoes, are highly perishable and normally not storable. Other fruit commodities, including apples, oranges and grapes, can be stored for some time with proper refrigeration. In this paper, we focus on the farmers' welfare study for perishable goods. To the extent that other fruit commodities share similar pricing patterns as the perishable commodities, the method and analysis applied in this paper has the potential extension to account for storability in future studies.

## IV.Model

Suppose that a common produce commodity (for example, the iceberg lettuce consumed in Los Angeles) is sold at either grocery retail markets or at other final markets, such as restaurants and cafeterias in hospitals, schools, or other institutions. Let market 1 denote the aggregate grocery retail market (the retail market), and market 2 denote the aggregate of all other markets (the food service sector). Figure 1 illustrates the basic setup for the two market outlets. The left quadrant depicts the retail market, where $D_1^R$ denotes the retail demand from final consumers for the commodity, and $D_1$ denotes the derived farm demand from grocery retailers under perfect competition in procurement. The right quadrant depicts the aggregate food service market, where $D_2^F$ denotes the final demand for the commodity in food service market, and $D_2$ denotes the derived farm demand of the food service sector under perfect competition in procurement. For ease of illustration, $D_1$ and $D_2$ are assumed to be identical on the graph, and the initial harvest level, $Q_0$, is divided equally between the two markets (figure 1). $H$ denotes the per unit harvest cost, which equals a constant, depending upon what the costs are.

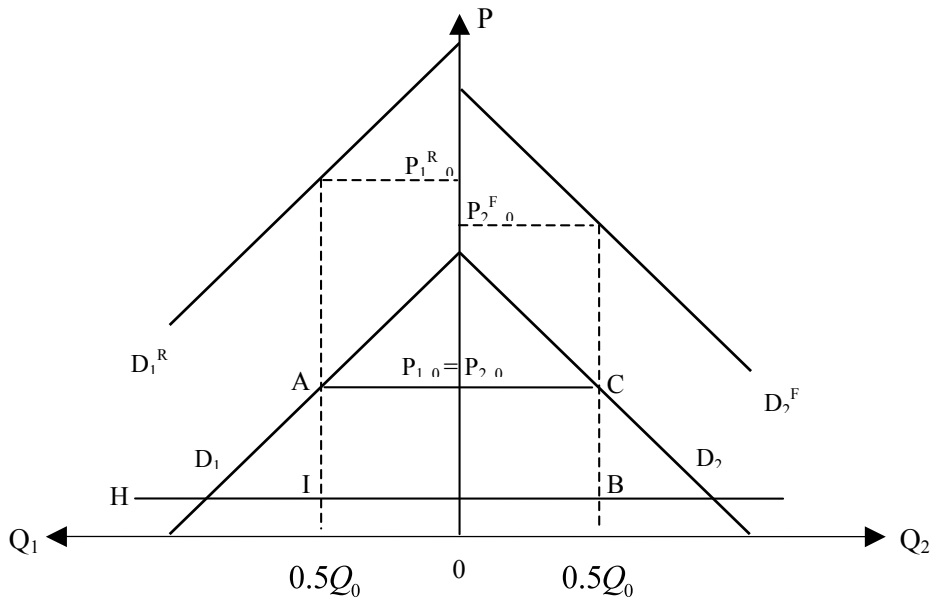


**Figure 1: Retail Demand ($D_1^R$), Food Service Demand ($D_2^F$), and Farm Demands ($D_1$ and $D_2$)**

Suppose that constant returns to scale applies for the produce commodity in the transfer from the farm to both final markets, and constant costs occur during the shipping, handling, and selling of this commodity at each market. The amount of the commodity sold to final consumers in each market is equal to the amount procured from farmers by each market. Given total harvest $Q_0$, final prices are given by $P_{1,0}^R$ and $P_{2,0}^F$ at the retail market and food service market, respectively, and farm price is given by $P_{1,0} = P_{2,0}$ under perfect competition. The initial farm income (farm revenue minuses the harvest cost) is given by the area AIBC.

In a dynamic model setting, we assume that the farm supply of the produce commodity is exogenously determined in a closed economy, and there are random supply shocks over time due to unexpected factors, such as the weather. There is no storage for the perishable commodities,

and the market will always clear between the retail market and the food service sector at the current period. In addition, suppose that there is no retail demand shift in the model.[2]

If both retail and food service markets operate competitively in selling and procuring the commodity, final sale prices at each market will equal the product cost plus the fixed markups. We assume that the food service sector operates competitively in selling and procuring the commodity, in that it consistently applies the markup-pricing rule. Meanwhile, we assume that grocery retailers utilize different retail price behaviors.

### *1. Impact of Retail Pricing Behavior on Farmer Welfare*

Let farmers' welfare from this perishable product be represented by farmers' expected utility, $EU(R)$, which is a function of the farm income from this product, $R$. Farm income in our model is a random variable due to the presence of random farm supply shocks and the existence of alternative retail pricing behavior. If the farmer is risk neutral, his welfare depends only on the expected farm income. If instead the farmer is risk-averse, then the expected utility of the farmer increases with his expected farm income and decreases with the riskiness of his farm income.[3]

If the retail market utilizes fixed pricing, periodic sale, or high-low pricing in practice, the retail price to a large extent no longer responds to farm level supply shocks and the farm

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[2] In reality, there are expected demand shifts (such as holiday effects or demand responds to supply seasonality) and unexpected demand shifts (such as food safety issue or change of overall economy). Because supply should be conditioned to meet those expected demand shifts, it should be justified not to include both expected demand and supply shift in the model. One the other hand, the unexpected demand shocks had nothing to do with our proposed welfare study, so we do not want to complicate the model unnecessarily with unexpected demand shift.

[3] It has been proved in the literature that the expected utility function, $EU(R)$, for a risk averse agent facing random income, gives rise to a mean variance expected utility function (Sinn, 1983; Mayer, 1987; Eichner, 2004). For example, the maximization of expected utility for a farmer who has an negative exponential utility function and faces normally distributed farm income is equivalent to the maximization of a mean-variance function of the form: $U(\mu,\sigma,\lambda) = \mu - \frac{\lambda\sigma^2}{2}$.

price, and thus the derived farm demand for retailers no longer exists. The quantity retailers buy from farmers is determined by retail price and the demand from final consumers. The farm price paid by retailers is forced through arbitrage to equal the farm price paid by the food service sector. If harvest cost is relatively small, the expected farm income under these alternative retail pricing behaviors in general will be less and the variation of the farm income will be higher, compared to those wherein retailers utilize the markup-pricing rule.

Taking fixed retail pricing as an example, we see that at times of positive supply shocks, fixed retail pricing behavior results in farmers' income loss. Likewise, during times of negative supply shocks, fixed retail pricing results in farmers' income gain. The losses in general outweigh the gains, as long as the random supply shocks have zero mean, and the demands are decreasing functions of sales for all market outlets. Meanwhile, farmers' income variation under fixed retail pricing is higher than that under markup pricing case. Figures 2, 3 and 4 lead us through the graphical analysis on how retailers' fixed retail pricing behavior may induce farmer welfare loss.

Suppose at time 1, production increases from the mean harvest level ($Q_0$) to $Q_0 + \Delta$, where $\Delta$ denotes a small positive constant, while demand remains unchanged. Figure 2 illustrates a market setting in which the farm income decreases under increased production, as the retailers' fixed retail price causes the additional volume to be sold through the food-service sector. Suppose that each of the two markets allows the downstream price to change in response to the increase in production, then each sells $0.5(Q_0 + \Delta)$, and the farm price falls to $P_{1,1} = P_{2,1}$. Farm income from both markets changes from the initial level AIBC to the area MKUP. However, if retailers adopt fixed pricing strategy despite the farm supply shock, then the retail price remains the same as $P_1^R{}_{,1} = P_1^R{}_{,0}$, and sales at retail market remain at $0.5Q_0$. In order for the

market to clear, the food service sector now sells $0.5Q_0 + \Delta$, with the farm price in the food service market falling to $\hat{P}_{2,1}$. Due to the arbitrage condition, the farm price paid by retailers equals the farm price paid by the food service sector, that is $\hat{P}_{1,1} = \hat{P}_{2,1}$. The farm income from both markets changes from the area AIBC to the area FIXD. It is shown from the graph that FIXD< MKUP. Figure 2 indicates that, with positive supply shock, the total farm income under retailers' fixed retail pricing strategy is less than the total farm income under the markup retail pricing strategy. The farm income loss due to retailers' fixed pricing behavior is marked as the shaded area in figure 2.

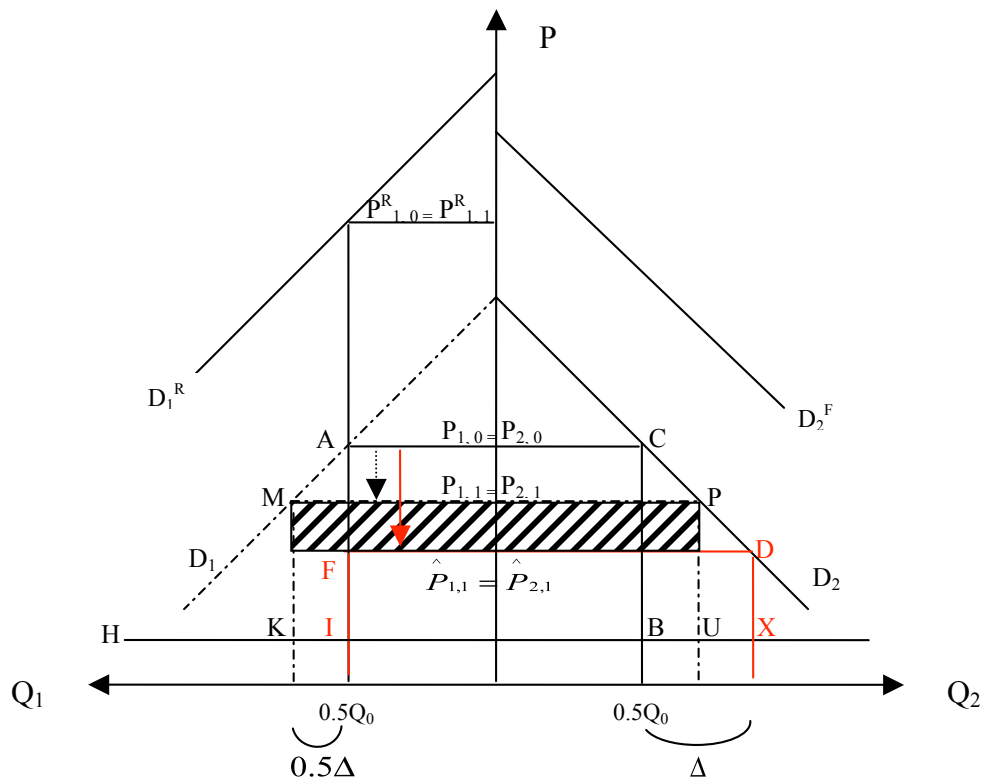


**Figure 2: Implication of Fixed Retail Pricing on Farmer Welfare under positive supply shock**

Suppose at time 2, farm production decreases to $Q_0 - \Delta$. Figure 3 illustrates a market setting wherein the farm income from decreased production is greater when retailers fix retail

price, causing the farm price to increase to accommodate the decreased farm supply in food service sector.

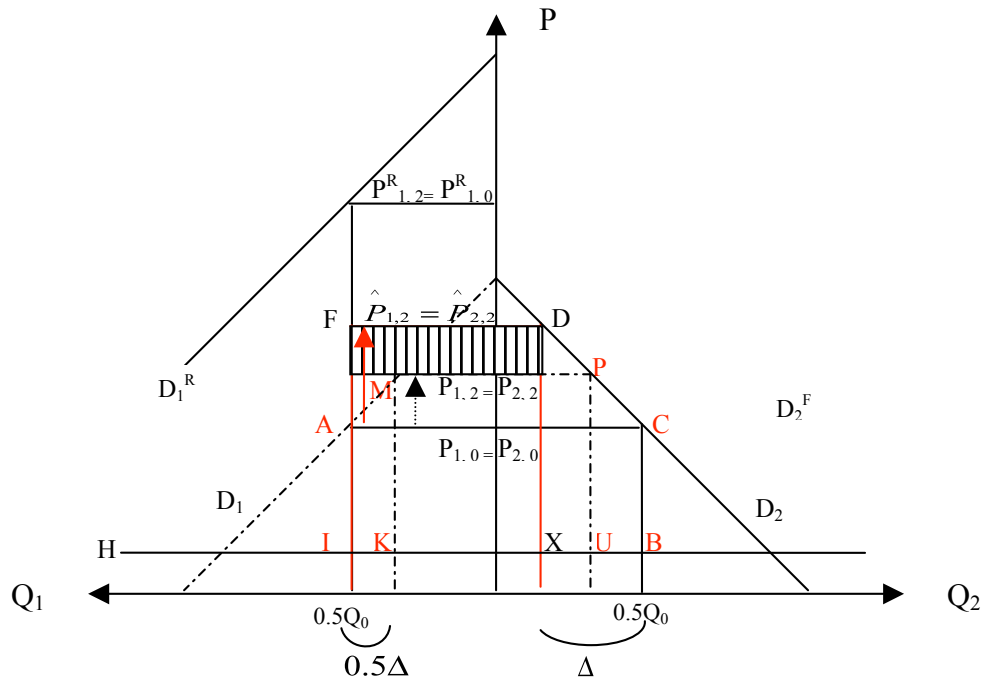


**Figure 3: Implication of Fixed Retail Pricing on Farmer Welfare under negative supply shock**

If both markets allow their prices to change in response to the increase in production, each sells $0.5(Q_0 - \Delta)$ and farm price in each market increases to $P_{1,1} = P_{2,1}$. Total farm income changes from the area AIBC to the area MKUP. If instead, retailers keep price fixed at $P^R_{1,2} = P^R_{1,0}$, then retail sales remain at $0.5Q_0$. The food service sector now sells $0.5Q_0 - \Delta$, which is less than the quantity sold under the case in which grocery retailers allow the retail price to change according to the market conditions. The farm price paid by the food service sector is higher in responding to decreased sales in the food service market. And due to the arbitrage between the two markets, the farm price paid by the grocery retailer equals the farm price paid

by the food service sectors, shown as $\hat{P}_{1,1} = \hat{P}_{2,1}$ on the graph. As a result, with the negative supply shock, the total farm income under the case when retailers adopt fixed retail pricing strategy is greater than the total farm income under the case when both retailers and food service sector adopt markup price. The farm income gain is marked as the shaded area with the vertical lines.

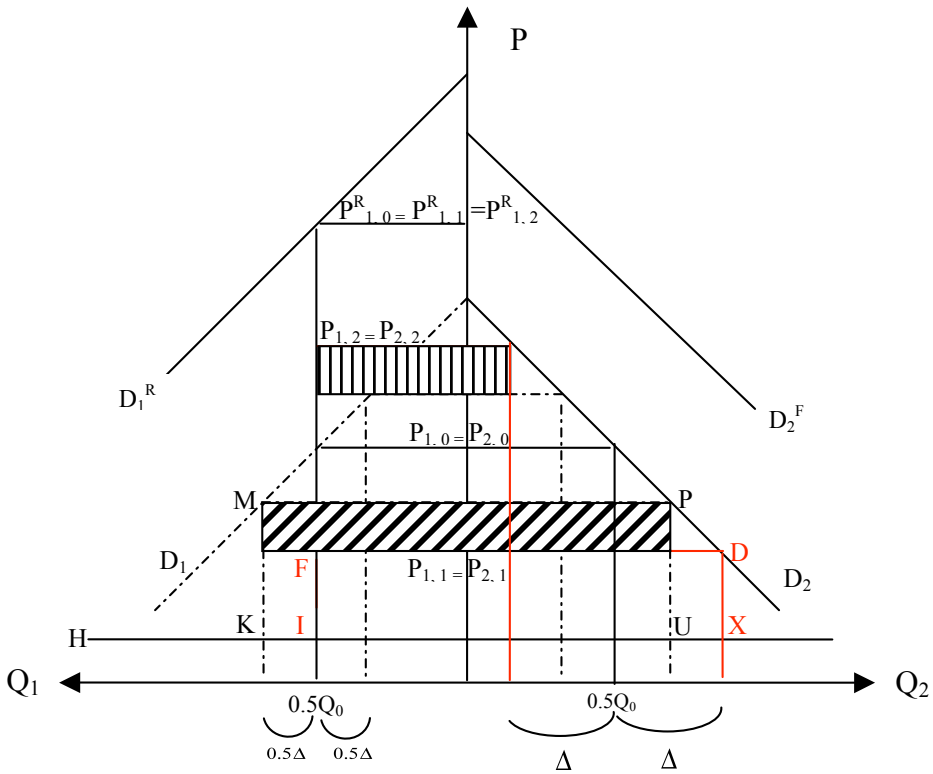


**Figure 4: Implication of Fixed Retail Pricing on Farmer Welfare**

Figure 4 combines the potential farm income loss and gain due to retailers' fixed pricing behavior. Graphically, the upward diagonal line shaded area is larger than the vertical line shaded area, which indicates that the income loss incurred from a positive supply shock outweighs the gain incurred from a negative supply shock, assuming the average production change is zero.

In addition to the potential farm income loss, the above graphical comparison reveals that retailers' fixed retail pricing strategy tends to increase the volatility of the farm price, compared to the baseline mark-up pricing case. Increased farm price volatility is associated with increased farm income risk which further deteriorates the expected utility for risk-averse farmers.

### *2. Estimation of The Impact of Alternative Retail Pricing Behavior on Farmer Welfare*

How important are different retail pricing strategies in affecting farmer welfare for a produce commodity? In this subsection, we conduct analytical estimations to explore the direction and magnitude of these impacts.

Suppose that total consumer demand for the farm product is in linear form as $Q = a + c - bP$, and divided between retail market and the food service sector. Retailers set their price strategically and face retail demand from final consumers

$Q_1 = \rho(a + c_1 - bP_1^R)$, $0 < \rho < 1$.

Food service sector always allows prices to fluctuate accordingly to the market conditions, and faces final demand $Q_2 = (1-\rho)(a + c_2 - bP_2^F)$.

The parameter $\rho$ measures the share of total farm demand by the retail market, whereas $c$, $c_1$ and $c_2$ are cost parameters, such that $c = \rho c_1 + (1-\rho)c_2$. The inverse retail demand is $P_1^R = a/b + c_1/b - (1/b\rho)Q_1^R$, and the inverse final demand by the food service sector is $P_2^F = a/b + c_2/b - (1/b\rho)Q_2^F$. Under perfect competition, $c_1/b$ and $c_2/b$ are the per-unit costs for a commodity to travel from the farm to the retailers' shelves or to the food service counter, i.e., the markups in each downstream market.

If both markets allow prices to respond to supply changes efficiently, then the derived farm demand by retailers is $Q_1 = \rho(a - bP_1)$, and the derived farm demand by the food service sector is $Q_2 = (1-\rho)(a - bP_2)$. If only the food service sector allows price to fluctuate freely but the retail market does not, then the derived farm demand by retailers no longer exists, and the derived farm demand by the food service sector is determined by residual demand $Q_2 = (1-\rho)(a - bP_2)$, in which case, $Q_2 = Q - Q_1$.

The mean harvest $Q_0$ is normalized to be 1 without losing generality: $Q_0 = Q_1 + Q_2 = 1$. The farm supply shock at period $t$, denoted by $\Delta_t$, is assumed to be normally distributed random variable with mean zero and variance $\sigma^2$: $\Delta_t \sim N(0, \sigma^2)$. The farm production at each period, denoted by $Q_t$, is thus given by $Q_t = Q_0 + \Delta_t$. Similarly, farm prices at the mean harvest are normalized to be $P_{1,0} = P_{2,0} = 1$. The absolute value of the farm price elasticity of total demand evaluated at the mean harvest level $(P_1 = P_2, Q_0) = (1,1)$ is $\varepsilon = -(\frac{dQ}{dP})(\frac{P}{Q}) = b(\frac{P}{Q})\Big|_{\substack{P_1=P_2=1 \\ Q_0=1}} = b$, which is the normalized equilibrium elasticity. The relationship among the demand parameters is then given by $a = 1 + \varepsilon$ and $b = \varepsilon$. Given this relationship, the derived demand by food service sector is $Q_{2,t} = (1-\rho)(1 + \varepsilon - \varepsilon P_{2,t})$. At the mean harvest level, the proportion of farm supply goes into retail market is $Q_{1,0} = \rho$, and the proportion of farm supply goes into the food service sector is $Q_{2,0} = 1 - \rho$.

Let $R_t$ denote farm income at time $t$, which equals the total farm revenue from both the retail market and the food service sector minus harvest costs: $R_t = P_{1,t}Q_{1,t} + P_{2,t}Q_{2,t} - H \cdot Q_t$, $t = [1,...52]$, where $H$ is the per-unit harvest cost. The yearly farm income is then given by

$\sum_{t=1}^{52} R_t$ . Let $R(a)_t$ denote farm income under the baseline mark-up pricing case, $R(b)_t$ , $R(c)_t$ , and $R(d)_t$ denote farm income under fixed pricing, periodic sale, and high-low pricing cases, respectively.

In order to incorporate the expected income and the income risk faced by farmers, we use two measurement criteria, $\Delta(\sum W_t)$ and $s.d.(W_t)$, to compare farmers' welfare under different retail pricing strategies.

The total yearly farm income difference, denoted by $\Delta(\sum W_t)$, equals the percentage difference of total yearly farm income between the alternative strategic retail pricing regime and the baseline case. For example, the total yearly farm income difference between high-low pricing regime and the baseline mark-up price case will be $\Delta(\sum W_t(d)) = \frac{\sum_{t=1}^{52} R(d)_t - \sum_{t=1}^{52} R(a)_t}{\sum_{t=1}^{52} R(a)_t}$, where $\sum_{t=1}^{52} R(d)_t$ and $\sum_{t=1}^{52} R(a)_t$ represent the sum of weekly farm income for all 52 weeks under high-low pricing regime and mark-up pricing regime, respectively.

The standard deviation of farm income from period to period, denoted by $s.d.(W_t)$, measures the weekly farm income volatility induced by alternative retail pricing strategies, whereas higher standard deviation corresponds to higher income risk to farmers. Both measurements are specified in percentage terms. If we further specify farmers' welfare difference between alternative retail pricing case and the baseline markup pricing case as

$EU(\tilde{R}) - EU(R) = f[\Delta(\sum_t W_t), s.d.(W_t)]$, then for risk-averse farmers, $f$ is a function that is increasing in $\Delta(\sum W_t)$, and decreasing in $s.d.(W_t)$.

Suppose with random farm supply shocks, $\Delta_t$, the total farm supply at period t is $Q_t = Q_0 + \Delta_t = 1 + \Delta_t$. Under mark-up pricing case, denoted as case (a), wherein both retailers and the food service sector allow prices to vary freely according to supply shocks, we get the farm price by setting total farm supply equal to total derived farm demand, i.e. $1 + \Delta_t = a - bP$. Then the farm price is given by $P = \frac{1+\varepsilon-(1+\Delta_t)}{\varepsilon} = \frac{\varepsilon - \Delta_t}{\varepsilon} = 1 - \frac{\Delta_t}{\varepsilon}$, and the farm income is

$R(a)_t = P_{1,t}Q_{1,t} + P_{2,t}Q_{2,t} - HQ_t = P_{2,t}Q_t - HQ_t = (1 - \frac{\Delta_t}{\varepsilon} - H)(1+\Delta_t)$ ,

or $R(a)_t = 1 + \Delta_t - \frac{\Delta_t}{\varepsilon} - \frac{\Delta_t^2}{\varepsilon} - H - H\Delta_t$.

Under the fixed pricing case, denoted as case (b), retailers keep the retail price fixed regardless of farm supply shocks, i.e. $P_{1,t}^R = P_{1,0}^R$. Because the retail price does not respond to the change in production, the retail market always sells $\mathrm{Q}_{1,t} = \mathrm{Q}_{1,0} = \rho$. To clear the market, the food service sector now sells $\mathrm{Q}_{2,t} = 1 + \Delta_t - \rho$. Given perfect competition in the food service sector, the farm price paid by the food service sector, $P_{2,t}$, is determined by setting sales in the food service sector equal to its derived demand: $1 + \Delta_t - \rho = (1-\rho)(1+\varepsilon - \varepsilon P_{2,t})$,

and $P_{2,t} = 1 + \frac{1}{\varepsilon} - \frac{1+\Delta_t - \rho}{(1-\rho)\varepsilon} = 1 + \frac{1}{\varepsilon} - \frac{1}{\varepsilon} - \frac{\Delta_t}{(1-\rho)\varepsilon} = 1 - \frac{\Delta_t}{(1-\rho)\varepsilon}$, or $P_{2,t} = \frac{\varepsilon - \rho \cdot \varepsilon - \Delta_t}{(1-\rho)\varepsilon}$. Due to the arbitrage condition that links the retail market and the food service sector, the farm price paid by retailers is the same as farm price paid by food service sector: $P_{1,t} = \frac{\varepsilon - \rho \cdot \varepsilon - \Delta_t}{(1-\rho)\varepsilon}$. Farm

income under fixed retail pricing regime, denoted as $R(b)$, is given as

$$R(b)_t = P_{1,t}Q_{1,t} + P_{2,t}Q_{2,t} - HQ_t = P_{2,t}Q_t - HQ_t = (P_{2,t} - H)(1+\Delta_t).$$

Thus, $R(b)_t = [1 - \frac{\Delta_t}{(1-\rho)\varepsilon} - H](1+\Delta_t)$, or $R(b)_t = \frac{(1+\Delta_t)(\varepsilon - \varepsilon\rho - \Delta_t - H\varepsilon + H\varepsilon\rho)}{(1-\rho)\varepsilon}$.

The difference in farm income between the fixed retail pricing regime and the mark-up pricing regime at week $t$ is: $R(b)_t - R(a)_t = \frac{(1+\Delta_t)(\varepsilon - \varepsilon\rho - \Delta_t)}{(1-\rho)\varepsilon} - (1 - \frac{\Delta_t}{\varepsilon})(1+\Delta_t)$. After simplification, we obtain $R(b)_t - R(a)_t = \frac{(1+\Delta_t)(-\Delta_t * \rho)}{(1-\rho)\varepsilon}$. By rearranging the terms, we get

$R(b)_t - R(a)_t = -\frac{1}{\varepsilon}\frac{\rho}{(1-\rho)}(\Delta_t + \Delta_t^2)$, which contains the products of the inverse of the farm demand elasticity, the initial market share between grocery retail and the food service sector, and the first and second order of the farm supply shock. Holding everything else constant, the absolute difference in farm income between the fixed pricing case and the markup pricing case decreases in the initial equilibrium of the farm demand elasticity, increases in the relative market share between grocery retail and food service sector, and is larger when the supply shock is positive.

The percentage difference for the yearly farm income between the fixed retail pricing and the mark-up retail pricing regime is given by

$$\Delta(\sum W_t(b)) = \frac{\sum_t R(b)_t - \sum_t R(a)_t}{\sum_t R(a)_t} = \frac{\sum \frac{(1+\Delta_t)(-\Delta_t * \rho)}{(1-\rho)\varepsilon}}{\sum (1 - \frac{\Delta_t}{\varepsilon} - H)(1+\Delta_t)} = \frac{\sum \frac{(-\Delta_t * \rho)}{(1-\rho)}}{\sum (\varepsilon - \Delta_t - \varepsilon H)},$$ the sign of which depends on the values of $\varepsilon$, $\Delta$, $\rho$ and $H$.

If $H = 0$, i.e., the per-unit harvest cost is negligible, then the yearly income difference for farmers between the fixed retail pricing and mark-up retail pricing regime is: $\Delta(\sum W_t(b)) = \sum \frac{(-\Delta_t * \rho)}{(1-\rho)(\varepsilon - \Delta_t)}$. If the random farm supply shocks, $\Delta_t$, are sufficiently small, and $\varepsilon$ is large enough, such that $(\varepsilon - \Delta_t) > 0$,

the following outcomes are possible: $\begin{cases} If\, \Delta_t > 0, then \frac{(-\Delta_t \rho)}{(1-\rho)(\varepsilon - \Delta_t)} < 0 \\ If\, \Delta_t < 0, then \frac{(-\Delta_t \rho)}{(1-\rho)(\varepsilon - \Delta_t)} > 0 \end{cases}$.

The absolute value of a negative income change is larger in magnitude than the positive income change, because $(\varepsilon - \Delta_t)$ is relatively smaller when $\Delta_t > 0$. Therefore, the mean farm income change is negative.

We have shown that with linear demand functions, when the harvest cost in negligible and the farm supply variation is relatively small, fixed retail pricing behavior tends to reduce farm income, compared to markup pricing behavior. This result also holds for nonlinear demand function as long as the farm demand from the food service sector is downward sloping and differentiable at the initial equilibrium quantity. [4]

### 3. *Harvest Cost Will Affect Farmer Welfare Implication*

What will happen to the above welfare comparison if the harvest cost cannot be ignored? For example, based upon data from the Cost and Return Studies by University of California

[4] Exceptions to this conclusion may occur when the exogeneity assumption for total farm supply fails to hold. A typical example is that in times farmers may well elected to leave excess farm supply uncollected on the field in order to maintain farm price no less than marginal harvest cost. Detailed analysis on this issue can be found on next subsection at page 28 and 29.

Cooperative Extension, we estimate the harvest cost for California fresh-marketed iceberg lettuce is around 60% of the average gross return. [5]

The total farm supply, $Q$, equals to the total farm production for most of the cases. Total farm production is considered exogenous since once farmers determine the total acreage committed to a product at the beginning of a crop year, its production variation afterwards depends mainly upon weather shocks. There are occasions when the total production is sufficiently large that it drives the farm price to the level of the harvest cost. In these cases, the per-unit harvest cost places a lower bound on the farm price because farmers will leave crops in the field, unless price is at least sufficient to cover the costs of harvesting. In such cases, farmers' harvest decisions endogenously determine the total farm supply and limit the possible income loss for farmers.

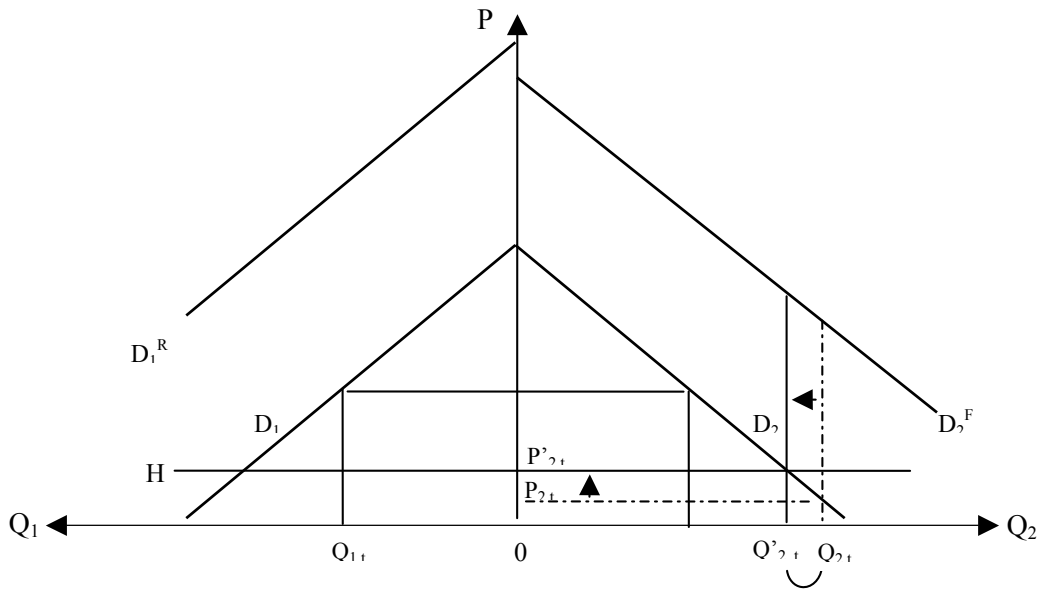


**Figure 5: Marginal Harvest Cost Forms Lower Bound for Farm Price**

[5] We calculate the average gross returns per acre of iceberg lettuce during year 1999 to year 2003, and divide it by the estimated harvest cost per acre to get the percentage harvest cost.

Figure 5 illustrates the situation wherein the harvest-cost constraint for farm price binds. Suppose the total potential farm supply at time $t$, $Q_t = Q_{1,t} + Q_{2,t}$, is big enough such that, the farm price will drop below the harvest cost ($P_{2,t}$), if all product is offered to the market. In order to maintain the farm price at least equal to the marginal harvest cost, only certain amount of product, $Q_{1,t} + Q'_{2,t}$, will be harvested and supplied to the market. The amount of excess supply, $Q_{2,t} - Q'_{2,t}$, is left in the field, and the farm price at time $t$ is constrained to the harvest cost level: $P'_{2,t} = H$.

Adoption of alternative retail pricing strategies tends to reduce farm income, whereas the existence of harvest cost, acting as a lower bound for farm price, tends to reduce the undesired part of the farm price volatility and prevent farmers from income loss. The joint effect on farmer welfare, counterbalancing between retail price strategies and the form of farm price floor by harvest cost, depends on three key model parameters: farm demand elasticity, farm supply volatility, and the level of harvest cost.

Analytical solution helps to clarify this intuition and verify some of the sign of the welfare changes under simple cases, but it is far from sufficient in examining the welfare implication under more complicated settings or addressing the magnitude of the welfare changes. Hence, simulations of retail pricing behavior and implication for farmer welfare are needed.

## V. Simulations of Retail Pricing Behavior and Implication for Farmer Welfare

The first goal of these simulations is to evaluate farmers' welfare effect induced by alternative retail pricing behaviors, compared to the baseline markup pricing behavior. The second goal is to determine how diversified retail pricing behaviors affects farmers' welfare. Using mark-up

pricing as the baseline case, we carry out 10,000 simulations of welfare comparison under each alternative price regime, as well as the aggregate regime, which incorporates the coexistence of all four types of pricing behaviors. In order to isolate the welfare impact due to retailers' pricing behavior, the simulations in this section were carried out with harvest cost set to be zero, and thus farm price is restricted to be non-negative. The simulation software used are Matlab and Crystal Ball.

### *1. Determinants of The Parameter Values*

Specifying plausible parameter values for $\rho$, $\Delta$, and $\varepsilon$ is the first step of the simulation. The quality of the parameter values, evaluated by how closely they reflect the real world practice, is crucial to determine the relevance of the simulations to reality, and the applicability of the conclusions in this paper for policy concerns.

According to the data from USDA's marketing bill, about 60% of the total consumer's expenditure for domestically produced farm goods are made in retail stores, and 40% are made in the food service sector. Thus the initial market share of total farm supply of the retail market, $\rho$, is determined to be 0.6.

Farm supply shocks, $\Delta_t$, are assumed to be normal random variables with mean zero and variance $\sigma^2$: $\Delta_t \sim N(0,\sigma^2)$. The variance of actual U.S. total shipment of fresh lettuce and tomato (including both domestic production and import) are applied to estimate the variation of supply shocks, $\sigma^2$.[6] Since we normalize the mean farm supply to be 1, a reasonable setting for

[6] The average variation of monthly total shipment of fresh lettuce and tomato are applied to estimate the variance of supply shocks. The use of monthly data, instead of weekly data (due to data availability), may result in underestimation of the supply variation.

$\sigma^2$ is to divide the actual farm supply by its mean, so that $E(Q)=1$, and calculate the variance of supply based on the normalized farm supply: $\sigma^2 = \text{var}(Q_t / E[Q_t])$.

The own price elasticity of farm demand evaluated at mean harvest level is set to be $\varepsilon = 0.4$ in the simulation model. SZC's (2003) estimate of $\varepsilon$ for fresh lettuce is 0.433, using the same dataset as used in this study. In addition, the investigation of demand elasticity estimations from a broad range of literature for lettuce, tomatoes, apples, oranges sold in the US market further confirm the validity of our choice of elasticity above (USDA, ERS). [7]

**Table 1: Initial Values of Parameters**

| Parameters | Notation | Initial value |
|---|---|---|
| Share of retail market | $\rho$ | 0.6 |
| Farm demand elasticity | $\varepsilon$ | 0.4 |
| Supply shocks | $\Delta$ | $\Delta_t \sim N(0, 0.117^2)$ |
| Farm value share | $P_2 / P_1^R$ | 25% |

Farm value share, which is the percentage of the farm price to the retail price ($P_2 / P_1^R$), is set to be 25% based upon USDA data.[8] Since the farm price at the mean harvest level is normalized to $P_2 = 1$, the equilibrium retail margin under perfect competition is equal to 3: $c_1 / b = P_1^R - P_2 = 3$. Table 1 summarizes the parameter values used in the simulation.

[7] Most of the reported demand elasticities for these commodities are inelastic, ranging from around 0.1 to 0.9. Notice that elasticity estimates from literature are consumer demand elasticity, instead of farm demand elasticity. Given the constant return to scale and fixed proportional farm value share assumptions, the formula to convert consumer demand elasticity to farm demand elasticity, is: $E_f = E_r(P_f / P_r)$, which indicates that the farm demand elasticity is in general lower than the consumer demand elasticity.

[8] The farm value share is derived from USDA data by averaging the mean farm value share for iceberg lettuce and fresh field-grown tomato (23%), and the mean farm value share of fresh vegetables (27%) produced in the U.S. during year 1998-1999.

### 2. *Retail Pricing Behavior and Farmer Welfare Simulation*

This subsection reports Monte Carlo simulations for different retail pricing behaviors and their implications for farmers' welfare. By closely relating parameters to the dataset, these simulation results show that, if retailers adjust price in a way that partially or fully ignore supply shocks, it in general hurts farmer welfare. At the aggregate level, when different retail pricing behaviors coexist, their impact on farmers' welfare is also negative and significant. These results indicate that the loose connection between retail price and farm level price, and the diversified retail pricing behaviors, are harmful to producer interests, under zero harvest cost assumption.

#### *a) Markup pricing (baseline case)*

Scenario (a) simulates the baseline case when all retailers adopt markup pricing strategy, and set retail price equal to the acquisition costs plus a constant unit cost of retailing: $P_1^R = P_2 + c_1 / b$. In this case, random supply shocks are absorbed efficiently by both the retail and the food service markets. Figure 6 shows the distributional results of farm income under mark-up pricing regime based on 10,000 simulations. The mean of the yearly farm income level is about 50.24, and 90% of the total farm income simulation results fall into the range between 48.01 and 52.38. Other statistics for the welfare results, including standard deviation, median, bands for 95% confidence interval can also be found in figure 6. The standard deviation of weekly farm income is 0.18. These welfare results under the mark-up pricing case serve as benchmarks to compare how alternative retail pricing regimes affect farmers' welfare differently.

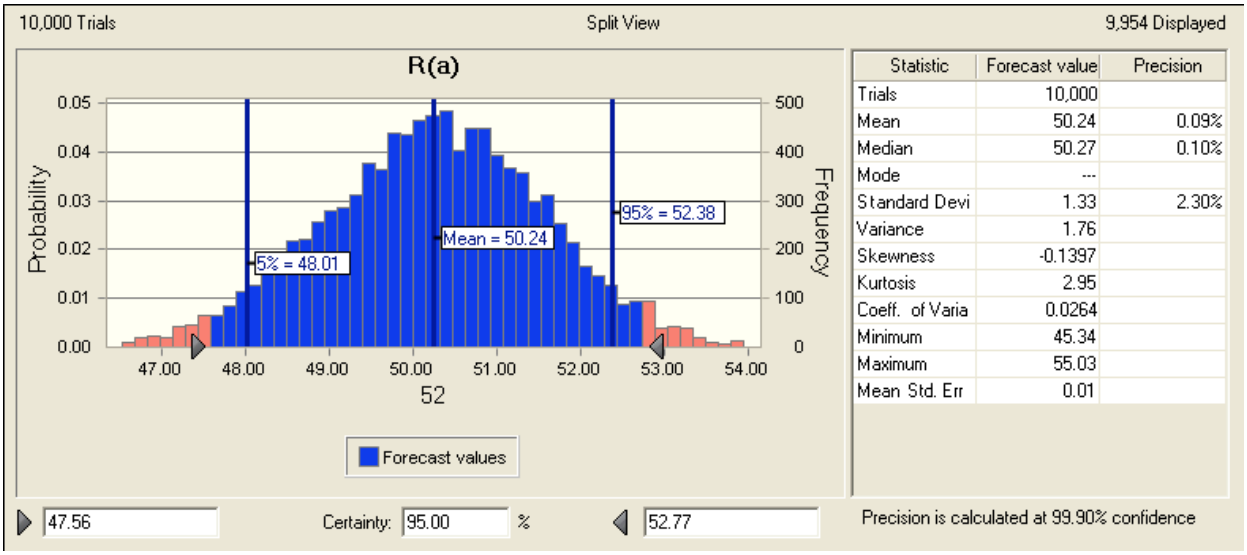


**Figure 6: Simulation on Farmer Welfare under Mark-up Pricing Regime**

### *b) Fixed retail pricing*

Scenario (b) represents the case when all retailers adopt fixed pricing strategy, while the food service sector uses competitive pricing. The fixed retail price equals the normalized equilibrium farm price under mean harvest plus a fixed retail margin: $P_1^R = 1 + c_1 / b$. Although there are random farm supply shocks from time to time, this retail price remains constant. Figure 7 shows the simulated total farm income difference between fixed retail pricing regime and baseline markup pricing regime. The null hypothesis is that there is no significant farm income loss due to retailers' fixed pricing behavior, compared to the case under markup pricing behavior. The total farm income difference between fixed retail pricing regime and markup pricing regime, given by $\Delta(\sum W(b)) = \frac{\sum R(b)_t - \sum R(a)_t}{\sum R(a)_t}$, is between -10.88% and 7.16% within 90% confidence interval, with the mean about -1.63% (figure 7). These simulation results show that, when

random farm supply shocks are present, it is likely that retailers' fixed retail price will reduce farm income.

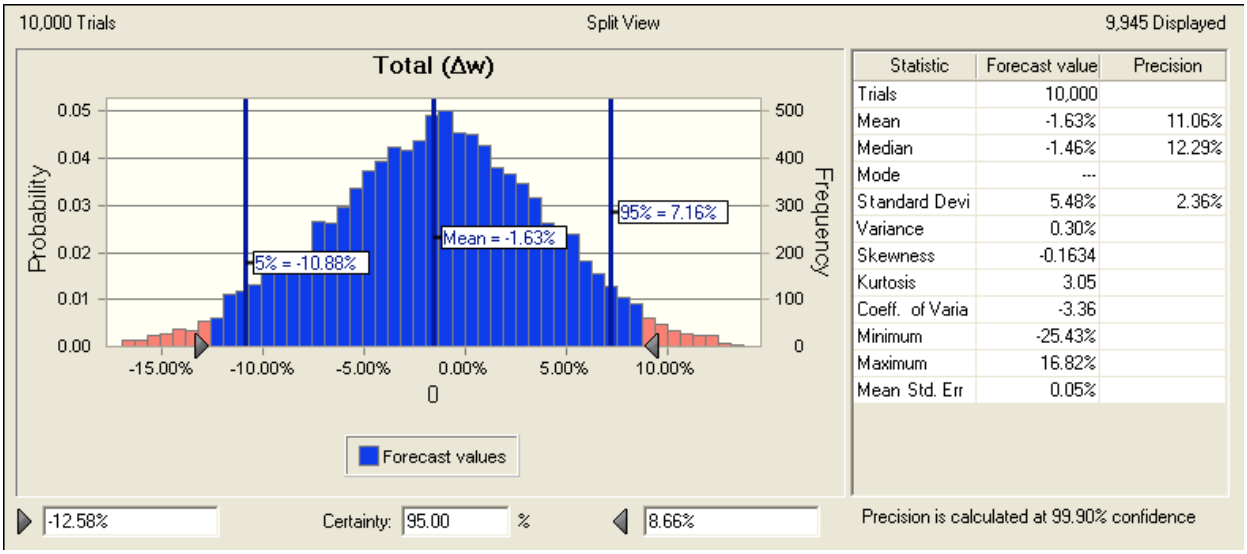


**Figure 7: Total Farm Income Difference under Fixed Pricing Regime**

Figure 8 shows the development of weekly farm income from one set of simulation under fixed pricing case, $R(b)_t$, and under markup pricing case, $R(a)_t$. The farm income exhibits higher volatility if retailers adopt fixed retail price. Based on 10,000 simulations, the standard deviation of weekly farm income is 0.54 for fixed pricing regime, which is much higher than that under baseline mark-up pricing regime (0.18). These results indicate that retailer's fixed pricing behavior not only tends to reduce total farm income in a given year, it also tends to induce higher farm income risk, both of which diminish the welfare for risk-averse farmers.

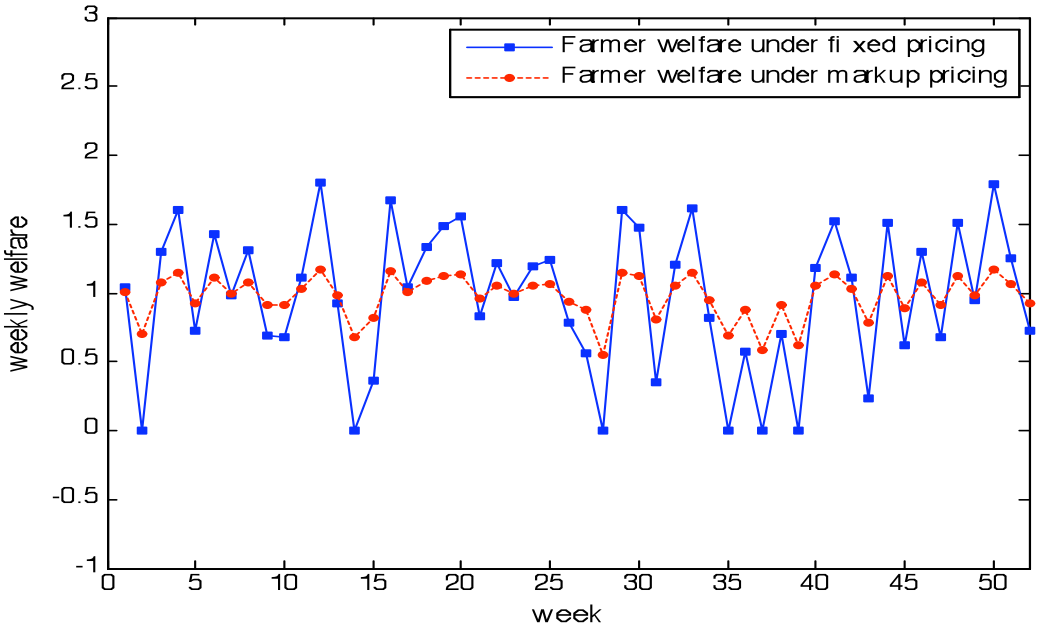


**Figure 8: Weekly Farmer Welfare under Fixed pricing and Markup Pricing**

### *c) Periodic sale*

Periodic sale represents the scenario when the retail price for a product stays at a certain level for extended periods, interrupted by a discount, then restores to the initial price level, and the cycle repeats throughout the year. In this case, in general a single "regular" price or several mass point prices exist. Figure 9 describes the simplified retail price movement under periodic sale regime, where $P_R^N$ denotes the non-sale price in the retail market, $u_1$ is the number of periods between sales, $u_2$ is the price discount in sale period, and $P_R^N - u_2$ is the sale price in the sale period.

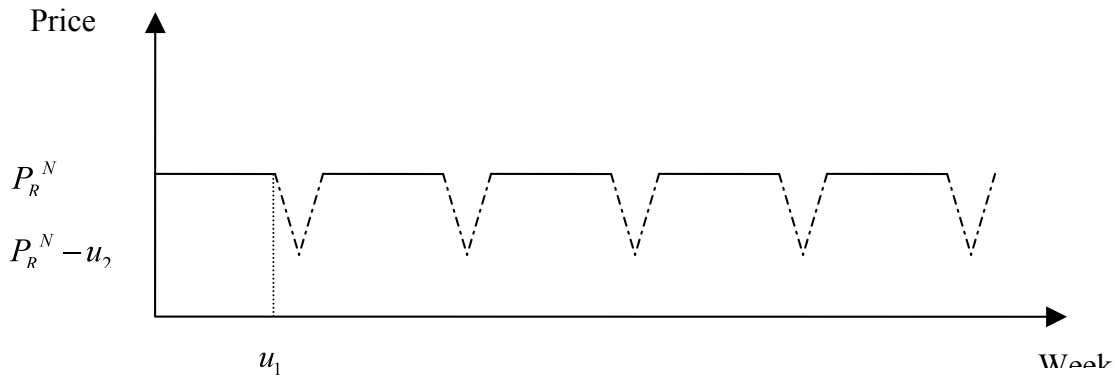


**Figure 9: Retail Price under Periodic Sale Regime**

Assume that all retailers adopt periodic sale strategy, and they follow exactly the same pricing pattern for the commodity. To study the welfare effect between periodic sale strategy and baseline markup pricing strategy, a total quantity constraint is imposed to the model, which assumes that in a given year the total quantity sold in retail market under the periodic sale regime are the same as that under the mark-up pricing regime. This assumption helps isolate the retail price effect from the quantity effect. The null hypothesis for the simulation model is that holding market power (total retail sales) constant across the two alternative pricing regimes, retailers' adoption of periodic sale pricing behavior will hurt farmers' welfare, compared to markup pricing.

Following the same model setting specified in section four, the total quantity sold in the retail market in the baseline markup pricing case is $\bar{Q}_1 = \sum_{t=1}^{52} \rho(1+\Delta_t)$, and the total quantity sold in the retail market under periodic sale strategy, denoted as $Q_1^c$, is calculated as $Q_1^c = \rho \cdot \left[(a + c_1 - bP_R^N)\mu_1 + (a + c_1 - b(P_R^N - \mu_2)\right] \cdot [\frac{52}{(\mu_1 + 1)}]$ . Under the total quantity constraint, $Q_1^c = \bar{Q}_1$, the non-sale retail price, $P_R^N$, is solved to be:

$P_R^N = \frac{1}{b}[a + c_1 - \frac{1}{52} \cdot \sum_{t=1}^{52}(1+\Delta_t) + \frac{1}{(\mu_1+1)} b\mu_2]$. Under the normalization condition (i.e., $b = \varepsilon$, and $a = 1+\varepsilon$), the non-sale retail price is: $P_R^N = \frac{1}{\varepsilon}[1 + \varepsilon + c_1 - \frac{1}{52} \cdot \sum_{t=1}^{52}(1+\Delta_t) + \frac{1}{(\mu_1+1)} \varepsilon\mu_2]$.

The simulation process includes five steps: First, we draw the random supply shocks for each of the 52 weeks, and compute $P_1$ and $Q_1$ for each period under mark-up pricing regime to get the total retail demand for the whole year. Second, using the same draws of farm supply variation, for a set of $u_1$ and $u_2$, we compute the non-sale price $P_R^N$ and the sale price $P_R^N - u_2$, such that the total quantity sold at retail in the baseline case equals the quantity sold in the periodic sale case. Third, we plug the retail price into the final retail demand function to compute the quantity sold in the retail market at each period, $Q_R$. Fourth, we solve the quantity demanded by the food service sector, $Q_2$, and the farm price, $P_2$. Finally, we compute and compare the total welfare differences for farmers under the two scenarios.

Let us take the case where $u_1 = 3$ and $u_2 = 0.4$ as an example to present the detailed simulation results (Case 1 in Table 2). In this case, retailers keep price at a non-sale price for three weeks, followed by a price cut that is about 10% off the non-sale price in the fourth week. The retail price moves back to the original price in the fifth week and stays for another three weeks, and then reduces by 10% again. This cycle repeats throughout the year, regardless the presence of random farm supply shocks.

The distributional results from 10,000 simulations show that farmer's yearly total income loss is around -1.65%. The mean standard deviation for weekly farm income derived from simulations is 0.55, which is much higher than the mean standard deviation under markup pricing case (0.15).

Table 2 summarizes the simulation results under different parameter values of $u_1$ and $u_2$, some with longer price duration for the non-sale price within each price cycle (Case 2), and some have larger price cut in sales periods (Case 3). These results reveal that even if retailers acquire the same total amount of products from farmers as those under mark-up pricing regime in a given year, offering occasional sales leads to farm income loss.

Meanwhile, we notice that if the retailer offers higher discount (e.g. 20% off the non-sale price), there is nearly no income difference between periodic sale regime and the markup-pricing regime. How could steeper sales cause less impact to farm income? Although seemingly contradicting our intuition, this result reflects the joint effect to farmers induced by the alternative retail pricing behavior and the farm price floor constrained by the harvest cost. Recall that in this section, the harvest cost is assumed to be zero, and farm price is then constrained to be non-negative. In essence, the harvest-cost constraint places a lower bound on the farm price, whereas there is no comparable upper bound, meaning that farmers benefit fully from volatility-induced price increases but are protected from the worst price decreases. Thus higher farm price volatility caused by alternative retail pricing behavior may not be bad for farmers who are protected by harvest-cost constraint. This finding becomes more obvious in the next section when the harvest cost is higher.

**Table 2: Farmer Welfare Results under Periodic Sale Regime**

| **Parameters and results** | **Notation** | **Case 1** | **Case 2** | **Case 3** |
|---|---|---|---|---|
| Weeks between two sales | $u_1$ | 3 | 4 | 3 |
| Price discount (% off retail price) | $u_2$ | 10% off | 10% off | 20% off |
| Mean total farm income difference, (Standard deviation in parentheses) | $\Delta(\sum W)$ | -1.66% (0.014) | -1.74% (0.013) | 0.03% (0.017) |
| Standard deviation for weekly farm income | $s.d.(W)$ | 0.55 | 0.54 | 0.68 |

The standard deviations of weekly farm income under periodic sale regime are much higher than that under markup pricing regime, which indicate higher risk to farmers. In addition, Table 2 shows that the variation of weekly farm income relates closely to the magnitude of discount offered by retailers. The larger the discount offered, the higher the variance in farm income.

**d) *High-low pricing***

Under high-low retail pricing practice, we observe more frequent price variation, and the price variations are mainly induced by retailer's strategic choice of a pricing format, rather than by changes of the product cost. Thus the price fluctuation will be different than that under the markup pricing regime. In some cases when retail price rises under mark-up pricing regime, the retail price in high-low pricing regime may happen to undertake a price discount. Such counter directional price movements are often observed in the dataset.

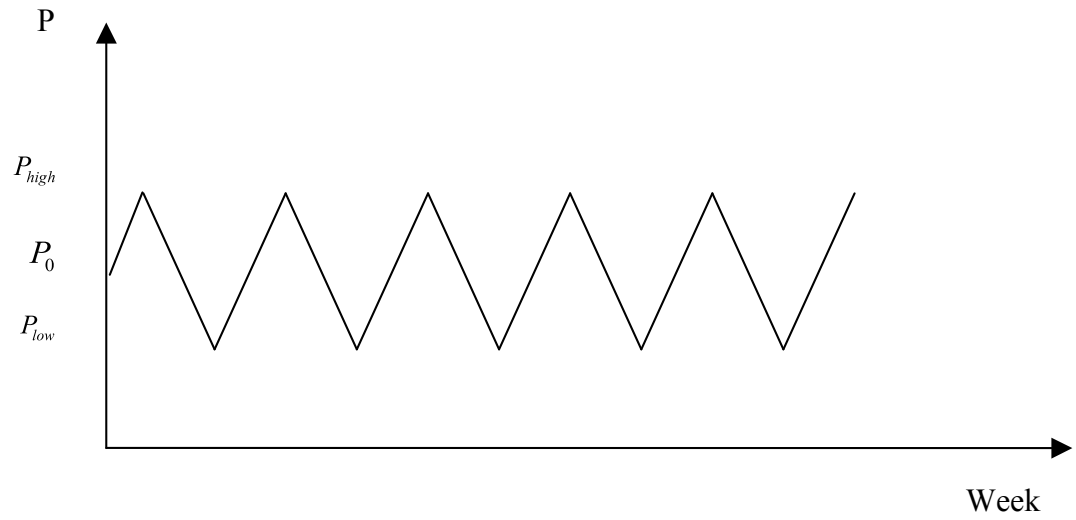


**Figure 10: Retail Price Movement under High-low Pricing Regime**

Figure 10 illustrates a stylized retail price movement under high-low pricing regime. Let $P_0$ denote the initial retail price, $k_1$ and $k_2$ represent price increase and price discount respectively. The starting price at the first week equals $P_0$. In the second week, the price goes up to its high price level, where $P_{high} = P_0 + k_1$. In the third week, the retail price restores the mode price. Then it drops to its low price level in the fourth week, where $P_{low} = P_0 - k_2$. In the fifth week price moves back to $P_0$ and the above cycle repeats itself throughout the year.

Intuitively, high-low retail pricing may be harmful to farmer welfare in the sense that if retailers ignore farm supply shocks when adjusting retail price, it may well induce severe farm price variation. Suppose there is a positive supply shock, in which case more products are available to the market. If both retailer and food service sector follow markup price setting, the price at each market will drop, and the quantities consumed by each market will increase. Instead, if retailers follow the high-low pricing pattern, they may happen to increase the retail price in the retail market, regardless of the positive farm supply shock. The high retail price

lowers retail sale, and consequently retailers buy less from farmers. As a result, food service sector will have to sell additional amount of product to clear the market. The farm price drops more than if retailers had adopted markup price strategy, and farmers experience welfare loss. Although in times of negative farm supply shocks, farmers benefit from higher farm price, the overall welfare effect may still be negative if the gains are outweighed by the losses.

In order to compare the welfare difference under high-low pricing strategy and mark-up pricing strategy, a total quantity constraint is applied to the model, which assumes in a given year the total retail sale under high-low pricing regime is equal to the total retail sale under mark-up pricing regime. The null hypothesis for the simulation model is that holding total retail sale constant, retailer's high-low pricing behavior will hurt farmer welfare.

The total quantity sold in retail market in the baseline case, denoted as $\bar{Q}_1$, is calculated as $\bar{Q}_1 = \sum_{t=1}^{52} \rho(1+\Delta_t)$, and the total retail sale under high-low price strategy, denoted as $Q_1^d$, is calculated as $Q_1^d = \rho \cdot [4(a + c_1 - bP_0) - b(k_1 - k_2)] \cdot \frac{52}{4}$. By setting $Q_1^d = \bar{Q}_1$, we get $\rho \cdot [4(a + c_1 - bP_0) - b(k_1 - k_2)] \cdot \frac{52}{4} = \sum_{t=1}^{52} \rho(1+\Delta_t)$, so we can solve the retail mode price $P_0$ such that $P_0 = \frac{1}{b}[a + c_1 - \frac{1}{52}\sum_{t=1}^{52}(1+\Delta_t)] - \frac{1}{4}(k_1 - k_2)$. Using the normalization condition and plugging in the equilibrium demand elasticity (i.e., $b = \varepsilon$, and $a = 1+\varepsilon$), we obtain

$$P_0 = \frac{1}{\varepsilon}[1 + \varepsilon + c_1 - \frac{1}{52}\sum_{t=1}^{52}(1+\Delta_t)] - \frac{1}{4}(k_1 - k_2).$$

Each simulation process contains five steps: First, we draw the randomly varied farm supply shocks, and compute $P_1$ and $Q_1$ to get the yearly total retail demand under mark-up

pricing regime. Second, using the same draws of farm supply variation, we solve for retail prices under high-low pricing regime, such that the total quantity of retail sale under high-low pricing regime equals the total quantity of retail sale under the baseline regime. Third, we compute the retail quantity sold in every period under high-low pricing regime, $Q_1$, and solve for the residual demand quantity and farm price in the food service sector, $Q_2$ and $P_2$. Finally, based on arbitrage condition that the price retailers pay to farmers equals the price paid by the food service sector, we calculate and compare the welfare differences for farmers between those under the high-low pricing regime and the mark-up pricing regime.

There are two possible stylized scenarios under high-low pricing regime. One is the symmetric scenario, in which the price increase equals price cut and the timing of price changes is symmetric. The other refers as the asymmetric scenario, where either the timing or the magnitude of price changes, or both, is no longer symmetric. It is possible that both symmetric and asymmetric price movement exists under different circumstances. In this paper, we will use both case to carry out the simulation on welfare implication.

***Scenario (1) Symmetric price movement under high-low pricing regime, where price increase equals price cut ( $k_1 = k_2$).***

In this scenario, we assume that the retail price follows a symmetric movement under high-low pricing strategy, where the magnitude of price increase and price cut are the same, and the periods between price increase and price cut are the same. For example, with $k_1 = k_2 = 0.2$, the high price is about 10% higher than the low price, i.e., $(P_{high} - P_{low}) / P_{low} = 10\%$. The simulation results show that the total yearly welfare between high-low pricing regime and the baseline regime is -1.77%. The standard deviation on weekly welfare is 0.54 (recall that the standard

deviation on weekly welfare under the baseline is 0.15). The negative welfare difference indicates that retailers' high-low pricing behavior tends to reduce farm income, whereas the higher weekly welfare variation shows increased risk to farmers from week to week.

Table 3 summarizes welfare results under different choice of $k$ s. According to the model, larger $k_1$ and $k_2$ refer to bigger price increase and price discount. For example, $k_1 = k_2 = 0.4$ corresponds to the high low price gap of 22%, while $k_1 = k_2 = 0.6$ corresponds to 35% price difference between high and low price. We find that when the high-low retail price gap goes up to 22%, there is nearly no welfare loss to farmers (-0.2%). As the high-low price gap increases to 35%, the simulation shows farmers could even benefit from retailers' high-low pricing behavior (2.81%). These results again show that higher price volatility at the retail market may not always reduce expected farm income. The reason is that price is constrained to be nonnegative, ruling out the most severe price decreases, whereas there is no corresponding upper bound on price increases.

**Table 3: Simulation Results on Farmer Welfare Difference for Symmetric Price Change under High-low Pricing Regime ($k_1 = k_2$)**

| **Parameters and results** | **Notation** | **Case 1** | **Case 2** | **Case 3** |
|---|---|---|---|---|
| Retail price change | $k_1, k_2$ | 0.2 | 0.4 | 0.6 |
| % difference between high and low price | $(P_{high} - P_{low}) / P_{low}$ | 10% | 22% | 35% |
| Mean total welfare difference, (standard deviation in parentheses) | $\Delta(\sum W)$ | -1.77% (0.001) | -0.2% (0.001) | 2.81% (0.020) |
| Standard deviation for weekly welfare | $s.d.(W)$ | 0.54 | 0.61 | 0.72 |

For the standard deviation of weekly farm income, the higher the price gap, the higher farm income varies, which once again indicates higher retail price variation associates with higher farm income risk.

***Scenario (2) Asymmetric price movement under high-low pricing regime***

There are ongoing arguments on whether food retail price moves up and down symmetrically or asymmetrically. Some empirical paper declare there is no asymmetry found in the magnitude or frequency of price increases, relative to price decreases (Powers and Powers, 2001). Other researchers believe that either the timing, or the magnitude of price changes, or both, is not symmetric in terms of the retail price adjustments for farm commodities (Kinnucan and Forker, 1987; Zhang, Fletcher, and Carley, 1995; Azzam, 1999; Levy et, al, 2004).

Prior literature offers different explanations on the source of price asymmetry. Kinnucan and Forker (1987), and Zhang, Fletcher, and Carley (1995) observe while wholesale price moves symmetrically retail price seems to have more price increase than price decrease, and argue that retail prices tend to respond more efficiently to price increase rather than price decrease. Azzam (1999) uses spatial competition and monopolistic price adjustment to explain anomaly price adjustment. Instead, Levy et, al, (2004) argue that consumers have rational inattention, which means only price change above certain threshold will cause the change in consumer behavior, so it will be profitable for retailers to strategically undertake more price increase than price decrease.

The observations on price asymmetry by earlier researchers are consistent with my understanding from the scanner dataset that there are more frequent price increases than price decreases. We also observe that the magnitude of price increase tends to be smaller than the price discount. Figure 11 illustrates hypothetic price asymmetry movement that we specified to undertake the welfare simulation.

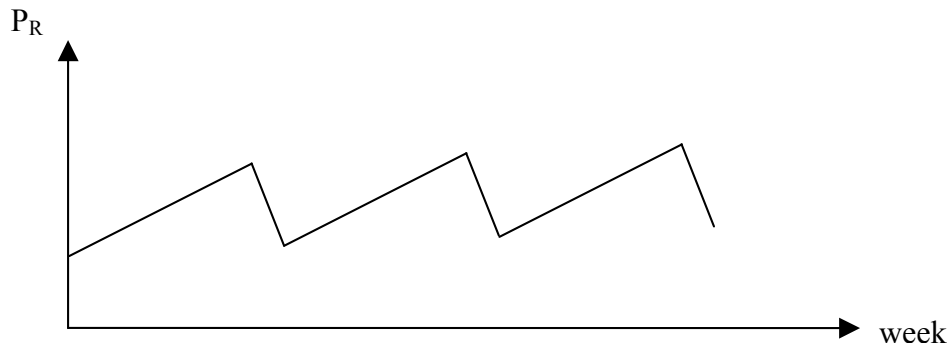


**Figure 11: Asymmetric Price Movement**

Assuming at time zero, the retail price is $P_0$. In the first week price increase to $P_0 + k_1$, in the second week price goes up again to $P_0 + 2k_1$, and the third week it continuously goes up to $P_0 + 3k_1$. In the following week, price drops to $P_0 + 3k_1 - k_2$. This price pattern repeats through out the year. In the simulation, we set $k_1 = 0.1$ and $k_2 = 0.3$.

According to the simulation results, the farm price and income difference tend to have larger variation, when retailer stick to high-low pricing regardless the presence of farm supply shocks. The total farm income is about 1.89% lower than that under markup pricing regime. The standard deviation for weekly farm income is 0.52, higher than that under markup pricing regime. These results indicate that asymmetric high-low pricing movement leads to negative impacts on farmers' welfare. [9]

### *3. Farmers' Welfare Effect under Aggregate Price Regime*

Above we have shown that these alternative retail pricing behaviors (namely fixed pricing, periodic sale and high-low pricing), if adopted by all retailers, tends to reduce expected farmer

[9] Welfare simulations are also done for other specifications of price asymmetry. The results do not change the above conclusion.

income while increasing the variation of farm income, compared to mark-up pricing behavior. Constrained by non-negative harvest cost, the expected income loss induced by alternative retail pricing behaviors becomes smaller as the retail pricing volatility increases, but the uncertainty of farm income increases.

What will happen to farmers' welfare if we pool different retail pricing behaviors together? There are many examples in the dataset, which exhibit the coexistence of different pricing patterns across chains. For example, there are four different retail chains in our data sell the same kind of iceberg lettuce (PLU code 4061) in Dallas during year 1998 to 1999. The weekly scanner data indicate that the price variations at each chain store are very different from one another, which corresponds to at least three different pricing patterns. It is not clear whether the coexistence of these diversified prices will reinforce or offset one another, neither is it so intuitive as to conclude that at the aggregate level the loose connection of retail price to farm price will hurt farmer welfare.

***1) How to get the aggregate price across different price behaviors***

To plausibly aggregate prices across different retail strategies, we need to find reliable answers to some key questions: How many retailers are adopting each of these different pricing strategies? What amount of products does each type of retailers sell? Do retailers tend to offer sale at the same time or not? The answer to these questions lead to two decisions: one is to assign weight to each type of price strategies, and the other is to decide the timing for the aggregation across different retail price movements.

For the weighting issue of the price aggregation, ideally, one should use the percentage quantity sold by each type of retailers as the weight assigned to each type of price strategies. The

advantage of the dataset is that it provides information on volume and value sold at each store for each product, which facilitates in estimating the weight for different retail strategies. In the simulations below, we generate some stylized weights assumptions that capture some of the most observed situations.

For the timing issue of the price aggregation, there are evidences in the literature supporting both synchronization (chains offer sales at the same time) and staggering (chains offer sales at different time) on cross-store retail price movements. Lach and Tsiddon (1996) claim cross-store staggering and within-store synchronization in the timing of price changes using an Israeli dataset on processed meat and liquor products. Ratfai (2003) uses food retail data from Hungary and finds synchronous price changes tend to be concentrated at certain time of the year, the third quarter, but not other times. The analysis in SZC (2003) tended to show correlations of retail prices almost at zero, suggesting there is no synchronization in the retail price adjustment across chains.

Whether synchronization exists or not across the retail-price movements affects the aggregation across different types of retail prices, especially for periodic sale and high-low pricing practices. Recall that both periodic sale and high-low pricing practitioners offer retail sale at some point of time. Whether competing retailers tend to offer sale at the same time or not may lead to different aggregate welfare effect for farmers.

From the dataset, we can observe examples of both synchronization and staggering price movements across chains. Instead of formally testing for synchronization or staggering across retail price adjustments, we carry out the welfare study using both possible situations. All other assumptions applied for individual pricing behaviors still hold in this aggregate price regime (refer to section 3 for details).

### 2) *Welfare simulation for aggregate price regime*

#### i. *Trial one—equal weight for each type of retailer, while sales offered at the same period*

Suppose that retailers from each type have the same market share for a certain product, thus the weight equals 1/4 for markup pricing, fixed pricing, periodic sale, and high-low pricing retailer. Assume that the periodic sales retailer keeps price at its non-sale price for 4 weeks and then offers a 20% sale. Also assume that starting from the mode price, the high-low pricing retailer sets price at a mode plus 5% increase in week one, then increases it by 5% in week two. The price goes up again by 5% during week three, and followed by a 15% discount at the fourth week. This case corresponds to the situation when retailers offer retail sale at the same time. Table 3 shows the weights and the specification of price setup for each type of retailer.

**Table 4: Weights and Price Setup for Each Type of Retailers under Aggregate Regime (Trial 1)**

| | Mark-up pricing | Fixed pricing | Periodic sale | High-low |
|---|---|---|---|---|
| Weight | ¼ | 1/4 | 1/4 | ¼ |
| Price increase (k1) | --- | --- | 0 | 5%,10%,15% |
| Price cut (k2) | --- | --- | 10% | 15% |

According to the simulation, the mean total farm income difference under aggregate price regime is -2%, compared to mark-up pricing regime. The standard deviation of weekly farm income is 0.52, which is much higher than that under the markup-pricing regime (0.18).

#### ii. *Trial two—different weights for each type of retailer, while sales offered at the same time period by retailers*

In this trial, different weights are assigned to each type of retailers based on samples from the data (Table 5). For example, there are 15 retail chains that sell red delicious apple, where six out of the 15 chains use fixed pricing strategy, five chains use periodic sale strategy, and the others use either high-low pricing or mark-up pricing strategy. Accordingly, we allow fixed pricing and periodic sale to have more weight than the other two pricing strategies.

**Table 5: Weights and Price Setup for Each Type of Retailers under Aggregate Regime (Trial 2)**

| | Markup pricing | Fixed pricing | Periodic sale | High-low |
|---|---|---|---|---|
| Weight | 1/6 | 1/3 | 1/3 | 1/6 |
| Price increase (k1) | --- | --- | 0 | 5%,10%,15% |
| Price cut (k2) | --- | --- | 10% | 15% |

The simulation results reveal that the total farm income difference is about -2.03%, compared to markup pricing case. The standard deviation of weekly farm income is 0.52. These results are similar to the last trial, and again verify there is farmer welfare loss under the diversified retail pricing behaviors.

***iii. Trial three—same weight for each type of retailer, while sales offered at different period***

In this case, equal weight of 1/4 is assigned for each type of retailers. The sale prices are allowed to happen at different period. This corresponds to the case when cross-store retail price movements are staggering.

The simulation results show that the mean of the total farm income is around -1.91%. The standard deviation of weekly farm income is still about 0.52. These results are similar to previous results in trial one and two, which shows the staggered price adjustment will not change their jointly negative effect to farmer welfare.

## VI. Harvest Cost Forms A Lower Bound for Farm Price

In the last section, by setting harvest cost to be zero, we isolated the effect of retail pricing on farmers' welfare and found that retail pricing strategies, if fully or partially ignoring farm supply shock, tend to reduce farmer welfare. In this section, we focus on the possible endogeniety of farm supply and show how harvest cost forms a lower bound constraint for farm price to change the welfare effect to farmers. The aggregated price regime is used in carrying out the welfare simulation in compare to markup pricing regime.

Harvest decision may endogenously determine farm supply because no crops will be harvested for a price below the marginal harvest cost. For lettuce, harvest cost includes the cost of cutting, packing, hauling, cooling and selling of the product. For tomatoes, it includes picking up, hauling to shed, packing and selling. The estimation of the harvest cost for fresh-marketed lettuce and tomato is around 60% of the farm price, based upon the Cost and Return Studies by University of California Cooperative Extension.

If we include a normalized estimate of harvest cost that equals to 0.6 into the welfare simulation for aggregate pricing case, about 1/3 of the times during the 52 week periods the farm price will be determined by the harvest cost constraint (figure 12). This simulation result is consistent with Sexton and Zhang (1996), who found that the harvest-cost constraint set price about one third of the time for California iceberg lettuce. The existence of harvest cost, acting as a lower bound for the farm price, restricts farmers' welfare loss. The higher the harvest cost, the more likely the lower bound constraint for farm price binds.

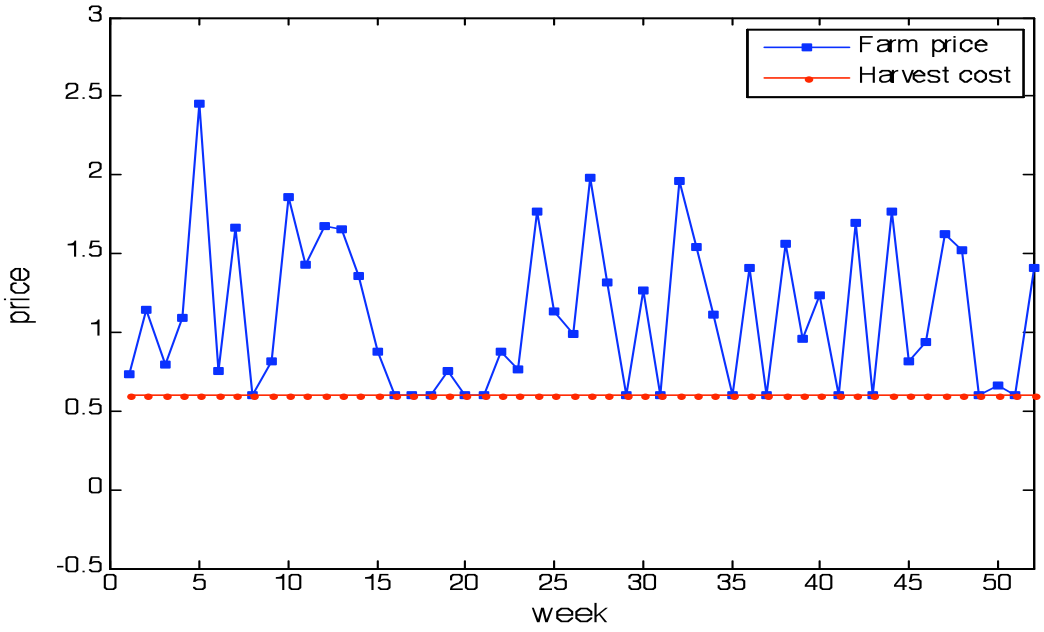


**Figure 12: Harvest Cost Serves as a Lower Bound for the Farm Price**

Figure 13 shows that the harvest cost positively correlates to the change of total farm income. Note that 0.05 on the vertical axis represents 5% total farm income difference, while 0.1 on the horizontal axis represents a per-unit harvest that equal 10% of the initial equilibrium farm price. Holding the demand elasticity and farm supply shock the same as prior levels, when harvest cost is zero, there could be about 2% welfare loss induced by diversified retail pricing behaviors. The welfare loss becomes smaller as the harvest cost becomes larger. With harvest cost greater than 20% of the equilibrium farm price, we start to see positive change of total welfare, which indicate that the aggregated retail pricing strategies although inducing higher farm price variation, may indeed increase farmer welfare. Whether the joint welfare effect from increased expected farm income and increased income risk leads to higher or lower welfare to farmers depends largely on farmers' risk attitude.

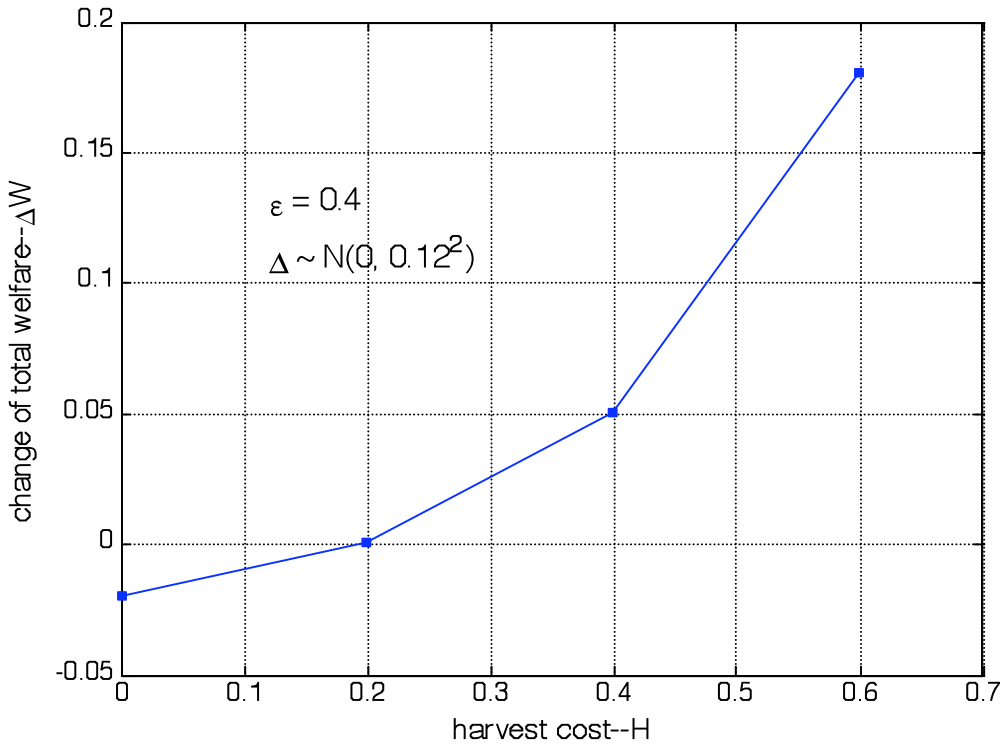


**Figure 13: Harvest Cost Positively Correlates to the Change of Total Farm Income**

## VII. Sensitivity Studies

In this section, we carry out the sensitivity studies for harvest cost, farmer supply variation, and the demand elasticity, to see how the change of parameters changes the welfare comparison between the aggregate pricing regime and the baseline markup regime. These revisits of the choices of parameters enable us to discern the robustness of our results and to broaden the application of the conclusions.

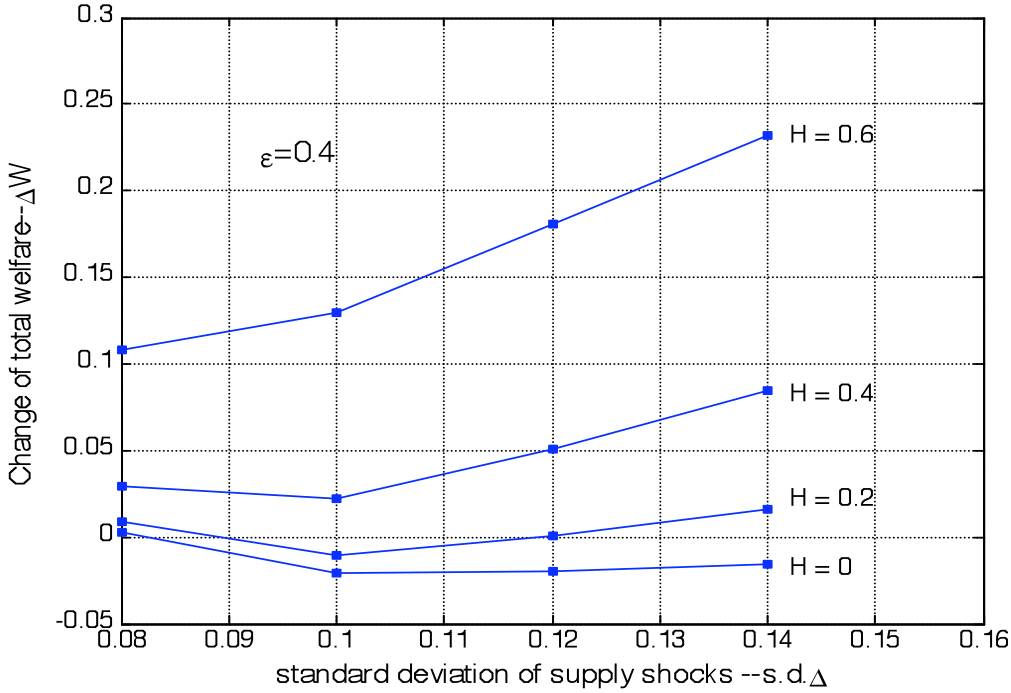


**Figure 14: Supply Variation in General Positively Correlates to Change of Total Welfare**

Figure 14 shows that in general the farm supply variation positively correlates to change of total farm income. Exception of this occurs at low supply shock level, where kinks present around $s.d.(\Delta) = 0.1$. In this figure, the farm demand elasticity is fixed at the initial choice ($\varepsilon = 0.4$), and the harvest cost are shown at different levels from 0 to 0.6, which corresponds to 0% to 60% of the initial equilibrium farm price.

There are different estimates of the demand elasticity for produce products in the U.S. The majority of these elasticity estimates for lettuces, tomato, apples and oranges are between 0.1 and 0.9. For example, Huang's (1993) elasticity estimates are -0.14 for lettuces, -0.56 for tomato, -0.20 for apples and -0.996 for oranges. Henneberry's (1999) estimates are -0.23 for tomato, and -0.59 for apples.

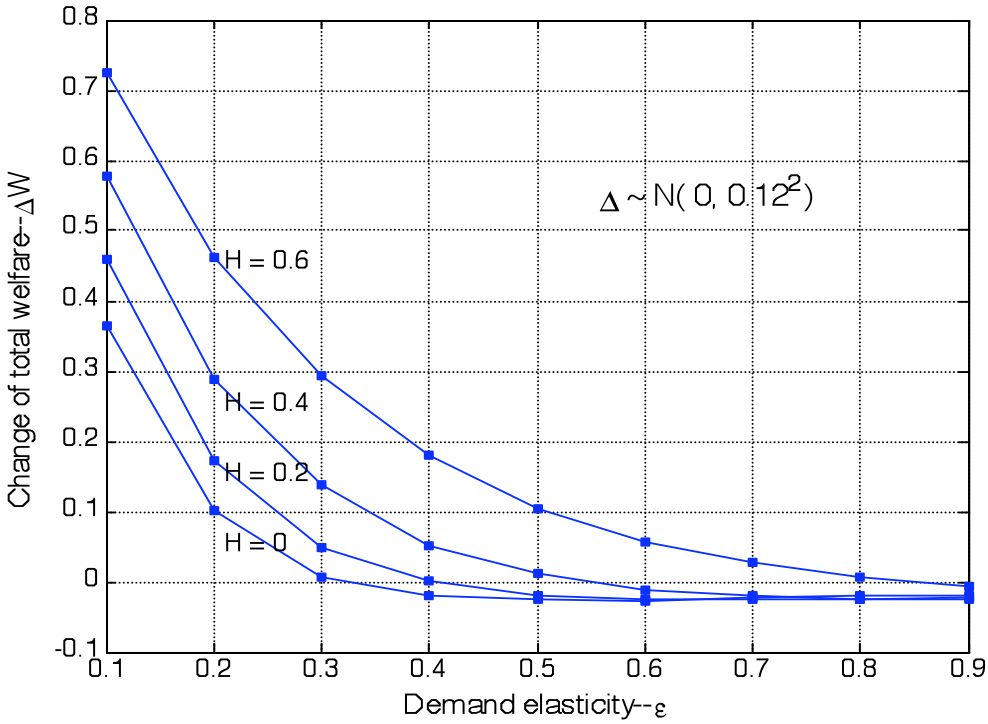


**Figure 15: Demand Elasticity Negatively Correlates to the Change of Total Welfare**

Figure 15 shows that the farm demand elasticity negatively correlates to the change of total welfare, when random farm supply shocks are still set to the initial level: $\Delta_t \sim N(0, 0.12^2)$. The higher the demand elasticity, the less farm price responds to change of demand quantity, and the less farm income difference induced by alternative retail pricing behaviors. When the elasticity is relatively larger, say above 0.9, almost any level of harvest cost will not prevent welfare loss. When the elasticity is small, it is likely that farmers will benefit from higher farm price volatility induced by alternative retail pricing behaviors.

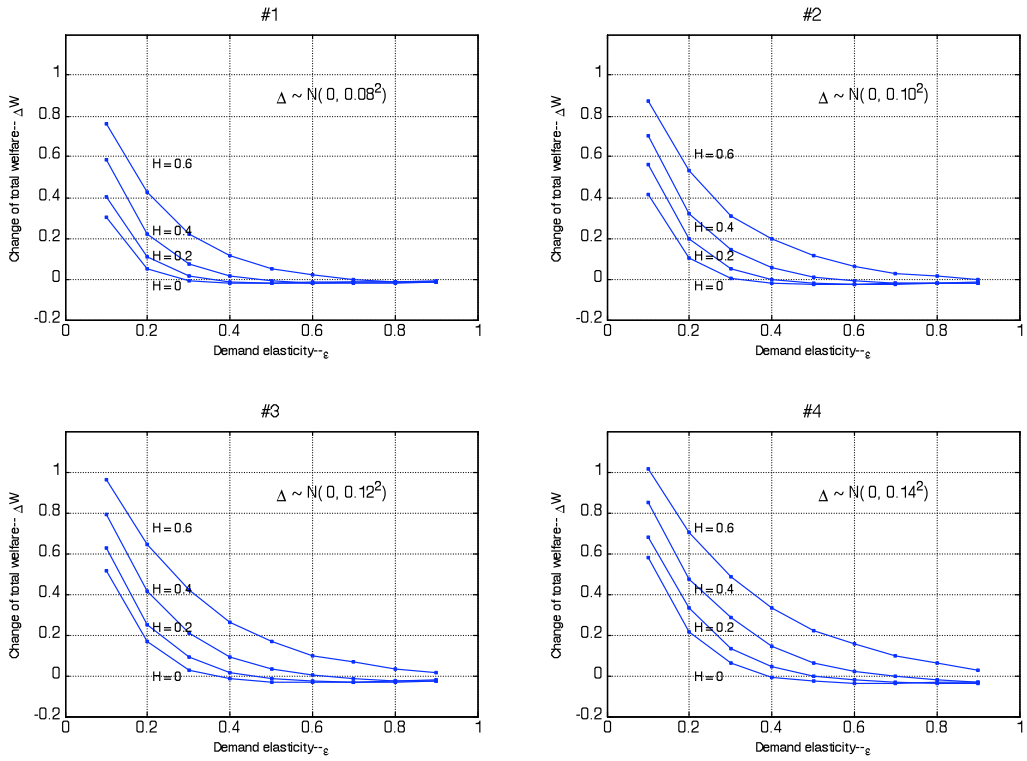


**Figure 16: Welfare Implication under Different Values of $\varepsilon, \Delta, H$**

Figure 16 shows farmer welfare implication under different values of harvest cost, farm supply variation and farm demand elasticity, which helps to shed light on how the simulated farm income difference is likely to be under different combination of the three factors. For example, the random supply shock derived from U.S. supply for apples is $\Delta_t \sim N(0, 0.14^2)$, the mean absolute value of the estimated demand elasticity is $\varepsilon = 0.81$, and the harvest cost is 60% of the equilibrium farm price. As shown in plot #4 in figure 16, at the aggregate level, the diversified retail pricing behaviors increase expected farm income by about 6%, compared to markup pricing regime.

## VIII. Farmer Welfare under Risk Aversion

Although the alternative-pricing regimes can lead to higher expected farm income than under the markup-pricing regime, it also evokes higher income volatility. Higher income volatility indicates higher risk, which reduces the utility of risk-averse farmers. In this chapter, we formally incorporate farmers' risk attitude into the welfare measurement.

Let farmers' welfare from this perishable product be represented by farmers' expected utility, $EU(R)$, which is a function of the farm income from this product, $R$. Farm income in our model is a random variable due to the presence of random farm supply shocks and the existence of alternative retail pricing behavior. The farmers' risk preferences are specified in terms of a utility function that is linear in expected income, $\mu$, and variance of income, $\sigma_R^2$. If the farmer is risk neutral, his welfare depends only on the expected farm income. If instead the farmer is risk-averse, his utility from risky farm income increases with the expected farm income and decreases with the riskiness of the farm income.

### 1. *Review on Risk Aversion*

Arrow (1951, 1971) and Pratt (1964) introduce the basic concepts for risk attitude measurement, including the measures of absolute risk aversion (ARA) and relative risk aversion (RRA). These primary measures of the risk aversion involve the concavity of the utility function. Suppose that the utility function is given by $U(x)$, where $x$ is the risky payoff. The absolute Arrow-Pratt risk aversion coefficient, defined as $R_A(x) = -\frac{U''(x)}{U'(x)}$, can be interpreted as the percent change in marginal utility at any level of income. ARA does not depend on the level of the risky income.

One the other hand, the relative Arrow-Pratt risk aversion coefficient, defined as $R_R(x) = -\frac{U''(x)}{U'(x)}x$, depends upon the level of the risky outcome. Arrow's (1974) hypothesis was that absolute risk aversion tends to decline with wealth, while relative risk aversion tends to increase with wealth.

### 2. *How Risk Averse Are Farmers?*

Many studies have found evidence of risk aversion among farmers. However, there is no consensus on the nature and the magnitude of the risk aversion (Friend and Blume, 1975; Antle, 1989; Pope and Just, 1991). Some empirical findings (Lins et al., 1981; Chavas and Holt, 1990) support Arrow's hypothesis on decreasing absolute risk aversion (DARA), and increasing relative risk aversion (IRRA), others (Pope and Just, 1991) support constant relative risk aversion (CRRA).

The estimates of risk aversion coefficients are very different in different studies. In the summary table in Saha, Shumway and Talpaz (SST,1994), the reported coefficient of ARA ranges from 0 to 15, the majority of which fall into the range of 0 to 6. Other than those summarized by SST (1994), Binswanger found that the majority of individuals in six Indian villages had partial Arrow-Pratt risk aversion coefficients .32 to 1.74. Antle's (1987) econometric estimates based on rice producers found the mean partial Arrow-Pratt coefficient to be in the range of .19 to 1.77. Antle (1989) finds the mean partial Arrow-Pratt coefficient estimates to be 1.11 and 1.40. Myers (1989) uses maximum likelihood methods to estimate the relative risk aversion parameter for US corn, wheat and soybean, and reports a relative risk aversion coefficient between 1.6 and 4.4. The mean estimate of the RRA is around 3.5.

Given the ambiguity of empirical evidence regarding the observed nature of absolute and relative risk aversion, we will use a range of risk aversion parameter to carry out the welfare comparison.

### 3. *The Use of Mean-variance Utility Function*

A widely applied expected utility function in literature is the negative exponential utility function: $U(x) = -e^{-\lambda x}$, where $\lambda > 0$, $U'(x) = \lambda e^{-\lambda x}$, $U''(x) = -\lambda^2 e^{-\lambda x}$, $R_A(x) = -\frac{U''(x)}{U'(x)} = \lambda$, and $R_R(x) = -\frac{U''(x)}{U'(x)} x = \lambda x$. The negative exponential function imposes constant absolute risk aversion (CARA) and increasing relative risk aversion (IRRA).

It has been proven in the literature that the expected utility function for a risk averse agent facing random income gives rise to a mean-variance utility function under widely applicable assumptions about the preferences (Sinn, 1983; Meyer, 1987; Eichner, 2004). Initially, assumptions of normally distributed outcome or agent's preferences are quadratic are imposed in order to apply mean-variance utility function upon risk analysis. Levy and Markowitz (1979) justify the practice of using mean-variance analysis by showing that mean-variance analysis can be regarded as a second order Taylor-series approximation of standard utility functions (such as the negative exponential utility), and thus relax the assumption of normality and quadratic. They show that the second order approximations are highly correlated to actual values of power and exponential utility functions over a wide range of parameter values. Hlawitschka (1994) extends the Levy and Markowitz result to show that the mean-variance ranking is highly correlated to the ranking based on the true utility function, and that third or even higher order approximations do not necessarily improve the rank correlation. Sinn (1983) and Meyer (1987) argue that if all

attainable distributions differ only by location and scale parameter, then for a wide range of economic decision problems, the MV approach is equivalent to the EU approach.

Instead of using a conventional expected utility (EU) function, we will assume farmers' preference satisfy that of a mean-variance (MV) utility function of the form:

$V(\mu,\sigma_R) = \mu - \frac{\lambda\sigma_R^2}{2}$, where $\mu$ is the expected farm income, $\sigma_R$ is the standard deviation of the farm income, and $\lambda$ is farmers' risk aversion parameter.

It can be shown that this MV utility form also represents CARA or IRRA. The partial derivatives of the mean-variance utility function are calculated as: $V_\mu(\mu,\sigma_R) = \frac{\partial V(\mu,\sigma_R)}{\partial \mu} = 1$ and $V_\sigma(\mu,\sigma_R) = \frac{\partial V(\mu,\sigma_R)}{\partial \sigma_R} = -\lambda\sigma_R$. Define $S(\mu,\sigma_R) = -\frac{V_\sigma(\mu,\sigma_R)}{V_\mu(\mu,\sigma_R)}$, then $S(\mu,\sigma_R) = \lambda\sigma_R$. Mayer (1987) show the detailed proof that $\partial S(\mu,\sigma_R)/\partial\mu = 0$ for $\mu$ and all $\sigma_R > 0$ if $V(\mu,\sigma_R)$ displays constant absolute risk aversion for all x, and $\partial S(t\mu,t\sigma_R)/\partial t > 0$ if $V(\mu,\sigma_R)$ displays increasing relative risk aversion for all x. In our case, both conditions satisfied, since $\partial S(\mu,\sigma_R)/\partial\mu = 0$ and $\partial S(t\mu,t\sigma_R)/\partial t = \lambda\sigma_R > 0$.

The MV model treats expected returns, standard deviations as population parameters, in practice we can use the sample expectation and sample variance from the Monte Carlo simulation to approximate the true mean $\mu$ and variance $\sigma_R$.[10] Based on the estimates from literature, farmers' risk aversion parameter is set between 0 and 8, in increments of 1 in the simulation studies.

[10] For verification purpose, we also use the negative exponential expected utility function to do the same welfare simulation and get compatible results as using the MV approach.

### 4. *Farmer Welfare under Risk Aversion*

Farmers' welfare difference between the aggregate case and the baseline case is given by: $\Delta V_{agg} = [V_{agg}(\mu,\sigma_R) - V_{mp}(\mu,\sigma_R)] / V_{mp}(\mu,\sigma_R)$, which captures the percentage difference between alternative pricing regimes.

Figure 17 reports sensitivity analysis for alternative risk-aversion coefficients, while holding other parameters constant. Under the initial parameter choices (zero harvest cost, demand elasticity equals 0.4, the variance of supply shock equal to $0.12^2$) and farmers' risk neutrality, $\Delta V_{agg} = -4\%$. It is clear that farmers experience higher relative utility loss as they become more and more risk averse. This happens because under alternative retail pricing behaviors there is larger volatility for farm income, compared to the baseline case.

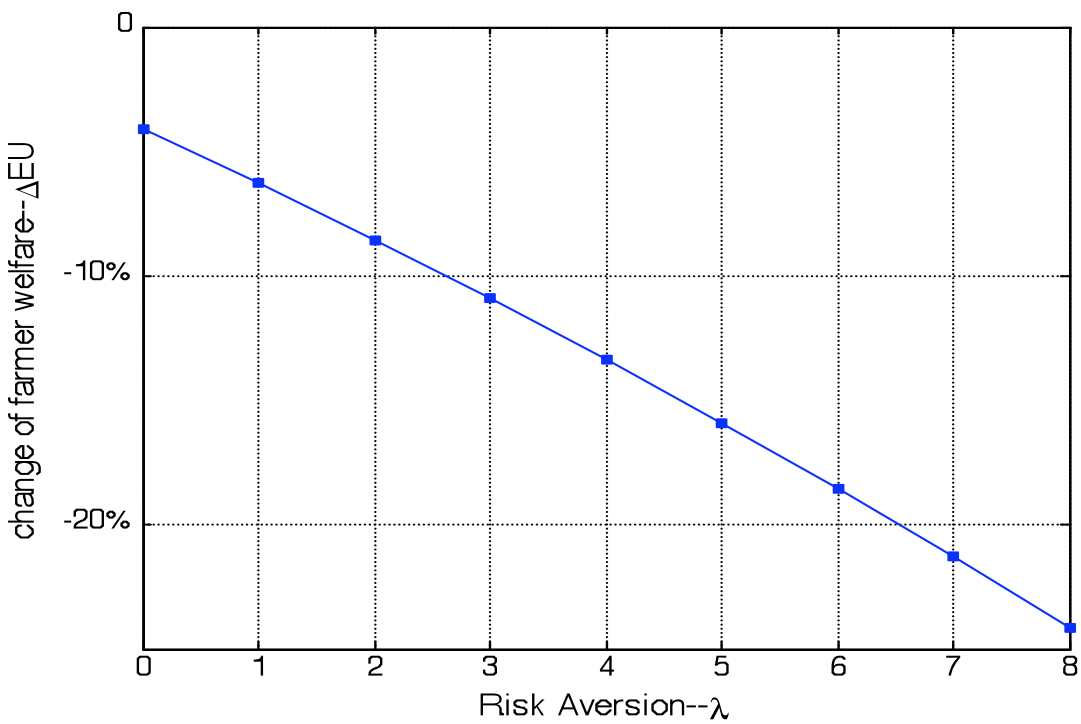


**Figure 17: Risk Aversion Negatively Correlates to the Change of Total Welfare**

Figure 18 combines risk-aversion coefficients from 0 to 8 and harvest cost variables from 0 to 0.6. Notice that for harvest cost equal to 0.4 or 0.6, under risk neutrality farmers would prefer retailers' alternative pricing behavior, which leads to higher expected farm income. However, as farmers become more and more risk averse, these gains become smaller and smaller. If farmers are high risk-averse ($\lambda > 6$), then they would prefer retailers' markup pricing behavior to the diversified alternative pricing regimes, because the gains from higher expected income no longer offset the increased risk under retailers' alternative pricing behavior.

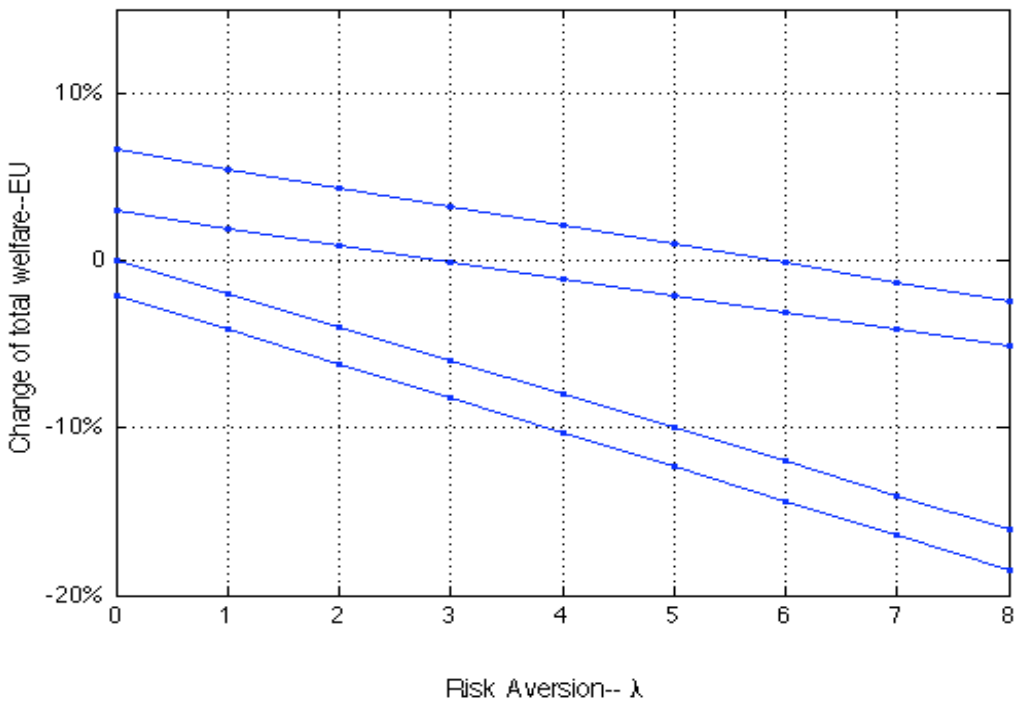


**Figure 18: Farmer Welfare under Risk Aversion at Different Level of Harvest Cost**

## IX.Conclusions

Using mark-up pricing as a baseline case, this paper simulates how different retail pricing behaviors affect farmers' welfare. The study shows that if harvest cost is sufficiently low, retail prices adjusting only partially, or not at all, to supply shocks tends to diminish farm income relative to the baseline case. In addition, these alternative retail-pricing behaviors exacerbate farm price volatility compared to markup pricing, exposing farmers to greater income risk, which further reduces the welfare of risk-averse farmers. This result remains true under an aggregate price regime that accounts for the coexistence of different pricing strategies across chains. These results indicate that the price dispersion in the retail market and the loose connection between retail price and farm price can be harmful to producer interest under certain conditions.

However, we also find that if a sufficiently large harvest cost places a lower bound on the farm price, whereas there is no comparable upper bound, alternative retail pricing behavior may increase farm income, compared to the markup pricing case. This is because the farmers benefit fully from volatility-induced price increases but are protected from the worst price decreases. Meanwhile, increased farm price volatility induced by retailers' alternative pricing strategies also increases farm income risk. The welfare for risk-averse farmers increases with the expected farm income and decreases with risk. The overall welfare effect to farmers induced by different retail pricing behaviors depends on the level of the harvest cost, the farm demand elasticity, the magnitude of farm supply shocks, and the specification of farmers' risk attitude.

The method and conclusions in this paper have potential policy application to other countries, including less developed countries. More than half the population typically engages in agricultural activities in these countries, most of whom are among the poorest population, so

farmers' welfare evaluation and improvement represent critical policy concerns for these countries. To the extend that retail chains in these countries set price in similar patterns to those observed in the US, the methods and conclusions presented in this paper should apply.

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