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Investigating Impacts of Fuel Costs on Retail Prices for Local and Non-local Milk Products

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Recent high oil prices may have effectively lessened existing price gaps between locally produced goods and competing non-local markets, therefore making it more affordable for people to purchase local goods.

Also in this issue

Each item in the typical American meal or snack has traveled an average of 1,500 miles. If every person in the United States ate just one meal per week containing only foods grown locally, U.S. oil consumption would decrease by over 1.1 million barrels of oil per week.

While eating local is proposed as an easy and relatively cost-effective way to reduce our impact on the environment, in a recent *ARE Update* article Sexton (Vol. 13, No. 2) shed some more light on this discussion by outlining health and environmental welfare implications of restructuring food towards "local" production, looking at a variety of crops and products in the United States. Sexton highlights that not all crops (and fresh products) would be available locally—thus decreasing consumer choices and welfare. Also, Sexton contends that switching to local farms may be inefficient, as it would eliminate economies from large-scale production and comparative advantages that emerge when regions specialize in producing foods to which they are relatively best suited and then engage in trade with other regions.

Our focus is to investigate whether increasing oil prices may be transferring demand to locally produced goods by reducing price gaps between local and non-local products because local goods are transported shorter distances. Increases in costs of inputs needed to produce a food product, including the costs to transport the product from production or processing location to the retail store, should over time "pass-through" to affect the retail price paid by consumers.

Although this is the first paper to investigate different price pass-through rates for local and non-local foods, numerous studies have examined the impact of energy prices on overall food prices, but with no distinction made between local and non-local goods. These studies stress the importance of assessing the amount of energy used to produce a product in determining its impact on the product's price, and in our paper we investigate discrepancies in pass-through of input prices into retail prices by distinguishing local and non-local milk products in the analysis.

Data and Empirical Strategy

We use an Information Resources Incorporated (IRI) panel scanner data set of weekly prices for numerous milk products produced by several vendors sold at several retail stores in 51 different cities located in 32 states (Table 1). Milk was chosen because both local and non-local versions are available in many states and stores, and since milk items have barcodes, prices are easy to track over time. It is also available in many sizes, brands, and types (organic, non-fat, chocolate, etc.). This allows us to include a large variety of items for each store and increases our sample size. The prices span five consecutive

Table 1. Summary of Store Locations for the Scanner Dataset

Region	State	Cities/Regions
East Coast	GA	Atlanta
	MA	Boston, New England, Pittsfield
	NY	Buffalo/Rochester, New York City, Syracuse
	NC	Charlotte, Raleigh/ Durham
	PA	Harrisburg/Scranton, Philadelphia
	CT	Hartford
	RI	Rhode Island
	VA	Richmond/ Norfolk, Roanoke
	SC	South Carolina
	D.C.	Washington D.C.
Gulf Coast	AL	Birmingham
	TX	Dallas, Houston
	MS	Mississippi
	LA	New Orleans
	NM	West Texas/ New Mexico
Midwest	IL	Chicago, Peoria/ Springfield
	OH	Cleveland, Toledo
	IA	Des Moines
	MI	Detroit, Grand Rapids
	WI	Eau Claire, Milwaukee, Green Bay
	IN	Indianapolis
	MO	Kansas City, St. Louis
	TN	Knoxville
	MN	Minneapolis/St. Paul
	OK	Oklahoma City, Tulsa
	NE	Omaha
Rocky Mtn	UT	Salt Lake City
West Coast	CA	Los Angeles, San Diego, San Francisco, Sacramento
	AZ	Phoenix
	OR	Portland
	WA	Seattle/Tacoma, Spokane

years, beginning on January 1, 2001 and ending on December 31, 2005. In addition, we use weekly gasoline prices from the Energy Information Administration for the corresponding period, where prices are categorized by region, grade, and type of gasoline. A composite of U.S. No. 2 diesel prices for all sellers is also included because it is assumed that milk products from both local and non-local vendors are shipped to stores in large vehicles that require diesel. Finally, the price per barrel of oil is included as a proxy for future gasoline prices.

We wish to estimate variations in price caused by changes in input costs, and to differentiate changes in costs for locally produced versus non-locally produced products. We also controlled statistically for unobserved variables that vary across states but not over time, and variables that vary over time but not across states—what economists call time and location fixed effects.

Results

Four empirical specifications were estimated in order to measure the differences in input-price pass-through between local and non-local milk products. Results are presented in Table 2. Results that are statistically significant are denoted with an asterisk. The estimates in the first column display only the effect of time and location, explaining variations in milk prices. This allows us to see the extent to which changes in milk prices are the result of regional and seasonal variations, such as temperature and various other weather conditions which are not included in the overall price model. Location and time explain 7.1% of the variation in milk prices— this is shown in Table 2 by the "R^2 statistic" reported at the bottom of the table.

The results shown in column 2 also include time and location fixed effects, but add product characteristics in an effort to discover how much of the variation in milk prices can be attributed to differing characteristics among the products. Here we see that product characteristics, such as size in fluid ounces, local product indicator (LOCAL) and product/brand-fixed effects, explain an additional 24.7% of the variation in prices relative to the specification in column 1.

The third specification (column 3) adds variables for current and lagged fuel costs. As noted, we include three different measures of fuel costs: Diesel Price, Gas Price, and Barrel Price. To allow for delayed pass-through of cost changes, we also include the diesel price lagged one, two, and three weeks—denoted as Diesel 1, Diesel 2,

Table 2. Results of Price Regressions, Dependent Variable: Price of Milk Product i at Time t

	Coefficient			
	1	2	3	4
Fluid oz.		0.014*		0.0140*
LOCAL		0.0094*	0.7701*	0.6646*
Diesel Price			0.0764*	0.0374*
Gas Price			0.0193*	0.0426*
Barrel Price			0.0007*	0.0006*
LOCAL Diesel			0.0133	0.1079*
LOCAL Gas			-0.006	-0.0328*
LOCAL Barrel			-0.0064*	-0.0079*
Diesel 1			0.1077*	0.0869*
Diesel 2			0.1080*	0.0871*
Diesel 3			0.1080*	0.0874*
LOCAL Diesel 1			-0.1188*	-0.1039*
LOCAL Diesel 2			-0.1238*	-0.1075*
LOCAL Diesel 3			-0.1205*	-0.1053*
State Fixed Effects	Yes	Yes	Yes	Yes
Year Fixed Effects	Yes	Yes	Yes	Yes
Product Fixed Effects	No	Yes	No	Yes
R Squared	0.071	0.318	0.08	0.323

Number of observations for each sample: 16,103,465
** Significant at the 1% level*

and Diesel 3 in Table 2. Then, to ascertain whether there is a different effect on pass-through for locally produced milk products, we interact the variable denoting a local product (LOCAL) with each of the six variables measuring fuel costs. We also include as an explanatory variable an indicator for a local product with the variable LOCAL. These interaction variables are denoted as LOCAL Diesel, LOCAL Gas, LOCAL Barrel, LOCAL Diesel 1, LOCAL Diesel 2, and LOCAL Diesel 3 in Table 2.

In column 3 of Table 2, we add gas prices and LOCAL variable indicators to the specification listed in column 1 of the same table. This model shows the role of fuel prices in explaining variations in products' prices, in addition to the differences explained by differences in space and time. After subtracting the explanatory power provided by the location and time variables, we see by comparing the R^2 statistics that gas and oil prices explain only a small fraction of the variation in milk prices—about .07%.

The final column 4 of Table 2 combines the previous three specifications. Here, we are able to ascertain the full impact of gas/oil prices on local goods. All parameters are statistically significant in this specification. Note first that locally produced milk products are more expensive, other factors constant by about $0.66. All six of the fuel cost variables are positive, meaning that higher fuel costs pass through to cause higher retail prices. However, in five of the six instances the interaction of the LOCAL variable with the fuel-cost variables has a negative coefficient. This result means that locally produced milk products experienced less of a price increase due to higher fuel costs than non-local products, no doubt due to the fact that local products are transported a shorter distance than non-local products. In most cases the coefficient on the interaction variables involving LOCAL are of a similar magnitude to the corresponding coefficient on the fuel-cost variable, meaning that there is little impact of higher fuel costs on prices of locally produced milk. For example, the coefficient for Diesel 1 (diesel price, lagged one week) is 0.1077, and the coefficient for LOCAL Diesel 1 is -0.1188.

Conclusion

Our main finding is that there is a substantial and negative difference in the way increases in oil prices affect the price of local and non-local milk products. This means that increased oil prices lead to larger price increases for non-local goods than they do for local milk products. Concerns about the health and environmental costs of transporting food have lead to an increased awareness and abundance of local food products. The monetary costs of transporting food reached new heights in 2008 when oil prices spiked to record highs. The price of a barrel of oil in May 2007 went from $65 dollars to an all time high of $147. During this same time, the average price of a gallon of gasoline rose to $4.11.

Given our empirical findings, the extremely high oil prices may have reduced or eliminated price gaps between the two types of goods, making it more affordable for people to purchase locally produced goods. What remains to be studied is whether the changes in relative prices have caused consumers to eat more locally grown food and, more importantly, whether eating local has empirically measurable health and environmental impacts, as discussed in Sexton (2009).

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Faculty Profile: Katrina K. Jessoe (Clark)

Katrina Jessoe (Clark)
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Katrina Jessoe joined the faculty of the Department of Agricultural and Resource Economics at UC Davis as an assistant professor in August 2009. Katrina earned her Ph.D. in environmental and natural resource economics from the School of Forestry and Environmental Studies at Yale University. She received a B.A. in Ecology and Evolutionary Biology from Princeton University, and a Masters in Environmental Management from the Bren School at the University of California, Santa Barbara. While at UCSB, she worked as a summer intern at Resources for the Future.

Katrina's dissertation, "The Economics of Drinking Water Quality," evaluates the impacts of drinking water regulations in rural India and the United States. In rural India, her research examines whether the expansion of protected groundwater supplies, a government-sponsored intervention designed to improve human health, reduced private expenditure on drinking water quality, offsetting some of the water quality and health gains from source protection. She finds that source protection reduces the probability of in-home treatment by 27 to 39 percentage points, offsetting some of the quality gains from improved sources. Her research demonstrates that behavioral choices partly counteract the health benefits from source water quality improvements.

At Davis, she plans to continue researching questions at the intersection of environment and economic development. An ongoing research project (co-authored with Reena Badiani) explores the impact of subsidized electricity tariffs for agricultural users on groundwater extraction, agricultural productivity, and industrial development. Preliminary results suggest that a 10% decrease in subsidies would reduce groundwater extraction by 5.5%, costing farmers 12% in agricultural revenue. The authors are now considering the implications of these subsidies for crop choice, rural wages, and electricity theft in the rural and industrial sectors.

A second portion of Katrina's dissertation (co-authored with Lori Bennear and Sheila Olmstead) investigates if the regulatory design of the Total Coliform Rule (TCR), a rule governing bacterial contaminants in drinking water supplies, motivates water suppliers to strategically avoid drinking water violations. The structure of the TCR—a percentage-based rule—provides incentives for some piped drinking water systems to avoid violations by taking additional water quality samples. In the United States, water systems that take at least 40 samples in a month incur a monthly TCR violation if more than 5% of those samples test positive. Water suppliers that are in violation of the TCR may strategically draw additional negative samples to remain below the 5% violation threshold. This research estimates the prevalence of this behavior and its potential impact on violations using monthly data for more than 500 Massachusetts water systems. Results provide evidence that strategic over-sampling is occurring and find that almost one-third of monthly TCR violations may go undetected due to this strategic behavior.

Since moving to Davis, Katrina has begun collaborations with UC Davis professors Jeffrey Williams and David Rapson. Jessoe and Rapson, have partnered with a Connecticut electric utility to implement a randomized controlled trial to assess the value of home area network technology (a portfolio of devices that provides real-time electricity information to customers), and compare this value to that of other interventions designed to manage energy consumption.

Their research will weigh in on the debate surrounding the comparative power of price and non-price interventions to influence individual behavior. It will also contribute to policy discussions about the impact and importance of a next-generation residential energy technology that is central to energy conservation strategies in the United States.

Katrina lives in San Francisco with her husband, Austin Clark. In her free time, Katrina enjoys being outdoors—whether it be playing tennis, hiking, or exploring the neighborhoods of San Francisco—traveling, and spending time with her family.

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The Problem of Over-Shooting Supplies of a Tree Crop

Steven C. Blank

California producers comprise a large share of the market for many perennial specialty crops, so supply changes in California have a large effect on market prices. We look at the impacts of ever-increasing California supplies of walnuts and almonds and discuss possible grower risk-management strategies and industry strategies to expand demand to match higher supplies.

Since 2001 average walnut yields have increased dramatically—up from 1.5 tons to 2.25 tons per acre in 2010. Prices fell more than yields increased in some years, thus creating lower total sales revenues per acre for California growers.

Tree crops have been a large and important part of California's agricultural production sector for decades, yet those crop markets still suffer from a unique problem brought on when the production of a perennial crop is highly concentrated. In brief, the problem is that total industry supplies of a tree crop (or any other perennial crop with a long timespan between planting and reaching full production) will often have significant effects on total industry revenues received by growers, such that growers are punished for increases in industry output. In a mature market total industry supplies can "over-shoot" the quantities demanded, causing a large price decline that leads to a decline in total industry revenues for the crop year.

This article uses the almond and walnut industries in California as examples to illustrate this over-shooting problem. Recent data from each market are used to illustrate the problem. Then, the simple economics underlying the problem are explained. Finally, some implications of the problem are outlined.

The Downside of California's Dominance in Tree Crop Markets

A key factor in the over-shooting problem is that almond and walnut growers in California each produce over 99% of the total crop in the United States; they effectively comprise the market in this country because only small "hobby" farms exist in the 25–30 other states reporting some almond or walnut output. This creates some unique economic challenges and opportunities for growers in California. Strategies must be developed at the industry-level to handle ever-increasing supplies without depressing grower prices, and at the grower level to manage the income risk inherent in these settings.

Production decisions are made at the farm level but when aggregated, they have dramatic effects on the financial results of the entire industry due to California's dominant role in the domestic market, as well as its prominent role in the global export market. In particular, industry yields and total output are directly linked to market prices, as shown below.

The fact that over 99% of both almond and walnut production in the United States is concentrated in California means that most orchards are in a similar climate zone and, thus, subject to the same production situation.

That causes supply fluctuations in the same direction for nearly all producers and, hence, the entire industry. Next, those supply fluctuations directly lead to price swings because, effectively, California's supplies are the domestic market's *total* supplies. As a result, nearly all producers in California have similar annual financial returns per acre in mature orchards, compared to growers of other tree crops.

Historical Evidence of Over-Shooting

The domestic markets for almonds and walnuts are volatile due to the influence of new acreage coming into production, thus causing significant changes in total supplies. The two California industries have a history of "over-shooting" the quantity demanded over time, thus depressing prices and incomes for some years.

This situation happened to almond growers in the 1990s, despite the market being much larger and more established compared to the markets for walnuts and other nut crops. It also happened to walnuts in the 2000s.

In essence, over-shooting results from individual decisions within a perennial crop industry that has relatively good market prospects. Growers are attracted to the profit potential for such a crop, and they plant new acreage. Unfortunately, it does not take much increase in acreage to expand supplies of the commodity beyond the level needed to satisfy the fairly stable domestic demand.

This problem is complicated by the fact that an almond tree normally takes six or more years to produce a full crop of nuts, and produces for 30-plus

Table 1. California Almond Production and Market Data, 2002–2010									
	2002	2003	2004	2005	2006	2007	2008	2009	2010
Bearing Acreage (acres)	545,000	550,000	550,000	590,000	610,000	640,000	680,000	718,000	740,000
Yield per Acre (pounds)	2,000	1,890	1,840	1,550	1,840	2,170	2,400	1,956	2,230
Production (million pounds)	1,090	1,040	1,010	915	1,120	1,390	1,630	1,410	1,650
Grower Price ($/pound)	1.11	1.57	2.21	2.81	2.06	1.75	1.40	1.60	NA
Value of Production billion $)	1.20	1.60	2.20	2.53	2.26	2.40	2.35	2.3	NA
Value of Production ($/ac)	2,203	2,909	4,000	4,281	3,703	3,753	3,451	3,239	NA

Sources: Noncitrus Fruits and Nuts 2004 Summary, U.S. Department of Agriculture, National Agricultural Statistics Service (USDA NASS), Fr Nt 1-3 (05), July 2005; Noncitrus Fruits and Nuts 2007 Preliminary Summary, USDA, NASS, Fr Nt 1-3 (08), January 2008; and Noncitrus Fruits and Nuts 2009 Yearbook, USDA, NASS, May 2010. NA = data not available

years, meaning that farmers have to forecast domestic demand decades in advance before making the decision to plant new acreage. If there is no coordination of planting decisions within the industry, too many growers may "jump in" during some years.

This type of over-shooting adversely affects all growers because prices drop significantly. For almonds, there is clear evidence of over-shooting in the 2005–2009 data in Table 1. Total industry revenues per acre were much lower in 2009 than they were in 2005; prices fell more than output increased over the period.

For walnuts, there is evidence of over-shooting in the 2005–2008 data in Table 2. Total industry revenues per acre were much lower in 2008 than they were in 2005 through 2007; just as for almonds, walnut prices fell more than output increased over the period.

Revenue Effects of Expanding Output

Total industry revenue is the product of average yields per acre times the number of bearing acres harvested times the average market price. In recent years, both yields and total acreage of almonds and walnuts have increased. As a result, it should not be surprising that there have been significant swings in prices for both almonds and walnuts.

Almonds

Almond yields per acre have increased in most years recently (second row of Table 1). For example, between 2005 and the peak year of 2008, there was a 55% increase in average yield. Despite a slight decline during the next two years, the average yield in 2010 was the second-highest on record. The scale of the growth in yield, combined with steadily increasing acreage, pushed total production (shown in the third row of Table 1) to record levels in 2008, and then again in 2010.

This creates a challenge to the industry because of its implications for almond prices and for the industry's profitability in serving market segments that are expanding much more slowly over time. For example, most domestic market segments have relatively smooth levels of (inelastic) demand across time, so buyers for those market segments want a relatively stable flow of a commodity. The supply expansion continues to outpace growth in domestic markets for almonds. As a result, yearly crop surpluses go into export markets, most of which have lower average prices, thus lowering growers' average revenues per pound.

Changes in almond supplies have the potential to significantly influence prices for U.S. growers. Historically, California's increasingly large crops have significantly depressed average prices for producers. Note the decreasing prices for 2005–08 shown in the fourth row of Table 1. The average price in 2008 of $1.40 per pound was only about half of the average price of $2.81 per pound received by growers in 2005. As a result, the total value of utilized production, (which is the quantity used, not stored) shown in the fifth row of Table 1, is lower in 2008 ($2.35 billion) than it was in 2005 ($2.53 billion), despite the record yields produced during 2008.

The risks to individual growers can be seen more easily when looking at gross revenues per acre. As shown in the bottom row of Table 1, revenue per acre (expressed as dollar "value of production per acre") was significantly higher in 2005 ($4,281) than it was in 2008 ($3,451). In other words, prices fell more than yields increased, thus creating *lower* total sales revenues per acre for California growers. The problem is apparent again in the revenue per acre results for 2009.

This downward trend in revenues is a major challenge to the industry because individual producers must manage their personal financial risks associated with the underlying market price swings. Simply stated, declines in sales revenues mean declines in profitability that can threaten the economic sustainability of many producers.

Walnuts

Walnut yields per acre had been fairly stable for decades until 2001, when average yields exceeded 1.5 short tons for the first time. Since that year, average yields have increased dramatically, up to 2.25 tons per acre in 2010 (second row of Table 2). That means there was a 50% increase in average yield over the nine-year period of 2001 to 2010. The

Table 2. California Walnut Production and Market Data, 2002–2010

	2002	2003	2004	2005	2006	2007	2008	2009	2010
Bearing Acreage (acres)	210,000	213,000	214,000	215,000	216,000	218,000	223,000	227,000	227,000
Yield per Acre (short tons)	1.34	1.53	1.52	1.65	1.60	1.50	1.96	1.93	2.25
Production (short tons)	282,000	326,000	325,000	355,000	346,000	328,000	436,000	437,000	510,000
Grower Price ($/ton)	1,170	1,160	1,390	1,570	1,630	2,290	1,280	1,690	NA
Value of Production (million $)	329.94	378.16	451.75	557.35	563.98	751.12	558.08	738.53	NA
Value of Production ($/ac)	1,571	1,775	2,111	2,592	2,611	3,445	2,503	2,503	NA

Sources: 2010 California Walnut Objective Measurement Report, USDA, NASS, September 3, 2010; California Walnut Acreage Report, USDA, NASS, May 26, 2006.
NA = data not available

average yield in 2010 was the highest on record. The scale of the growth in yield, combined with steadily increasing acreage, pushed total production (shown in the third row of Table 2) to a record level of 510,000 tons in 2010.

Changes in walnut supplies have significantly influenced prices for U.S. growers. Note the increasing prices for 2005-07, shown in the fourth row of Table 2. The average price in 2007 of $2,290 per ton was about 46% above the average price of $1,570 per ton received by growers in 2005. As a result, the total value of utilized production, shown in the fifth row of Table 2, is higher in 2007 ($751 million) than it was in 2005 ($557 million), despite the lower yields produced during 2007. Conversely, yields per acre and total production increased significantly in 2008, causing the average price to drop about 46% to $1,280 per ton. As shown in the bottom row of Table 2, revenue per acre was significantly lower in 2005 ($2,592) than in 2007 ($3,445).

In 2008 the drastic price decline caused average revenues per acre to fall to $2,503—lower than they had been in 2005, despite a 23% expansion of production in 2008 compared to 2005. Again, prices fell more than yields increased in some years, thus creating *lower* total sales revenues per acre for California growers in those years.

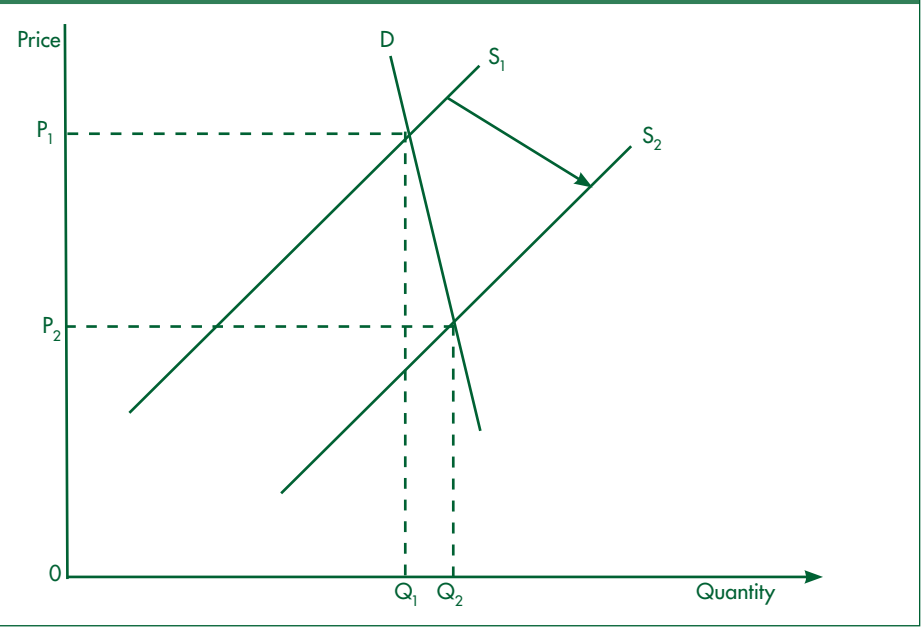
The Economics of Over-Shooting

Over-shooting can occur in any commodity market, but it is more prevalent and problematic in mature markets for perennial crops. A "mature" market is one in which demand (i.e., consumption) per capita is fairly stable because consumption uses and patterns are fairly specific and stable, so increases in total demand are mostly due to an increasing population. In economic terms, this means the "demand curve" is inelastic in the short-term. Figure 1 illustrates how such a stable market reacts to changes in supplies available.

In the hypothetical market illustrated in Figure 1, the dramatic revenue effects of a supply increase can be seen. The original quantity demanded is Q_1 and the average market price is P_1. The total revenue is the area inside the rectangle created by the dashed lines from Q_1 and P_1 to the demand curve. After the supply curve expands from one year to the next (from S_1 to S_2), the new quantity demanded from the industry is Q_2 and the new market price is P_2. The industry's total revenue is the area in the new rectangle created by the dashed lines from Q_2 and P_2 to the demand curve. The percentage of change in quantity is much smaller than the percentage change in price, thus the resulting revenue totals have decreased from the first year to the second. The growers have expanded their output and been "rewarded" with a decrease in their sales revenues!

In the real markets for both almonds and walnuts, demand has expanded over time partly in response to marketing efforts by the industries. For

Figure 1. Inelastic Demand Means Revenue Declines When Supplies Over-Shoot



both crops, most of the growth in demand has come from expanding into new markets—especially overseas. In recent years, about 60–70% of California's almonds and 50–60% of walnuts have been exported. However, domestic markets have grown also—although more so for almonds.

Domestic per capita consumption of almonds was fairly stable during the 1980s and 1990s, averaging about 0.6 pounds per year, before rapidly rising to about 1.2 pounds in 2008. In comparison, consumption per capita of pistachios was 0.2 pounds in 2008, and for walnuts it was 0.5 pounds. Domestic per capita consumption of walnuts is the second-highest for any nut and has not expanded in decades. In general, walnut per capita consumption has averaged about 0.4 to 0.5 pounds per year since before 1980.

Changing demand requires long-term investment, usually taking years as marketers find new markets, inform potential consumers, and capture sales opportunities. Thus, the demand curve in Figure 1 is gradually moving to the right, slowly helping to alleviate the effects of over-shooting.

Implications of Over-Shooting

Only an industry-wide approach can influence the total supply of a crop. Individual growers have negligible effects on total supplies, thus they cannot solve the over-shooting problem; they can only develop risk management plans for dealing with the revenue effects of the phenomenon.

The geographically concentrated nature of many California tree crop industries would facilitate industry-wide efforts aimed at "supply control." The ultimate goal of such strategies is to gain control over total industry supplies of a commodity so that price levels can be controlled to some extent. One example of a supply-control program used in California is a "tree-pull" effort, in which an industry tries to reduce its total acreage and, thus, total output.

The almond and walnut industries each have supply-control programs in their arsenals as part of the federal marketing orders that authorize various forms of collective action in the industries. The Almond Board has occasionally utilized supply control in the form of required reserves held by handlers. However, a reserve program has not been implemented since the 1990s, and there is apparently no appetite among growers or handlers in either the almond or walnut industries to use supply-control programs.

This makes demand expansion the main industry tool to combat declining prices due to ever-expanding supplies. The data shown in the two tables indicate that the almond and walnut industries, in general, have each done a good job of expanding markets so as to keep revenues increasing in most years. The potential of these industries to produce ever-larger crops through expanding acreage and yields means, moreover, that the almond and walnut industries must continue to invest in efforts to expand markets for their crops.

However, the instances of over-shooting supplies noted in this article point out that tree crops are a volatile investment. In any perennial crop industry, individual growers are subject to the revenue risks caused by overshooting and, therefore, should have a management plan in place. The choices facing an individual farmer are whether or not to produce the crop and, if so, how to manage the revenue risk over time. The choice depends on the rate of return expected on the investment, as well as the compatibility of the crop with the interests and skills of the farm household.

Part of this assessment will involve risk and the farmer's tolerance for it. As a person's level of risk aversion increases, it is increasingly likely that some degree of "investment" diversification is needed to reduce the household's exposure to swings in total income over time. This means more-risk-averse people should produce more than just tree crops, adding other commodities to their "crop portfolio" to spread their financial risk across commodity markets.

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Smallholder Livestock Production and the Global Disease Risk

Drew Behnke, Samuel Heft-Neal, Jenny Ifft, Ricardo Soares Magalhaes, Joachim Otte, Dirk Pfeiffer, David Roland-Holst, and David Zilberman

Emergence of highly contagious diseases from animal populations have heightened public awareness of global linkages between livestock production and public health. We examine livestock management practices for smallholders in developing countries and their linkage to the global commons of viral disease resistance. We conclude that a pro-poor multilateral initiative is needed to reduce animal and pandemic disease risks.

Recent emergence of highly contagious diseases from animal populations, including Severe Acute Respiratory Syndrome (SARS) and Highly Pathogenic Avian Influenza (HPAI), have raised public awareness of global linkages between livestock production systems and public health. The "globalization" of HPAI, for example, reminds us that local animal husbandry can impact global health risk. Because of dramatic changes in personal mobility and the emergence of worldwide agro-food networks, human populations now share a global commons of disease resistance that is now more apparent and immediate for everyone. Today's reserve of human immunity is constantly under threat from emerging viral organisms, many of which are incubating continuously within other animal populations.

Linkages between smallholder livestock management and global disease risk are apparent in Bovine Spongiform Encephalopathy (BSE), HPAI, SARS, and other contagious diseases of animal origin. Repeated HPAI outbreaks have drawn attention to this issue, and concerns for biosafety justify a better understanding of smallholder risk and disease incidence. For example, smallholder populations have suffered disproportionately from human infection, but this is to be expected because they are so numerous and often live within close proximity to animal populations.

Higher absolute human morbidity and mortality among this population does not, however, support an inference that smallholder practices are aggravating pandemic risk. Indeed, many aspects of smallholder production systems, including animal dispersion, genetic variety, etc., actually contribute to risk reduction. A balanced perspective on this issue can promote a better understanding of the role of smallholders in local, national, and global disease risk.

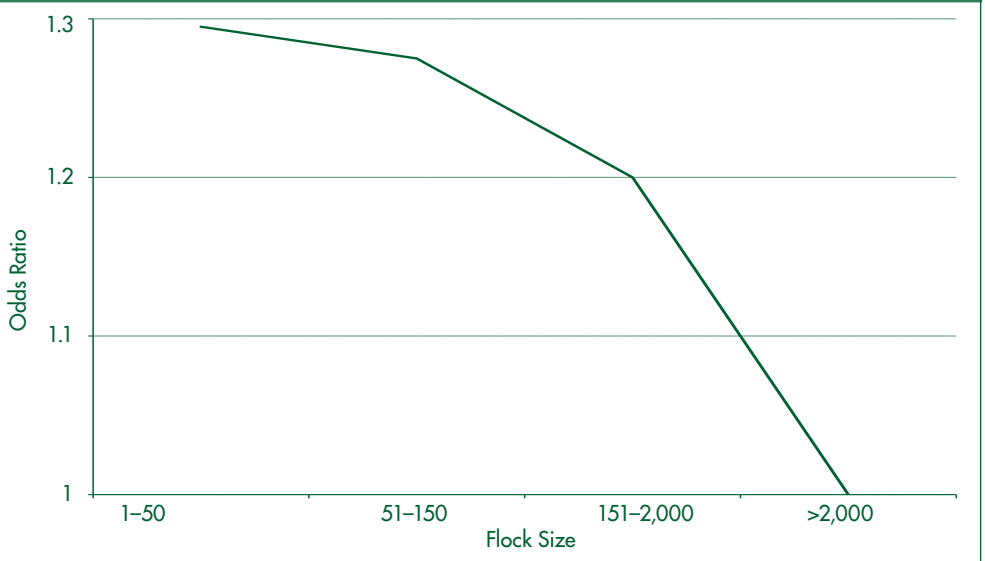
Smallholder Livestock Keeping and Biosafety

Because of their financial circumstances, smallholders are constrained from making significant investments in modern sanitary and phytosanitary (SPS) technologies for animal production and marketing. It should be recognized, however, that smallholder production presents important natural defenses to disease.

Despite their wide geographic and demographic dispersion, smallholder farmers have many fundamental attributes in common. These include significant reliance on local resources, such as plant and animal genetic material from established legacy varieties. Local varieties have three characteristics relevant to disease evolution: local adaptation, genetic divergence, and physical isolation. Specifically, legacy species have established themselves as robust against local environmental, nutritional, and biological stresses. Such hardiness can reduce vulnerability to opportunistic diseases that infect animals in less opportune conditions (such as those in large-scale production systems). Secondly, legacy varieties are genetically divergent, having evolved in enclave gene pools for long periods. This confers antiviral protection on them because they lack genetic homology with dominant commercial varieties that provide the most intensive substrate for viral incubation. Third, geographic isolation lowers risk for smallholder animals by reducing opportunities for viral transmission via interaction with outside animal communities.

Another important characteristic common to most smallholders is extensive production—animals are raised in free range and/or open air settings. This approach makes sense economically, making fuller use of marginal natural resources and ill-defined property rights, but it also confers two important animal health advantages. Firstly, animals are exposed to more diverse environmental stress and thereby become better able to mobilize immune resources against new viral agents. Second, viruses are themselves vulnerable to environmental stress. HPAI, for example, is extremely labile and becomes unstable without ambient moisture or upon exposure to sunlight. By keeping animals in more demanding conditions, smallholders reduce both the risk of original infection and also limit viral colonization and propagation.

Figure 1. Odds Ratios for HPAI Suppression in Viet Nam



Ratio of observed likelihood of poultry stock culling, by source of chicks, outside source/own source

Disease Transmission across the Food Supply

Smallholder populations may have more numerous human infection events, but this does not mean disease risk is flowing from smallholders to other producer and consumer populations. Certainly, vertical movement of infected livestock along the food supply chain will shift risk from producers toward consumers, but smallholder systems make very limited individual contributions to total supply chain risk. These producers are usually removed from consumers by market intermediaries who consolidate and process animals, multiplying opportunities for disease transmission in more stressful circumstances.

Because smallholders are vastly more numerous, they create more opportunities for individual infection which are unfortunately aggregated by downstream assembly and resale activities. Thus, investments in downstream biosafety, coupled with traceability that can isolate sources of infection, should be higher priority than blanket suppression of smallholder production. Because smallholders apparently represent lower per capita infection risk, an intensive, downstream approach to surveillance would be more cost effective than an extensive (farm by farm) approach.

Evidence on horizontal animal health risk, i.e., transfer of infection among producers, is more ambiguous. Clearly, this depends on individual producer biosafety, but also on the magnitude and direction of resource flows across producer populations.

In the livestock sector, these patterns are especially complex because of specialization at different stages of animal production and processing. Large-scale production at all stages can be highly concentrated, with small numbers of large, intensive facilities and even fewer responsible enterprises. In the poultry sector, individual large-scale egg and chick producers can sell to thousands of smallholders, and any upstream risk will multiply accordingly.

Large producers generally have more advanced biosafety capacity, but the intensity of their operations also poses higher risks for viral infection and propagation. Smaller producers seek to improve their balance sheets by acquiring stock from larger producers, but this relationship bridges biosafety regimes and is a primary threat to biocontainment. When small producers participate in such high-dispersion horizontal supply chains, they expose themselves to specific risk from their suppliers and to systemic risk from the distribution system.

To see the significance of this in practical terms, consider the results in Figure 1. This graph depicts results for Viet Nam poultry, showing the relative odds of experiencing a livestock cull for HPAI. For the ratio in question, the numerator is the observed likelihood of a cull for farms buying day-old chicks from outside suppliers, while farms in the denominator are self-sufficient.

More concerted efforts are needed to identify transmission pathways between diverse animal populations. In the case of HPAI, for example, migratory birds have been identified as a vector of global transmission, yet their effectiveness is not well documented and many experts believe this source has become a euphemism for illegal transboundary livestock trade. As yet, unexplained links between livestock varieties, including chickens, quail, ducks and pigs, may also be important to the cause of HPAI. Better evidence and more research is needed in this area.

Ultimately, patterns of disease risk transfer are an empirical question, but such imformation on HPAI remains fragmentary and inconclusive. The frequency of reported smallholder outbreaks, for example, is probably due more to their overwhelming numerical majority than to differences in biosafety. If disease risk were uniformly distributed across all production technologies, smallholders would account for well over 90% of reported outbreaks. Before resources are committed to restructuring the poultry sector, particularly in ways that increase the vulnerability of poor rural majorities, much more evidence and research is needed.

Conclusions

In an increasingly globalized food supply chain, livestock management and marketing practices everywhere influence human health risk. At the present time, smallholders are facing the prospect of significant adjustment costs because they have been implicated in adverse biosafety events like SARS and HPAI. If this approach is seen as punitive, it will undermine effective reporting and control responses, needlessly enlarging outbreaks and extending genetic incubation time.

Because of their ubiquity, smallholder livestock producers can play an essential constructive role in global disease prevention. Limiting opportunities for the emergence of pandemic pathogens is something that benefits everyone, everywhere, even if it is happening at the most microeconomic level. Smallholders need only modest but positive incentives to contribute to the global commons of disease prevention, while high-income countries will benefit most in economic terms. Recognizing these facts provides a strong collaborative basis for a pro-poor multilateral initiative to reduce animal and pandemic disease risks.

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