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Are Natural Gas Flows Responsive to Price Spikes?

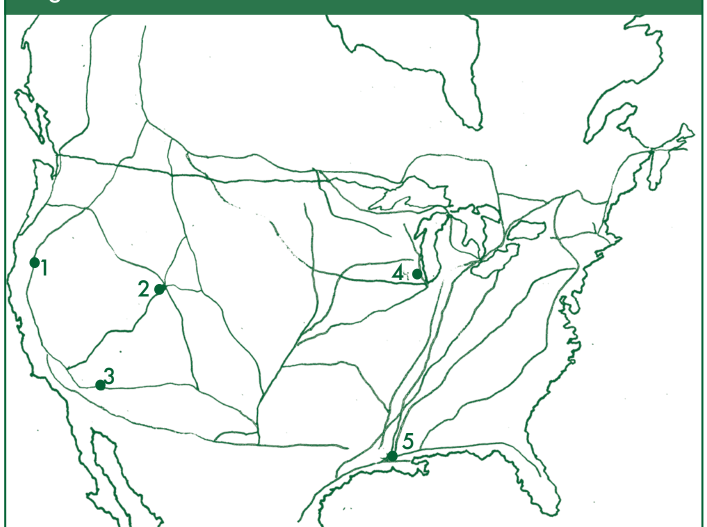
Rocio Uria and Jeffrey Williams

Differences in natural gas prices between pricing centers in California and other locations in the North American network have displayed, in the last few years, values that are difficult to justify in terms of traditional spatial price equilibrium models. Here, we document those extreme values and offer some explanations.

Even though most observers have concentrated on the worldwide increases in the price of energy in the last few years—spot prices of natural gas are now in the range of 6-8 $/MMBtu (million British thermal units), far above the 2-3 $/MMBtu of six or seven years ago—the spatial patterns in the price increases have been interesting in their own right, especially involving natural gas in California relative to elsewhere. Spatial differentials involving California have often been much too large to be justified in terms of transportation costs. Those large differentials have not always been to California's disadvantage. For much of early 2005 (and again in early 2006), price differentials were such that California should have been exporting natural gas, although it continued, of course, to import. Some of the explanation for these oddities can be found in capacity constraints in pipelines, in inventory availability, in changing seasonal needs, and in the pervasiveness of long-term contracts. However, not all price differentials make sense, at least not with the conventional concept of spatial price equilibrium.

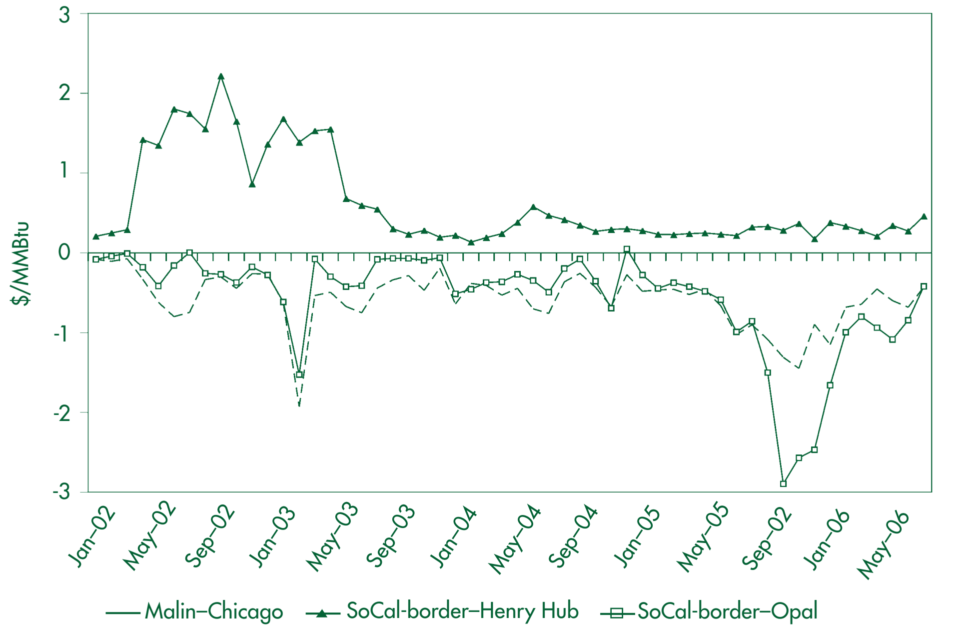
Figure 2 displays the evolution over the last four years of price differences involving locations at the California border and three selected pricing points within the North American network. These points are marked on the map in Figure 1. Opal, which is a gathering hub from producing wells, is representative of the price of gas produced in the Rocky Mountains, much of which flows to California. Whereas the Opal hub has direct connections to California; for the other two, the connections are indirect. Chicago citygate and Henry Hub, which is the crossing point for many pipelines in southern Louisiana, compete with California for gas from Alberta and from the Permian Basin in west Texas respectively. The circumstances behind

Figure 1. United States Natural Gas Network and Hubs



1. Malin 2. Opal 3. SoCal-border
4. Chicago Citygate 5. Henry Hub

Figure 2. Selected Natural Gas Price Differentials (January 2002 – June 2006)



each of the three extreme peaks and troughs in Figure 2 are different. We describe each of them and investigate whether flow volumes into California adjusted to these extreme changes in the relative value of gas elsewhere.

Behavior of Spatial Price Differences

From 2002 through 2006, prices were higher at the Southern California border than at Opal, which is consistent with the latter being located in a producing area and California importing gas from there. The large spatial differential observed for this series in 2002 was due to capacity constraints in the Kern River pipe-line—the pipeline that brings Rockies gas to Utah, Nevada, and California. That pipeline's capacity doubled in the spring of 2003 at which point the price difference decreased abruptly: from more than 1.00 $/MMBtu to an average 0.32 $/MMBtu after May 2003.

Does the 0.32 $/MMBtu difference prevailing after May 2003 itself makes sense? According to the published tariff, the variable cost per MMBtu transported in the Kern River pipeline is 0.06 $/MMBtu, much below $0.32. The compressors burn some of the natural gas to push the rest along the pipeline. Thus, in order to calculate the minimum price differential for which transporting gas from the Rockies to California is economical, fuel losses incurred by compressors during transportation must also be included. The percentage loss depends on the number of compressors, which is a function of miles traveled. For gas coming to California, the loss is approximately three percent which, given price levels, amounts to about 0.15 $/MMBtu. Thus, the total variable cost per unit of gas is on the order of 0.21 $/MMBtu, which is slightly below but comparable to the observed post-expansion price differences in Figure 2. After May 2003, the prevailing 0.32 $/MMBtu difference seems to make sense. The pre-expansion differential is therefore the implicit price of the capacity constraint.

Whereas the SoCal border–Opal differential has always been positive, the spatial differentials with respect to consuming centers east of the Rockies have usually been negative, as is the case for the other two series in Figure 2. Chicago competes with California for Canadian gas and is willing to pay higher prices, hence the negative difference. As for the third series in Figure 2, gas produced in the Permian Basin in west Texas can be directed either east or west. Natural gas in California typically trades at a discount relative to the Henry Hub, providing one more indication of the higher willingness to pay for gas in eastern than in western markets.

Prices in California and competing markets east of the producing areas departed considerably on two occasions during this period. First, in February of 2003, spot prices skyrocketed in Northeastern markets due to a cold snap at the end of a colder-than-normal winter in that region. At the New York citygate, for example, the spot price on February 25, 2003 was 25.67 $/MMBtu. However, one week before it had been 10.11 $/MMBtu and one week after it was back down to 9.58 $/MMBtu. Second, Hurricane Katrina had a great and lasting impact on natural gas prices. The Henry Hub price was 9.86 $/MMBtu

Table 1. Trend, Seasonality, and Spikes on the Selected Price Differentials

	Constant	Trend	Season	February 2003	post-Katrina	R-squared
SoCal-border–Opal	**1.097** (4.124)	0.004 (0.740)	**0.321** (2.323)	0.236 (1.059)	–0.030 (–0.361)	0.73
Malin-Chicago Citygate	**–0.249** (–3.176)	**–0.006** (–2.514)	**–0.177** (–3.099)	**–1.603** (–30.711)	**–0.596** (–9.158)	0.72
SoCal-border–Henry Hub	0.018 (0.211)	**–0.014** (–4.915)	–0.103 (–1.175)	**–1.361** (–21.519)	**–1.720** (–8.444)	0.83

Note: t statistics are in parentheses. Coefficients in bold are significant at the 5% level.

the last trading day before the hurricane hit the coast of Louisiana on August 29, 2005 and climbed up to 12.35 $/MMBtu the day after.

The 25 percent increase at the Henry Hub brought about by Katrina rippled throughout the country and became amplified on eastern markets and muffled in western markets. For instance, the New York and Boston citygates experienced 33 percent and 32 percent price increases, respectively. On the other hand, prices increased by 17 percent at Opal and by 15 percent at the Southern California border. As shown in Figure 2, the price difference between Henry Hub and California pricing points fell dramatically and took long to recover. The Malin–Chicago difference also experienced a plunge, although it was smaller in magnitude.

Spatial Prices and Flows of Natural Gas

Given the magnitude of the price differences in February 2003 and late 2005, economic models of spatial price equilibrium would surely predict a reversal in flow. In practice, the flexibility of flow patterns will depend on the number of arbitrage paths in the network and the portfolio of market services available to customers.

The North American natural gas pipeline and storage network is highly developed, with over 70 trading points and almost 400 underground storage facilities spread throughout the United States and Canada. The New York Mercantile Exchange (NYMEX) offers an actively traded natural gas futures contract which calls for delivery at the Henry Hub. As liquidity in spot and futures markets increased over the last decade, the extent to which long-term contracts are used for purchasing natural gas has decreased. A large proportion of natural gas purchases and transportation decisions are taken during the last five business days of each month—the so-called bidweek—for gas flowing the following month. Subsequent adjustments to the monthly commitments can be made through additional transactions in the daily spot market. Every producing region has alternative destinations to which it can send its gas and every market center can obtain its gas from alternative sources. Thus, producers and buyers can arbitrage spatial price differentials to the extent that capacity limits and institutions permit.

To assess if actual molecules of natural gas are flowing toward the areas in which they are most highly valued at each moment in time, we examine spatial price differentials and flow patterns focusing on events that triggered acute price spikes during the period of analysis, namely January 2002- June 2006. Table 1 emphasizes trends and seasonal factors in the price differences. The negative gaps between Malin and Chicago, and between SoCal-border and the Henry Hub, have widened over the period of analysis. No statistically significant seasonality can be found in the SoCal-border–Henry Hub differential. For the other two series, however, relative prices shift from the injection season to the winter months. The price difference between Malin and Chicago decreases by 0.17 $/MMBtu during the injection season, while the difference between SoCal-border and Opal increases by 0.32 $/MMBtu during that same period. By a relative seasonality argument, we should expect Canadian flows to the West Coast to be relatively smaller during the injection season than during the winter months and Rockies flows to California to be relatively higher during the summer.

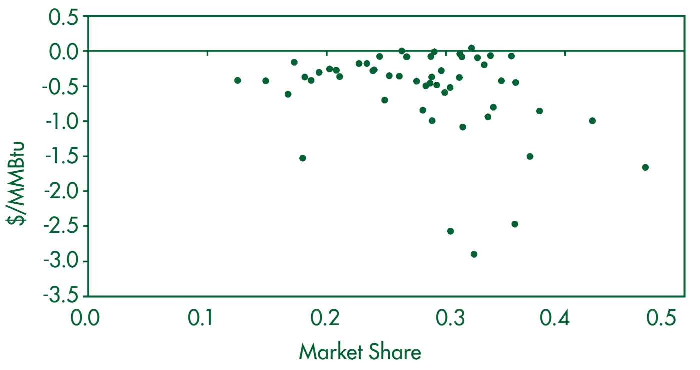
Table 2. Trend, Seasonality, and Effect of Price Spikes on Selected Market Shares

	Constant	Trend	Season	February 2003	post-Katrina	R-squared
Canada–West	**0.1817**	−0.0003	**−0.0150**	**−0.0649**	−0.0156	0.27
	(22.543)	(–1.388)	(–2.181)	(–9.350)	(–1.474)	
Canada–Chicago	**0.2073**	0.0002	**0.0116**	**0.0284**	**0.0079**	0.26
	(38.488)	(1.522)	(2.359)	(5.821)	(2.051)	
Rockies–West	**0.2537**	**−0.0015**	**0.0262**	−0.0106	0.0059	0.89
	(23.729)	(3.911)	(3.023)	(–1.197)	(0.784)	
Rockies–East	**0.4359**	0.0008	**0.0289**	0.0013	**−0.0208**	0.55
	(43.792)	(1.811)	(3.302)	(0.164)	(–2.205)	
Permian–West	**0.2338**	**0.0025**	**−0.0380**	**−0.0868**	−0.0330	0.52
	(9.269)	(4.374)	(–2.442)	(–4.601)	(1.466)	
Permian–East	**0.5408**	**−0.0032**	**0.0806**	**0.0871**	−0.0076	0.66
	(18.616)	(–4.539)	(4.919)	(4.139)	(–0.350)	

The magnitude, trend, and seasonal factors of market-share series representative of the competition between eastern and western market centers for each of the producing regions serving California are summarized in Table 2. These regressions also control for the effects of the cold spell in the winter of 2003, the abrupt change in prices triggered by Hurricane Katrina and, in the regressions involving to the Rockies, for the Kern River pipeline expansion.

The constant in the regressions presented in Table 2 can be interpreted as the baseload market share that deliveries on westbound versus eastbound pipelines represent for each of the producing regions. Market shares on Canadian gas imports by states on the Pacific Coast versus the Midwest are similar and have remained stable over the period considered. However, a much larger proportion of gas exports from the Rockies and the Permian Basin goes to eastern rather than western

Figure 3. Share of Permian Exports Going West versus West–East Price Differential



states. The western market share has trended upwards for Permian gas but downwards for gas from the Rockies.

Seasonality in market shares is strong and consistent with what spatial price equilibrium models would predict given the seasonality in price differences presented in Table 1. Deliveries of Canadian gas to the western states, and to California in particular, decrease during the injection season as the premium that eastern markets are willing to pay over California is higher at that time of year. For Rockies gas, the seasonal shift is positive in both the eastern and western directions implying that the remainder (namely northbound exports) go down during the summer months. For Permian gas, even though no statistically significant seasonality appears in the price difference, the share of gas flowing toward eastern markets increases during the summer months.

The short-lived price spike observed in February 2003 had a larger effect on flows than the sustained increase in the East–West difference that followed Hurricane Katrina. In February 2003, western market shares in Canadian and Permian exports decreased by six and eight percentage points, respectively, relative to what would be normal at that time of the year. However, no statistically significant effects are observed for westbound flows in the September–December 2005 period despite the significant widening of the gap in California versus Chicago and Henry Hub prices. The different reaction of markets to these two events is puzzling, at least at first glance.

A combination of magnitude and timing of price increases can provide some explanation. All months in the winter of 2003 had been colder than normal, prompting large withdrawals from storage. So when temperatures plunged at the end of February, not much gas was left near the market centers where heating demand was peaking. Thus, all the adjustments had to come through reallocation of pipeline flows. The average daily flow received in California from Canada during the week of February 24–28, 2003 was 38 percent lower than the average daily flow in that path for the whole winter. Meanwhile, the average daily deliveries from the TransCanada pipeline into the Northeast were 67 percent higher than the average for the whole winter. Also, the price increases observed on those days in February 2003 were much larger than those observed in the aftermath of Hurricane Katrina. The hurricane hit near the end of the injection season when all storage facilities were close to full. Apparently, the magnitude of the spatial differences —given the inventory situation—was not enough to trigger a large redirection of flows.

Figure 3 shows, at most, a weak relationship between western bound flows from the Permian Basin and a price difference—SoCal-border minus Henry Hub. This differential is representative of relative competition between market centers located east and west of the Permian Basin. To analyze price responsiveness of flows toward California, we estimated elasticities of the corresponding residual supply curves that California faces for Canadian, Rockies, and Permian gas. According to that analysis, flows toward California are inelastic (that is, unresponsive) to changes in the relevant spot price difference beyond seasonal changes, reflecting the strength of demand in the California market versus competing locations.

In sum, the effect on California of a weather shock elsewhere, such as a hurricane or a cold snap, depends very much on where in the continent-wide network it happens and when. The fact that only a small portion of total natural gas flows is traded in the daily spot market, paired with inflexible end-use demand levels, limits the ability to modify flow decisions in response to short-lived spatial arbitrage opportunities. Pipeline capacity constraints and requirements to maintain operating pressure are additional factors to explain the resistance to move away from planned flows. Also, the possibility of injecting or withdrawing gas weakens the link between prices and flows. When storage cannot be used as a buffer (which happened in February 2003) observed behavior shows that it is feasible to reallocate large volumes on short notice, but only with substantial changes in price.

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Role of Direct Marketing in California

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Farmers' markets re-emerged after passage of the Farmer-to-Consumer Direct Marketing Act of 1976. This article investigates the benefits of direct marketing and the characteristics of producers who utilize this alternative marketing system, and provides an appraisal of its future prospects.

Farmers' markets have become a common sight in many communities throughout California and the nation. However, the marketing of produce by farmers directly to consumers is not a recent innovation; it was the norm during the nineteenth century, but waned in popularity when improved refrigeration and transportation made it possible to ship produce longer distances. Nationally, the resurgence of direct marketing is linked to the passage of the Farmer-to-Consumer Direct Marketing Act of 1976. In California, the Department of Food and Agriculture enacted regulations in 1977 that exempted farmers from packing, sizing, and labeling requirements for their fresh fruits, nuts, and vegetables and enabled them to sell only those products which they grow themselves at Certified Farmers' Markets, if they are certified by their county agricultural commissioner.

Thirty years later, there are more than 4,385 farmers' markets in operation across the nation. The number of farmers' markets increased by 150 percent between 1994 and 2006. There are approximately 500 farmers' markets in California, with half of them operating year-round.

Community Supported Agriculture programs (CSAs) have become another popular form of direct marketing; usually, these programs involve prepaid subscriptions to purchase part of a farm's production for a month, quarter, or longer time period. Some producers offer "u-pick" programs, allowing consumers to pick berries, apples, and other crops directly at their farms. Other forms of direct marketing by agricultural producers to consumers include roadside farmstands and sales through the Internet or mail order. This article examines the benefits of direct marketing to consumers and producers and the characteristics of producers who utilize this marketing system. It concludes with an appraisal of the outlook for direct marketing.

Benefits to Consumers and Producers

Many small-farm programs encourage producers to participate in farmers' markets and other forms of direct marketing. Previous studies indicate that direct marketing offers benefits to both consumers and producers. Consumers have reported that quality is the number one reason they shop at farmers' markets; they are attracted by the fresh-picked, and vine- and tree-ripened produce. They also gain a stronger sense of food safety by knowing more about the food they are consuming—how it was produced and who produced it. Consumers value the opportunity to meet producers and "attach a face to the food they eat." The relationships they develop with the producers of their food reduce the degree of information asymmetry they have about the food they purchase.

Producers have indicated that direct marketing provides a means of increasing their profitability because they can generate sales at "full retail," when, on average, they receive less than 20 cents of the consumer's food dollar. It also enables them to move smaller volumes of produce and to sell ripe fruit that is too delicate for the traditional packing and shipping process. Because of the limited capital investment required, direct marketing is seen as a means of entry for new small farms. Direct marketing also improves producers' access to market information and provides them with an opportunity to integrate into the community and expand their customer base.

National and Statewide Trends

Data from USDA's Census of Agriculture provide insights regarding the producers who engaged in direct marketing to consumers. USDA began tracking the significant growth in producers' direct marketing revenues with the 1992 Census of Agriculture. Nationally, the number of farms engaged in direct marketing increased from 86,432 in 1992 to 110,639 in 1997 and 116,733 in 2002. The rise in sales has been even more dramatic—increasing from

Table 1. Direct-Marketing Revenues of Agricultural Producers by Year (in $1,000)

Rank 2002	State	2002	1997	1992	% Change 1992-2002
1	California	114,356	73,179	35,967	217.9%
2	New York	59,724	40,088	32,321	84.8%
3	Pennsylvania	53,760	48,745	35,806	50.1%
4	Michigan	37,269	28,720	21,093	76.7%
5	Washington	34,753	13,700	10,863	219.9%
6	Massachusetts	31,315	19,825	14,982	109.0%
7	Wisconsin	29,072	21,866	13,889	109.3%
8	Texas	25,639	17,379	12,188	110.4%
9	Minnesota	22,763	14,198	9,434	141.3%
10	Oregon	21,411	14,287	10,323	107.4%

Source: USDA/NASS, 2002 Census of Agriculture

Table 2. California Farms Engaged in Direct Marketing by Acreage Class, 2002

	FARM SIZE–ACRES												
	All Sizes	1–9	10–49	50–69	70–99	100–139	140–179	180–219	220–259	260–499	500–999	1,000–1,999	2,000+
Number of Farms Direct Mktg	6,436	2,704	2,302	302	223	206	149	76	67	151	113	71	72
Percent of All Farms in Size Class Engaged in Direct Mktg	8.1%	12.4%	8.4%	7.3%	5.5%	5.9%	5.6%	4.5%	4.6%	3.3%	3.1%	3.0%	3.0%
Direct-Mktg Revenues ($1,000)	114,356	11,841	28,356	6,652	9,132	5,813	5,587	5,528	6,391	13,886	8,846	7,928	4,396
Average Direct-Mktg Revenues/Farm ($)	17,768	4,379	12,318	22,026	40,951	28,218	37,497	72,737	95,388	91,960	78,283	111,662	61,056
Direct-Mktg Share of Total Revenues	0.4%	1.7%	1.2%	0.8%	0.8%	0.4%	0.6%	0.8%	0.7%	0.5%	0.2%	0.2%	0.1%

Source: USDA/NASS, 2002 Census of Agriculture

$404.1 million in 1992 to $591.8 million in 1997 and $812.2 million in 2002—more than doubling during the ten-year period. Nevertheless, direct marketing sales represented only 0.4 percent of total farm revenues in 2002.

California has led the nation in direct marketing revenues since the reporting began (Table 1); the state's agricultural producers generated $114.4 million in sales through direct marketing in 2002. This represented a 45 percent increase from the $78.7 million revenues in 1997. New York ranked a distant second with $59.7 million in direct-marketing revenues in 2002. California's prominence in direct marketing is not surprising; given its favorable growing conditions, the prevalence of production of high-value crops and producers' relative proximity to major metropolitan areas with high consumer demand.

Farm Size

Direct marketing is usually linked to small farms, in terms of both acreage and sales. Thus, it is not unexpected that the farms in the smallest acreage and sales classes represented the largest group of direct marketers in 2002 in California (Tables 2 and 3). Although the number of farms involved in direct marketing tended to decrease as farm sales increased, there were 139 farms with sales of $1 million or more that engaged in direct sales to consumers. The incidence of direct marketing declined with overall sales class size (based on total farm sales, not just direct marketing revenues), ranging from 10.3 percent for farms with sales between $10,000 and $24,999 down to 2.8 percent for farms with $1,000,000 or more in sales.

Although direct marketing revenues accounted for a decreasing share of total revenues as sales-class size increased, there was direct positive correlation between sales-class size and both total and average direct marketing revenues; the largest sized farms generated the highest direct marketing revenues ($37.2 million—which represents a third of the state's total direct marketing revenues). The largest farms averaged $267,324 from direct marketing sales; this is contrary to the perception that direct marketing is dominated by small producers. While direct marketing generates a small share of the state's

Table 3. California Farms Engaged in Direct Marketing by Sales Class, 2002

	TOTAL FARM REVENUE SALES CLASS IN DOLLARS								
	All Sales Classes	Under $10,000	$10,000–$24,999	$25,000–$49,999	$50,000–$99,999	$100,000–$249,999	$250,000–$499,9999	$500,000–$999,999	$1,000,000+
Number of Farms Direct Mktg	6,436	3,756	970	580	379	356	162	94	139
Percent of All Farms in Sales Class Engaged in Direct Mktg	8.1%	10.2%	10.3%	8.1%	5.6%	4.9%	3.9%	3.0%	2.8%
Direct-Mktg Revenues ($1,000)	114,356	5,682	6,501	7,722	9,956	15,847	13,462	18,028	37,158
Direct-Mktg Share of Total Revenues	0.4%	6.3%	4.2%	3.0%	2.0%	1.4%	0.9%	0.8%	0.2%
California-Average Direct-Mtkg Revenues/Farm	$17,768	$2,798	$6,702	$13,314	$26,269	$44,514	$83,099	$191,787	$267,324
U.S. - Average Direct-Mktg Revenues/Farm	$6,958	$1,404	$4,836	$9,179	$15,293	$24,590	$43,700	$73,781	$142,442

Source: USDA/NASS, 2002 Census of Agriculture

Table 4. California Farms Engaged in Direct Marketing by Major Crop Type, 2002

	MAJOR CROP TYPE										
	All Crop Types	Veg./ melon farming	Fruit/ tree nut farming	Green-house, nursery & floriculture production	Other crop farming	Beef cattle ranching & feedlots	Dairy cattle & milk production	Hog & pig farming	Poultry/ egg production	Sheep & goat farming	Animal aquaculture & other animal production
Number of Farms Direct Mktg	6,436	785	2,785	326	148	805	49	215	216	644	443
Percent Engaged in Direct Mktg	8.1%	27.1%	7.6%	7.4%	3.1%	6.8%	2.1%	34.3%	23.6%	25.9%	4.4%
Direct-Mktg Revenues ($1,000)	114,356	26,334	55,677	7,718	3,791	3,523	3,471	2,891	NA	1,263	6,298
Avg. Direct-Mktg Revenues/Farm	$17,768	$33,546	$19,992	$23,675	$25,615	$4,376	$70,837	$13,447	NA	$1,961	$14,217
Direct-Mktg % of Total Revenues		0.54%	0.65%	0.23%	0.21%	0.27%	0.09%	10.81%	NA	2.92%	3.65%

NA = Number of Observations too Small to Report   *Source: USDA/NASS, 2002 Census of Agriculture*

agricultural revenues overall, it is an important source of revenue to those producers who use this alternative marketing system; among participating operations, it contributed at least a fifth of the sales revenues within each sales class. Furthermore, farms in California generated a higher proportion of their revenues from direct marketing within each sales- class size, when compared to the nation as a whole.

Crop Type

As expected, fruits and nuts comprised the largest crop category among California's direct marketers in 2002 (Table 4). However, the highest participation rates for direct marketing were for the state's animal operations (hog–34 percent), sheep/goat–26 percent and poultry/egg–24 percent), as well as vegetable and melon producers (27 percent). Additionally, the vegetable and melon operations ranked second in total direct marketing revenues, surpassed only by the 2,785 fruit/nut operations that generated almost half (49 percent) of California's direct marketing revenues. This is expected since produce comprises the majority of the product sold directly to consumers at farmers' markets and through CSAs.

Another unexpected finding is that the 49 dairy producers who engaged in direct marketing had the highest average revenues from direct marketing of any crop/commodity category—$70,837; this was significantly higher than the second highest average of $33,546 for vegetable/melon farms. Although hog farming is very limited in California, 10.8 percent of the total revenues of hog operations were attributable to direct marketing. The only other farm types for which direct marketing generated at least one percent of total revenues were aquaculture (3.7 percent) and sheep/goat farming (2.9 percent). This alternative system appears to provide marketing opportunities for producers who are otherwise too small to supply large-scale processors. Consumer interest in meats from alternative production systems is growing; it is unclear whether more livestock producers will opt to direct market, or if existing producers will expand their operations and move into more traditional marketing systems.

Counties

Given California's dominance in direct marketing, it is not surprising that the top three counties and 13 of the top 20 counties for direct marketing revenues nationally in 2002 were in California (Table 5). The 92 operations in Yolo County led the nation with $8.3 million in direct marketing revenues in 2002, averaging $90,304 per farm in direct sales to consumers. Yolo County producers' prominence in direct marketing in 2002 is remarkable given that the county ranked, respectively, 25th and 58th nationally in 1997 and 1992. Nevertheless, revenues from direct marketing comprised only 2.6 percent of the value of Yolo County's total agricultural production ($315.2 million) in 2002.

Following Yolo County producers were farmers in San Joaquin County, whose direct marketing revenues totaled $8.2 million. Producers in Fresno County ranked third nationally with direct marketing revenues of $7.8 million (while leading the nation in the overall agricultural production of $2.8 billion in 2002). Worcester County producers in Massachusetts placed fourth in the United States with $7.6 million in direct marketing sales. Overall, seven of the top ten counties for direct marketing sales were in California. The high sales volumes from direct marketing in most of these counties are related to their relative proximity to major population areas, as well as their diverse crop mixes.

Yolo County producers can be seen at the local farmers' markets in Davis and Woodland. They also travel to farmers' markets in San Francisco, the East Bay, and Marin County. However, it is likely that much of the growth in their direct marketing revenues can be attributed to CSAs that connect consumers with farmers through direct purchases of shares of farm product. Currently, seven Yolo County farms operate CSAs; most market their fruit, vegetables, nuts, flowers, and value-added products to consumers throughout the Bay Area, as well as to local families in Yolo and Sacramento Counties. They are clearly capitalizing on their proximity to major metropolitan markets.

Table 5. Direct-Marketing Revenues by County-Top 20

Rank	State/County	Direct Sales	Rank	State/County	Direct Sales
1	California/Yolo	$8,308,000	11	California/Merced	5,436,000
2	California/San Joaquin	8,165,000	12	Connecticut/Hartford	5,367,000
3	California/Fresno	7,752,000	13	New York/Ulster	5,051,000
4	Massachusetts/Worcester	7,644,000	14	California/Stanislaus	4,920,000
5	California/San Diego	7,299,000	15	New York/Suffolk	4,866,000
6	Massachusetts/Middlesex	7,108,000	16	California/Riverside	4,473,000
7	Pennsylvania/Lancaster	7,073,000	17	Washington/Skagit	3,695,000
8	California/Kern	6,558,000	18	California/Santa Cruz	3,556,000
9	California/Tulare	6,520,000	19	California/San Luis Obispo	3,364,000
10	California/Sonoma	5,866,000	20	California/Ventura	3,350,000

Source: USDA/NASS, 2002 Census of Agriculture

Prospects for Direct Marketing

The next Census of Agriculture will be conducted in 2008. Although it is highly likely that producers in California will lead the nation again in direct marketing revenues, the future ranking of specific counties is less clear. What is clear, though, is that direct marketing generates a significant portion of the total revenues for producers who utilize this alternative system, and that its utilization is not limited solely to smaller producers or fruit and vegetable growers. It is possible for producers to generate revenues in excess of $250,000 annually from direct marketing. However, there are additional costs associated with direct marketing and little is known about its profitability relative to conventional marketing methods. This topic warrants further analysis.

Current consumer interest in sustainable production, locally grown produce, artisanal foods, grass-fed beef, and free-range poultry appears to provide a promising outlook for direct marketing. However, demand could become significant enough that grocery chains would expand their offerings of such foods; this could have an adverse impact on direct marketing since grocery stores are a more convenient shopping outlet. But consumers who value their relationships with producers will continue to use direct marketing.

Two structural characteristics of direct marketing appear to constrain its growth. Direct marketing is often very labor intensive; farmers' markets require considerable effort (often directly by the producer) to load, unload, and transport products to each market, as does the fulfillment of Internet/mail orders to individual consumers. In addition, the expansion of product offerings, such as meat, fish and poultry, is welcomed by consumers but the infrastructure and food safety requirements associated with processing, packaging, transportation and storage of such products can be challenging to most direct marketers.

Collaboration could expand direct-marketing opportunities by alleviating these structural constraints; currently, producers usually engage in direct marketing on an individual basis. Instead, producers could coordinate among themselves to process, transport, market, and fill orders for their products jointly, while preserving the separate identities of their products. This collaboration could be structured formally as a service cooperative or less formally by producers taking turns to perform various activities. The cooperation would also enable producers to meet the product volume and variety requirements of larger customers, including institutional food service operations. Additionally, producers could coordinate their marketing activities with downstream entities while maintaining their identities throughout the marketing system to the consumer. For example, the leading natural foods chain, Whole Foods, now identifies specific gowers when displaying their produce and other products, as well as having the producers interact with consumers in some stores. Public markets, which preceded grocery stores, could be resurrected to provide permanent or semi-permanents stalls for producers, including overnight storage for perishable products.

Producers have been successful in developing new forms of direct marketing. Incorporating collaboration could broaden the consumer base and considerably increase producers' revenues from direct marketing.

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Do Residential Water Consumers React to Price Increases? Evidence from a Natural Experiment in Santa Cruz

Shanthi Nataraj

Using a "natural experiment" from the city of Santa Cruz, California, we find that a 100 percent increase in the marginal price of water resulted in a 15-25 percent decrease in demand among high-use consumers. Our results suggest that price can be an effective water demand management tool, and that increasing-block pricing can successfully encourage water conservation among high-use households while maintaining overall affordability.

In recent years, water utilities in the western United States have found it increasingly difficult to meet the growing demand for water. The rapid growth in demand, coupled with the decreasing availability of new water supplies, has prompted many utilities to encourage water conservation among residential consumers.

Water utilities use a wide range of measures to promote conservation. During droughts, they often resort to water rationing, lawn-watering prohibitions, and other mandatory controls. At other times, they encourage voluntary water-saving measures; for example, several cities offer rebates for purchasing low-flow washing machines, or conduct public education campaigns.

Many economists argue that price can also be a powerful tool for encouraging conservation. If we disregard fixed costs and assume that water is a renewable resource (ignoring, for example, aquifer depletion), then an efficient market will set the marginal price of water (the price of one additional unit) equal to the marginal cost (the cost of producing one additional unit).

However, public utilities have historically set water prices far below marginal cost. There is an ongoing debate about how much prices must be raised in order to reduce water demand. While many studies have attempted to measure consumer reactions to price, it is difficult to disentangle the effects of a price increase from other factors that affect demand. Some studies have concluded that the typical city must increase water prices many times over in order to significantly affect demand. Large price increases are often infeasible, though, as many people consider access to water to be a basic right. If a public utility sets a high price for water, poor households may find it too expensive.

In this article, we use a "natural experiment" in the city of Santa Cruz, California in 1995 to estimate the effects of a price increase on demand. Santa Cruz employs an increasing-block pricing (IBP) system, which (in theory) encourages conservation among high-use consumers while maintaining overall affordability. Unlike previous studies, the nature of the increase allows us to separate the effects of price from the effects of weather and other factors that affect demand. Our results indicate that high-use consumers do react to price increases; a 100 percent increase in the marginal price of water resulted in a 15-25 percent decrease in demand among high-use consumers over a one-to three-year period. These findings suggest that IBP may be an effective tool for targeting households with high water use, while keeping water affordable for most households.

Do Prices Matter?

Over the past two decades, a growing number of water utilities have introduced IBP to augment revenues and promote water conservation. Figure 1 shows an example of an IBP system with three blocks. Consumers pay $1/unit for the first 10 units, $2/unit for units 11-20, and $3/unit for all units over 20. The first few units are inexpensive, so everyone, even the poor, can afford an essential amount of water. High-use consumers face higher marginal prices, encouraging them to conserve water.

However, there is an ongoing debate about whether residential water consumers actually respond to price changes. One argument in favor of the notion that they do not is that the typical water bill is a small fraction of income, so the price must be increased many times over before consumers notice. Another argument is that IBP structures are so complex that the typical consumer does not know what marginal price she faces. For example, readers of this article might ask

Figure 1. Example of a Three-Block IBP System

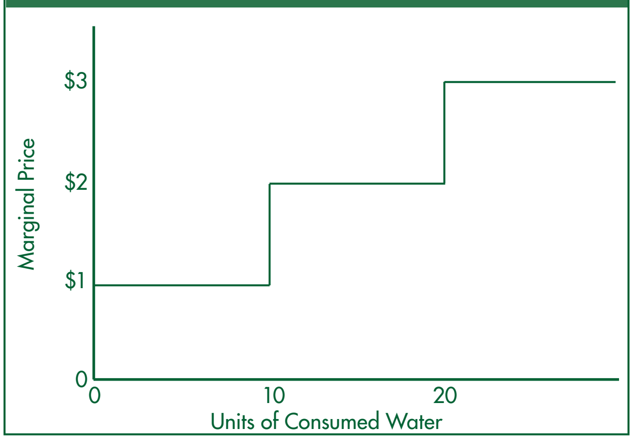
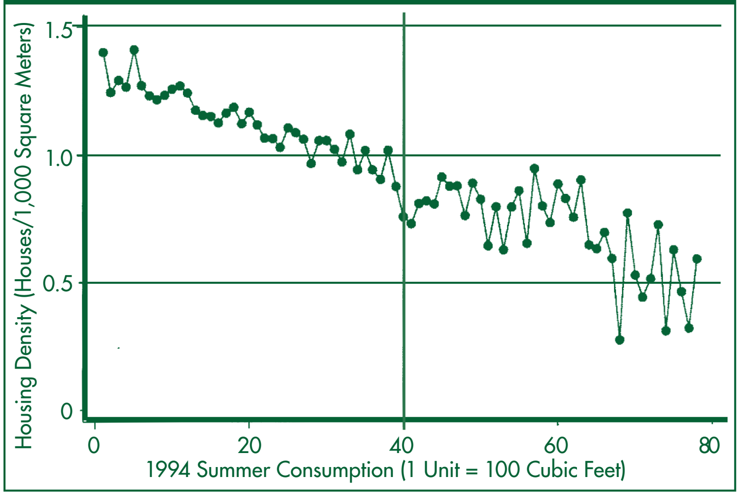


Figure 2. Housing Density by Summer 1994 Consumption



themselves whether they consider their water pricing structures when deciding how often to water their lawns.

To gain information about this issue, numerous studies have estimated how much a change in the price of water will affect the demand for water (the price elasticity). Unfortunately, it is difficult to get a "clean" estimate of the elasticity because many factors, other than price, affect demand. Studies that rely on price variation across cities often fail to account for why different cities set different prices. For example, if Tucson is more prone to water shortages than Phoenix, it may set a higher water price and its consumers may be more conservation-oriented. The lower demand in Tucson may be due not only to higher prices, but also to conservation measures practiced by its citizens. Longitudinal studies (those that consider price changes over time) can avoid this problem, but often fail to control for other factors that change concurrently with prices. Many significant price changes occur during droughts, when non-price policies, such as rationing and conservation education efforts, are also introduced.

A Natural Experiment

To determine how people react to price, we would ideally conduct a "controlled experiment" by randomly assigning high prices to some people (the "treatment" group) and low prices to others (the "control" group), and then measuring water use in the two groups. Since no water utility is known to have randomly assigned prices to its customers, we use a change in the IBP structure in Santa Cruz, California as a "natural experiment." Although prices were not randomly assigned, the nature of the change provides us with comparable treatment and control groups.

Prior to 1995, Santa Cruz consumers faced a low marginal price for units one through eight (Block 1), and a higher marginal price for units nine and above (Block 2). In the summer of 1995, the city introduced Block 3, beginning at 40 units, with the Block 3 price set at approximately twice the Block 2 price.

We assign households to treatment and control groups based on their historical consumption (over 40 units and under 40 units, respectively). In the summer of 1995, the treatment group suddenly faced a 100 percent marginal price increase, while the control group faced a price increase of a few cents.

However, we cannot simply compare the treatment and control groups, because the two groups differ on the basis of characteristics that affect water use. For example, previous studies suggest that outdoor water use is one of the most important drivers of residential water demand; consumers with large yards consume much more water than consumers with small yards.

Figure 2 illustrates this relationship in Santa Cruz with a plot of housing density against summer 1994 water use (i.e., water use prior to the price change). Housing density is a "proxy" for lot size; we expect consumers with lower housing density to have larger houses/yards. The vertical line at 40 units on Figure 2 divides control households (to the left) from treatment households (to the right). Control households have higher housing density than treatment households; therefore, the two groups may not be comparable.

To overcome this dissimilarity between treatment and control households, we employ a "regression discontinuity" (RD) approach that exploits the sharp difference in marginal price for households that consumed just below and just above the 40-unit "discontinuity." As shown on Figure 2, households that consumed 70 units of water in the summer of 1994 had much lower housing density (larger yards) than those that consumed ten units. However, households that consumed 45 units had similar housing density (yard size) as those that consumed 35 units. Control and treatment households near the discontinuity are also similar in terms of eight other characteristics that affect water use (income, number of residents, number of rooms, number of bedrooms, resident age, house age, population density, and home ownership). While these households are not exactly alike, they are as similar as we might hope for in the absence of a controlled experiment. Therefore, we can estimate price elasticity by comparing water use for the treatment and control households near the discontinuity. We use a "difference-in-differences" approach, which compares the change in the treatment households' use, from 1994 to 1995, to the change in the control households' use over the same period.

Table 1 presents the elasticity estimates over one-, two-, and three-year periods (1994-95, 1994-96, and 1994-97). The first column of results shows the price elasticity using all treatment and control households. These results indicate that increasing the marginal price by 100 percent resulted in a 25 percent decrease in demand among the treatment households from 1994-1995. The effect grew larger over time, with a decrease in demand of 50 percent among treatment households by 1997.

However, as discussed above, using all of the control and treatment households may not be appropriate, since the two groups differ along many dimensions. To address this concern, Table 1 also presents the elasticity estimates from the RD approach. The RD elasticity estimates are somewhat lower than the estimates for all households, and suggest that increasing the marginal price by 100 percent resulted in a 15-25 percent decrease in demand among households near the discontinuity.

The results presented in Table 1 represent the "short-run" price elasticity. In the context of water demand, we can think of short-run reactions to price increases as those that can be immediately implemented. For instance, during the first summer in which a consumer is faced with high water prices, she might water her lawn at night, rather than during the day, to decrease the amount of water lost to evaporation. If high water prices persist over several years, she can take additional conservation measures that are less easily implemented. When purchasing a new washing machine, she may opt for a low-flow model; when landscaping a section of her yard, she may choose plants that require less water. As we would expect, the short-run price elasticity for water is typically lower than the long-run price elasticity.

Most previous studies indicate that in the short run, the demand for water is inelastic (in other words, a 100 percent increase in price decreases demand by less than 100 percent). Our results fall within the range of previous estimates, but are lower (suggesting a smaller reaction to price) than most. Our findings may be somewhat lower than other studies' for two reasons. First, previous elasticity estimates may unintentionally include the effects of weather or non-price conservation measures, especially if they cover periods of drought. Second, our RD results are valid for a very specific group of consumers—those near the 40-unit discontinuity. These households are far from typical; their bi-monthly water use is approximately twice the average water use in Santa Cruz. If different segments of the population respond differently to price changes, then our results are not strictly comparable to previous studies that consider both low-use and high-use consumers.

Table 1. Price Elasticity Estimates

	All Households	Households Near Discontinuity		
		Within 20 Units	Within 10 Units	Within 5 Units
1994–1995	−0.263***	−0.108***	−0.206***	−0.238**
1994–1996	−0.453***	−0.168***	−0.199***	−0.158
1994–1997	−0.522***	−0.233***	−0.249***	−0.138

**** Significant at the 1% level. ** Significant at the 5% level.*

The relevance of the RD approach to only a small group of consumers could be considered a drawback. However, this high-use group is precisely the segment targeted by many water conservation programs. Recall that the intent of an IBP system is to encourage conservation among consumers who use significant amounts of water, while maintaining affordable prices for most households. The fact that the introduction of a third price block, targeted at high-use consumers, produced a 15-25 percent decrease in their demand, supports the use of IBP as a effective method for discouraging "excess" use.

Conclusions

Santa Cruz' introduction of a third price block in 1995 allows us to make a "clean" estimate of price elasticity using an RD approach. The RD elasticity estimates indicate that the introduction of a third price block, which doubled the marginal price faced by high-use consumers, decreased their demand by 15-25 percent over a one- to three-year period. The results suggest that price increases can be an effective tool for demand-side management, and that adding a block to an existing water pricing system can encourage conservation among high-use consumers while maintaining overall affordability.

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For additional information, the author suggests the following sources:

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