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Improving Air Quality by Reformulating Gasoline: How California Got It Right

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Regulations intended to improve air quality by changing the composition of gasoline have resulted in significant improvements in air quality in Southern California.

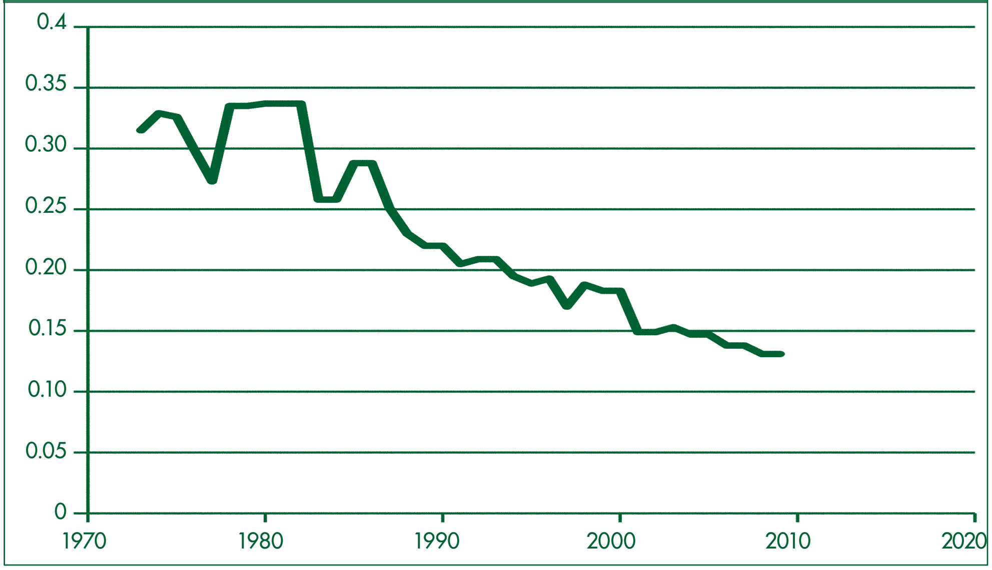
Also in this issue

Next ARE Update.....

Starting with the passage of the 1963 Clean Air Act, U.S. government agencies at the federal and state level have designed and implemented a significant number of policies to improve air quality. The Clean Air Act regulated six criteria pollutants (Ozone, particulate matter, NOx, SO_2, Carbon Monoxide and Lead), all of which are thought to have negative consequences for human health. Ozone is an odorless gas invisible to the human eye which, if found at ground level, has been linked to asthma, increased susceptibility to pneumonia and bronchitis, as well as damage to crops and natural vegetation. Studies have shown that even relatively small short-term increases in ambient ozone concentrations can result in a significant increase in deaths. Ozone is not directly emitted by any point source, but forms in the atmosphere through a set of complex chemical reactions. The formation of ozone requires two classes of man-made and naturally occurring chemicals that react in the atmosphere—volatile organic compounds (VOCs) and oxides of nitrogen (NO_x). The first reliable measurements of ambient ozone concentrations were made in 1965. The maximum one-hour ozone concentration for that year in the South Coast Air Basin was 0.58 ppm, which is roughly five times the currently allowable maximum hourly concentration set by the national ambient air quality standards. Figure 1 displays the history of eight-hour average concentrations for the South Coast Air Basin since 1973. Over this period, this measure of ozone concentrations has improved by 50%, which is an impressive achievement given the increases in population and income over this period. On the flip side, however, despite more than four decades of air quality regulation, many places continue to experience ambient concentrations of ozone that violate the standards set by the Environmental Protection Agency (EPA). While the South Coast Air Basin has experienced tremendous improvements in air quality, it is still in violation of the national eight-hour standard for more than 100 days out of the year.

In order to bring jurisdictions into compliance with federal regulation, a variety of novel policy tools at the federal and state level have been proposed and implemented. Discussion of any new regulation brings with it the question of how flexible or prescriptive it should be. More flexible regulation allows the regulated firm to choose how to meet a standard, while a more prescriptive approach specifies precisely what the firm must do to comply. In one particular set of gasoline regulations targeted at reducing ozone pollution, regulators have imposed both types of regulation: a performance standard, which allows the firms to choose how to meet an overall emissions standard,

Figure 1. Average Eight-hour Ozone Concentrations (ppm) for the South Coast Air Basin



and a chemical content specification, which dictates the chemical composition of the gasoline. After years of experience with these regulations, the question is how have they performed in reducing ozone pollution?

The gasoline content regulations we study were designed to reduce the concentrations of ground level ozone. Since one cannot target emissions of ozone directly, these regulations attempt to reduce the emissions of the precursor pollutants. The regulations mostly target the emissions of VOCs, which include a large number of chemicals with varying degrees of ozone-forming potential. Some VOCs are almost 80 times more reactive than others.

One key feature of gasoline reformulation policy is that the stringency of regulations required by EPA varies quite drastically across states and counties. Further, some places have designed their own standards and boutique fuels, which in some cases are more stringent than those required by EPA. The earliest gasoline regulations were in the form of a performance standard, which targeted the Reid Vapor Pressure (RVP) of gasoline. RVP is measured in pounds per square inch and is a measure of how much of the VOCs evaporate from gasoline.

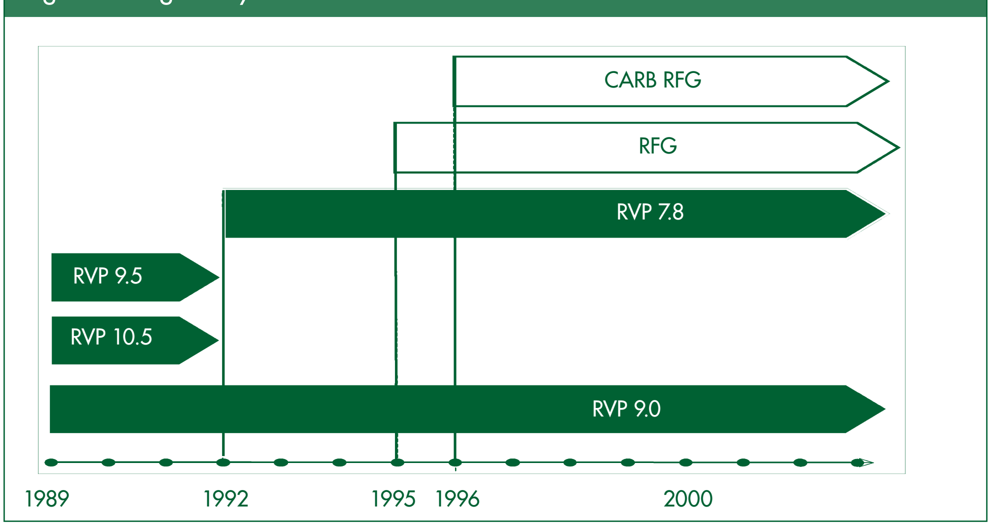
This regulation was implemented in two phases. Phase I, which lasted from 1989 through 1991, included differing degrees of stringency by place and month of the year, since ozone is largely a summertime problem. Phase II started in 1992 and imposed the most stringent of the phase I requirements on all states. Further, phase II tightened standards for areas in violation of the Clean Air Act ozone standards in southern states. This phase II regulation is still in place today, although in many areas these regulations were replaced by federal reformulated gas (RFG) or California Air Resources Board (CARB) standards. As of 1995, federal RFG was required in areas in severe non-attainment of the national ozone standard. RFG regulations are more stringent than those of RVP.

Two states, California and Arizona, have implemented even more stringent gasoline regulations. Most importantly, CARB gasoline imposes tighter VOC emissions standards *and* limits the concentrations of olefins and aromatic hydrocarbons, both of which are highly reactive in forming ozone. Figure 2 displays the sequence of these gasoline regulatory standards.

We exploit the sequential nature of this patchwork of regulations—which includes both more flexible (RVP and RFG) and more prescriptive (CARB) approaches, combined with a rich database of ambient ozone concentrations from across the country—to construct a careful comparison of how effective the different regulations were at achieving their stated goal.

Figure 3 depicts the time path of summer ozone concentrations in counties under different forms of regulation. Panel (a) compares the ozone concentrations in counties treated with a stringent RVP phase II standard to counties with a much more relaxed RVP standard. The introduction of the RVP phase II standard in 1992 does not appear to have substantially affected summertime ozone concentrations. Panel (b) suggests that the introduction of federal RFG in 1995 may have caused

Figure 2. Regulatory Timeline: 1996 – CARB RFG



slight improvements in ozone concentrations. However, panel (c) shows a substantial decrease in ozone concentrations in California around 1996, which is the year CARB gasoline was introduced in all California counties. It is not possible to determine from this graph alone whether the improvements in air quality can be attributed to CARB gasoline or to other confounding factors acting over the same time period. We therefore turn to statistics-based econometric methods to extract the impact of these regulations on air quality.

Specifically, we estimate the impacts of the gasoline regulations discussed above on ozone concentrations by collecting daily measurements of ambient ozone concentrations from hundreds of ozone monitors nationwide during 1989–2003. Further, we have collected a rich and spatially specific dataset of which regulations were in effect at what date. Due to the discrete nature with which these regulations were implemented, we can exploit a before and after comparison as well as a comparison across monitors.

There is an advantage of the regulations studied here, from a statistical perspective. Compared to standards for vehicle emissions control equipment which only produce effects slowly as the vehicle fleet turns over, the adoption of a gasoline content standard immediately affects all on-road vehicles. We therefore use our data to look for step changes in ambient ozone concentrations at the times and locations in which gasoline regulations were imposed. We use two methods.

First, we adopt a difference-in-difference (DD) estimation technique, which compares changes in air quality before and after the introduction of a policy to changes experienced in areas that did not adopt such a policy. Second, we exploit a regression discontinuity (RD) design that examines changes in ozone concentrations immediately before and after gasoline regulations came into

Figure 3a. RVP Summer Maximum Concentration Trends

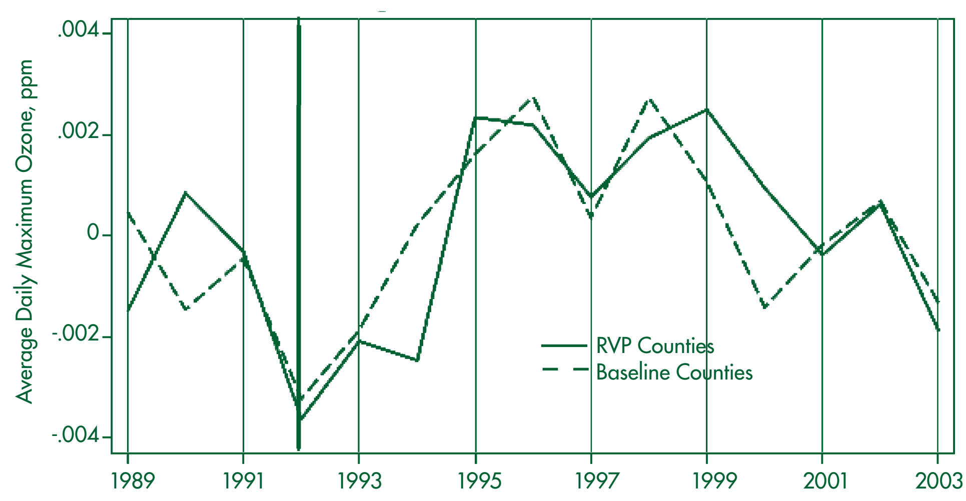


Figure 3b. RFG Summer Maximum Concentration Trends

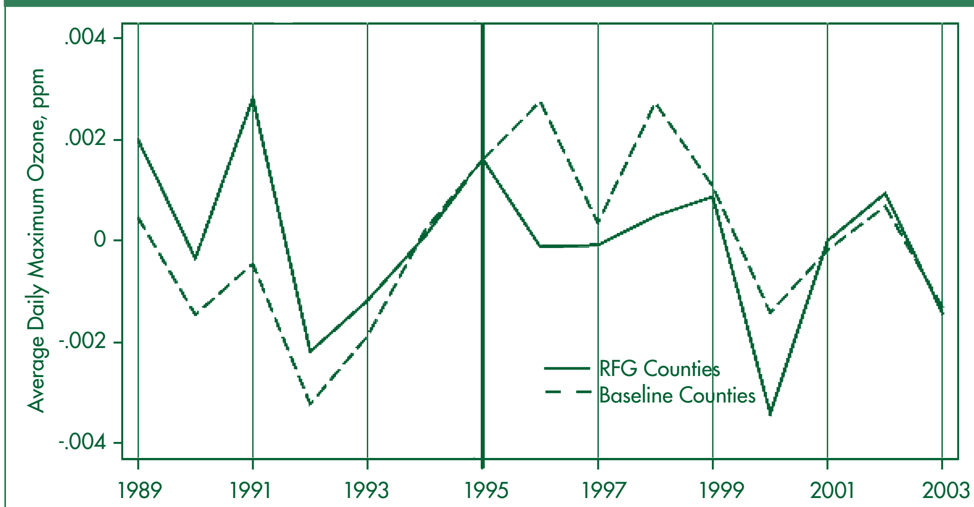
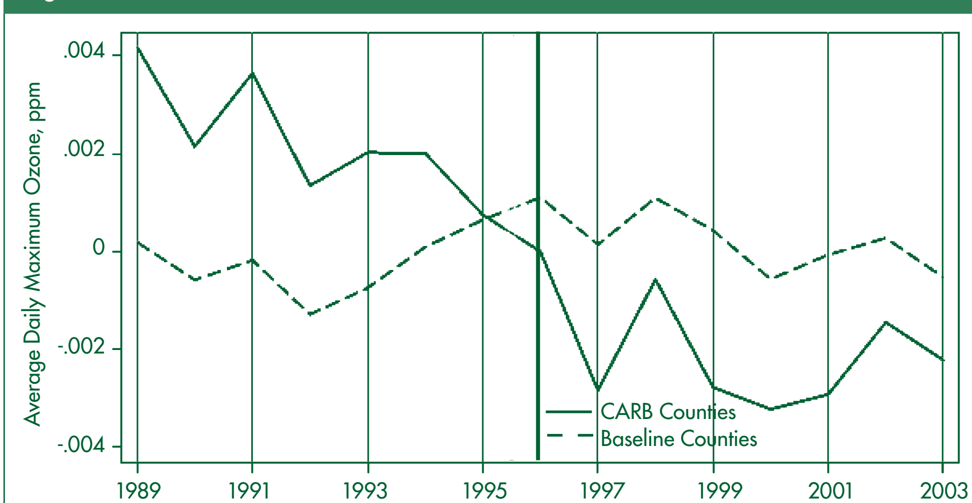


Figure 3c. CARB Summer Maximum Concentration Trends



Note: The vertical axes display deviations of the ozone concentrations from their mean after the effects of weather have been statistically removed.

effect at a single monitor. The latter strategy does not utilize other "non-treated" monitors as controls, yet allows for tremendous flexibility and location specificity of the estimated effects.

Our main finding is that the effectiveness of gasoline regulations varies significantly with the degree of flexibility with which refiners are allowed to respond. The federal regulations (RVP and RFG) limit the total evaporation of VOCs from gasoline, without taking into account which VOCs are best at forming ozone. We find that these regulations, on average, have no economically or statistically significant effect on ambient ground-level ozone concentrations.

We argue that this result is likely due to the rational behavioral response of refiners to the federal standard: they minimize the cost of producing the required fuels by removing a VOC that is not strongly related to ozone formation. Refiners do not appear to reduce concentrations of the more highly reactive VOCs since this is more expensive and the federal regulation provides no incentive to do so.

California's gasoline regulations, however, strictly limit the VOCs most important in forming ozone, which prevents refiners from avoiding the costly abatement of these substances. We find that California has enjoyed a large improvement in ground level ozone concentrations: our estimates suggest that CARB gas reduced ground-level ozone concentrations by 16% in California's worst air quality area: the Los Angeles–San Diego area. We conduct a very conservative back-of-the-envelope calculation and show that the benefits outweigh the regulation's cost, based on its impacts on mortality alone.

These very different outcomes suggest a potential trade off when setting the degree of flexibility for environmental regulations. More flexible regulatory approaches, such as RVP and RFG, are designed to minimize the cost to producers to satisfy the regulation. Our analysis suggests this increased flexibility has resulted in lower environmental benefits. Recent literature on the effectiveness of pollution regulation suggests this trade off appears to not be limited to gasoline reformulation. Cap and trade systems, for example, have become increasingly popular, as they will reach a reduction of total emissions (cap) while allowing actual abatement to be distributed (traded) across heterogeneous firms to minimize the cost of meeting the emissions standard.

If, however, marginal benefits of emissions reductions differ across space (e.g., due to the distribution of the exposed population), standard permit-trading systems may not achieve the first-best welfare outcome. Fowlie (2009) finds that the benefits of a major U.S. NO_x cap-and-trade program were undercut because NO_x abatement was concentrated in low marginal damage areas rather than dense urban centers. She argues that less flexible regulation, which would have weighted emissions by local marginal damages, would have yielded a more desirable outcome.

In our study, the consequences of increased regulatory flexibility are severe. While the flexible RVP/RFG standards result in lower abatement costs than CARB gasoline (1–1.5 cents per gallon vs. 8–11 cents per gallon), the federal regulations appear to have no measurable effect, while California's regulation resulted in significant improvements in air quality. Anticipating firms' most probable response when implementing flexibility mechanisms in regulation is of first order importance, even in command-and-control regulation such as gasoline content standards. Regulators should weigh the benefits from increased flexibility against the reductions in compliance costs to regulated agents.

In the case of gasoline regulations aimed at reducing ozone emissions, the more flexible regulatory standard allowed refiners to implement the most cost-effective technique from their standpoint, but the goal of the regulation was not achieved. It has been the more prescriptive regulatory standard that was effective at actually reducing ozone concentrations, albeit at a higher compliance cost to the refiners. These outcomes highlight the need for environmental regulations to anticipate and mitigate the behavioral responses of the regulated entities when faced with a more flexible regulatory approach.

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For additional information, the authors recommend:

"Clearing the Air? The Effects of Gasoline Content Regulation on Air Quality." Auffhammer, Maximilian and Ryan Kellogg. 2009. UC Berkeley: Center for the Study of Energy Markets. Retrieved from: http://escholarship.org/uc/item/74s774zj.

"Emissions Trading, Electricity Industry Restructuring, and Investment in Pollution Control." Fowlie, Meredith. Forthcoming in *American Economic Review*. http://nature.berkeley.edu/~fowlie/emissionstradingelectricity.pdf.

Costs of Methyl Iodide Non-Registration

Rachael E. Goodhue, Peter Howard, and Richard Howitt

The California Department of Pesticide Regulation has proposed to register methyl iodide, a fumigant that may be a technically feasible alternative to methyl bromide in some uses. To the extent that currently registered alternatives cannot substitute perfectly for methyl bromide, methyl iodide has the potential to offer a better option for growers, so that non-registration could generate costs for California agriculture.

On April 30, 2010 the California Department of Pesticide Regulation (CDPR) proposed to register five pesticide products containing the fumigant methyl iodide (MeI) previously registered by the U.S. EPA in 2008. MeI was registered by the EPA in part because unlike the fumigant methyl bromide (MBr), MeI does not damage the ozone layer in the upper atmosphere. The use of MBr in pre-plant soil fumigation was an important pest and pathogen management tool for growers of many crops for decades. Due to its negative effect on the atmosphere, however, its use is being phased out.

At this point in time, all MBr used in the United States must either come from existing stocks or qualify for a critical use exemption (CUE) approved by national and international authorities. Available stocks are anticipated to be negligible from 2011 on, and it is very unlikely that the United States will apply for any CUEs for use in 2015 or later.

Consequently, it's a matter of great importance to identify technically and economically feasible alternatives to MBr for uses that are permitted currently under CUEs. There is considerable interest in MeI as a potential replacement for MBr in some uses.

We examine the potential value of MeI to California agriculture when MBr is no longer available. MeI has been characterized as the alternative that is the closest to being a "drop-in" replacement for MBr, due to its broad control spectrum, high vapor pressure relative to other alternatives, and the ability to apply it using the same equipment as MBr. Overall, MeI performs comparably to MBr for nematode, weed, and fungi control, based on results of laboratory and field trials. Of course, the efficacy of MeI is not constant, but depends on field conditions, soil type, application method, application rate, crop, and use regulations. Some use regulations, such as limits on application rates, may limit the efficacy of MeI products directly. Others, such as buffer zones, limit the land to which it can be applied.

Revenue Loss Analysis

Because MeI has the ability to act against a broad spectrum of pests, it may be able to manage pest and/or disease pressures that are not managed effectively by other MBr alternatives. Information contained in MBr critical use exemption (CUE) requests for specific crops provides one measure of the potential costs to California agriculture of the non-registration of MeI. To the extent that currently registered alternatives cannot substitute perfectly for MBr, there is the potential for MeI to offer a better option for growers.

We use the data prepared for four CUE applications approved by the EPA and forwarded to the international Methyl Bromide Technical Options Committee for approval for 2011, along with acreage and price information for ten associated crops. In 2007, the crops considered here accounted for almost a quarter of California's total cash farm receipts.

We use 2011 CUE nominations in order to provide a forward-looking analysis. As existing stocks of MBr are exhausted, the pattern of its use will change so that 2009 values are of relatively limited use even for short-term projections. By 2011, less than 10% of the MBr used in the United States is predicted to come from existing stocks.

Our approach to estimating the cost of MeI non-registration assumes that the loss of gross revenues from the unavailability of MBr could not be mitigated through other alternatives. Thus, the loss in gross revenues from MBr unavailability represents an estimate of the economic cost from non-registration of MeI. One definition of the losses that would occur is obtained from CUE applications, which are required to include an estimate of the yield loss that would occur if the application was denied. This estimate applies only to the acreage for which the CUE is requested; the presumption is that registered alternatives to MBr are technically and economically feasible on other acreage.

This analysis assumes that the technical efficacy is identical for MeI and MBr, yields are identical, the cost per acre of applying the two fumigants is identical, and that the applicable regulations are identical. If MeI is less efficacious, more expensive, or is subject

Table 1. Effect of Denial of MeI Registration on Gross Crop Revenues:
CUE Acres Only, Yield Loss Estimates from 2011 Critical Use Exemption (CUE) Applications*

	Yield loss (%)	2007 Planted acreage	2007 Harvested acreage	2011 CUE acreage	Gross revenues MeI available $millions	Gross revenues MeI not available $millions	Change (%)
Almond[a]	-4	21,080	615,000	217	2,154	2,155	0.01
Cut flower[b]	-20	8,126	8,126	716	182	166	-8.81
Table Grape[a]	-10	2,977	82,000	0	–	–	0
Raisin Grape[a]	-10	906	227,000	106	602	608	1.19
Wine Grape[a]	-10	9,112	480,000	254	1,854	1,860	0.28
Nursery (fruit&nuts)[c]	-100	N/A	N/A	N/A	86	165	161.19
Nursery (roses)[d]	-100	N/A	N/A	12	36	35	-1.32
Stonefruit[a]	-4	8,913	302,000	1,662	865	869	0.41
Strawberry[e]	-15	35,500	35,500	13,444	1,339	1,305	-2.49
Walnuts[a]	-4	3,185	218,000	274	754	761	0.95
TOTAL					7,951	7,920	-0.39

Legend

a. Assumes all acres in full production and affected proportionately

b. Acreage from 2007 U.S. Census of Agriculture.

c. 2006 gross revenues from NASS, 2007.

d. 2008 gross revenues nursery, rose category from CDFA CAC data 2009.

e. Assumes the same shares of revenues from fresh strawberries for all strawberry acreage.

* *This analysis does not address the regulatory scenario of fumigants other than MBr being further restricted, or the possibility that new pest and/or disease problems may emerge.*

to more regulations, then the costs of non-registration would decrease.

In order to compute revenue changes, we use own-price elasticities of demand from the existing literature when available. California is an important supplier of many of the crops we consider; consequently, a decrease in California production may result in an increase in price. The own-price elasticity of demand captures this effect. Results are reported in Table 1.

The decline in production if MeI is not available is computed by multiplying the estimated percentage yield loss in the second column by the 2011 CUE acreage in the fifth column. Multiplying this number by the 2007 California price per unit of the commodity in question provides the reduction in gross revenues due to the non-availability of MeI. For example, the reduction in gross revenues for almonds is computed by multiplying 4% yield loss by the 217 requested CUE acres by the base yield of almonds by the price of almonds per ton. This results in estimated revenue losses of $1 million.

Gross revenues if MeI is available is computed by multiplying 2007 harvested acreage by base yields and prices and assuming zero yield losses.

Gross revenues if MeI is not available is computed by subtracting the loss due to the non-availability of MeI. Planted acreage is included in the table in order to provide a measure of how large CUE acres are as a share of planted acres; for perennial crops, harvested acres are not a reasonable proxy for planted acres. In the case of almonds, the 2011 requested CUE acreage was equal to about 1% of the 2007 almond acreage planted (21,080), but a negligible share of the 615,000 acres harvested.

Cut flowers sustain the largest percentage revenue loss: 9%. This is due to the relatively large (20%) yield decrease reported in the CUE application and the relatively large share of planted acreage for which a CUE is requested, as well as to the very elastic demand assumed for cut flowers. While losses to nursery crops are assumed to be 100% on affected acres, the share of acreage requested in the CUE relative to total acreage is quite small, leading to small percentage losses. Yield losses for other crops are mostly or completely offset by price increases received for the remaining production. In the case of strawberries, our loss estimates reflect the success that the industry has had in identifying alternatives to MBr, which serve as alternatives to MeI and mitigate the costs of the denial of registration.

In addition to direct effects on agriculture, changes in agricultural revenues affect other economic activity. Based on a multiplier of 1.77 from the IMPLAN model of the California economy, there would be a $55 million reduction in total economic activity in California. Total employment would decline by 820.

An important caveat to this analysis is the use of CUE acres; to the extent that users rely on using MBr from existing stocks, CUE acreage requests will understate the use of MBr. Table 2 addresses this concern. It assumes that the yield losses reported in the 2011 CUE nominations apply to all harvested acreage. Because some acreage in each of these crops is using MBr alternatives, these estimates will exceed the cost of MeI non-registration under current regulations. Consequently, we are able to place an upper bound on the potential cost of MeI non-registration due to additional acreage of these crops using MBr from existing stocks.

Due to inelastic demand, revenues from almonds, raisin grapes, winegrapes, stonefruit, and walnuts are not impacted adversely. Losses for strawberries increase to 7%. Because of the assumed perfectly elastic demand, cut flower losses are 20%. Because a 100% yield loss is assumed for nursery crops due to the nematode-free certification requirement, losses are also 100%.

It is important to note that the estimates in Table 2 should not be interpreted as estimates of the cost to these commodities of eliminating all fumigant use. The yield losses in the 2011 CUE nominations do not represent this elimination scenario. In the absence of any fumigant use, higher yield losses would be predicted.

Total revenues for these ten crops decline by $38 million. Again, applying multipliers from the IMPLAN model of the California economy, total economic activity would decrease by $67 mission and employment would decrease by approximately 1,005.

Table 2. Effect of Denial of MeI Registration on Gross Crop Revenues: Yield Loss Estimate from 2011 Critical Use Exemption (CUE) Applications

	Yield loss (%)	2007 Harvested acreage	Gross revenues MI available $millions	Gross revenues MI not available $millions	Change (%)
Almond[a]	-4	615,000	2,154	2,168	0.62
Cut flower[b]	-20	8,126	182	146	-19.99
Table Grape[a]	-10	82,000	623	617	-0.99
Raisin Grape[a]	-10	227,000	602	648	7.65
Wine Grape[a]	-10	480,000	1,854	2,003	8.00
Nursery (fruit and nuts)[c]	-100	N/A	165	N/A	-100
Nursery (roses)[d]	-100	N/A	36	N/A	-100
Stonefruit[a]	-4	302,000	865	882	1.98
Strawberry[e]	-15	35,500	1,339	1,239	-7.41
Walnuts[a]	-4	218,000	754	833	10.49
TOTAL			8,573	8,535	0.45

* *This analysis does not address the regulatory scenario of fumigants other than MBr being further restricted, or the possibility that new pest and/or disease problems may emerge.*

[a-e] *See the legend in Table 1.*

1,3-D Township Caps

Current restrictions on the use of other fumigants increase the costs of the denial of MeI registration for California agriculture. For example, one important fumigant-specific regulation limits the amount of 1,3-dichloropropene (1,3-D) that can be applied within a township in a given year. Even if MeI is not the most efficacious alternative to MBr, it could serve as an alternative for growers affected by township caps on 1,3-D. Strawberries and sweet potatoes are two crops that utilize pre-plant soil fumigation relatively intensively and have production concentrated in specific townships. Thus they may be disproportionately affected in those areas by the non-registration of MeI, because it would deny them an alternative to 1,3-D.

However, even if perennial crops are not heavy users of pre-plant soil fumigation using 1,3-D in any individual year, they are subject to special dynamic considerations that may cause them to be affected by the caps. Pre-plant fumigation use is governed by replant rates, which vary over time. Because application rates are relatively high for a perennial replant, demand in specific years could exceed the township cap, even if average annual demand does not. Another potential concern regarding perennials is that the loss of MBr may alter the effective lifetime of a planting by reducing plant vigor and productivity. If the economic life of an orchard, grove, or vineyard is reduced when pre-plant fumigation with currently registered MBr alternatives is used, but pre-plant fumigation with MeI would eliminate this reduction, then reduced life spans for perennials would be an additional cost of the denial of the registration of MeI.

Specific Pest and Disease Considerations

MeI has the potential to perform better for a number of specific pests and diseases than currently available MBr alternatives. We discuss only a few. For example, pre-plant soil fumigation with MBr combined with chloropicrin has been a means of protecting the vigor of perennial crops replanted on ground previously in those crops. MeI may be an effective management tool in the absence of MBr, although its potential is dependent on soil type and other considerations, as noted earlier. For almonds and stonefruit, MeI could be a tool for managing peach replant disorder. Studies suggest that its efficacy may be limited by the maximum application rate permitted. Similarly, grapes are subject to vineyard replant disorder. Vineyard replant disorder, loosely speaking, refers to a loss of vigor in vines planted to fields previously in vineyards, compared to vines planted in fields with a different previous crop. While the precise cause (or causes) of vineyard replant disorder are unknown, growers have used MBr successfully to control it.

One factor often, but not always, associated with replant disorders is high nematode populations. There is evidence that MeI plus chloropicrin (Pic), or 1,3-D plus Pic, are effective tools for nematode management in grapes. For walnuts, 1,3-D does not control nematodes as well as MBr does in finer soils. Application rate restrictions prevent the use of enough 1,3-D to compensate for its lower efficacy. However, as is the case for other perennials, the replant problem is more complex than a nematode infestation, and many walnut trees fail to produce if replanted in non-fumigated soil. Notably, the requested acreage in the 2011 CUE application appears relatively small, given the difficulties of managing nematodes in the finer-textured soils in which a majority of California walnuts are grown. This divergence may be due to the relatively high cost of MBr per acre given current and projected market conditions.

In the cut flower industry, MeI would provide a means of managing weeds in a short production cycle system that includes a large number of diverse species. A broad spectrum preplant control method is very valuable for multiple reasons. These crops are susceptible to a variety of pathogens and differ in their sensitivities to each one. Because so many different crops are grown successively, often on very short production cycles, herbicides may carry over into the next cycle and damage the crop. Studies suggest that MeI may be able to address these needs, although the evidence does not establish that it is likely the best alternative to MBr in all situations.

Nursery stock for on-farm use, such as trees and vines intended for transplanting for commercial fruit and nut production, is required under California law to be free of economically important nematodes. Fumigation with MBr is the conventional nursery treatment specified for nematode-free certification, although in certain cases 1,3-D use is permitted. MeI has not been shown to provide control equivalent to MBr at application rates permitted by U.S. EPA.

Macrophomina phaseolina and *Fusarium oxysporum* are responsible for charcoal rot and Fusarium wilt, respectively, in strawberries. The pathogens have emerged in fields that have been treated with drip-applied bed fumigation, using alternatives to methyl bromide for multiple years. The prevailing hypothesis among researchers is that the bed-only drip applications allow pathogens to persist in the untreated furrows. At the present time, potentially efficacious solutions to the management of these pathogens include long-term rotations of infected ground and flat fumigation. Long-term rotations out of strawberries into non-host crops are generally not economically viable. The use of flat fumigation is limited by township caps for 1,3-D and rate maximum permitted for Pic, which restrict the ability of growers to flat-fumigate at sufficiently high rates for pathogen control in many areas.

Conclusion

The cost of denying registration of MeI products to California agriculture depends on a number of factors. First, MeI may not be as effective as MBr or as other MBr alternatives for specific production systems. For example, MeI does not provide sufficient control of nematodes for fruit and nut nursery stock in heavy soils at permitted application rates. In such cases the cost of non-registration is lower, because the use of MeI provides fewer benefits. In other cases, MeI has the potential to dominate other alternatives to MBr, although in most of these instances more research is needed. Technical efficacy is a prerequisite, but it is not the only consideration. The prices of MeI and its substitutes will matter, as will regulations governing their use.

The analysis focused on the costs of the denial of MeI registration given *current* regulatory conditions. Looking forward, it is clear that the cost of non-registration of MeI would be highly dependent on the effects of the 1,3-D township caps, and on the extent to which crops with CUE applications for 2011 would be able to transition to fumigants other than MeI, or to non-fumigant alternatives, such as steam or substrates, once the MBr ban is complete. Losses would also depend on demand conditions. If new competitors emerge, then for any reduction in the quantity produced, there will be a smaller price response, so revenue losses will increase.

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For additional information, the authors recommend:

"Costs of Methyl Iodide Non-registration: Economic Analysis." Rachael Goodhue, Peter Howard and Richard Howitt. Final report submitted to the California Department of Food and Agriculture, May 2010.

How Do Forward Contracts Affect Strawberry Prices?

Sandeep Mohapatra, Rachael E. Goodhue, Colin A. Carter, and James A. Chalfant

The widespread use of contracts to market produce complicates the interpretation of market prices, and raises questions about the effects of contracting on the prices and risks faced by growers, shippers, and buyers who do not use contracts. This article examines the effects of informal forward contracts for strawberries on spot market prices and their volatility.

Both informal and formal contracting arrangements are increasingly used by growers and shippers to market agricultural commodities to food retailers. Both types of contracts complicate the interpretation of price signals, as indicators of trends and current conditions in agricultural markets. Increasingly, the "spot" prices observed at wholesale markets represent a small share of the total volume marketed. This is the case for a large number of produce items important in California.

Presumably both parties to a contract perceive that they are better off under the arrangement, or they would not continue with it. But it is difficult to predict the effects of contracting on the rest of the industry: what happens to the average price, or the variation in prices, for growers, shippers, and wholesale/retail firms who do not engage in contracting? In this article, we report our research results on the effects of pre-commitment (i.e., informal forward) contracts used to market California's fresh strawberries, focusing on the effects of pre-commitments on both the mean and variance of spot prices.

Pre-Commitment Contracts and Strawberry Prices

We expected that we might find that spot prices become more volatile, and less representative of the true prices, as greater volumes are marketed under forward contracts. In effect, the prices for a portion of total production are fixed with forward contracting, meaning that price changes are concentrated on a subset of the volume sold. As a result, variation in spot prices may be magnified, as fluctuations in supply and demand are accommodated by a smaller share of the market—the spot market is said to be "thin." Thus, the traditional view implies that the reduction in price uncertainty that is enjoyed by participants in contractual arrangements comes at the cost of increasing the risks experienced by other market participants. This means growers and shippers who do not market strawberries using pre-commitments may bear more risk. Unless they also receive higher average prices, they would be worse off due to contracting.

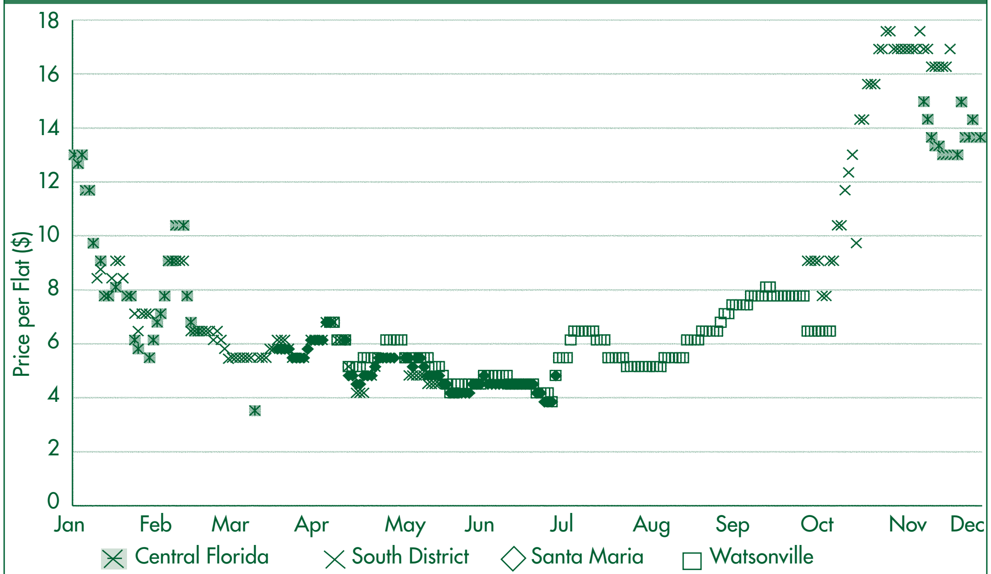
However, it may be that the belief that price stability in one part of the industry causes greater price instability in the other part is overly simplistic. Certainly, if nothing else were to change, it is natural to expect that stabilizing price at some average level, in some markets, causes the remaining markets to be subject to greater fluctuations from demand or supply shocks. But it is misleading to treat all other behavior as unaffected by contracting. For instance, retailers may be willing to commit more shelf space to strawberries, or to display them more prominently, if they have been able to guarantee supply, or insure against large price movements, through contracting. They may also commit to larger promotional efforts, which, if effective, increase the industry-wide demand and, hence, raises prices received by growers and shippers. The effect of contracting is therefore more complicated, and its effects potentially more varied, than the traditional view might imply.

It is therefore necessary to examine how both the mean and variance of spot prices are affected by contracts. Growers and shippers who do not use pre-commitments may receive higher prices to compensate for greater price risk, or they may actually enjoy lower risk, due to the possible market-stabilizing effects of pre-commitment contracts.

Increased use of contracts has paralleled increased concentration in food retailing, and increased vertical integration in the food markets. Agricultural economists studying market conditions therefore encounter substantial difficulty in determining the actual prices and volumes under contract. They must develop new ways to interpret price and volume data since, in general, contract terms are not publicly observed. Widely available market data tend to include only general comments about patterns observed. Fortunately, the use of pre-commitment contracts varies throughout the year, and by growing region, so it is possible to make inferences about the effects of contracting from publicly available data.

To investigate the effects of contracting, known as pre-commitments,

Figure 1. Daily Spot Prices by Region: 2003



Source: Mohapatra et al., 2007.

we made use of data from the USDA's *National Berry Report* to evaluate how these informal contracts in the market for fresh strawberries affect spot-market prices. The goal was to see if we could determine anything about the effects of contracting from the comments concerning pre-commitments in these USDA reports.

The contracts are between retailers and strawberry shippers, who market fresh strawberries for growers. Informal contracts arose during the late 1990s and early 2000s, and continue to co-exist alongside formal contracts. These pre-commitment contracts specify a volume, a delivery date, and a "lid" price for a future sale. The retailer pays the minimum of the lid price or the spot price, at the time of delivery (about two to four weeks later). Because strawberries are highly perishable, shippers and retailers developed informal contracting as a means to manage their risk. This allows retailers to count on a supply of strawberries at some point in the future—for instance, to plan to advertise strawberries in weekly circulars, a commitment they might make perhaps two to four weeks in advance of a sale. Around holidays such as Easter and Mother's Day, it is common for retail food circulars to feature fresh strawberries prominently, and it is therefore in the retailer's interest to secure a known volume of berries adequate to support the promotional effort.

As the grocery retailing sector has consolidated, major retailers have sought to control their costs by altering procurement practices. One way to do this is to deal with a smaller number of larger shippers. By the late 1990s, five or six large shippers marketed approximately three-fourths of California's fresh strawberry production, out of roughly 60 shippers in total.

Shippers, similarly, have responded to retailers' preferences by altering their own strategies. Traditionally, shippers were concentrated in one or two of the five main North American growing regions for fresh strawberries (three primary California regions—South Coast, Santa Maria, and Watsonville—and Florida and Mexico). Each region had its own harvest season, and while they overlapped, each dominated a portion of the year. No single region provided strawberries throughout the year. Recently, major shippers lengthened their marketing seasons by expanding into more than one growing area, to allow them to market strawberries throughout the year.

These large shippers account for the vast majority of pre-committed strawberry sales. Similarly, large retailers represent the majority of pre-commitment purchases. This pattern adds an interesting wrinkle to the interpretation of spot-price volatility: the volatility in spot prices may be concentrated on a particular subset of the industry, namely the smaller firms.

The *National Berry Report* includes comments relating to market conditions, and sometimes these comments pertain to pre-commitment prices. If such a comment pertaining to pre-commitments appears—for instance, that pre-commitment prices were observed in a particular range—then there was at least one pre-commitment sale at a price below the spot price, on that day. Table 1 summarizes the data. The average spot prices vary by region, reflecting the higher early-season prices (beginning in December and extending into the early months of the new calendar year), a pattern that is also reflected in the spot prices shown for calendar year 2003, in Figure 1. Table 1 also shows the frequency with which pre-commitment comments were observed, for the four strawberry-producing regions we studied. For instance, in Central Florida pre-commitments were used in at least 42% of the weeks studied.

As the season progressed from winter months where Central Florida is the dominant growing region to those where California dominates (moving from south to north as the year progresses), both mean prices and the frequency of pre-commitments changes. Early in the season, especially tied to promotions surrounding Easter and Mother's Day, retailers are more likely to seek pre-commitments. The share of the national market promoting strawberries is highest, early in the season, so the notion that pre-commitments support promotions is consistent with this pattern. Later in the season, retailers have less interest in pre-commitments, relative to shippers, and are less likely to promote strawberries.

The goal of our study was to see if there were patterns in the use of pre-commitments, to provide information about their effect on spot prices and producer welfare. One hypothesis is that pre-commitments exclude smaller shippers from certain markets, and the growers served by these small shippers do not share in any benefits from forward sales by pre-commitment. In contrast, another hypothesis is that the larger shippers provide a service, on which the smaller shippers and growers can effectively free ride, because pre-commitments bring stability to the market, smoothing week-to-week price fluctuations. Many studies have examined whether producers gain or lose from price volatility, and usually the results depend on very specific assumptions—for instance, can producers adjust production volumes after they observe price, or must they make their decisions about the price they receive before adjusting volume? For strawberries, certainly, most choices are made at the beginning of the season. As harvest occurs throughout the growing season, growers can do very little to respond to changes in prices. Thus, our analysis did not involve considerations of grower responses to price risk; once the strawberries are harvested, growers and shippers are interested in marketing them promptly at the best price.

Conclusion

To determine the effects of pre-commitments, we studied the pattern of mean prices and their variance, to see how these depended on the region and the extent of pre-commitments. We used statistical techniques to study price behavior and we separated out factors affecting the mean level of prices from factors affecting their volatility.

Table 1. Average Prices and Pre-Commitment Use, By Growing Region

	Spot Price ($ per flat)		Pre-commitment (1 = contract observed)	
	Mean	Standard Deviation	Mean	Standard Deviation
All Regions	6.36	2.64	0.25	0.43
All Regions (1995)	6.18	1.91	0.20	0.40
All Regions (2003)	7.19	3.38	0.27	0.44
Central Florida	8.51	3.16	0.42	0.49
South District, CA	7.52	3.29	0.23	0.42
Santa Maria, CA	5.15	1.30	0.16	0.37
Watsonville, CA	5.37	1.34	0.24	0.42

Source: Mohapatra et al., 2007.

Our finding is that pre-commitments raise average spot prices in all growing regions and, moreover, they reduce the volatility of spot-market prices in at least some regions. We found that pre-commitments reduced spot price volatility for Central Florida and the South District in California, while the effects of price volatility later in the season—for Santa Maria and Watsonville—were more difficult to measure. It is likely that the effect on volatility is not as strong for Santa Maria and Watsonville, or that the relationship is more complicated. As we noted, the interest on the part of retailers in pre-commitments varies throughout the season, so it may be that their role is more ambiguous, later in the season, when Santa Maria and Watsonville are the dominant growing regions.

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Further reading pertaining to contracting:

"Effects of Forward Sales on Spot Markets: Pre-Commitment Sales and Prices for Fresh Strawberries." Mohapatra, S., R. E. Goodhue; C. A. Carter and J. A. Chalfant. *American Journal of Agricultural Economics* 92(1) (2010): 152-163.

"Grower-Winery Contracts in California: Use and Design." R. E. Goodhue, D. M. Heien, H. Lee, and D. A. Sumner. *California Agriculture* 56(3) (2002): 97-102.

"The Red Edge: Demand-Enhancing Strategies for California Strawberries." C. A. Carter, J. A. Chalfant, and R. E. Goodhue. *The Economics of Commodity Promotion Programs: Lessons from California*. Kaiser, Alston, Crespi and Sexton, eds. New York: Peter Lang Publishing Inc., 2005.

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