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The Economic Importance of Methyl Bromide: Does the California Strawberry Industry Qualify for a Critical Use Exemption from the Methyl Bromide Ban?

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Methyl bromide has been applied to California strawberries for forty years. However, it will be banned in the United States and other developed countries in 2005. Critical use exemptions provide a mechanism that allows its continued use after this date for industries that do not have technically and economically feasible alternatives, and are consequently subject to significant market disruption. Integrating scientific and economic results from a multidisciplinary research project, we evaluate whether California strawberries are eligible for a critical use exemption.

Methyl bromide (MBr) is an efficacious soil fumigant that controls a wide range of pests, including weeds, nematodes, and other pathogens. Mixed with chloropicrin, it is widely used for pre-plant fumigation in vegetable and fruit crops. Because it is an ozone-depleting chemical, MBr is being phased-out in the United States under the Montreal Protocol.

In the United States and other developed countries, MBr use was reduced to 75% of 1991 baseline levels in 1999. In 2001, the use dropped to 50% of the 1991 level,

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and in 2003, it fell to 30%. MBr will be banned in 2005. Developing countries, such as Mexico, will ban MBr in 2015.[1] In part, the phaseout was intended to reduce the effects of the ban on MBr users by allowing time for the development of alternatives. The agreement also provides for the possibility of an exemption for critical uses (Article 2H, paragraph 5). A critical use exemption (CUE) allows a specified amount of MBr for a particular time period. In order to obtain a CUE, the following criteria must be met:

> That a use of methyl bromide shall qualify as 'critical' only if the nominating Party determines that:
>
> (i) The specific use is critical because the lack of availability of methyl bromide for that use would result in a significant market disruption; and
> (ii) There are no technically and economically feasible alternatives or substitutes that are available to the user that are acceptable from the standpoint of environment and health and are suitable to the crops and circumstances of the nomination . . .
>
> (Decision IX/6, Parties to the Montreal Protocol)

In addition, to be eligible for a CUE, past and current research efforts regarding alternatives must be documented.

We considered whether the California strawberry industry qualifies for a CUE based on these criteria, and drew implications for exemptions in general, and on the exemptions process. We evaluated the economic feasibility of currently registered alternatives to MBr for California strawberry producers, given their degree of technical feasibility. We examined whether significant market disruption will occur as a result of the ban. This exercise has implications beyond the strawberry industry. The Environmental Protection Agency's (EPAs) interpretation of these criteria allows for significant discretion in awarding an exemption. We evaluated the economic feasibility of alternatives and the likelihood of significant market disruption, and identified what factors outside our analysis may have influenced our conclusions. This procedure could be applied to other MBr uses. We also examined the broader policy implications of our analysis.

Use of MBr on Strawberries

In 2003, the United States submitted a proposal to the Ozone Secretariat of the United Nations for a 2005 CUE for sixteen uses: commodity storage, food processing, and fourteen crops, including strawberries. The California strawberry industry subsequently received exemptions through 2006. The request was based on a domestic application process conducted by the U.S. EPA. Our analytical approach relied on the information the EPA required in its CUE application form. The CUE application requested information on costs of production using MBr and currently available alternatives, as well as current industry revenues. It did not request any information regarding demand elasticities or estimates of changes in consumer surplus (which most definitions of significant market disruption would include).

Strawberries are a particularly interesting commodity to evaluate, due to the strawberry industry's behavior during the phaseout. Strawberries' share of total California MBr use rose from 24% in 1991 to 57% in 2001 (table 1).[2] All MBr use in California declined by 65% between 1991 and 2000; however, use on strawberries dropped only 17%. In contrast, nursery use declined by 73%, grape applications

Table 1. Methyl bromide consumption, 1991–2001: Total California use and selected crops

	Total Use	Strawberries	Carrots	Nursery	Grapes	Almonds
1991						
lbs	18,683,972	4,357,236	1,294,670	1,901,110	1,480,017	631,432
acres		33,226	8,317	6,758	*797,872*	24,519
lbs/acre		137	156	281	2	26
1992						
lbs	19,025,148	4,682,323	357,346	2,093,042	1,930,933	1,422,903
acres		29,403	2,093	12,715	5,593	18,407
lbs/acre		159	171	165	345	77
1993						
lbs	14,768,033	3,471,944	952,024	1,910,929	1,300,140	781,995
acres		*159,381*	5,721	7,694	3,602	*370,175*
lbs/acre		22	166	248	361	2
1994						
lbs	16,960,421	4,134,643	1,330,165	1,905,682	2,107,594	885,113
acres		23,171	7,898	8,154	5,923	25,851
lbs/acre		178	168	234	356	34
1995						
lbs	17,565,348	4,236,217	795,417	2,068,130	1,730,616	929,520
acres		23,793	4,684	7,118	4,963	22,823
lbs/acre		178	170	291	349	41
1996						
lbs	16,022,069	4,375,225	391,920	1,113,882	1,779,237	532,008
acres		21,344	2,188	16,581	5,250	16,092
lbs/acre		205	179	67	339	33
1997						
lbs	15,663,832	4,042,928	143,730	1,541,822	1,558,307	893,299
acres		21,746	945	15,312	4,226	20,791
lbs/acre		186	152	101	369	43
1998						
lbs	13,569,875	4,252,131	5,129	2,090,352	752,083	459,260
acres		20,291	35	17,141	2,165	14,980
lbs/acre		210	147	122	347	31
1999						
lbs	15,342,080	5,171,766	400	1,972,820	1,061,897	336,671
acres		25,493	2	16,257	2,918	16,703
lbs/acre		203	200	121	364	20
2000						
lbs	10,862,836	4,226,040	4,502	1,339,129	378,666	147,402
acres		22,580	14	12,285	1,359	8,904
lbs/acre		187	322	109	279	17
2001						
lbs	6,615,844	3,765,630	0	507,774	116,155	37,034
acres		22,241	0	14,395	388	7,843
lbs/acre		169	0	35	299	5

Source: California Department of Pesticide Regulation Pesticide Use Reports, various years.
Note: Probable data errors italicized.

fell by 92%, and almond use by 94%.[3] MBr on carrots, which accounted for 7% of all use in 1991, rapidly declined to a negligible amount by 1998, and by 2001 it was nonexistent.

The limited decline in strawberry MBr use is influenced by three interrelated factors: first, strawberries are a very high value crop. Strawberries generate a high marginal value product from MBr, relative to other crops. Second, industry researchers have experienced significant difficulty in finding technically feasible alternatives that perform as well as MBr across the broad spectrum of pests it controls. Given the high per acre value of strawberries, growers found it more profitable to continue to use MBr than to move to an alternative, even as the price of MBr increased during the phaseout. Using simulation analysis, Lynch found that California strawberries had the highest valuation of MBr, compared to the second best pest control strategy. Finally, many growers recall the pre-fumigation era, or are only one generation removed from it. Prior to the adoption of pre-planting soil fumigation using an MBr-chloropicrin mix, strawberry yields were dramatically lower and, to some extent, more variable, due in part to pathogen problems, particularly Verticillium wilt, and root disease caused by *Phytophthora fragariae* Hick (Wilhelm and Paulus). Perhaps memories of the pre-fumigation period have made some growers reluctant to move to alternatives before it is necessary. In the context of these confounding factors, it is difficult to use behavior during the phaseout period to predict the economic feasibility of alternatives and the potential for significant market disruption when MBr is banned. Instead, we used field trial results, cost data, and market-level information.

Because of the importance of MBr to American agriculture, other economists have examined aspects of the MBr ban and the transition to alternatives. Previous studies are reviewed in Carter et al. in this issue. With the exception of Carpenter, Gianessi, and Lynch, these studies estimated substantial declines in producer and consumer surplus for strawberries, which could be interpreted as evidence of significant market disruption.

Our work is distinguished from these other studies by the integration of economic and scientific analysis in a single research framework. We were able to use field trial data to directly consider differences in weed-control costs. This integration was not costless; our work focused on a single crop, while other analyses address many. Unlike previous analyses, we evaluated whether the California strawberry industry meets the criteria for receiving a critical use exemption from the 2005 ban.

Research Methods

Our data were generated by a multidisciplinary project that included plant pathologists, a nematologist, a weed scientist, a horticulturalist, a soil scientist, and an economist. We analyzed weed-control costs and chemical material costs in the field-level analysis. We restricted our attention to currently registered because there is no guarantee that unregistered alternatives will be approved for use by commercial strawberry producers in California by 2005.[4] Three chemicals are currently available: chloropicrin and 1,3-dicloropropene (1,3-D) applied via shank or the drip-irrigation system, and metam sodium applied via the drip-irrigation system. We did not consider organic production, nor did we evaluate integrated pest management techniques in conjunction with the examined alternatives.

Table 2. Fumigant material costs. California, fall 2000

Material	Average Price (lbs)	Maximum Price	Minimum Price
PIC	2.40	3.00	1.90
PIC EC	2.40	2.60	1.90
Inline	2.30	2.48	2.13
TEL C35	2.695	2.89	2.50
MS	0.745	n.a.	n.a.
MBPIC 67-33	2.60	n.a.	n.a.

Source: Collected from industry members.

The project began in August 2000 with the application of emulsified fumigants in a strawberry field at Martinez Farms, near Oxnard, California. Drip-applied treatments were chloropicrin (PIC EC) at 16.8 gallons per acre (GPA), and the 1,3-D product Inline at 22.6 GPA. The Inline plots utilized VIF tarps, which may have contributed to enhanced weed control relative to the other treatments that used standard tarp.[5] Shank-applied materials included the 1,3-D product Telone C35 (TEL C35) at 282 pounds per acre (lbs/acre), chloropicrin (PIC) at 141 lbs/acre, and MBr-chloropicrin (MBPIC 67-33) at 175 lbs/acre. Metam sodium at 26.1 GPA was applied to one set of plots five days after the initial fumigation. No metam sodium was applied to a second set. Each treatment was replicated once in one-acre plots.

The strawberry variety "Camarosa" was planted between October 5 and October 8, 2000. Within each plot, three subplots were established, each one bed wide by 100 ft long. In these subplots, weed counts and weeding times were measured on 30 November 2000, 30 January, 29 March, and 24 May 2001. The experimental data were combined with information on fumigant material and tarp costs for fall 2000 (see table 2). Weeding costs were calculated using the University of California (UC) strawberry weeding cost per hour of $9.38 for the Oxnard plains region (Klonsky and Demoura 2001b).

Weed Populations and Weeding Times

Table 3 shows weed populations and weeding times for each. MBPIC 67-33 had the lowest weed populations and weeding times. Researchers have established that on average, chloropicrin or 1,3-D alone do not control weeds as well as MBr does. The field trials tested the hypothesis that metam sodium significantly improved weed control. Metam sodium significantly reduced weeding times for chloropicrin products, but not for Inline or TEL C35. However, improved weed control did not necessarily translate into improved economic performance. The addition of metam sodium reduced costs for chloropicrin products by less than 1%.

Except for PIC, with or without MS, alternative fumigants resulted in higher costs of fumigation materials plus weeding labor than MBPIC 67-33 (table 4). However, these cost comparisons cannot include all aspects of treatment efficacy. PIC provides more variable weed control, so our calculations of cost differences may overstate the expected value of PIC treatments. Improved weed control is

Table 3. The number of weeds per acre and weeding times in the fumigant evaluation at Oxnard, California

Fumigant	No. Weeds per Acre	Weed Time Hours per Acre
PIC EC	9,693 (2178)[a]	47.7 (2.6)
PIC EC + MS	5,627 (549)	37.3 (0.8)
Inline + VIF	7,006 (1108)	35.3 (2.7)
Inline + VIF + MS	4,501 (442)	38.1 (1.1)
PIC	7,950 (1497)	38.4 (1.7)
PIC + MS	5,264 (1948)	28.7 (4.1)
TEL C35	4,102 (1053)	28.8 (3.6)
TEL C35 + MS	2,468 (254)	27.7 (1.7)
MBPIC 67-33	2,105 (323)	26.5 (1.7)

[a]Standard error in parentheses.

a major reason why MBr plus PIC, rather than PIC alone, became the preferred fumigant forty years ago (Wilhelm and Paulus).

Applying Experimental Plot Results to Commercial Fields

As is always the case when undertaking research, there are a number of factors that limit the direct application of experimental results to commercial production. Our estimates are likely to understate the relative costs of alternative treatments, for at least five reasons. First, we evaluate material costs. Such costs may not reflect custom fumigation charges paid by growers that include material and application costs. Second, we did not consider the added cost of sequentially applying metam sodium.

Third, we did not consider differences in application costs. Application costs for drip-applied materials are higher than for shank materials. Drip application of chemicals requires producers to purchase more robust (and more expensive)

Table 4. Total weeding and fumigant costs per acre as a function of current material prices

	Fumigant Material Price		
Fumigant	Minimum	Average	Maximum
PIC EC	$1,135.79	$1,279.93	$1,419.17
PIC EC + MS	$1,112.67	$1,265.30	$1,413.02
Inline + VIF	$1,342.19	$1,415.62	$1,489.05
Inline + MS + VIF	$1,442.89	$1,524.81	$1,606.72
PIC	$996.60	$972.06	$1,169.90
PIC + MS	$980.05	$964.00	$1,170.32
TEL C35	$1,526.55	$1,304.12	$1,715.85
TEL C35 + MS	$1,590.67	$1,376.72	$1,796.94
MBPIC 67-33	$1,154.98	$980.44	$1,188.28

tubing and other equipment than if drip irrigation was the sole intended use. Further, experimental and field experience suggest that there is a steep and long learning curve associated with the use of drip fumigation. Some producers have already incurred these learning costs. Others have chosen to pay for custom drip applications instead. Fumigation costs as a share of total cultural costs range from 8% for materials and labor in the Santa Maria region to 24% for custom fumigation in the Watsonville region (Bendixen, Klonsky, and Demoura; Klonsky and Demoura 2001a). Accordingly, changes in fumigation application costs could affect cultural costs significantly.

Fourth, we did not have yield data from our field trials. Due in part to the differences between pathogen problems in commercial fields and field trial tests, scientists are reluctant to provide a single number summarizing average yield loss. Overall, project members, other researchers, and industry members estimate that *average* yield losses may be as high as 15% due to such factors, and concur that some yield loss will occur on average, most likely in the 10–15% range. Shaw and Larson's meta-analysis of experiments with alternative strawberry fumigants suggests that growers should expect a yield loss of at least 10.5% as a result of the ban. Repeated use of alternatives on the same soil and potential differences between experimental and label application rates are two factors suggesting this is a lower-bound estimate.

Yield losses of this magnitude would significantly affect grower returns. Based on the UC cost budget for the Oxnard Plains, a 10% loss in fresh market yield decreases revenue more than total fumigation costs. Even if higher prices result from the ban, the revenue decrease will almost certainly be larger than the increased fumigation costs per acre. A large-scale pathogen infestation, such as the outbreak of the foliar disease anthracnose due to infected nursery stock in the 2002 season, can be extremely costly, due to yield losses or other factors. In that case, growers bore the costs of replanting, excluding the actual plants.

Fifth, it is difficult to extrapolate from experimental to commercial field conditions. In our case, variability in weed populations and lighter than average weed densities resulted in differences in weeding times between our MBPIC 67-33 control plot and the UC budget estimate. Our average experimental weeding time for the methyl bromide control plot, 25.5 hours per acre, was roughly one-third of the budgeted time of seventy-six hours per acre (Klonsky and Demoura 2001b).

If we adjust weeding times to reflect the percentage of the base treatment weeding time, the relative costliness of the alternatives remains unchanged, but per acre costs increase substantially. These higher costs suggest that alternative fumigants are less likely to be economically viable when weed populations and weeding times are higher. The value of metam sodium is relatively greater when weeding times are higher. Adjusting total weeding times to reflect the cost budget base, the use of metam sodium is cost effective with either shank or drip-applied PIC in its current price range, although it is still not cost effective with 1,3-D products.[6,7]

Effect of Fumigant Prices on Relative Cost Effectiveness

Table 4 reports total weeding and material costs using the minimum, average, and maximum prices reported for each alternative material. Depending on relative price changes, the relative viability of these treatments may change after the phaseout.

There is no guarantee that prices will remain constant once MBr is banned, and demand for alternatives will increase. In fact, given a small number of manufacturers and distributors, economic theory would lead us to predict that fumigant prices will rise, perhaps at different rates. This observation is especially important for 1,3-D, which is a patented chemical controlled by a single company.

The prices of alternatives will not be determined by relative efficacy for strawberries alone. While strawberries are highly reliant on fumigation, and account for a significant share of MBr consumption in the United States, other crops also utilize it. The efficacy of alternatives for other crops will influence the price and economic viability of every alternative treatment for strawberries.

Clearly, such effects limit the literal value of any simple cost analysis. However, cost analysis does provide some insight into the economic viability of alternative treatments, when combined with sufficient analysis of industry-level responses. It also bounds the relative price changes for any single chemical that will not affect its relative cost effectiveness.

Break-Even Price and Industry Equilibrium

Given the increase in per acre costs, it seems likely that some acres will exit from strawberry production, *ceteris paribus*. This has two effects: first, acreage exit suggests the possibility of significant market disruption; second, the resulting price increase improves the economic viability of remaining acreage. Clearly, acreage exit would suggest that alternatives are not viable for the industry as a whole. In reality, acreage exit is likely to be associated with producers for whom the available alternatives are less cost effective due to soils, climate, management ability, and/or other reasons.

Ideally, we would have an estimate of cost differences across producers, the size of each producer group, and the production function for each type of producer for each alternative. Informal observations by researchers and strawberry growers suggest that alternatives differ in their technical feasibility across growing regions and other variables, which support the hypothesis that cost effectiveness would differ across producers. Unfortunately, producer-level information is unavailable. Instead, we assumed that all producers have identical per acre costs. We evaluated the changes in prices and total production necessary for growers to break even using each alternative treatment.

Tables 5 and 6 report the fresh price increases and associated acreage declines necessary for greater revenues per acre to cover the higher average production costs for each alternative, so that strawberry producers break even.[8] We report these break-even estimates for 0%, 5%, 10%, and 15% yield reductions for each treatment. The estimates are calculated using a demand elasticity for fresh California strawberries of −1.9 (Han). We assumed the processing price remains constant, due to the large number of close substitutes for frozen strawberries. Quantity adjustments represent the shifts required to move to the new long-run equilibrium associated with each alternative. With constant yields, the estimated cost increase will require a relatively small decrease in acreage for each alternative to break even. Greater yield differences result in significantly larger price

Table 5. Percentage fresh price increase necessary to break even given costs and yield change

	Yield Decrease			
Fumigant	**0 (%)**	**5 (%)**	**10 (%)**	**15 (%)**
PIC EC	1.6	7.5	14.9	21.9
PIC EC + MS	1.5	7.4	14.8	21.9
Inline	2.3	8.1	15.7	22.7
Inline + MS	2.9	8.7	16.4	23.3
PIC	0.0	6.0	13.1	20.3
PIC + MS	−0.1	6.0	13.0	20.3
TEL C35	1.7	7.6	15.0	22.1
TEL C35 + MS	2.1	8.0	15.5	22.5

and acreage adjustments. Larger adjustments suggest there is a greater potential for significant market disruption. Assuming that other suppliers do not increase their market production, acreage must decline by 13.3–34.3%, depending on the alternative, in order for growers to break even with the expected yield loss of 10–15%.

Table 7 estimates the loss in consumer surplus associated with the break-even decline in acres. Given the anticipated yield loss of 10–15%, consumer surplus will decrease from 43.4% to 68.8%. These numbers can be viewed as upper bounds on the magnitude of the consumer surplus loss because they assume that other suppliers do not increase their production. There is no guarantee that competing suppliers' production will remain constant, as discussed in Carter et al. Shifts in sellers' market shares are potentially another indicator of significant market disruption. On the other hand, such shifts may reduce consumer surplus losses.

Table 6. Percentage acreage decrease necessary to break even given costs and yield change

	Yield Decrease			
Fumigant	**0 (%)**	**5 (%)**	**10 (%)**	**15 (%)**
PIC drip	−3.0	−9.7	−16.5	−31.4
PIC drip + MS	−2.9	−9.6	−16.3	−31.2
Inline drip	−4.4	−11.0	−17.9	−33.0
Inline drip + MS	−5.5	−12.1	−19.0	−34.3
PIC shank	0.1	−6.8	−13.3	−27.7
PIC shank + MS	0.2	−6.7	−13.3	−27.6
TEL C35 shank	−3.3	−10.0	−16.7	−31.7
TEL C35 shank + MS	−4.0	−10.7	−17.5	−32.6

Table 7. Percent change in consumer surplus associated with break-even acres

	Yield Decrease			
Fumigant	**0 (%)**	**5 (%)**	**10 (%)**	**15 (%)**
PIC drip	−6.0	−26.5	−48.6	−66.0
PIC drip + MS	−5.7	−26.2	−48.4	−65.8
Inline drip	−8.7	−28.6	−50.8	−67.6
Inline drip + MS	−10.8	−30.2	−52.5	−68.8
PIC shank	0.2	−21.6	−43.5	−62.3
PIC shank + MS	0.3	−21.5	−43.4	−62.2
TEL C35 shank	−6.5	−26.8	−49.0	−66.3
TEL C35 shank + MS	−7.9	−28.0	−50.2	−67.1

Other Factors

The preceding analysis holds all other factors constant. At least four other factors may be important determinants of the actual empirical effects of moving to alternatives. First, as noted earlier, material costs may change when methyl bromide is no longer available. Any such cost changes would affect the economic viability of alternatives.

Second, there has been an extraordinary amount of public and private research and development examining potential MBr alternatives. The federal government has invested a substantial amount of money in research regarding methyl bromide alternatives for various commodities, including California strawberries, as has the California Strawberry Commission. Strawberry shippers and producers have invested in research that will aid them in remaining profitable after the ban. This research may result in alternatives with greater economic viability than those currently available. Under the Montreal Protocol, in order to receive a critical use exemption, applicants must demonstrate that they have invested in research regarding alternatives, and are continuing to do so. Thus, even if the California strawberry industry is granted a critical use exemption, we can expect research efforts to continue, and ultimately expand the set of available alternatives (though possibly at a slower rate than innovations would have been induced in the absence of an exemption).

Third, our analysis does not include organic or reduced-input production alternatives. Accordingly, we cannot directly compare the performance of such systems to the alternatives we evaluate. Organic strawberries account for a small, but growing, share of strawberry production. According to the UC production budget series, organics are substantially less profitable per acre than conventional strawberries. Although growers avoid some costs, organic strawberries require substantially more hand-weeding than conventional production, and have yields ranging from 20% to 39% below conventional strawberries (Carpenter, Gianessi, and Lynch). Depending on the efficacy of MBr alternatives, the expected returns to research regarding organic methods and the economic viability of organic production may increase after the ban. However, the impact of increased organic production is limited by a number of factors.

As the quantity of organic strawberries increases, the price premium relative to conventional strawberries is likely to fall. Hence, reductions in production costs per unit of organic strawberries will not guarantee that profitability will increase as production expands. The expansion of organic strawberry production is also limited by the effective requirement that strawberries can only be grown on a given field in one out of every three (or more) years. Thus, an organic strawberry grower must control (at least) three times the organic acreage he intends to plant to strawberries. Given the high cost of land in strawberry production regions, it may prove difficult to acquire additional land, profitably farm it through the three-year organic certification process, and continue to farm it profitably while rotating organic crops. Of course, it is not impossible to do so; individual operations, such as Swanton Farms, have proven to be very successful at organic strawberry production. However, there is no guarantee that expansions in organic acreage will prove as profitable.

Fourth, we do not consider the effects of other regulations. Our stated policy interest is in evaluating the appropriateness of a critical use exemption for commercial strawberry production in California. Carter et al. discuss the effects of regulatory uncertainty in the context of the MBr ban. For our analysis, the most important regulatory consideration is that registration uncertainty and costs may limit the set of MBr alternatives. One potential alternative, propargyl bromide, is unregistered. No commercial manufacturer has been willing to commit the substantial sums required to complete the national and California registration processes, and it will likely remain unregistered.

Iodomethane (IM) has shown promise as an alternative, but it is not currently registered for use on strawberries. Most observers predict that IM will receive its U.S. registration, and perhaps its California registration, in 2005. These predictions, of course, are not guarantees. Previously, most observers predicted that IM would receive its registrations in early 2003. Until IM is registered, growers face uncertainty regarding its availability after the methyl bromide ban. Until its label conditions are known, growers do not know whether application rate restrictions will prevent them from using IM at a high enough rate to be effective, or whether other use restrictions will prevent them from applying IM to all of their intended strawberry acreage. Growers cannot experiment with IM to evaluate its suitability for their particular conditions until it is registered. Hueth et al. analyze the economic viability of IM, but do not consider potential regulatory limitations.

Conclusion

At the field level, we find that given current material prices, per acre fumigant and weed-control costs are likely to increase, relative to methyl bromide, with the possible exception of shank-applied chloropicrin. Critically, changes in material prices will affect these costs, and may alter the relative cost effectiveness of the evaluated alternatives. Our estimates exclude equipment and application costs, which would further increase the costs of some alternatives. Economic viability is also affected by the revenues growers will obtain. This suggests that the field-level economic viability of alternatives cannot be evaluated independently of market-level effects.

To fully address the CUE criteria, we examine the market-level effects of the different alternatives. As a measure of disruption, we calculate the percentage changes in price and acreage necessary for producers to break even under each alternative for a range of yield declines. Potential disruptions are largest for the most expensive alternatives. Acreage declines and price increases are significant for all alternatives in the anticipated 10–15% yield loss range. These findings are consistent with the large surplus losses estimated by other researchers. Producer adjustments may be even larger if imports increase, which would suggest greater disruption of the production side of the market. On the other hand, consumers would see smaller changes in the price and quantity of fresh strawberries, which would reduce consumer disruptions.

Regulatory constraints are another important factor. The costs of registering a new pesticide at the state and federal levels, and the possibility of market-limiting use regulations deter the development of new methyl bromide alternatives.

Ultimately, parties to the Montreal Protocol will decide whether these effects constitute significant market disruption or economic nonviability. However, our analysis provides economic information based on the most current available scientific data. Uncertainty regarding the postban prices of alternative treatments increases the likelihood that the ban will result in significant market disruption. Further, the market-level analysis and the factors omitted from the field-level analysis suggest that the latter may overstate the economic feasibility of alternative treatments. Overall, our analysis is consistent with some degree of market disruption as a result of the methyl bromide ban, and suggests that market- and field-level factors must be considered when evaluating the economic feasibility of alternatives.

Our analysis has a number of limitations discussed earlier, including the standard limitations of field- and market-level projections using baseline data. First, our experiment provided only a single year of data, so we could not control for year-specific effects. Second, our data were from a single location in California. To the extent that the relative efficiency of alternatives differs across locations, our results may misstate the cost effectiveness of alternatives and the market-level price and acreage adjustments necessary for the remaining acreage to break even. Third, we did not include organic or reduced-input production systems. Despite these limitations, our analysis provides evidence regarding the eligibility of the California strawberry industry for a critical use exemption, and generates broader policy recommendations.

One emerging point that has broad applicability within agriculture is the importance of intellectual property rights. If a chemical is patented, then economic theory predicts that the patent holder will seek to maximize profits. Prices for that chemical will increase when the use of a competing alternative, such as methyl bromide or other treatments facing additional regulation is eliminated or restricted. Such behavior would suggest that our estimates based on current prices understate the likely cost increase. Perhaps a CUE could be made contingent on realized costs. Then, if material prices increase substantially in 2005, the CUE could be extended after 2006.

In general, this suggests that policymakers should collect and report price information. While this point may be obvious to an economist, it is not commonly done for agricultural chemicals and other inputs at a sufficiently disaggregated level. More specifically, it suggests that the CUE process should consider the potential effects of changes in materials prices and market-level price and quantity responses on the economic feasibility of alternatives. The current CUE application form does not ask for information regarding the sensitivity of economic feasibility to the prices of alternative treatments, or information regarding the market-level price determination process.

Another important point is that the cross effects of different governmental entities should be considered in any analysis of an existing or proposed policy. In our analysis of the CUE, the expense of the pesticide regulation process may limit the set of alternatives. This suggests that the relative returns to investing in research regarding organic production techniques and breeding varieties resistant to pests traditionally controlled via fumigation are higher than they would be in the absence of other pesticide regulations. It also suggests that the California Strawberry Commission and other industry groups should consider the cost effectiveness of registering alternatives for use on strawberries. Perhaps an alternative that is more economically viable and causes less market disruption than currently available ones could be made available through such efforts, mitigating the need for a CUE and enhancing the economic health of the strawberry industry. In addition to its direct effects, the availability of an additional alternative may partially mitigate price increases for currently available products, and enhance producer welfare.

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Endnotes

[1]Technically, the MBr phaseout and ban address consumption, which is defined as production plus imports less exports. Stockpiled MBr could be used after 2005.

[2]Table 1 uses data from the California Department of Pesticide Regulation's Pesticide Use Report (PUR) database. These data are the population of pesticide uses in California. The data are not error free. DPR analysts suggest that the reliability of the data increased substantially after 1991. The biennial *Agricultural Chemical Usage Survey for Vegetables* by the National Agricultural Statistical Service suggests a substantially larger decline in strawberry MBr use than the PUR database (U.S. Department of Agriculture, various years).

[3]While some crops, such as peppers and sweet potatoes, increased MBr use from 1991 to 2000, such crops account for only a small share of California MBr use.

[4]Researchers have evaluated other potential alternatives. Soil solarization, a nonchemical alternative, has not been shown to be technically feasible in the cool, foggy coastal regions where over 95% of California fresh strawberries are grown. Iodomethane and propargyl bromide are not currently registered for use on commercial strawberries.

[5]The efficacy of VIF tarp for weed control is currently being tested in field trials. Preliminary results on yellow nutsedge tubers indicate that VIF tarp improves control.

[6]The UC cost and returns study assumed a custom fumigation service is used, so the materials costs cannot be compared directly.

[7]We could not determine whether metam sodium would have been cost effective when applied following Inline if a standard tarp were used, rather than VIF.

[8]Under our specified parameters, the MBr treatment has slightly negative returns. Examining the changes in prices, acreage, and consumer surplus associated with the alternatives obtaining the same returns as MBr has a negligible effect on the reported changes: less than 1% for the 15% yield decline, and less than 0.5% for the smaller ones.

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