Determinants of Pesticide Registration for Food Crops

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Growers of fruits and vegetables and other so called 'minor crops' assert that Environmental Protection Agency (EPA) regulation of the pesticide industry unfairly limits the selection of pesticide active ingredients available to them (CAST 1992; Ollinger and Fernandez-Cornejo 1995). By limiting selection, EPA's crop-specific registration policy increases farmer pest control costs, leaves them particularly vulnerable to product cancellations or resistance development, and prevents them from benefitting from newer, safer, and more effective technologies. In response, the EPA has instituted a variety of initiatives intended to reduce the cost of pesticide registration, especially for reduced risk pesticides such as biologicals and for pesticide registrations for minor crops (EPA 1995a; EPA 1995b). This paper presents an evaluation of registration data to determine what crop and chemical characteristics are associated with low or declining likelihood of registration, and whether EPA initiatives are having their intended effects on those patterns.

The paper begins with a summary of the pesticide registration process, followed by data showing that most crops have a greater selection of active ingredients available to them now than in 1991, and that selection is on average newer and safer. Finally, a logit analysis of registration outcomes is presented showing evidence that registration likelihood has increased during the 1990s, especially for nonchemical pesticides, results consistent with EPA policy initiatives. Contrary to intentions, probability of registration is found to be decreasing in pesticide safety.

Pesticide Registration

Before a pesticide may be sold for use on a commercial food crop, the EPA requires a registrant to demonstrate first, that there exists a safe residue level for the active ingredient on the crop, and second, that there exists a use pattern that is reasonably safe to agricultural workers and the environment, and will ensure safe residue levels on the final commodity. The cost of meeting these standards is substantial, and does not end when a registration is granted. The EPA charges annual registration maintenance fees and additional testing is often required when new risks are suspected or when the original testing procedures no longer meet current standards.

Pesticide firms typically attempt to register their pesticides for large pesticide-market crops first, then for smaller crops in order of declining expected profitability, stopping when expected profitability reaches its minimum acceptable level. Registrations are dropped when, because of market changes, revenue falls below the cost of maintaining the registration on that crop, or when, because of EPA decisions, the cost of maintaining the registration increases.

Revenue potential is increasing in the value of a crop's pesticide market, and pesticide characteristics that determine the attractiveness of the pesticide to farmers. Field crops generally receive more herbicide applications than other crops. Insecticides are used more intensively on vegetables. Pesticides toxic to many pests appeal to farmers for their range of control, but highly targeted pesticides are useful for use in integrated pest management. Pesticide safety is also desired by farmers (Beach and Carlson 1993).

Crop and active ingredient characteristics also affect registration cost. EPA considers nonchemicals safer than synthetic pesticides and requires fewer safety tests (EPA 1995a, 1995b). Certain active ingredients are demonstrated safe after completion of basic tests, while others require more extensive and costly long term studies (40 CFR §158.202). Pesticide age also is a factor because as more is known about an active ingredient subsequent registrations are less costly. But the trend reverses for many older active ingredients because of re-registration requirements.

With these considerations, it is hypothesized that the probability of a positive registration outcome is increasing in crop market value. Registration should be increasing in safety because of higher potential revenues and lower registration costs. If EPA efforts to streamline the registration process are successful, the overall likelihood of registration should be increasing, especially for favored active ingredients and crops, such as biological pesticides and minor crops. If critics of EPA are correct, then older and less safe pesticides will have higher registration rates on minor crops.

Registration Data

Seventy-four field, vegetable, fruit, nut, root, tropical, and beverage crops are included in this study, along with national market value data from the USDA (various). Active ingredient characteristics were collected for every pesticide that appears on at least one of the included crops (EPA 1998a, 1998c; EXTOXNET 1998; Meister 1996; Thomson 1992, 1993; Ware 1994). Registration data were collected from NPIRS Pest-Bank in 1991 and 1995, and from the EPA's Pesticide Product Information System in 1997. A positive registration outcome is defined as the existence of at least one product containing a given active ingredient that is fully (not a special local need registration) registered for foliar application (for use on the crop itself) on the given crop or on a crop group (such as 'citrus' crops) that includes that crop.

Table 1 presents crop pesticide selection, safety, number of pests controlled, and age, averaged over crops of similar national value. The selection of registered insecticide and herbicide active ingredients increased for almost all crops between 1991 and 1997 (the only exception was sorghum). In general, larger value crops have more selection than smaller ones, though crop type matters as well. Crop value groups dominated by field crops, such as groups C and E, tend to have greater herbicide selection than would be expected based on crop value alone, while value groups dominated by vegetable and fruit crops, such as B and D, have larger than expected insecticide selection.

The number of pests controlled by the average pesticide available declined between 1991 and 1997 for all groups and their members (except group E, where wheat and soybeans had an increase in average number of weeds controlled by their herbicide selection). This decline may not be detrimental because it could reflect either a loss of broad spectrum pesticides or a gain of highly targeted active ingredients.

The average safety rating of crop pesticide selection increased for most crop value groups between 1991 and 1997. All crops experienced an increase in the average safety of their insecticide selection between 1991 and 1997. Across value groups, herbicides are on average safer for the large value crops, while insecticides are on average safer for the fruit- and vegetable-dominated value groups (A, B, and D).

The average age of both herbicides and insecticides declined between 1991 and 1997 for all groups, though for herbicides, some specific crops had an increase in average

age. Average selection age for insecticides declining for every crop.

Empirical Model and Results

This study employs a reduced form model wherein a representative pesticide firm evaluates annually the expected profitability of each combination of an active ingredient and a crop (all potential or existing registrations) to determine whether (depending on the registration status) to apply for, maintain, or withdraw the registration. That decision depends on profitability, which is an increasing function of factors that increase revenues, and a decreasing function of factors that cause EPA to increase registration costs. The profitability of a potential or existing registration is unobservable but the registration outcome is, enabling estimation of a logit (Equation 1) to measure the impact of the crop and active ingredient characteristics on the likelihood of a positive registration outcome.

$$P(r_{ijt}=1) = P(R_{ijt}-C_{ijt}+\varepsilon_{ijt}>0) = \alpha + \beta X_{ijt} + \varepsilon_{ijt} \qquad \text{(Equation 1)}$$

i=active ingredient, j=crop, t=time period

Table 2 presents the estimated coefficients, and their standard errors. The explanatory variables are almost all statistically significant at the 99% confidence level. Registration is increasing in crop market value. The coefficients on the interaction between crop market value and safety and age indicate that registration of safer, newer pesticides is increasing in crop value as well. This effect is ameliorated by a positive interaction between minor crops and safety, and negative interaction between those crops and age. The dummy variables on 1995 and 1997 registrations have negative coefficients, but interaction variables between those years and safety and nonchemical status are positive. Contrary to EPA intentions, registration is declining in safety, though interactions between safety and the later years and minor crops are positive.

Table 3 presents the estimated probabilities of a positive registration outcome for specific combinations of crop and active ingredient characteristics. The marginal effects of changes in characteristics are calculated by finding the differences between probabilities. The base herbicide combination, box 1, row A, is the 1991 probability of registration of a chemical herbicide of mean age (23 years), safety level (2.12), and pests controlled (141), on a field crop of median national crop value ($156,067,000). The base insecticide combination, box 9, row A, is an insecticide with the same characteristics. Moving horizontally or vertically between boxes changes a binary variable while holding all else constant. Moving within a box changes a continuous variable, all else constant.

As expected, increasing crop market value or pesticide pests controlled increases the likelihood of registration, though the effect is not dramatic. Adding 5 years to the active ingredient age caused a slight decline in the odds of registration, likely because pesticides of that age are subject to re-registration. Decreasing pesticide age to two years, a move not shown on this table, increases the likelihood of registration for vegetable crops by 1 to 7 percentage points, and less for herbicides.

Between 1991 and 1997 the likelihood of registration rose for all combinations of crops and chemicals except for those with the lowest safety level (level 1, a situation not included in this table). Vegetable crops do not have dramatically lower odds of registration than field crops. Nonchemical pesticides were much more likely to be registered than chemical ones, especially in 1997. The odds that a nonchemical insecticide was registered on a given crop tripled between 1991 and 1997.

Within every pesticide type classification, increased safety reduces the likelihood of gaining registrations. In 1997, a chemical insecticide that was one safety unit above the mean was more than 10 percentage points less likely to gain registrations, and nonchemical insecticides in the same situation were 30 percentage points less likely to gain registrations. This result is true at all initial safety levels, and it is not exclusive to minor crops. The coefficients on the interaction terms between safety and minor crops are positive indicating that for those crops the problem is less severe.

Conclusion

The results offer a mixed evaluation of the current system of pesticide registration. Summary statistics indicate that although selection is on average smaller for minor crops, the active ingredients that are available are not clearly inferior. There is evidence that the probability of registration is increasing, especially for nonchemicals. An unfortunate result is that safer active ingredients are less likely to gain registrations and thereby be disseminated to farmers. While this analysis cannot pinpoint blame for that result, it does indicate that the desirable registration environment, where at the margin, the safest active ingredient is promoted, does not currently exist.

Table 1--Active Ingredient Characteristics by Crop Value Group, 1991 and 1997

		Herbicides		Insecticides		Herbicides		Insecticides	
Crop Value Group		1991	1997	1991	1997	1991	1997	1991	1997
		Selection				Safety Rating			
A	<$100 M	2.6	7.8	18.3	31.0	1.57	1.81	2.03	2.38
B	$100-500 M	4.6	10.2	27.8	39.7	1.67	1.83	1.92	2.28
C	$500 M-1 B	14.6	18.6	22.1	35.4	1.91	1.85	1.82	2.27
D	$1-2 B	7.3	13.3	33.0	43.2	1.78	1.94	1.89	2.21
E	$5+ B	32.0	43.0	27.0	43.3	2.02	2.00	1.78	2.20
		Number of Pests Controlled				Age			
A	<$100 M	315	218	328	210	21	20	31	20
B	$100-500 M	269	218	303	214	24	21	30	21
C	$500 M-1 B	217	186	323	209	27	22	31	20
D	$1-2 B	268	230	266	214	26	24	29	22
E	$5+ B	184	183	285	211	25	21	29	22

Notes: M=million, B=billion. Selection is the average number of active ingredients available to crops in the value group.

Safety rating, number of pests controlled, and age are first averaged across active ingredients available to each crop, then averaged across crops in each crop value group. Safety rating is an EPA established rating where 1=highly toxic, 2=moderately toxic, 3=slightly toxic, and 4=practically non-toxic. The number of pests controlled by each active ingredient is calculated by aggregating all target pests listed on product labels that contain exclusively the active ingredient in question. Label information was obtained from EPA PPIS. Members of crop value groups: <$100 M: taro, bananas, ginger, coffee beets, brussels sprouts, papayas, endives, eggplants, hazelnut, figs, kiwis, dates, limes, tangelos, rye, artichokes, apricots, macadamias, olives, garlic, spinach, honeydews, tangerines, hops, nectarines, pistachios, plums, pineapples, mint; $100-500 M: watermelons, sweetpotatoes, asparagus, prunes, cranberries, cherries, cauliflower, pecans, cantaloupes, cucumbers, avacados, cabbage, celery, sunflowers, lemons, walnuts, pears, broccoli, carrots, peppers, peaches, grapefruit, sweet corn, oats, onions, strawberries, almonds, mushrooms; $500 M-1 B: beans, sugarcane, barley, lettuce, sugar-beets, rice, peanuts; $1-2 B: apples, sorghum, tomatoes, oranges, grapes, potatoes; $5+ B: wheat, soybeans, field corn.

Table 2--Determinants of Pesticide Registration

Variable	Co-efficient	Standard Error	Variable	Co-efficient	Standard Error
Intercept	-0.4489‡	0.1794	Crop val*ai age	-1.5E-9	4.59E-10
Yr 1995	-0.2790	0.0908	Crop val*safety	2.54E-8	7.887E-9
Yr 1997	-0.0380‡	0.0881	Yr 95*safety	0.1294	0.0479
Crop value	2.377E-7	3.08E-8	Yr 95*nonchem	0.7061	0.0918
Crop value sq	-1.2E-14	1.8E-15	Yr 97*safety	0.0693‡	0.0463
Vegetable crop	-0.3998	0.1480	Yr 97*nonchem	0.8527	0.0891
Fruit crop	-0.2699‡	0.1464	Safety*veg	0.3480	0.0539
Nut crop	-0.0227‡	0.1953	Safety*fruit	0.2626	0.0535
Root crop	-0.3885	0.1806	Safety*nut	0.0979‡	0.0716
Trop/bev crop	-1.0091	0.1980	Safety*root	0.3489	0.0658
Herbicide ai	-1.2417	0.0345	Safety*trop/bev	0.2354	0.0718
Age of ai	-0.0156	0.0045	Age*veg	-0.0177	0.0031
Age squared	0.0005	0.0001	Age*fruit	-0.0098	0.0031
Safety rating	-1.3784	0.1489	Age*nut	-0.0144	0.0041
Safety rate sq	0.1791	0.0355	Age*root	-0.0252	0.0038
Pest controlled	0.0051	0.0001	Age*trop/bev	-0.0304	0.0040
Nonchemical	1.2242	0.0721			

Notes: N=47,508; Model χ^2=11,979; degrees of freedom=32.

All coefficients are significant at the 99% level except those indicated by ‡.

Table 3--Estimated Probability of Active Ingredient Registration

	Registration Year and Crop Type							
	1991				1997			
Chemical/ Nonchemical	Field Crops		Vegetable Crops		Field Crops		Vegetable Crops	
	Herbicides							
Chemical	1		2		3		4	
	A	**0.0546**	**A**	**0.0507**	**A**	**0.0605**	**A**	**0.0562**
	B	0.0581	B	0.0541	B	0.0644	B	0.0599
	C	0.0513	C	0.0477	C	0.0569	C	0.0529
	D	0.0171	D	0.0159	D	0.0204	D	0.0189
	E	0.0584	E	0.0543	E	0.0646	E	0.0601
Nonchemical	5		6		7		8	
	A	**0.1641**	**A**	**0.1538**	**A**	**0.3393**	**A**	**0.3222**
	B	0.1735	B	0.1628	B	0.3545	B	0.3370
	C	0.1554	C	0.1456	C	0.3249	C	0.3083
	D	0.0559	D	0.0519	D	0.1423	D	0.1331
	E	0.1741	E	0.1633	E	0.3554	E	0.3380
	Insecticides							
Chemical	9		10		11		12	
	A	**0.1665**	**A**	**0.1561**	**A**	**0.1822**	**A**	**0.1710**
	B	0.1761	B	0.1652	B	0.1924	B	0.1807

	C	0.1578	C	0.1478	C	0.1727	C	0.1620
	D	0.0568	D	0.0528	D	0.0671	D	0.0625
	E	0.1767	E	0.1657	E	0.1930	E	0.1813
Nonchemical	13		14		15		16	
	A	**0.4047**	**A**	**0.3862**	**A**	**0.6400**	**A**	**0.6220**
	B	0.4209	B	0.4023	B	0.6553	B	0.6377
	C	0.3892	C	0.3710	C	0.6249	C	0.6067
	D	0.1700	D	0.1594	D	0.3647	D	0.3471
	E	0.4219	E	0.4032	E	0.6562	E	0.6386

Notes:

A = Median national crop value and mean active ingredient age, safety level, and number of pests controlled.

B = Same as A except crop value = mean national crop value.

C = Same as A except active ingredient age = mean plus 5 years.

D = Same as A except active ingredient safety level = mean plus 1 unit.

E = Same as A except active ingredient number of pests controlled = mean plus 10%.

Median national crop value is $156,067,000. Mean national crop value is $660,035,000. Mean active ingredient age is 23 years. Mean active ingredient safety level is 2.12. Mean active ingredient number of pests controlled is 141.

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