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HOUSEHOLD USE OF AGRICULTURAL CHEMICALS FOR SOIL-PEST MANAGEMENT AND OWN LABOR FOR YARD WORK

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Abstract

In spite of its potential health and environmental risks and contribution to agribusiness, the use of agricultural chemicals for yard care has not been well studied. In our discrete-continuous choice model, estimated with data from a national survey, a household chooses how much money, if any, to initially spend on types of agricultural chemicals and applicators and how much time to subsequently spend on other yard work. Households in big cities or with large gardens are more likely to use organic chemicals. The probability that a household chooses a mix of do-it-yourself and hired applications of synthetic chemicals increases with income and the number of minors or presence of preschoolers. Among households that apply only synthetic chemicals without hired help, those with young children, with higher incomes, in big cities, and with male heads spend more on the chemicals. The time that such households spend on other yard work increases with expenditures on the chemicals. Cancellation of a pesticide registration might create an extra private cost for households with young children even though the ban might reduce external costs.

Key Words: agricultural chemicals; do-it-yourself application; discrete-continuous choice; fertilizers; hired application; lawn and garden; organic chemicals; pesticides; synthetic chemicals; yard care

Household Use of Agricultural Chemicals for Soil-Pest Management and Own Labor for Yard Work

1. Introduction

The use of pesticides and fertilizers on residential landscapes is a matter of concern to government officials who manage water quality and protect public health. For example, Phase II of the Clean Water Act's Stormwater Program has, since March 2003, required operators of small municipal separate storm sewer systems in the U.S. to conduct public education and outreach that encourage households to properly use synthetic pesticides and fertilizers (EPA 2006). Pesticides in stormwater runoff from yards and other urban sources can pollute streams (e.g., Gilliom et al., 6 and 8). The Food Quality Protection Act of 1996 explicitly requires assessments of risks of exposure of children to pesticides used outdoors (Benbrook) because accidental poisonings occur (e.g., Belson et al.) and, in some but not all studies (e.g., Daniels et al.), the odds of certain cancers increase with chronic exposure. Use of pesticides on residential landscapes can also cause pet illness (e.g., Beasley) and kill birds or impair their reproduction (e.g., Brewer et al.).

In the U. S., at least 50% of all households with yards use agricultural chemicals (Templeton et al. 1998). Households spent \$1.5 billion for pesticides and synthetic fertilizers that they applied outdoors in 1995 (Hatton). Real expenditures (2000 \$s) for pesticides that households applied indoors and outdoors grew 4.0% per year during 1995-2001, from \$1.66 to \$2.10 billion (BEA; Kiely et al., 25). In 1995 11.5% of all households hired someone to apply synthetic chemicals to their yards and paid \$3.1 billion for the service (Templeton et al. 1998, 418A and 419A). Real expenditures (2000 \$s) for professional lawn care and landscape maintenance grew 8.9% per year during 1995-2001, from \$5.6 billion to \$9.4 billion (Butterfield).

In spite of the scrutiny of policy makers and size of household expenditures, the use of pesticides and fertilizers for yard care has not been thoroughly studied. Previous research has only dealt with a household's decision to keep a yard and use yard chemicals (Templeton et al., 1999), the frequency of its application of lawn fertilizer and weed killers (Creason and Runge), and its willingness to pay for control of nuisance pests (Jakus). In this paper we present a theoretical model of household choices about how much money, if any, to initially spend on hired application and types of agricultural chemicals and how much time to subsequently spend on other yard work. We use data from a national survey to describe the five most common strategies—which includes non-use of chemicals—that households choose to manage soil fertility and yard pests and estimate a model of the determinants of the choice. We then empirically analyze expenditures of money for synthetic chemicals and time for subsequent yard work by households that apply only these chemicals without hired help.

In caring for their yards, households are farmers. Pest thresholds and pesticide use of commercial farmers have been extensively analyzed (e.g., Carlson and Wetzstein). However, households tend to have higher pest thresholds, apply more herbicides and fewer insecticides per acre on an annual basis, and take fewer precautions than most commercial agricultural producers (Templeton et al. 1998, 420A and 421A). They also face less regulation, manage considerably smaller farms with different cropping patterns, and have more non-financial objectives for management of pests or soil fertility than commercial farmers (Templeton et al., 1998). Furthermore, people typically do not sell ornamental plants, edible produce, or services that they produce in their yards. Instead, they consume these commodities on-site, usually for reasons other than sustenance. Hence, an analysis of input use for yard care requires a model that is different from, but related to, those of the use of chemical inputs for commercial agriculture.

2. A Model of Household Consumption and Production of a Yard

Households consume goods and services from yards that they manage. They dislike, in varying degrees, environmental and human exposure to pesticides (e.g., Templeton et al 1998, 419 A). Their attitudes about yard work vary from favorable to unfavorable (e.g., Gardner, 3). People also consume alternative commodities, such as watching movies and recreating in parks. The presence of children and other household characteristics affect these preferences.

Households use fertilizers and pesticides, if any, to promote plant health and reduce damage from pests in their yards (e.g., Gardner, 3). Although some pesticides are less-toxic and some fertilizers are naturally organic, most agricultural chemicals are synthetic. People must spend time to apply these chemicals. In addition to or instead of applying pesticides and fertilizers, households can hire a lawn care company or handyman to apply chemicals, typically synthetic ones. After observing the effects of the local agro-climate and any chemicals applied, households spend time on other yard tasks, e.g., mowing. Although essential, time for these tasks might differ from what was originally planned. Yard and household characteristics affect the productivity of agricultural chemicals and labor. To produce the alternative commodity, households use a good or service purchased with income not spent on agricultural chemicals or hired applicators and time not spent on yard work.

To formalize these assumptions in the spirit of Antle's sequential model, let production of yard goods and services, $\mathrm{Y}^i\left(\mathbf{X}^i, \varepsilon \mid \mathbf{K}\right)$, initially depend on the amounts, if any, of two types of agricultural chemicals that households and professionals might apply, $\mathbf{X}^i \equiv \left\langle \mathrm{X}^s, \mathrm{X}^o, \mathrm{X}^{hs}, \mathrm{X}^{ho} \right\rangle$, and stochastic agro-climatic conditions (ε), given household and yard characteristics, **K**. Chemical-applicator strategy *i* equals *n* for *n*o application of chemicals ($\mathbf{X}^n = \mathbf{0}$), *s* for do-it-yourself without hired application of *s*ynthetic chemicals , $\mathbf{X}^s \equiv \left\langle \mathrm{X}^s > 0, \mathrm{X}^o = 0, \mathrm{X}^{hs} = 0, \mathrm{X}^{ho} = 0 \right\rangle$, *dhs* for *d*o-it-yourself and *h*ired application of *s*ynthetics, $\mathbf{X}^{dhs} \equiv \left\langle \mathrm{X}^{s} > 0, \mathrm{X}^{o} = 0, \mathrm{X}^{hs} > 0, \mathrm{X}^{ho} = 0 \right\rangle$, *so* for do-it-yourself without hired application of both *s*ynthetic and *o*rganic chemicals (only $\mathrm{X}^{s} > 0$ and $\mathrm{X}^{o} > 0$), and *o* for do-it-yourself without hired application of *o*rganic chemicals (only $\mathrm{X}^{o} > 0$). Although 16 strategies are logically possible, the previous five are the most common and the focus of our empirical analysis. Given the *i*-th strategy, let production be subsequently a function of realizations of agro-climatic conditions (*e*) and own labor for other yard tasks (L^{i}), or $\mathrm{Y}^{i}\left(\mathrm{L}^{i}, \mathbf{X}^{i}, e \mid \mathbf{K}\right)$. The production function is C^{2} and strictly quasiconcave.

Application time (M) and exposure danger (D) are increasing concave and convex functions of agricultural chemicals ($\mathbf{X}^{i}$). Let the twice continuously differentiable and strictly quasiconcave production function for the alternative commodity be A(H, Q), in which H and Q are household time and a marketed good or service that costs p per unit. Given prices of agricultural chemicals ($\underset{1\mathrm{x}4}{\mathbf{c}}$) and no waste of predetermined time (T) or income (I), $\mathrm{H} = \mathrm{T} - \mathrm{M}(\mathbf{X}^{i}) - \mathrm{L}^{i}$ and $\mathrm{Q} = \dfrac{\mathrm{I} - \mathbf{c} \cdot \mathbf{X}^{i}}{\mathrm{p}}$. The utility function, $\mathrm{U}^{i}\left\langle \mathrm{Y}^{i}, \mathrm{M}, \mathrm{D}, \mathrm{L}^{i}, \mathrm{A} \mid \mathbf{K} \right\rangle$, is also C^{2} and strictly quasiconcave.

2.1 Discrete Choice about Type of Agricultural Chemicals and Applications

A household chooses the *i*-th chemical-application strategy if the expected utility of it exceeds the expected utilities of all other strategies, that is, if, $\forall j \neq i$,

$$E\left[\mathrm{U}^{i}\left\langle \mathrm{Y}^{i}\left(\mathrm{L}^{pi}, \mathbf{X}^{i*}, \varepsilon\right), \mathrm{M}(\mathbf{X}^{i*}), \mathrm{D}(\mathbf{X}^{i*}), \mathrm{L}^{pi}, \mathrm{A}\left(\mathrm{T} - \mathrm{M}(\mathbf{X}^{i*}) - \mathrm{L}^{pi}, \frac{\mathrm{I} - \mathbf{c} \cdot \mathbf{X}^{i*}}{\mathrm{p}}\right) \mid \mathbf{K} \right\rangle\right] >$$

$$E\left[\mathrm{U}^{j}\left\langle \mathrm{Y}^{j}\left(\mathrm{L}^{pj}, \mathbf{X}^{j*}, \varepsilon\right), \mathrm{M}(\mathbf{X}^{j*}), \mathrm{D}(\mathbf{X}^{j*}), \mathrm{L}^{pj}, \mathrm{A}\left(\mathrm{T} - \mathrm{M}(\mathbf{X}^{j*}) - \mathrm{L}^{pj}, \frac{\mathrm{I} - \mathbf{c} \cdot \mathbf{X}^{j*}}{\mathrm{p}}\right) \mid \mathbf{K} \right\rangle\right],$$

in which $\mathbf{X}^{i^*}$ maximizes expected utility of the *i*-th strategy and $\mathrm{L}^{pi} \equiv \arg\max E[\mathrm{U}^i]$ is **p**lanned labor after the chemical application(s). In terms of exogenous variables, the discrete choice is *i* if $E[\mathrm{U}^i\langle \mathrm{I}, \mathrm{T}, \mathbf{c}, \mathrm{p}, \mathbf{K}, \varepsilon\rangle] > E[\mathrm{U}^j\langle \mathrm{I}, \mathrm{T}, \mathbf{c}, \mathrm{p}, \mathbf{K}, \varepsilon\rangle]\ \forall j \neq i$.

2.2 Continuous Choice about the Type of Agricultural Chemicals and Application

If a household picks strategy *i*, it has also chosen $\mathbf{X}^{i^*}$ and planned subsequent yard work, L^{i^*}, to maximize expected conditional utility. For example, if a household applies only synthetic chemicals without hired help, then X^{s^*} solves this problem:

$$\max_{\mathrm{X}^s > 0} E\left[\mathrm{U}^s\left\langle \mathrm{Y}^s\left(\mathrm{L}^{ps}, \mathrm{X}^s, \varepsilon\right), \mathrm{M}(\mathrm{X}^s), \mathrm{D}(\mathrm{X}^s), \mathrm{L}^{ps}, \mathrm{A}\left(\mathrm{T} - \mathrm{M}(\mathrm{X}^s) - \mathrm{L}^{ps}, \frac{\mathrm{I} - \mathrm{c}^s\mathrm{X}^s}{\mathrm{p}}\right) \mid \mathbf{K}\right\rangle\right].$$

$E\left[\mathrm{U}_\mathrm{Y}^s \mathrm{Y}_{\mathrm{X}^s}^s\right] = E\left[\mathrm{U}_\mathrm{A}^s(\mathrm{A}_\mathrm{Q}\frac{\mathrm{c}^s}{\mathrm{p}} + \mathrm{A}_\mathrm{H}\mathrm{M}_{\mathrm{X}^s}) - \mathrm{U}_\mathrm{M}\mathrm{M}_{\mathrm{X}^s} - \mathrm{U}_\mathrm{D}\mathrm{D}_{\mathrm{X}^s}\right]$ is the first order condition for X^{s^*}. In words, a household would apply synthetic chemicals such that the expected marginal utility of extra goods or services from a yard treated with them, $E\left[\mathrm{U}_\mathrm{Y}^s \mathrm{Y}_{\mathrm{X}^s}^s\right]$, equals the expected forgone marginal utility of the marginal product of the input not purchased and household time not spent for the alternative commodity, $E\left[\mathrm{U}_\mathrm{A}^s(\mathrm{A}_\mathrm{Q}\frac{\mathrm{c}^s}{\mathrm{p}} + \mathrm{A}_\mathrm{H}\mathrm{M}_{\mathrm{X}^s})\right]$, minus the expected marginal disutilities of application time, $E\left[\mathrm{U}_\mathrm{M}^s \mathrm{M}_{\mathrm{X}^s}\right]$, and potential danger, $E\left[\mathrm{U}_\mathrm{D}^s \mathrm{D}_{\mathrm{X}^s}\right]$. If $E\left[U_{\mathrm{X}^s\mathrm{X}^s}^s\right] < 0$, a household's potential expenditures on synthetic chemicals can be written as $\mathrm{c}^s\mathrm{X}^{s^*}\langle \mathrm{I}, \mathrm{T}, \mathrm{c}^s, \mathrm{p}, \mathbf{K}, \varepsilon\rangle$, whether it actually purchases them.

2.3 Continuous Choice about Subsequent, Other Yard Work

The household's subsequent yard work depends on the *i*-th chemical-applicator strategy and realization of biophysical conditions (*e*). For example, if a household applies, without hired help, only synthetic chemicals, then optimal yard work, L^{s*}, solves this problem:

$$\max_{\mathrm{L}^s>0} \mathrm{U}^s\left\langle \mathrm{Y}^s\left(\mathrm{L}^s, \mathbf{X}^{s*}, e \,\middle|\, \mathrm{K}\right), \mathrm{M}(\mathbf{X}^{s*}), \mathrm{D}(\mathbf{X}^{s*}), \mathrm{L}^s, \mathrm{A}\left(\mathrm{T}-\mathrm{M}(\mathbf{X}^{s*})-\mathrm{L}^s, \frac{\mathrm{I}-\mathbf{cX}^{s*}}{\mathrm{p}}\right) \middle| \mathrm{K}\right\rangle.$$

The first-order condition is $\mathrm{U}^s_\mathrm{Y}\mathrm{Y}^s_\mathrm{L}+\mathrm{U}^s_\mathrm{L}=\mathrm{U}^s_\mathrm{A}\mathrm{A}_\mathrm{H}$. In words, the marginal utility of yard goods and services, the production of which increases with time in subsequent yard work ($\mathrm{U}^s_\mathrm{Y}\mathrm{Y}^s_\mathrm{L}$), plus the marginal utility or disutility of that work itself (U^s_L) equal the forgone marginal utility of the alternative commodity, the production of which decreases with yard work ($\mathrm{U}^s_\mathrm{A}\mathrm{A}_\mathrm{H}$). Given the second-order condition and implicit function theorem, potential yard work other than application is $\mathrm{L}^{s*}\left\langle \mathrm{I}, \mathrm{T}, \mathrm{c}^\mathrm{s}, \mathrm{X}^{s*}, \mathrm{p}, \mathbf{K}, e\right\rangle$, whether it actually does it.

3. Two-Part Econometric Model and Estimation Procedures

3.1 Discrete Choice of Agricultural Chemical-Application Strategy

The household knows its expected utility of each strategy, but a researcher does not. Let $E(U^i)=V^i=\overline{V}^i+\upsilon^i$, $i = n, s, dhs, so$, and o. $\overline{V}^i$ represents the deterministic and knowable portion of the expected utility of choice *i* and υ^i represents an independently and identically distributed random, but unobservable, portion of the expected utility of *i* that has, on average, no effect on the choice. Thus, the household's choice in the researcher's mind is probabilistic: $P^i=\Pr\left(V^i\geq V^j\right)=\Pr\left(\overline{V}^i+\upsilon^i\geq\overline{V}^j+\upsilon^j\right)=\Pr\left(\upsilon^i-\upsilon^j\geq-\overline{V}^i+\overline{V}^j\right)$. If $\upsilon^i-\upsilon^j$ is symmetric, $P^i=\Pr\left(\upsilon^i-\upsilon^j\leq\overline{V}^i-\overline{V}^j\right)\ \forall j\neq i$. If υ^i is an i.i.d, extreme-value random variable, then $P^i=\frac{\exp(\overline{V}^i)}{\sum_{\forall j}\exp(\overline{V}^j)}$. Let $\overline{V}^n=0$, $\overline{V}^s=\mathrm{Z}'\alpha^s$, $\overline{V}^{dhs}=\mathrm{Z}'\alpha^{dhs}$, $\overline{V}^{so}=\mathrm{Z}'\alpha^{so}$, and $\overline{V}^o=\mathrm{Z}'\alpha^o$, in which Z is a vector of income (I), proxies for time (T), a location variable that might affect prices (p and **c**), and other characteristics (**K**) of the household and yard.

3.2 Conditional and Sequential Continuous Choices

If $V^i > V^j \ \forall j \neq i$, then the household chooses the *i*-th strategy and potential expenditures of any money for the strategy and time for subsequent work become actual expenditures. For example, if $V^s > V^j \ \forall j \neq s$, the household chooses to apply, without hired help, only synthetic chemicals. As a result, potential expenditures of money for chemicals and time for subsequent yard work become actual expenditures, $\mathrm{c}^s\mathrm{X}^s$ and L^s. That is, $\mathrm{c}^s\mathrm{X}^{s*}\langle \mathrm{I}, \mathrm{T}, \mathrm{c}^s, \mathrm{p}, \mathbf{K}, \varepsilon \rangle = \mathrm{c}^s\mathrm{X}^s > 0$ and $\mathrm{L}^{s*}\langle \mathrm{I}, \mathrm{T}, c^s, \mathrm{X}^{s*}, \mathrm{p}, \mathbf{K}, e \rangle = \mathrm{L}^s > 0$. Specify that $\ln(\mathrm{c}^s\mathrm{X}^s) = \mathrm{Z}'\beta^s + \eta_s$ and $\ln(\mathrm{L}^s) = \mathrm{Z}'\boldsymbol{\gamma}^s + \ln(\mathrm{c}^s\mathrm{X}^s)\gamma^s_{\mathrm{K}+1} + \omega_s$, in which $\begin{pmatrix} \eta_s \\ \omega_s \end{pmatrix} \sim N_2\left[\begin{pmatrix} 0 \\ 0 \end{pmatrix}, \begin{pmatrix} \sigma_s^2 & \rho\sigma_s\sigma_{\mathrm{L}^s} \\ \rho\sigma_s\sigma_{\mathrm{L}^s} & \sigma^2_{\mathrm{L}^s} \end{pmatrix}\right]$, for estimation.

Chemical-applicator strategies *dhs*, *o*, and *so* have analogous expenditure equations that have choice-specific marginal effects. However, strategies *dhs* and *so* have third equations for expenditures of money on hired application and organic inputs. Strategy *n* has one equation, which pertains to time on yard work. These equations depict actual behavior because hypothetical behavior of households that do not choose the other strategies is unobservable and actual expenditures for synthetic chemicals is relevant to policy makers and sales forecasters (e.g., Donaldson et al.).

3.3 Estimation Procedures

As specified, our discrete-continuous choice model constitutes a two-part econometric model (Duan et al.). The likelihood function of a two-part model is a truncated, joint probability density function, just as the likelihood function of a sample-selection model is. However, one factors the likelihood function of a two-part model into separate multiplicative terms, each of which depends on parameters exclusive to it and, thus, estimates each term separately to obtain a unique global maximum (Duan et al.). Thus, our likelihood function is factored into the product of the unconditional probabilities of chemical-application strategies times the conditional density functions for positive expenditures of money and time.

Parameters of the multinomial logit model were estimated with ML, a maximum likelihood procedure, and the Newton-Raphson algorithm of iteration of Time Series Processor (TSP), Version 5.0. The standard errors were computed from the inverse of the analytic, second-partial derivatives of the log-likelihood function with respect to the parameters. Parameters of the two-equation model of expenditures of money for do-it-yourself application of synthetic chemicals and time for subsequent yard work were estimated with LSQ, TSP's generalized least-squares procedure for multiple equations. The standard errors were computed from the analytic first derivatives of the residuals with respect to the parameters. The model of yard work of non-users was estimated with least squares. Models of continuous choices for chemical-and-application strategies *o*, *sh*, and *so* were not estimated because of small sub-samples.

4. Data Sources and Variables

Most of our data came from a stratified, random survey of households in the United States that was conducted in January-February 1996 by the Gallup Organization, Inc. for the National Gardening Association. Gallup had conducted this survey every year since 1979 until 2000. The annual NGA survey includes questions about expenditures to control insects outdoors and various household characteristics. To the standard questions in the annual survey, we added questions about yard characteristics, hours spent in yard work per week, time spent applying agricultural chemicals during the growing season, and expenditures on do-it-yourself agricultural chemicals other than insect controls during 1995. Use of data from household recollection is common in the published literature (e.g., Jakus). Nonetheless, 14 households whose respondents were not household heads or not married to them were excluded to reduce recollection errors and improve the correspondence between characteristics of the respondent and the decision-maker for yard care. To determine minimum daily temperatures that affect a yard's micro-climate, we matched the zip-code location of each household to the closest reporting weather station in the Cooperative Summary of the Day database from the National Climatic Data Center.

Table 1 includes descriptive statistics about expenditures by do-it-yourself (DIY) households, or households that do yard work without hired help, except for possible hired application of some synthetic chemicals. DIYCHEM is expenditures for outdoor insect controls plus expenditures for all types of fertilizers, herbicides, fungicides, and snail or slug controls that a household applied outdoors during the 1995 growing season. DIYCHEM divided by yard size is DIYCHEMIN. PROCHEM represents payments to professionals, neighborhood teenagers, or handymen for application of synthetic fertilizers and pest controls, which exclude termiticides. ALLCHEM = DIYCHEM + PROCHEM. ALLCHEM divided by yard size equals ALLCHEMIN, monetary expenditures per acre. OTHWORK equals the average hours that the household spent for yard work per week times the number of weeks in the 1995 growing season minus the number of hours that a household spent to apply chemicals during the season. OWORKIN is OTHWORK divided by yard size.

The largest share, 51.5%, of households purchased only synthetic chemicals and applied them without hired help. Expenditures by households in this group accounted for 52.3% of expenditures on agricultural chemicals for do-it-yourself application. 'Synthetic chemicals' includes insecticidal dusts, water soluble chemical insecticides, ready-to-use insect control sprays, fungicides or fungus controls, ready-to-use or concentrate weed controls or herbicides, weed and feed fertilizers, dry or granular chemical fertilizers, and liquid or water soluble fertilizers (NGA, 279). The smallest share, 4.3%, of households purchased organic chemicals. Their purchases represented only 3.3% of all expenditures on agricultural chemicals for do-it-yourself application. 'Organic chemicals' includes natural or less-toxic insect controls, blended all-natural organic fertilizers, blood meal, bone meal, rock powders, and manures (NGA, 279).

Households that purchased both synthetic and organic chemicals were 6.1% of the sample, yet their purchases were 12.1% of all expenditures on agricultural chemicals for do-it-yourself (DIY) application. Households that applied but also hired others to apply only synthetic chemicals represented 9.5% of the sample. However, their purchases were a disproportionate 32.3% of all expenditures on agricultural chemicals for DIY application. Households that did not spend time or money for do-it-yourself application of agricultural chemicals were 28.6% of the sample.

Table 2 contains descriptive statistics of independent variables. Households reported their pre-tax incomes in one of 22 Gallup-created intervals: $0 to $1,999, $2,000 to $2,999, then $1000 increments to $6,999, $7,000 to $9,999, $10,000 to $11,999, $12,000 to $14,999, $15,000 to $19,999, then $5,000 increments to $39,999, $40,000 to $49,999, $50,000 to $59,999, $60,000 to $64,999, $70,000 to $74,999, $100,000 to $149,999, and $150,000 or more. INCOME ($1000s) equals the upper bound of an interval plus one dollar divided by $1000 for households with pre-tax incomes in bounded ranges because respondents tend to under-report income (CB 2004, 4). INCOME equals 200 for households with pre-tax incomes greater than or equal to $150,000. The median income of the sample was $35,000, only $900 more than median income of the population of the U.S (CB 1999). For the model of subsequent yard work, INCNOAC ($1000s) is the household's income minus its expenditures on agricultural chemicals that it applied.

AGE is the age of the household head. NUMCHILD is the number of children, people who are less than eighteen years of age, in a household. CHILDLT6 equals one if a household has any child less than 6 years of age. Given the importance of children in EPA's risk assessments, the effects of NUMCHILD and CHILDLT6 were separately estimated in different specifications of the two-part model.

MALEHEAD equals one if the head of a household is male. TWOFULL equals one if a household has at least two full-time workers. BIGCITY equals one if a household is located in a Census-Bureau-designated 'urbanized area' with more than 100,000 people. An 'urbanized area' is one or more incorporated 'places' and the adjacent densely settled, surrounding territory, or urban fringe, that together have at least 50,000 persons (CB 1995). GROWDAYS is the number of consecutive days after the last frost of 1995 in which the minimum daily temperature exceeded 32 ˚F. YARDSIZE equals the reported area of the household's lot times the sum of the reported shares of any lawn, trees and shrubs, and garden in the lot. GARSHARE is garden area divided by yard size.

TWOFULL was excluded from the multinomial logit models because none of the households that chose chemical type-applicator strategy *o* or *os* had at least two adult members who were employed full time. MALEHEAD and GROWDAYS were excluded from the logit models because neither statistically affected any choice in preliminary tests.

5. Empirical Results

5.1 Differences in Expenditures by Type of Chemical and Application (Table 1)

A household that applies and pays someone to help apply only synthetic chemicals spends more money, on average, for the chemicals that it applies by itself than a household that applies both synthetic and organic chemicals without hired help. In turn, the household that applies both synthetic and organic chemicals spends more money, on average, for them than a household that applies only synthetic or organic chemicals. Moreover, the household that chooses do-it-yourself and hired applications of synthetic chemicals spends more per acre for these treatments than a household that applies only synthetic or organic chemicals.

Differences in time spent on yard work other than chemical application follow a similar pattern with one exception. In particular, a household that applies both organic and synthetic chemicals without hired help spends more time, on average, for other yard work than a household that applies only synthetic or organic chemicals spends. The exception is that a household with a yard treated with do-it-yourself and hired applications of synthetic chemicals spends less time on other yard work than a household with a yard treated with only DIY applications of synthetic and organic chemicals. Similarly, the household that applies and also pays someone to apply only synthetic chemicals spends less time per acre on other yard work than a household that applies organic chemicals with or without synthetic chemicals. Finally, a household that applies only synthetic chemicals spends more time on other yard work, on average, than a household that uses no agricultural chemicals.

5.2 Effects on Expected Utilities of Chemical-Application Strategies (Table 3)

The garden's share of the yard's area has positive and statistically significant effects on expected utilities of all four strategies that involve agricultural chemicals. The marginal effect is larger for a household that applies only organic chemicals than a household that applies only synthetic chemicals or one that also hires help with the application.[1]

Income has positive and statistically significant effects on expected utilities of the three strategies that involve synthetic chemicals. The positive effect is statistically larger for do-it-yourself with hired applications of synthetic chemicals than mere DIY application of them.

The expected utilities of the two strategies that involve organic chemicals will be higher if a household lives in a big city rather than a small one or town.

The age of the household head, the number of minors, and the presence of children less than six years old have positive and statistically significant effects on the expected utility of hiring others to help apply synthetic chemicals.

5.3 Mean Effects on Probabilities of Chemical-Application Strategies (Table 4)

The probabilities that a household treats its yard with agricultural chemicals increase, on average, from a low of 0.006 percentage points for do-it-yourself application of organics to a high of 0.19 percentage points for DIY application of synthetics, as income increases $1000. Moreover, the mean marginal effect of income on the probability of DIY applications with hired help increases whereas the mean effects on probabilities of other chemical strategies decrease, as income increases. In fact, income's effect on the probability of DIY with hired applications of synthetic chemicals becomes larger than its effect on the probability of mere DIY application of them at incomes greater than $20,000 in the model with NUMCHILD and greater than $12,000 in the model with CHILDL6. Income's effects on the probability that a household applies only organics and the probability that it applies only synthetics become negative at amounts greater than $40,000 and $60,000, respectively.

The probabilities that a household uses agricultural chemicals increase, on average, as garden's share of the yard increases. Moreover, the marginal effect of garden's share on the probability of DIY application of organic chemicals increases whereas its effects on the probabilities of other chemical strategies decrease, as garden's share increases.

Households in big cities are, on average, 5 percentage points more likely to apply only organic chemicals and, depending on the model's specification, 6.3 or 6.7 percentage points more likely to apply synthetic and organic chemicals than households elsewhere.

A household with children less than 6 years old is 16.15 percentage points more likely, on average, than a household without any preschooler to apply synthetic chemicals with hired help. If the number of minors increases by one, the probability that a household chooses DIY-with-hired application of synthetic chemicals increases 2.59 percentage points. If the age of the household head increases one year, the probability that the household chooses DIY-with-hired application increases, on average, 0.3 to 0.4 percentage points.

5.4 Expenditures by Households That Apply only Synthetic Chemicals (Tables 5 and 6)

Among households that apply only synthetic chemicals and do not hire help, monetary expenditures on these chemicals increase 4.6 percent in the model with NUMCHILD or 4.5 percent in the model with CHILDLT6 for each 10 percent increase in income (Table 5). Households with children less than six years old spend 49 percent more on synthetic chemicals than those without preschoolers spend. Male-headed households spend, depending on the model's specification, 42.6 or 47.3 percent more than female-headed households. Households in big cities spend 35 or 32 percent more for synthetic chemicals than others.

The same households reduce their expenditures of time for subsequent yard work by 2.9 in the model with NUMCHILD or 3.9 percent in the model with CHILDLT6 for each ten-percent increase in their disposable income (Table 6). However, an increase in monetary expenditures on synthetic chemicals of ten percent leads to an increase in time for other yard work of 2.38 or 4.67 percent because the chemicals increase the quality and the quantity of plants that need care. The mean estimated net elasticity of time for other yard work with respect to income net of expenditures on agricultural chemicals, $\hat{\gamma}^s_{\text{LINCNOAC}} + \hat{\gamma}^s_{\text{cX}} \cdot \hat{\beta}^s_{\text{LINCOME}} \cdot \overline{\left(\frac{\text{INCNOAC}}{\text{INCOME}}\right)}$, is -0.186 in the NUMCHILD model and -0.185 in the CHILDLT6 model. Thus, the negative, direct effect of income on other yard work dominates the positive, indirect effect of income through expenditures.

Other characteristics of the household and yard also affect own labor for other yard work. Households that apply only synthetic chemicals and do not hire application help spend 43.8 percent or 41.0 percent less time in other yard work, if they have at least two adult members who work full time. The time for subsequent yard work increases 13.9 percent with each additional child (Table 6). The presence of preschoolers does not, however, matter. The length of the growing season and yard size positively affect time for other yard work.

5.5 Miscellaneous Results

The income elasticity of predicted actual expenditures on synthetic chemicals by the *n*-th do-it-yourself household that applies only these chemicals or switches to this strategy as income increases is $\hat{\beta}^s_{\text{LINCOME}} + \text{INC}_n \cdot \left(\hat{\alpha}^s_{\text{INC}} - \sum_{\forall j} \hat{\alpha}^j_{\text{INC}} \hat{P}^j_n\right)$. This elasticity is, on average, 0.548 in the two-part model with NUMCHILD and 0.514 in the two-part model with CHILDLT6.

The log likelihoods and goodness-of-fit measures of the multinomial-logit probabilities and the synthetic-chemical-expenditures equation are slightly higher with the CHILDLT6 specification. However, the sum of the log likelihoods of the three equations of the discrete-continuous choice model with CHILDLT6, -542.799, exceeds the sum of the log likelihoods of the three equations with NUMCHILD by only 2.283 (Tables 3, 5, and 6).

No variable had a statistically significant effect on the yard work of households that do not use agricultural chemicals.

6. Discussion

As income increases, the marginal benefits of a yard and marginal costs of time for soil-pest management increase. Synthetic chemicals enable households to improve the yard and economize on scare time for soil-pest management. Hence, the marginal effects of income on expected utilities of strategies that involve synthetic chemicals and the mean marginal effects of income on the predicted probabilities that households choose these strategies are positive. The mean effects are consistent with income-induced increases in the probability that households in San Francisco use garden and yard chemicals (Templeton et al. 1999).

A household that applies only synthetic chemicals and does not hire application help spends more money on the chemicals as its income increases because its ability to pay to improve the yard also increases. An increase in its opportunity cost of time is another reason why the household spends more money on the chemicals but also is the reason why it spends less net time on other yard work as its income increases.

As income continues to increase and time becomes increasingly scarce, incentives for households to specialize in aspects of soil-pest management, particularly those related to the garden, grow too. Lawn-care professionals specialize in application of synthetic chemicals to lawns. The marginal benefits of professional lawn care increase with income. Thus, the marginal effect of income on the expected utility and, for most households, the probability of do-it-yourself with hired applications of synthetic chemicals exceeds the marginal effect of income on the expected utility and, for most households, the probability of mere DIY application of them. Households that choose DIY with hired application of synthetic chemicals spend more money for all chemical treatments per acre and the chemicals that they apply than households that apply without hired help only synthetic or only organic chemicals because they have significantly higher incomes (Table 2).

The more a household enjoys yard appearance, gardening, or both, the larger might be garden's share of the yard. Also, the greater is this share, the greater is the diversity of plants in the yard. As a result, the soil-fertility needs of plants and the variety of potentially plant-harming pests and diseases in a yard might also increase. Thus, as the garden's share increases, a household is more likely to use agricultural chemicals for at least one of these reasons: 1) to improve the appearance of the yard, 2) to enhance work in the garden, and 3) to help manage greater bio-physical complexity. These three motivations and a significantly larger share of the garden (Table 2) also can explain why households that choose one of the two organic strategies spend more time per acre on other yard work than households that choose do-it-yourself with hired application of synthetics.

The marginal effect of garden's share on the expected utility of DIY application of nothing but organics is larger than the marginal effects on the expected utilities of the three strategies that involve synthetics for two other possible reasons. As garden's share increases, the stronger might be a household's inherent dislike of human and environmental exposure to toxic substances or the more likely the household raises edible produce in the garden. For either reason, the marginal disutility of potential damage of synthetic chemicals increases and the marginal benefits of organic gardening grow. For the same two reasons, the marginal effect of garden's share on the probability of applying only organics grows and becomes the largest of the marginal effects of garden's share as this variable increases.

Using some natural chemicals, e.g., mixing composted manure with blood and bone meal and then spreading them, is more time-consuming than using synthetic alternatives, e.g., spreading nitrogen fertilizers. The relative time intensity of organic-chemical use is another reason, in addition to the garden-share related ones, why households that apply both synthetic and organic chemicals spend more time on other yard work than any other household and why households that use organic chemicals spend more hours per acre for other yard work than households that apply with hired help only synthetic chemicals.

Urban areas are more liberal-Democratic than rural areas (e.g., Gastner et al.). The demands for organic foods in the mid-1990s were heaviest in the West and urban areas of the U. S. (Klonsky, 238). Consistent with these facts are our conjectures that households in big cities have more favorable attitudes towards organic chemicals and better access to stores that sell them than households in other areas have. As a result, a household in a big city is more likely to choose one of the strategies that involve organics than a household elsewhere.

Among households that apply without hired help only synthetic chemicals, one in an urban area with more than 100,000 people spends more money on the chemicals than one elsewhere spends if the prices for the synthetics are higher in the big city and the demand for them is price inelastic. Are synthetic chemicals more expensive in big cities? In 2003 a price index of miscellaneous services and goods, which logically includes pesticides and fertilizers, was higher, on average, in big cities than other locations of sampled households[2]. As for the plausibility of price-inelastic demand, consider that in the Twin Cities metropolitan area, 95 out of 124 households indicated that they would 'do the same thing' and not reduce the frequency or amount of their chemical applications if the cost of these chemicals hypothetically increased 10 to 200 percent (Creason and Runge, 10 and A9).

A household that applies only synthetic chemicals spends more money on them in a big city for three other possible reasons. First, neighborhood pressures and local ordinances set minimum quality standards for yards (Jenkins, 174-175). These standards might be stronger in big cities. Second, big cities might provide proportionally less open space and fewer natural amenities. Third, the household's cost of time might be higher in a big city because commute distances and leisure opportunities are greater there. For any of these reasons, the household's demand for synthetics at any price might be higher in a big city.

Why does a household that applies synthetic and organic chemicals spend more money on these agricultural chemicals than a household that applies only synthetic chemicals? A household that applies only synthetics is less likely to live in a big city than a household that applies both synthetics and organics (Table 2). Thus, for the reasons discussed in the preceding two paragraphs, the monetary expenditures of the '*so*' household on synthetics might exceed the expenditures of the '*s*' household on them. Even if the '*so*' household substitutes, rather than complements, synthetics with organics, the household is also likely to spend more money on the organic alternatives than the '*s*' household spends on the related synthetics because natural chemicals are often more expensive per pound of nutrient or per unit of pest-control efficacy than synthetic counterparts (e.g., Whiting).

As the age of the head of a household increases, the opportunity cost of the time that the head has for soil-pest management increases for at least two possible reasons. First, the time that the household head allocates for all chores and leisure decreases because the time that he or she allocates to paid work increases. Second, the older the head gets beyond a certain age, the more physically difficult is yard work. As the household head's time becomes scarcer, the person is more likely to hire someone to help apply synthetic chemicals.

Male-headed households that apply only synthetic chemicals and do not hire applicators spend more for them than female-headed ones because men tend to be concerned more about lawn quality and less about risks of exposure to the chemicals than women. Socialization, horticultural education, and advertisements about lawn care for the past century have been male oriented (Jenkins, 117-132). "Despite many changes … in the relationship between the sexes, the front lawn remains unchallenged as a male domain" (Jenkins, 132). Moreover, social norms emphasize lawn care more than gardening (Jenkins). Finally, in 1992 men worked a disproportionately large fraction, 83%, of all hours of non-construction laborers and faced a higher risk of work-related injury and illness than women in these jobs (Ruser, 121). Non-construction labor is the occupation, among occupational types for which information is available, that is most similar to yard work. These facts are consistent with men being more willing to accept risks of exposure.

Why are households with young children more likely to hire someone to help with the application of synthetic chemicals? Young children probably spend more time playing in their backyards than other minors (e.g., EPA 1997). Also, if young people play more in the backyard than others, they might also be more exposed to nuisance pests. Moreover, insects and arachnids often cause more harm to young children than to others (Eldridge and Edman, 115, 119, 419, 423, 437-438). Households that apply synthetic chemicals only and without hired help spend more money on the chemicals if they have young children for the same possible reasons: to improve the health of the grass where the children play and to reduce the exposures of the children to nuisance pests.

As the number of children increases, a household that applies without hired help only synthetics spends more time on other yard work because the number of yard producers tends to increase as does the number of yard consumers. However, the presence of preschoolers does not matter for work time because preschoolers are not able to help with most yard tasks. If such a household has at least two adults who work full time, it will have less time for chores or leisure and, thus, spend less of it on yard tasks.

7. Conclusions

All households are not alike in their pest-soil management and other yard work because they differ about how important are yards, risks of synthetic chemicals, yard work, and alternative uses of their time and money. How important these things are, in turn, depends on attitudes, income, time endowments, and other characteristics of the household and yard. The heterogeneity of pest-soil management by households echoes the heterogeneity of commercial agriculture (e.g., Kuhn and Offutt).

The desire for a good-looking, productive yard that is treated with synthetic chemicals seems to become stronger than the concern about possible exposure risks as income rises even though a minority of households continues to apply both synthetic and organic chemicals. Expenditures on hired applications of synthetics and do-it-yourself applications of organics do not ‘crowd out’ expenditures on DIY applications of synthetics. DIY application of synthetic chemicals also stimulates other yard work.

The demand of do-it-yourself applicators for synthetic fertilizers and pesticides as a product group is income inelastic. Benefits of synthetic chemicals are larger for male-headed than female-headed households that apply only these chemicals and do not hire applicators. The time in other yard work, which increases with expenditures on synthetic chemicals, implies an extra benefit of these chemicals if yard work is a hobby or an extra cost if yard work is an unpleasant chore. The benefits for households in big cities are larger if demand is higher there than elsewhere but are smaller if quantity demanded is price-inelastic and less there than elsewhere. Households with young children might derive extra benefits from do-it-yourself and hired applications of synthetic chemicals.

Our theoretical model can be extended to characterize the private net costs of an EPA cancellation of a registered use of an active ingredient, given an alternative, Z, which costs w per unit. For example, the private cost to a DIY household that applies the pesticide is the most it would be willing to pay (WTP) to avoid the ban. That is

$$E\left[U^{s}\left\langle Y^{s}\left(L^{ps}, X^{s*}, \varepsilon\right), M(X^{s*}), D(X^{s*}), L^{ps}, A\left(T - M(X^{s*}) - L^{ps}, \frac{I - WTP - c^{s}X^{s*}}{p} \right) \mid \mathbf{K} \right\rangle \right]$$

$$\equiv E\left[U^{z}\left\langle Y^{z}\left(L^{pz}, Z^{*}, \varepsilon\right), M(Z^{*}), D(Z^{*}), L^{pz}, A\left(T - M(Z^{*}) - L^{pz}, \frac{I - wZ^{*}}{p} \right) \mid \mathbf{K} \right\rangle \right].$$

Estimation of the cost of the ban would require panel data on the quantities and prices of the pesticide and its alternative(s), in addition to household and yard characteristics.

In interpreting these results, we have raised numerous questions for future research. For example, to what extent do measurable attitudes about yard appearance, agricultural chemicals, yard work, and pests vary with garden's share, presence of young children, or other household characteristics? To what extent have these attitudes changed over time? Are prices for synthetic chemicals higher and demand for them price-inelastic in big cities? Is the demand for them higher in big cities at any given price? For which purposes and under what precautions do households, particularly those with young children, use certain types and quantities of these chemicals, particularly pesticides?

Nonetheless, the empirical results have implications for marketing and policy making. Marketing campaigns that target households by their specific strategies of soil-pest management are likely to be more effective than one-size-fits-all advertisements for agricultural chemicals. *Ceteris paribus*, the market for do-it-yourself application of synthetic chemicals will grow at least 50 percent as fast as household income will. The markets for professional lawn care and organic chemicals will grow with income and urbanization.

Cancellation of a pesticide registration might create extra private costs for households with young children even though the ban might reduce external costs. The heterogeneous demand of do-it-yourself households for agricultural chemicals gives policy makers a reason to subsidize safe and tax relatively unsafe ones. However, the effectiveness of these incentives will also depend on the extent to which subsidized products are more time-consuming to use and efficacious than the taxed ones and on differences in attitudes about yards, synthetic chemicals, pests, and yard work.

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Endnotes

1. We calculated likelihood ratio test statistics to test for differences in two marginal effects of a continuous variable or two discrete effects of an indicator variable on the expected utilities of two different chemical-application strategies. The values of the likelihood ratio test statistics are available from the corresponding author upon request.
2. Ninety of the 119 households lived in micropolitan and metropolitan areas that were included in American Chamber of Commerce Researchers Association's (ACCRA's) database of costs of

living (Yildirim). Fifty six of the ninety households lived in 31 unique big cities. Thirty four households lived in 17 unique locations that were not big cities. The means of the index of costs of miscellaneous goods and services in the sub-samples of big cities and other locations were 102.33 (s.d. = 6.69) and 99.96 (s.d. = 6.94). The probability of observing a value of the *t*-random variable in excess of 1.15 is 0.13.

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Table 1: Expenditures of Money for Applications of Agricultural Chemicals and Time for Other Yard Work in 1995

VARIABLE	Type of Agric. Chemical and Application	Mean	Std. Dev.	Min.	Max.	H_a: $\mu_i > \mu_j$	*p*-value
DIYCHEM (1995 $s)	DIY App. of Organic Chemicals (N_o = 10)	43	39	10	125	$\mu_{so} > \mu_o$	0.035
	DIY App. Of Synthetic Chemicals (N_s = 119)	58	53	3	250	$\mu_s > \mu_o$	0.192
	DIY App. Of Syn. and Org. Chem. (N_{so} = 14)	114	114	10	385	$\mu_{so} > \mu_s$	0.001
	DIY – Hired App. of Syn. Chem. (N_{dhs} = 22)	194	193	10	700	$\mu_{dhs} > \mu_{so}$	0.087
PROCHEM	DIY and Hired App. of Synthetic Chemicals	$162	$150	$1	$600	n. a.	n. a.
ALLCHEM	DIY and Hired App. of Synthetic Chemicals	$356	$328	$20	$1,250	n. a.	n. a.
DIYCHEMIN (1995 $s per acre)	DIY Application of Organic Chemicals	802	887	7	3,025	$\mu_s > \mu_o$	0.303
	DIY Application of Synthetic Chemicals	1,503	4,261	7	31,114	$\mu_{so} > \mu_s$	0.402
	DIY App. of Synthetic and Organic Chemicals	1,793	2,299	36	6,824	$\mu_{so} > \mu_o$	0.105
	DIY and Hired App. of Synthetic Chemicals	1,677	2,962	25	13,496	$\mu_{so} > \mu_{dhs}$	0.451
ALLCHEMIN ($s per acre)	DIY and Hired App. of Synthetic Chemicals	3,042	5,288	50	24,665	$\mu_{dhs} > \mu_o$ $\mu_{dhs} > \mu_s$	0.098 0.068
OTHWORK (annual hrs.)	Non-use of Agricultural Chemicals (N_n = 66)	163	247	18	1,217	$\mu_s > \mu_n$	0.096
	DIY Application of Organic Chemicals	164	73	62	336	$\mu_{so} > \mu_o$	0.035
	DIY Application of Synthetic Chemicals	210	222	14	1,546	$\mu_s > \mu_o$	0.260
	DIY App. of Synthetic and Organic Chemicals	318	247	35	785	$\mu_{so} > \mu_s$	0.045
	DIY and Hired App. of Synthetic Chemicals	145	136	6	515	$\mu_{so} > \mu_{dhs}$ $\mu_s > \mu_{dhs}$	0.005 0.116
OWORKIN (annual hrs. per acre)	Non-use of Agricultural Chemicals	2,082	2,992	3	12,705	$\mu_{so} > \mu_n$	0.005
	DIY Application of Organic Chemicals	4,098	5,333	53	14,640	$\mu_o > \mu_{dhs}$	0.040
	DIY Application of Synthetic Chemicals	3,915	8,769	23	58,279	$\mu_{so} > \mu_s$	0.342
	DIY App. of Synthetic and Organic Chemicals	4,898	5,845	299	20,518	$\mu_{so} > \mu_o$	0.367
	DIY and Hired App. of Synthetic Chemicals	1,532	2,750	7	12,808	$\mu_{so} > \mu_{dhs}$	0.013

DIY ≡ do-it-yourself, App. ≡ application. In Table 1 and Table 2, the *p*-value is the probability that a *T* random variable with N_i+N_j-2 degrees of freedom exceeds

$$\frac{\overline{X}_i - \overline{X}_j}{\sqrt{\left(\frac{1}{N_i}+\frac{1}{N_j}\right)\left[\frac{(N_i-1)\hat{\sigma}_i^2+(N_j-1)\hat{\sigma}_j^2}{(N_i+N_j-2)}\right]}}$$

for $i \neq j$, given $\sigma_i^2 = \sigma_j^2$.

Table 2: Descriptive Statistics for Independent Variables

VARIABLE	Chemical-Application Type	Mean[1]	Std. Dev.	Min.	Max.
INCOME (1000$s)	Non-use of Ag. Chemicals	$33.258[b]	$21.624	$5	$100
	DIY App. Organic Chem.	$44.000	$14.103	$30	$75
	DIY App. Synthetic Chem.	$44.403[d]	$30.842	$5	$200
	DIY App. Syn.-Org. Chem.	$48.929	$22.462	$10	$100
	DIY-Hired App. Syn. Chem.	$62.364	$52.974	$10	$200
AGE (years)	Non-use of Ag. Chemicals	50	16	23	83
	DIY App. Organic Chem.	50	15	32	70
	DIY App. Synthetic Chem.	48	16	20	85
	DIY App. Syn.-Org. Chem.	54	16	30	78
	DIY-Hired App. Syn. Chem.	53	18	23	85
NUMCHILD	Non-use of Ag. Chemicals	0.7	1.1	0	4
	DIY App. Organic Chem.	0.9	1.1	0	3
	DIY App. Synthetic Chem.	0.9	1.3	0	5
	DIY App. Syn.-Org. Chem.	0.7	0.8	0	2
	DIY-Hired App. Syn. Chem.	1.0	1.4	0	5
CHILDLT6	Non-use of Ag. Chemicals	0.20	0.40	0	1
	DIY App. Organic Chem.	0.20	0.42	0	1
	DIY App. Synthetic Chem.	0.19	0.40	0	1
	DIY App. Syn.-Org. Chem.	0.29	0.47	0	1
	DIY-Hired App. Syn. Chem.	0.32	0.48	0	1
BIGCITY (> 100,000)	Non-use of Ag. Chemicals	0.39[b]	0.49	0	1
	DIY App. Organic Chem.	0.80	0.42	0	1
	DIY App. Synthetic Chem.	0.50[c]	0.50	0	1
	DIY App. Syn.-Org. Chem.	0.86	0.36	0	1
	DIY-Hired App. Syn. Chem.	0.59[d]	0.50	0	1
YARDSIZE (acres)	Non-use of Ag. Chemicals	0.49	1.50	0.0017	9.0
	DIY App. Organic Chem.	0.52	0.88	0.013	2.7
	DIY App. Synthetic Chem.	0.45	1.14	0.0016	9.5
	DIY App. Syn.-Org. Chem.	0.12	0.13	0.031	0.56
	DIY-Hired App. Syn. Chem.	0.73	1.72	0.020	8.0
GARSHARE (per. pts.)	Non-use of Ag. Chem.	3[a]	8	0	50
	DIY App. Organic Chem.	25	30	0	80
	DIY App. Synthetic Chem.	9[c]	14	0	75
	DIY App. Syn.-Org. Chem.	12[e]	15	0	49
	DIY-Hired App. Syn. Chem.	7[d]	13	0	40
MALEHEAD	DIY App. Synthetic Chem.	0.62	0.49	0	1
TWOFULL	DIY App. Synthetic Chem.	0.10	0.30	0	1
GROWDAYS	DIY App. Synthetic Chem.	202	61	63	363

[1] Reject H_o: $\mu_i \leq \mu_{-i}$ for the *i*-th chemical-application type with the largest sample mean because *p*-value < 0.0001 (a), < 0.001 (b), < 0.01 (c), < 0.05 (d), or < 0.1 (e).

Table 3: Two Logit Models of Expected Utilities of Chemical-Application Strategies

	Model with Number of Children			Model with Preschoolers		
VARIABLE	Estimate	Std. Error	p-value[1]	Estimate	Std. Error	p-value[1]
	DIY Application of Synthetic Chemicals					
CONSTANT	-0.8537	0.8218	[.299]	-0.1893	0.7721	[.806]
INCOME	0.0199	0.0078	[.011]	0.0186	0.0077	[.016]
AGE	0.0013	0.0121	[.911]	-0.0078	0.0118	[.507]
NUMCHILD	0.1618	0.1604	[.313]			
CHILDLT6				-0.1899	0.4692	[.686]
BIGCITY	0.3787	0.3298	[.251]	0.3966	0.3308	[.231]
YARDSIZE	-0.0596	0.1277	[.641]	-0.0638	0.1275	[.617]
GARSHARE	0.0651	0.0211	[.002]	0.0652	0.0211	[.002]
	DIY and Hired Application of Synthetic Chemicals					
CONSTANT	-5.8313	1.5699	[.000]	-5.9486	1.5167	[.000]
INCOME	0.0343	0.0093	[.000]	0.0347	0.0093	[.000]
AGE	0.0430	0.0223	[.054]	0.0461	0.0218	[.034]
NUMCHILD	0.4439	0.2664	[.096]			
CHILDLT6				1.5319	0.7740	[.048]
BIGCITY	0.6347	0.5385	[.239]	0.5255	0.5459	[.336]
YARDSIZE	0.1586	0.1555	[.308]	0.1269	0.1598	[.427]
GARSHARE	0.0526	0.0270	[.051]	0.0507	0.0268	[.059]
	DIY Application of Synthetic and Organic Chemicals					
CONSTANT	-5.5262	1.8777	[.003]	-6.1478	1.9004	[.001]
INCOME	0.0241	0.0109	[.027]	0.0243	0.0108	[.025]
AGE	0.0299	0.0245	[.223]	0.0395	0.0250	[.114]
NUMCHILD	0.1855	0.3300	[.574]			
CHILDLT6				1.1458	0.9158	[.211]
BIGCITY	1.9131	0.8383	[.022]	1.8422	0.8471	[.030]
YARDSIZE	-2.0259	1.9117	[.289]	-1.9488	1.9075	[.307]
GARSHARE	0.0779	0.0259	[.003]	0.0777	0.0260	[.003]
	DIY Application of Organic Chemicals					
CONSTANT	-5.7706	2.1114	[.006]	-4.9075	1.9517	[.012]
INCOME	0.0200	0.0135	[.139]	0.0186	0.0136	[.172]
AGE	0.0163	0.0282	[.563]	0.0042	0.0268	[.874]
NUMCHILD	0.1974	0.3719	[.595]			
CHILDLT6				-0.3091	1.0674	[.772]
BIGCITY	1.8780	0.8914	[.035]	1.8944	0.8922	[.034]
YARDSIZE	0.0949	0.2504	[.705]	0.0953	0.2502	[.703]
GARSHARE	0.1030	0.0253	[.000]	0.1032	0.0253	[.000]
log likelihood, likelihood ratio to test zero slopes [p-value], and scaled R^2 (Estrella)						
	-251.901, 64.1785 [.000], 0.2553			-249.493, 68.9931 [.000], 0.2727		

[1] Reported p-value is calculated under H_0: $\alpha_k^i = 0$ instead of H_1: $\alpha_k^i \neq 0$.

Table 4: Means of Marginal and Discrete Effects[1] on Choice Probabilities

Strategy	None	DIY Syn.	DIY-Hired S	DIY SO	DIY Org.
VARIABLE	Model with Number of Children				
INCOME	-0.39%	0.19%	0.16%	0.038%	0.0060%
INC > $20K, 177 obs.	-0.37%	0.16%	0.17%	0.036%	0.0041%
INC > $35K, 114 obs.	-0.33%	0.12%	0.18%	0.031%	0.0014%
INC > $40K, 86 obs.	-0.30%	0.08%	0.19%	0.028%	-0.00032%
INC > $60K, 37 obs.	-0.22%	-0.02%	0.23%	0.019%	-0.0060%
AGE	-0.16%	-0.30%	0.31%	0.12%	0.029%
NUMCHILD	-3.54%	0.70%	2.59%	0.12%	0.12%
BIGCITY	-10.08%	-3.14%	1.61%	6.70%	4.91%
YARDSIZE	2.92%	3.76%	2.88%	-10.88%	1.32%
GARSHARE	-1.17%	0.83%	0.017%	0.14%	0.19%
GS >= 12%, 58 obs.	-0.61%	0.26%	-0.082%	0.10%	0.33%
GS >= 17%, 42 obs.	-0.45%	0.08%	-0.10%	0.089%	0.38%
VARIABLE	Model with Presence of Children				
INCOME	-0.38%	0.17%	0.16%	0.041%	0.0042%
INC > $12K, 211 obs.	-0.37%	0.16%	0.17%	0.040%	0.0038%
INC > $35K, 114 obs.	-0.32%	0.10%	0.19%	0.032%	0.00024%
INC > $40K, 86 obs.	-0.29%	0.060%	0.20%	0.030%	-0.0015%
INC > $60K, 37 obs.	-0.22%	-0.04%	0.25%	0.021%	-0.0082%
AGE	-0.05%	-0.52%	0.37%	0.20%	0.00078%
CHILDLT6	-4.08%	-16.38%	16.15%	6.14%	-1.84%
BIGCITY	-10.09%	-1.88%	0.62%	6.34%	5.01%
YARDSIZE	2.94%	3.40%	2.72%	-10.3%	1.27%
GARSHARE	-1.18%	0.84%	0.01%	0.14%	0.19%
GS >= 12%, 58 obs.	-0.61%	0.27%	-0.093%	0.10%	0.33%
GS >= 17%, 42 obs.	-0.46%	0.10%	-0.12%	0.10%	0.38%

1 The marginal effect of a continuous variable Z_k on the probability that household n chooses chemical-application strategy i is $\frac{\partial P_n^i}{\partial Z_{kn}} = P_n^i\left(\alpha_k^i - \sum_{\forall j} \alpha_k^j P_n^j\right)$. The discrete effect of a dummy variable Z_k on the probability that household n chooses strategy i is $P_n^i\left|(Z_k = 1) - P_n^i\right|(Z_k = 0)$. The reported effects are the sample means multiplied by 100%.

'DIY Syn.' and DIY-Hired S' refer to households that apply only synthetic chemicals with and without hired help. 'DIY SO' refers to households that apply synthetic and organic chemicals but do not hire help. 'INC' and 'GS' mean INCOME and GARSHARE.

Table 5: Two Models of the Log of Monetary Expenditures on Synthetic Chemicals by Households That Apply only These Chemicals without Hired Help

	Model with Number of Children			Model with Preschoolers		
VARIABLE	Parameter	Std. Error	*p*-value[2]	Parameter	Std. Error	*p*-value[2]
CONSTANT	0.9456	1.9375	[.626]	0.7056	1.8892	[.709]
LINCOME[1]	0.4573	0.1261	[.000]	0.4494	0.1246	[.000]
LAGE	-0.0640	0.2686	[.812]	0.1015	0.2647	[.701]
NUMCHILD	0.0219	0.0689	[.750]			
CHILDLT6				0.3993	0.2212	[.071]
MALEHEAD	0.3547	0.1727	[.040]	0.3870	0.1692	[.022]
TWOFULL	-0.1045	0.2685	[.697]	-0.0898	0.2646	[.734]
BIGCITY	0.2989	0.1689	[.077]	0.2783	0.1657	[.093]
LGROWDAYS	0.2046	0.2851	[.473]	0.1244	0.2840	[.662]
LYARDSIZE	0.0413	0.0525	[.432]	0.0407	0.0517	[.431]
GARSHARE	-0.0066	0.0055	[.235]	-0.0077	0.0055	[.160]
	F test of zero slopes [*p*-value], R^2, and log of maximized likelihood					
	3.4378 [.001], 0.2211, -147.236			3.8502 [.000], 0.2412, -145.679		

[1] 'L' followed by a variable name means the natural logarithm of the variable.

[2] *P*-value is the Prob[|T| > |*t*-value|].

In the test for heteroskedasticity the Lagrange multiplier and [*p*-value] are 1.8641 and [.172] in the model with NUMCHILD and 2.6749 and [.102] with CHILDLT6.

Table 6: Two Models of the Log of Time Expenditures on Other Yard Work of Households That Apply only Synthetic Chemicals without Hired Help

	Model with Number of Children			Model with Preschoolers		
Variable	Parameter	Std. Error	*p*-value[2]	Parameter	Std. Error	*p*-value[2]
CONSTANT	1.7722	1.9177	[.355]	2.4979	1.9619	[.203]
LINCNOAC[1]	-0.2942	0.1312	[.025]	-0.3948	0.1356	[.004]
LAGE	-0.0526	0.2657	[.843]	-0.3994	0.2750	[.146]
NUMCHILD	0.1387	0.0682	[.042]			
CHILDLT6				-0.2761	0.2326	[.235]
MALEHEAD	0.1085	0.1739	[.533]	-0.0642	0.1793	[.720]
TWOFULL	-0.5764	0.2658	[.030]	-0.5272	0.2749	[.055]
BIGCITY	-0.1113	0.1692	[.511]	-0.2097	0.1739	[.228]
LGROWDAYS	0.6913	0.2825	[.014]	0.7692	0.2951	[.009]
LYARDSIZE	0.1219	0.0520	[.019]	0.1076	0.0538	[.046]
GARSHARE	0.0055	0.0055	[.320]	0.0072	0.0058	[.208]
LCHEMEXP	0.2376	0.0906	[.009]	0.4672	0.0931	[.000]
	F test of zero slopes [*p*-value], R^2, and log of maximized likelihood					
	3.0599 [.002], 0.2208, -145.937			2.6735 [.006], 0.1823, -147.619		

[1] 'L' followed by a variable name means the natural logarithm of the variable.

[2] *P*-value is the Prob[|T| > |*t*-value|].

In the test for heteroskedasticity the Lagrange multiplier and [*p*-value] are 0.5071 and [.476] in the model with NUMCHILD and 0.02852 and [.866] with CHILDLT6.