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Research Article

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# Recycling on Semi-subsistence Farms: Household vs. Farm Factors

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## Abstract

As with food production, waste management on semi-subsistent farms is a joint outcome of household-specific and farm-specific resources. It is useful therefore to analyze waste-disposal decisions with this jointness in mind. We do so here with a sample of Chinese farms. Attention is given to five distinct types of waste: packaging materials, manure, wastewater, plastic mulch, and straw.

We find farm recycling to intensify as household cash income, farm manager's age and education, and farm workforce size expand. Recycling declines however as the number of dependents and farm cultivable area enlarge. Put differently, waste management improves as the family's labor and capital resources grow, but deteriorate if landholdings expand while capital and labor resources do not. The small family farm's recycling behavior, in short, appears to be entirely rational.

Specifically household and specifically farm factors are each important to the capital and labor mix that promotes recycling. In the aggregate, a one-percent variation in the principal household factors induces an average 0.35 percent change in recycling activity, while a one-percent variation in the principal farm factors induces an average 0.18 percent change. Assuming continued economic development, we find reason to be moderately optimistic about the future of small-farm waste disposal.

**Keywords:** Agricultural waste; Environmental quality; Rural development; Semi-subsistence households; Recycling; Waste disposal

## Introduction

As resource use in the world's developing areas moves from traditional to modern, the volume, variety, and intensity of waste products rise in tandem. The incidence of the disposal problem is widespread, spanning forestry, farming, animal husbandry, fisheries, agricultural processing, and the rural households associated with them. In agriculture in particular, extensive use of pesticides and chemical fertilizers, untreated livestock and poultry manure, artificial mulch disposal, and crop straw burning have polluted the rural environment to the extent of threatening farm product quality and human health. Ironically, the waste products themselves potentially have substantial ecological and economic value, and their effective utilization can enhance revenue and productivity as well as environmental benefits [1].

Systematic attention to waste practices is rather new to many areas of the developing world. Importantly however, the semi-subsistent household typically remains the fundamental unit of agricultural production and the principal waste disposal decision maker in these nations. Assessing the factors influencing rural household waste behavior can be of substantial use to these decision makers as well as to the governments that influence them. The present study offers a reference point for such an assessment, including an analysis of waste disposal types, of possible standards for evaluating them, and of the technical, behavioral, and policy factors influencing them. In few places has the importance of waste management been demonstrated more sharply than in China, and its Zhejiang Province is employed here as a case in point. Examining its rural waste activities in detail provides an improved look at prospects for environmental improvement in the world's small-farm sector.

Agricultural waste management has been addressed at both the macro and micro level. Stiglitz [2] notes that technical progress creates an impetus for sustained economic growth and is likely the key to mutual improvement in natural resource quality and economic growth [3]. For example, livestock manure and other farm wastes can be converted to biogas slurry [4] and bioethanol [5]. Azzam, Nene, and Schoengold [6] demonstrate how environmental regulation structure can affect the size distribution of U.S. hog operations. Van Horn et al. [7] assess dairy manure management systems that avoid nutrient loss and also realize a net return, and Scheinberg [8] has estimated the value-added of sustainable recycling possibilities in modernized waste management systems. Others have similarly examined willingness-to-pay [9].

An important branch of the literature considers policies that might enhance recycling. Mueller [10] argues that a subsidy for recycling is more effective than a fine for failing to recycle. Fielding et al. [11] and a number of others concentrate on the farmer's attitudinal or normative beliefs and on environmental education. As an example of farm recycling, Collins et al. [12] early analyzed the factors influencing California farm rice-straw disposal. Ekboir [13] and Hellin and Schrader [14] expanded the factor list, suggesting the farm's natural surroundings, soil conditions, production costs, and technological setup each have their imprint on straw utilization. A substantial literature is available on irrigation, manure management, and wastewater systems for small farms that pay special attention to their environmental implications [15].

In China, Ma et al. [16] stress the recycling behavioral importance of labor quality and agricultural training. Peng [17] examines Chinese agricultural waste use from the perspective of regulatory policy, technological and service systems, and waste utilization efficiency. On livestock as well as poultry farms, he says, recycling behavior has been

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strongly related to the farm's cultivated area and to local government pollution-control policies. Management-intensive farm operations, of the type considered in the present paper, are on the rise in China even among less-educated farmers [18]. Chen et al. [19] explore public participation in Chinese farm pollution control, such as training seminars, group diagnosis of disposal problems, and group monitoring.

Overall, this literature suggests waste-disposal effectiveness has varied with the type of waste as well as with farm household resources, attitudes, and training. A representative examination of the farm's environmental management would then seem to require substantial specificity in both the waste type and farm household's productive capacities. No study of that breadth has, to our knowledge, been conducted. The present paper therefore offers such an analysis, concentrating on typical dimensions of waste management activity and the household and farm factors that most likely conduce to them. Important implications emerge for not only environmental policy but the environmental consequences of long-term demographic trends.

## Data and Methods

### Hypotheses and data

Because farm waste products do not – even if potentially marketable – form part of the farmer's main business objectives, three conditions would seem necessary for them to be disposed of properly: (a) the attitude that they should be, (b) the skill in doing so, and (c) the physical capacities to exert the effort required. In semi-subsistent households, where productive resources are regarded and deployed jointly with those on the farm, we must search for these three conditions in both the home and farm.

Farm operator skills are approximated by household education levels, indicators of formal agricultural training and advice, and other demographic information such as the farm manager's gender. Otherwise, the human and physical capacity for waste disposal effort is reflected in the: (i) farm workforce and amount of arable land; (ii) size and composition of the household, typically only some of whom participate in farm work; (iii) family wealth or earnings, which influence the farm's access to the capital that provide production and waste-disposal services; and (iv) other factors associated with the farmers' skills, incentives, and energy. In general, we expect households with the greater human and physical resources to expend the greater effort disposing effectively of their wastes.

Data to test these expectations were drawn from an original 2012 field survey in Shaoxing and Wenzhou Districts, Zhejiang Province, China. Supplemental surveying and data cleaning were continued through 2013 and 2014. The survey questionnaire included: (a) the household farm's agronomic characteristics such as plant species, soil type, and cultivation methods; (b) its practices potentially affecting pollution; (c) a demographic profile of the respondent's farm family; (d) a depiction of local environmental conditions; (e) family and farm manager attitudes toward protecting the environment beyond the farm; (f) the household head's agricultural technological training and assistance; and (g) proxies for the household's farm objectives, such as its orientation toward market sales and the number of household members released to work in the city.

The survey employed both a questionnaire and semi-open-interview format and drew on a combination of stratified and random sampling. Inclusion of both Shaoxing and Wenzhou Districts provides extensive sample variation in local-development characteristics and natural resources. Located in the north of Zhejiang Province, Shaoxing is one of the economic powerhouses of the Yangtze River Delta region. In contrast, Wenzhou lies in the southeast of the Province, where per-capita GDP is in the lower-middle percentile of Zhejiang cities. Four townships were purposively selected – on the basis of mean annual grain output – from Shaoxing and five from Wenzhou, and from each township one to three villages drawn randomly. Twenty households were then drawn randomly from each such village. Three hundred questionnaires were distributed to this initial sample of 540 households, and at least three families in each of the nine townships and fifteen villages were interviewed. Of the 300 questionnaires distributed, 291 were enumerated and 283 screened as valid, providing a 94.3% post-distribution yield rate.

### Methods

Probit methods were used to analyze the factors influencing farm household waste-disposal practice. The model takes the form $Y = X\beta + \mu$, in which $Y = 1$ if the farm utilizes the best-practice approach – as judged by local agricultural extension personnel – to the given waste-disposal function or activity, and $Y = 0$ if it does not; **X** is the matrix of prediction factors; the vector of factor influences on the probability that the best-practice approach will be observed; and the disturbance term. In particular, the probit model can be expressed as

$$probit(y_{ij} = 1 | x_{ij}) = \varphi(x, \beta) = \varphi(\beta_0 + \beta_1 x_1 + \beta_2 x_2 + ......\beta_n x_n) \quad (1)$$

where subscript $i$ ($i$ =1, 2, 3, 4, 5) indexes the disposal activity and $j$ ($j$ =1, 2, … , 283) the surveyed household, $\varphi(.)$ is the probability that the standardized normal variate will be less than the selected critical point, and $\beta_s$ is the impact of the $s^{th}$ factor on the disposal behavior probability.

### Factors explaining waste disposal practice

Our model concentrates on the kinds of agricultural waste typical in China – fertilizer and pesticide packaging materials, manure, breeding wastewater, plastic mulch, and crop straw. Dependent variable $y$ in equation (1) accordingly consists of the farmer's choice between greater or lesser responsiveness to the best-practice recommendations, defined in more detail below, in each of these five waste-disposal categories.

As we have indicated, and consistent with the above literature, the factors most likely affecting waste practices in semi-subsistent farms can be divided between those in the home and in the farm field. Home factors ***H*** include: (i) the home's physical and financial capital resources, such as family size, earnings, and off-farm work; and (ii) such human capital factors as the age and general education of the household head. Field factors ***F*** include: (a) productive capacities such as the farm's workforce size and arable area and the gender of the farm manager; (b) such farm considerations as the extent of its orientation to commercial sales *versus* subsistence, and environmental conditions beyond the farm's boundaries; and (c) indicators of the farm manager's technical skills such as his/her earlier training and current exposure to technical advice.

We accordingly constructed the survey and empirical analysis around these determinants. Table 1 summarizes and further defines the specifications of the five important modes of farm waste disposal and possible behaviors associated with each, and the household and farm factors H and F that might influence them.

## Results and Discussion

### Descriptive statistics

Descriptive statistics of the five surveyed waste disposal practices and their twelve hypothesized determinants ***H*** and ***F*** are shown in Table 2.

| Symbol | Variable | Measure |
|---|---|---|
| Waste Disposal Categories | | |
| Disposal of | | |
| Packaging | Fertilizer/pesticide packing materials | 1 = disposes at garbage station; 0 = does not |
| Manure | Livestock/poultry manure | 1 = converts to biogas; 0 = does not convert |
| Wastewater | Livestock & poultry breeding wastewater | 1 = discharges after treatment; 0 = discharges untreated |
| Mulch | Agricultural plastic mulch | 1 = recycles or reuses; 0 = does not recycle |
| Straw | Crop straw | 1 = reutilizes; 0 = burns |
| Explanatory Factors | | |
| H | Household Characteristics | |
| Hsize | Family size | number of individuals in family |
| Hearn | Family earnings | annual family income (in ten thousands of yuan) |
| Hoff | Off-farm work | 1 = at least 1 member works off-farm, 0 = none do |
| Hage | Age of household head | 1 = middle-aged or above, 0 = young |
| Hedu | Education of household head | 1 = primary school or below, 2 = junior middle school, 3 = senior middle school or above |
| F | Farm Characteristics | |
| Flabor | Farm workforce | number of agricultural laborers |
| Farea | Arable area | crop planting area (in mu, 1 mu = 1/15 hectare) |
| Fgender | Gender of main farm mgr | 1 = male, 0 = female or both share mgmt |
| Fenvatt | Environmental attitude | 1 = considers environment beyond profitability; 0 = does not consider |
| Ftrain | Formal technical training | 1 = has received technical training, 0 = has not |
| Fadvice | Formal technical advice | 1 = has received technical advice, 0 = has not |
| Fcmrc | Commercial orientation | agricultural product sales/total agricultural output |

**Table 1:** Factors Hypothesized to Affect Waste Disposal on Semi-Subsistence Farms.

| Variable | Mean | Median | Max | Min | St. Dev. |
|---|---|---|---|---|---|
| **Waste-Disposal Categories** | | | | | |
| Packaging | 0.633 | 1 | 1 | 0 | 0.483 |
| Manure | 0.12 | 0 | 1 | 0 | 0.326 |
| Wastewater | 0.311 | 0 | 1 | 0 | 0.464 |
| Plastic Mulch | 0.113 | 0 | 1 | 0 | 0.317 |
| Straw | 0.134 | 0 | 1 | 0 | 0.342 |
| **Explanatory Factors** | | | | | |
| Household Characteristics | | | | | |
| Hsize | 4.643 | 5 | 13 | 2 | 1.443 |
| Hearn | 3.115 | 3 | 12 | 0.258 | 2.349 |
| Hoff | 0.82 | 1 | 1 | 0 | 0.854 |
| Hage | 0.721 | 0 | 1 | 0 | 0.449 |
| Hedu | 1.961 | 2 | 3 | 1 | 0.791 |
| Farm Characteristics | | | | | |
| Flabor | 2.24 | 2 | 6 | 0 | 1.19 |
| Farea | 4.291 | 3 | 23 | 0 | 3.629 |
| Fgender | 0.905 | 1 | 1 | 0 | 0.73 |
| Fenvatt | 0.799 | 1 | 1 | 0 | 0.402 |
| Fcmrc | 0.112 | 0 | 1 | 0 | 0.231 |
| Ftrain | 0.364 | 0 | 1 | 0 | 0.482 |
| Fadvice | 0.403 | 0 | 1 | 0 | 0.491 |

**Table 2:** Descriptive Statistics of Sample Variables.

Immediately evident is the absence of much standardization in waste disposal behaviors. About 37 percent (1.0 – 0.63) of households, for example, were not carrying used packaging materials to designated refuse areas. Eighty-eight percent (1.0 – 0.12) were not converting livestock or poultry manure to biogas, and 69 percent (1.0 – 0.31) were discharging wastewater in untreated form. Among best-practice disposal behaviors, plastic mulch, straw, and manure recycling were least in evidence.

Turning to the possible determinants of these behaviors, sample household size varied from two to 13 members and averaged 4.6. Eighty-two percent of families sent at least one member off the farm to work. Those remaining tended to be middle-aged or older: in about 72% (1 – 0.279) of families, the farm manager was at least 35 years of age. The average manager had barely completed (= 1.96) junior middle school. Mean family earnings were 31,150 yuan ($5,073). The composite picture is one of an aging, lightly educated household who's younger, more energetic, and better-educated members have gone off to the city for work.

The sample average farm is small and largely subsistent. A male manager supervises 2¼ workers (virtually all family members) on 4.3 mu (0.3 ha) of arable land. Only 36 percent of farm managers had at one time received formal agricultural training, and only 40 percent were currently receiving professional management advice. Eighty-percent say their attitude is one of environmental stewardship. Only 11 percent of the average farm's product value is marketed, the rest kept for home consumption. In summary, this farm sample is broadly typical of semi-subsistent households in developing areas of the world, providing a useful platform for assessing the environmental status in the small-farm sector.

A fringe of large farms is, however, well-represented in the sample. The largest operation was on 23 mu (1.5 ha) of arable land, about five times the sample mean. And the median operation (3.0 mu) was 30% lower than the mean (4.3 mu). Both these statistics suggest the arable-land distribution is right-skewed. Similar comparison of the sample maximum, median, and mean of household earnings in Table 2 implies that earnings frequencies are right-skewed as well. Right skews are nearly inevitable when resources are few because, on the left side of the distribution, resource levels cannot be negative.

Coefficients of variation (ratios of standard deviations to means) in Table 2 – ranging from 0.31 (household size) to 2.80 (plastic mulch recycling) and averaging 1.22 – suggest sample variation is very adequate for statistical tests. Interestingly, CVs are on average larger in the waste disposal behaviors themselves than in the household and farm characteristics variables hypothesized to explain them. This perhaps reflects the relative novelty of systematic waste management practices on these farms and represents a challenge to the modeler. Among household/farm characteristics, the greatest relative sample variability (2.06) is in commercial orientation (proportion of output value marketed) and the least is in household size and declared environmental consciousness.

## Estimation and results

As a preliminary to untangling the individual determinants of waste disposal practice, we first examined possible multicollinearity among the household and farm explanatory variables. To do so, we successively regressed each explanatory variable against the remaining ones and, for each regression, recorded the Minimum Tolerance and Maximum Variance-Inflation Factor (VIF). In no case does the Minimum Tolerance score fall short of 0.1 or the maximum Variance Inflation Factor exceed 10. Multicollinearity therefore does not appear to be severe among the explanatory variables.

A probit model was then fitted to estimate, for each waste category in Table 1, how household and farm characteristics affect disposal behavior. Because our focus is on the farm's and household's structural features such as size, wealth, and age, which should largely be exogenous to waste disposal behaviors, we follow the predominance of the literature in employing single-equation probits. These parameters do not themselves have strong intuitive interpretation. We consequently report in Table 3 the corresponding marginal probabilities instead, namely the effect on the indicated waste disposal behavior of a one-unit change in the indicated household or farm factor. A logit model generated nearly the same coefficient, sign, and standard error estimates as the probit did.

Approximately one-half the 60 parameters estimated in Table 3 are statistically significant at least at the 10% level. And differences across waste disposal categories in the number of statistically significant explanatory factors are not large. However, disposal categories do differ in which factors are most important for behavior. The most prominent exceptions are that the household head's age and the number of farm laborers affects almost every disposal behavior. Household size, earnings, and commercial-orientation effects are somewhat less pervasively, but still frequently, significant. The remaining factors are only spottily important. As we shall see, such cross-category importance corresponds only partly to a factor's strength when it is statistically significant.

## Effects of household characteristics

Household size and earnings – reflective of the family's physical capital – each significantly influence manure, wastewater, and straw treatment behavior. All else constant, the larger is the family the less attention it pays to these waste treatments; and the greater are its annual earnings, the more attention it pays to them. For example, lifting family size ($H_{size}$) by one (which, from the Table 2 means, implies a 21.5% size increase) reduces by 2.4 percentage points (that is, by 2.4 / 11.3 = 21.2%) the likelihood that plastic mulch will be recycled. Thus, a 1% boost in family size (controlling for those working on off and on farm, represented respectively by $H_{off}$ and $F_{labor}$) reduces mulch recycling by 1%. This gives a mulch recycling elasticity with respect to net family size of -1/1 = -1.00 in Table 4. Waste-disposal elasticities, of household size

| Variable | Packaging | Manure | Wastewater | Plastic Mulch | Straw |
|---|---|---|---|---|---|
| | Coefficient | Coefficient | Coefficient | Coefficient | Coefficient |
| Hsize | -0.024 | -0.0156* | -0.0123 | -0.0242** | -0.0274* |
| | (-0.85) | (-1.670) | (-0.48) | (-2.34) | (-1.84) |
| Hearn | 0.0097 | 0.00878* | 0.00447 | 0.01102** | 0.01629** |
| | -0.57 | -1.68 | -0.33 | -2.15 | -2.14 |
| Hoff | -0.03669 | 0.00814 | 0.03092 | 0.00226 | 0.0327* |
| | (-0.91) | -1.26 | -0.792 | -0.101 | (1.68) |
| Hage | 0.4022*** | 0.03148* | 0.3214*** | 0.06211*** | 0.9884*** |
| | (-6.69) | -1.8 | -6.39 | -2.77 | -3.12 |
| Hedu | 0.2583*** | 0.00689 | -0.05886 | -0.00183 | 0.0654*** |
| | -5.39 | -1.08 | (-1.48) | (-0.163) | -2.8 |
| Flabor | -0.00267 | 0.01334* | 0.0649** | 0.0288*** | 0.04206*** |
| | (-0.82) | -1.65 | -2.374 | -2.61 | -2.77 |
| Farea | -0.0192** | -0.00358 | -0.01109 | -0.0.01** | -0.00517 |
| | (-2.068) | (-1.487) | (-1.469) | (-2.44) | (-1.08) |
| Fgender | 0.01613 | -0.04848* | -0.04018 | -0.07337*** | -0.0236 |
| | (-0.351) | (-1.69) | (-0.841) | (-3.838) | (-0.74) |
| Fenvatt | 0.407*** | 0.01884 | 0.1099 | 0.3395** | 0.02177 |
| | -4.52 | -1.6 | -1.68 | -2.09 | -0.54 |
| Fcmrc | 0.166 | -0.0628* | 0.2369* | -0.0645 | 0.15623** |
| | -1.11 | (-1.56) | -1.92 | (-1.33) | -2.29 |
| Ftrain | 0.1279* | 0.01025 | 0.1289** | 0.02004 | -0.032967 |
| | -1.88 | -0.86 | -2.13 | -0.95 | (-1.07) |
| Fadvice | -0.0444 | 0.01615 | 0.2044*** | 0.0404** | 0.0527 |
| | (-0.602) | -1.11 | -3.24 | -1.62 | -1.38 |
| Pseudo $R^2$ | 0.3396 | 0.4832 | 0.2128 | 0.3296 | 0.2559 |

**Note:** Z-statistics are reported in parenthesis. Statistical significance at 10%, 5% and 1% are indicated as *, **, and *** respectively. Probit estimation with Stata 12.

**Table 3:** Determinants of Agricultural Waste-Disposal Behavior: Marginal-Probability Estimates, Probit Model, Zhejiang Province, China.

| Variable | Fertilizer Packaging | Manure | Wastewater | Plastic Mulch | Straw |
|---|---|---|---|---|---|
| $H_{size}$ | -- | -0.61 | -- | -1 | -0.95 |
| $H_{earn}$ | -- | 0.22 | -- | 0.3 | 0.38 |
| $H_{age}$ | -0.4 | -0.03 | -0.32 | -0.06 | -0.99 |
| $F_{area}$ | -0.13 | -- | -- | -0.38 | -- |
| $F_{labor}$ | -- | 0.25 | 0.47 | 0.57 | 0.7 |
| $F_{cmrc}$ | -- | -0.06 | 0.09 | -- | 0.13 |

[a]A value in the $H_{age}$ row is instead the change in the percentage of household heads that would pursue the indicated waste-disposal activity if an old household head were replaced by a young one.

**Table 4:** Waste-Disposal Elasticities: Proportional Changes in the Probability of the Indicated Disposal Activity Induced by a Unit Proportional Rise in the Indicated Factor [a].

as well as of other significant household and farm factors in this study, are shown also in Table 4. As can be seen there – and in the coefficient magnitudes in the top two rows of Table 3 – household-size effects on manure reutilization are proportionally about two-thirds as large as those on plastic mulch and straw reutilization.

Farm workforce size equals household size plus any hired workers and minus the household members who either work off-farm or are too young, old, or incapacitated for farm labor. Because farm workforce size and (as a binary indicator) any householder off-farm work are each controlled for in this model, household size represents the number of dependents – those in school or who remain at home. These members must be cared for, representing an added burden to the household heads and diverting time that otherwise could be devoted to farm work. Consequently, household size is negatively related to the amount of attention devotable to farm production and waste disposal, and it therefore is unsurprising that, *ceteris paribus*, the larger the household, the weaker that recycling tends to be.

Consider now the household earnings ($H_{earn}$) effects. Adding 10,000 yuan to the family's annual income raises the likelihood of plastic mulch recycling by 1.16 percentage points (i.e. 0.016) in Table 3. At sample mean, this corresponds to a 0.30% gain in plastic recycling for every 1% rise in household earnings, an elasticity of 0.30 in Table 4. As with the number of household dependents, earnings' proportionate effect on manure re-use is about two-thirds as high as it is on plastic mulch or straw re-use. New wealth brings new capital that can be applied directly to these recycling activities or, if applied to crop production instead, frees labor for waste disposal effort. So while larger households bring, other factors constant, significantly less attention to efficient waste disposal, greater household wealth brings significantly more attention to it.

The environmental implications of household-head age ( $H_{age}$ ) are especially intriguing. Except in package recycling – the least laborious of the five considered here – younger heads recycle waste less than older heads do. Family size, earnings, and other factors constant, switching from an older to a younger head reduces the likelihood of manure, wastewater, plastic mulch, and straw recycling by a respective 3, 32, 6, and 99 percentage points. The first and third of these are rather negligible. The last implies that few young household heads recycle straw, while approximately one-third of older heads do.

Younger heads' comparatively weak waste-disposal orientation is perhaps surprising in light of an expectation that the young would be environmentally better educated than the old. But especially in cross-sectional data, years-since-birth contains both an age effect and vintage effect. Younger heads would be expected to have more energy than older heads, implying *ceteris paribus* an expectation of greater waste recycling among the young. The vintage effect instead speaks to the era in which the head grew up. The sample's younger heads, brought up in the 1990s, were educated in a more environmental ethos. However, education, technical training, and declared environmental preferences are already controlled for in this model. Unaccounted for is the sense in many Chinese homes, as elsewhere, that as family endowment grows, the young pay less attention to conserving the next greater unit of that endowment. It would have been difficult to predict that, in four of the five waste disposal categories, the magnitude of this negative wealth-conservation effect would outweigh the positive physical-energy effect. On the other hand, it is not surprising. Diomedi and Nauges [20] find that older heads more frequently dispose properly of chemical containers than the young do, although the age effect is not as pronounced in their study as it is in ours.

The household head's education does in its own right boost attention to fertilizer package and straw reutilization. A junior middle-school graduate is 26 percentage points more likely to recycle packaging and 6 points more likely to recycle straw than a primary school graduate is.

### Effects of farm characteristics

Of the three factors mirroring the farm's productive capacity – farm workforce size, arable land area, and household head's gender – workforce size has substantially the strongest and most pervasive environmental effect. Only in packaging disposal, a comparatively low-effort activity, does a larger workforce not substantially lift the chance that recycling will be observed. In particular, an additional worker boosts the probability of manure-based biogas production by 1.3 percentage points, wastewater treatment by 6.5 points, plastic mulch recycling by 2.9 points, and straw reutilization by 4.2 points. In the proportional (elasticity) terms in Table 4, a 1% farm-worker expansion boosts manure recycling by 0.25%, wastewater treatment by 0.47%, plastic mulch re-use by 0.57%, and straw recycling by 0.70%. Clearly, the larger the workforce, the greater is the manager's incentive to allocate worker effort to waste disposal.

The two factors reflecting the farm's objectives – its declared orientation to the environment and a sales-based estimate of its commercial orientation – present some interesting contrasts. Household heads asserting an interest in environmental protection are, controlling for other factors, a substantial 41 percentage points more likely to recycle packaging material and 34 points more likely to recycle plastic mulch than those who assert no environmental interest. But in the remaining three waste-disposal categories, declared environmental concern seems to have had no effect on practice at all. Survey respondents can declare attitudes to a survey enumerator at relatively low cost, and about 80% of our respondents did claim to be environmentally motivated (Table 1). Plastic package and mulch require less recycling effort than do the other wastes considered here, and it is unsurprising that recycling these two wastes was especially common among our respondents. By the same token, the substantial labor and capital requirements of manure and wastewater processing explain why it is so little pursued relative to a farmer's declared environmental leaning.

Because it is provided in our model by an objective measure – the proportion of farm output marketed – the extent of the farm's commercial orientation is a different matter. The more commercially inclined the farm, the more that wastewater is treated (elasticity 0.09 in Table 4) and the more that straw is reutilized (elasticity 0.13), presumably because failure to do so would disrupt the farm's main revenue-generating activities or because the treated waste is itself a revenue source. Commercialization does impede manure recycling, although again quantitatively very little. In all four instances in which formal technical training and advice significantly affect waste treatment, it is in the hypothesized positive direction: the more the formal training provided, the greater the recycling. In particular, formal agricultural training boosts package and wastewater recycling by about 12 percentage points each.

On average, the three household-side waste disposal elasticities in Table 4 are greater than the three farm-side elasticities. This is so whether we look at the means of the actual elasticities or of the absolute-value elasticities. The former reflects an average capacity to improve waste disposal. The latter represents an average capacity to affect waste disposal at all, positively or negatively. In Table 4, the algebraic mean of the household elasticities is -0.18 and of the farm elasticities is 0.12, suggesting household factors are only moderately more powerful than farm factors are in improving aggregate recycling performance. The absolute-value mean of the household elasticities is, on the other hand, 0.35 and of the farm elasticities 0.18, implying that, in this study's setting, household characteristics have nearly double the influence farm characteristics do over recycling activity as such.

## Conclusions

In our semi-subsistent household sample, cash income, farm workforce size, the head's age, education, professional training, and advice, and declared environmental attitude tend to enhance farm recycling activity. The number of dependents and the farm's cultivable area tend to retard it. Extensive specification of these factors, and distinction between those in the household and on the farm, allows important nuance in factor interpretations. Controlled for environmental attitude, for example, the operator's age represents a combination of vintage and number of years since birth. Controlled for farm workforce, cultivable area, and education, household income reflects locational and other advantages in attracting supplemental cash.

Specifically household and specifically farm factors are approximately equally represented in the Table 4 list of what we find to be the most important waste-disposal determinants. Household inputs, however, appear to have somewhat greater recycling potency than do farm inputs. In particular, across the five waste-disposal dimensions, a one-percent variation in the principal household factors induces an average 0.35 percent change in recycling activity. Corresponding variation in the principal farm factors induces an average 0.18 percent change. The magnitudes of these resource effects are substantial considering that other household goals – food supply among them – compete with recycling in at least the short run.

Environmental policy makers in emerging economies will be especially concerned with the manner in which farm cleanup is influenced by economic development. Our Chinese sample suggests household cash income is environmentally constructive, helping to finance the new capital and labor resources that facilitate waste disposal. On the other hand, development also tends to depress fertility rates. Declining fertility reduces the demand for caregivers, who are then released for farm and other work. It also however suppresses household labor supply, for work both in the house and on the farm. It is net farm labor supply that, along with farm capital, that largely should drive the household's environmental behavior, especially for activities like waste disposal that usually have low immediate payoff relative to food production. If so, economic development should be friendly to farm recycling.

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