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The Economics of Adoption of Environmentally Beneficial Agricultural Practices: (EBAPs): An Analytical Review of Evidence

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ANNOTED SUMMARY OF EMPIRICAL LITERATURE

THE DEPENDENT VARIABLE

The empirical literature on soil conservation related technology adoption can be summarized into four broad groups: (i) adoption of soil conservation practices, (ii) adoption of conservation tillage practices, (iii) adoption of nutrients and nutrient management, and (iv) adoption of non-conservation related practices. Some studies deal with more than one type of adoption. These adoption studies are summarized in table 1.

Adoption of soil conservation practices

Eight of the eighteen reviewed studies fall under this category and include those conducted by Rose and Brownlea, Londhle et al., Lynne et al., Erwin and Erwin, Lichtenberg et al., Kairumba and Wheelock, Weaver and Abrahams, Hansen et al., and Noris and Batie. The dependent variable has been used in different form. For example, Rose and Brownlea study asked whether farmers had practiced soil conservation, while Londhle et al. study dealt with the perception of degree of soil erosion problem. Yet another group of studies addressed adoption of soil conservation or soil erosion control practices by asking number of practices farmers had adopted, which varied in number and type from one study to another (Erwin and Erwin, Lichtenberg et al., Weaver and Abrahams, and Hansen et al.). Soil conservation practices included adoption of sloping agriculture land technology, cover crop, filter strip, strip contours, participation in Crop Reserve Program (CRP), pasture/tree planting, crop rotation, drainage ditches, grass waterways, fallow, leaving crop residues on groups, and contour ridges. Noris and Batie used conservation expenditure as the dependent variable.

Adoption of conservation tillage practices

One-third of the study reviewed examined adoption of conservation tillage practices, and was addressed by Bultena and Hoiberg, Lee and Stewart, Rahm and Huffman, Belkap and Soupe, Lichtenberg et al., Weaver and Abrahams, and Noris and Batie. Conservation tillage was viewed in these studies as adoption of no till, minimum tillage, limited tillage, reduced tillage, efficiency of reduced tillage, or acreage under conservation tillage.

Adoption of nutrients and nutrient management

Only three of the eighteen studies reviewed dealt with adoption of nutrients and nutrient management issues. Daramola examined adoption of fertilizer and Lichtenberg et al. addressed fertilizer, manure and split application. Weaver and Abrahams used three variables--manure management, animal waste management and soil testing.

Adoption of non-conservation related practices

Four of the eighteen studies reviewed did not address soil conservation, soil erosion, or water quality issues. They include adoption of hybrid rice (Lin), number of good field days (Fletcher and Featherstone), and BST adoption (Zepeda, Kinnucan et al.).

THE EXPLANATORY VARIABLES

Several variables have been used in these studies to explain adoption at the farm level. These variables are broadly grouped into eight categories. They are discussed separately and are summarized in table 2.

Personal Attributes

Farmer's age, sex, race, education attainment, household size, agricultural experience, and off-farm employment are defined collectively as "personal attributes." Farmer's age variable was used by Bultena and Hoiberg, Daramola, Londhle et al., Lichtenberg et al., Weaver and Abrahams, Zepeda, Kinnucan et al., and Noris and Batie. Six of the eight studies using age variable had statistically significant result. Most of the studies suggested negative association between age and adoption. That is, younger farmers are more likely to adopt technologies than the older farmers. The only exceptions were Londhle et al.'s study in Philippines which dealt with sloping agriculture land technology. Noris and Batie found positive but non-significant association between age and conservation expenditure.

Only one study by Lin in China used sex as an explanatory variable to explain adoption of hybrid rice. His result suggested that female farmers were more likely to adopt hybrid rice varieties than male farmers, but the association between the variables was non-significant. Also only one study used household size to explain adoption, and the result was positive but non-significant. Noris and Batie used race variable and found non-white farmers were less likely to adopt technology.

More than two-thirds of the studies used education to explain technology adoption. Ten of the 13 studies using education variable defined the education variable as years of schooling (Bultena and Hoiberg, Rose and Brownlea, Daramola, Rahm and Huffman, Weaver and Abrahams, Lichtenberg et al., Erwin and Erwin, Belkap and Soupe, and Zepeda). Binary variables were defined by Londhle et al. (four years of schooling), Kinnucan et al. (high school/some college and college graduate/ otherwise), and Noris and Batie (high school graduates/ else and non-high school graduates/ else). Majority of the authors found positive sign for the education variable (Bultena and Hoiberg, Rose and Brownlea, Daramola, Belkap and Soupe, Erwin and Erwin, Lin, Lichtenberg et al., and Zepeda) while others found negative association (Rahm and Huffman, Londhle et al., Weaver and Abrahams, Kinnucan et al., and Noris and Batie). Thus, the empirical evidence of the role of education in technology adoption literature is mixed.

Farming or dairying experience was found to be positively associated with technology adoption (Belkap and Soupe, Lin, Lichtenberg et al., Weaver and Abrahams, and Kinnucan et al.). There exists a consensus among these five studies about the sign of the variable, although only three of them had statistically significant result (Lin, Lichtenberg et al., and Weaver and Abrahams).

Only two of the eighteen studies used off-farm employment of the farmers as an explanatory variable in a technology adoption model. Noris and Batie found negative and statistically significant association indicating that off-farm employed farmers are less likely to adopt technologies. Results drawn by Erwin and Erwin are mixed in sign (some positive and some negative coefficients), but non-significant.

Farm/ Firm Characteristics

The farm and firm characteristics include farm size, income, tenure, family labor, debt, milking system (on dairy farms), agricultural training, and size of the largest parcel owned by the farmer. Thirteen of the eighteen studies reviewed used farm size variable to explain adoption. Farm size variable was defined in several ways. For example, a group of studies used size of land ownership to represent farm size (Hoiberg and Bultena, Rose and Brownlea, Daramola, Rahm and Huffman, and Erwin and Erwin). Crop acreage was used by Belkap and Soupe, Kairumba and Wheelock, and Noris and Batie. Lee and Stewart categorized farms into three sizes--less than 140 acres, 140-700 acres, and more than 700 acres. For the Philippine case study, Londhle et al. categorized farms as less than one hectare and between one and two hectares. Herd size was used in two dairy studies that examined BST adoption by the farmers (Zepeda, Kinnucan et al.).

Majority of the U.S. studies reported a positive association between farm size and technology adoption. Lee and Stewart found a positive sign for larger farms (that is, more than 700 acres) but a negative sign for smaller farms (Less than 140 acres). A negative non-significant sign on herd size was reported by Zepeda which contradicts with Kinnucan et al.'s findings of positive and significant coefficient. This contradiction may have been associated with discrete and continuous definition of herd size adopted in the two studies. Erwin and Erwin also found a negative and significant association between farm size and perception of degree of soil erosion problem and a negative but non-significant association between farm size and soil conservation effort. However, the same study found a positive but non-significant relationship between farm size variable and number of erosion control practices adopted. Noris and Batie study found positive relationship between farm size and conservation expenditure and also a positive relationship between farm size and conservation tillage acreage. In general, the empirical results suggests that there exists economies of scale in adoption, and the contradictory results are attributed to variations in definition of the dependent variable.

In a separate study in Philippines, Londhle et al. found a positive and significant association between size of largest parcel of land and adoption of sloping agriculture land technology. The result provides an evidence that size of parcel matters in land constrained economies.

Eleven of the 18 studied reviewed used income as an explanatory variable to explain adoption (Bultena and Hoiberg, Rose and Brownlea, Daramola, Londhle et al., Belkap and Soupe, Lynne et al., Lichtenberg et al., Kairumba and Wheelock, Zepeda, Kinnucan et al., and Noris and Batie). Wide variations in the variable definition of income were found across these studies. For example, two studies used gross farm income (Bultena and Hoiberg, Daramola), three studies used total income (Lynne et al., Hansen et al., Belkap and Soupe), and one study used after tax total income (Noris and Batie). Rose and Brownlea used an indicator variable for declining income, and Lichtenberg used two variables--percentage income from farming and percentage income from crops. Two studies used binary variable for income (Londhle et al., Kairumba and Wheelock). In dairy farm studies, Zepeda used proxy variables--number of cows and production per cow, and Kinnucan et al. used average production per herd in the first half of the year.

The empirical findings of these studies suggest a mixed picture, and sign on income variable varies with the model estimated. For example, Noris and Batie found a positive association between income and conservation expenditure but a negative association between income and conservation tillage acreage. Both dairy studies (Zepeda and Kinnucan et al.) found negative relatioships between BST adoption and income's proxy variables. Similarly, Lichtenberg et al. found mixed results and sign on the income coefficient varied with the model estimated.

Half of the studies reviewed tenure variable to explain adoption (Bultena and Hoiberg, Lee and Stewart, Rahm and Huffman, Belkap and Soupe, Lynne et al., Lichtenberg et al., Kairumba and Wheelock, Weaver and Abrahams, and Noris and Batie).

Dummy variables for tenure status indicating full-time owner operator, part-time owner operator, non-operator, or renter/owner were used in four of the nine studies (Bultena and Hoiberg, Lee and Stewart, Lynne et al., Lichtenberg et al., Kairumba and Wheelock). Another tenure indicator variable used is percentage of cropland owned (Belkap and Soupe, Noris and Batie, Rahm and Huffman). Most of these studies reveal fairly consistent finding that owner operator, full time operator, or farmers having relatively larger share of cropland owned were positively associated with adoption decisions. However, part-time farmers were less likely to adopt technologies (Lee and Stewart). Lichtenberg et al.'s findings, however, revealed mixed results (i.e. some models had a positive sign and others had a negative sign).

A negative relationship between family labor and adoption was found in two studies (Lin, Rahm and Huffman), but only Rahm and Huffman reported statistically significant relationship. The results suggest that families with larger proportion of family labor are less likely to adopt technologies. One dairy study (Zepeda) used milking system to explain BST adoption by the farmers, and her results were statistically non-significant.

Four studies reviewed used farm finance variables to explain adoption. Belkap and Soupe used debt-asset ratio, Erwin and Erwin used a binary debt concern variable, Lynn et al. used portion of operating capital borrowed, and Noris and Batie used dollars spent annually toward debt payment. Only two of the four studies had at least one or two models statistically significant (Noris and Batie, Erwin and Erwin), and other two had non-significant coefficients. The direction of association between the farm finance variable and adoption is more or less consistent, and concern toward debt payment and smaller debt increased adoption by farmers.

Only two studies used agricultural training variables in adoption models (Rahm and Huffman, Belkap and Soupe). Both studies found negative but non-significant relationship between farmers who had studied vocational agriculture and adoption. Rahm and Huffman also found similar conclusion on variables such as farm operator completing agricultural education, and farm operator attending meetings, field-days, or demonstrations. However, the same study found strong negative association between farm operators or their spouses attending short courses. The available empirical evidence suggests that agricultural training has very little impact on adoption.

Conservation Practices

Conservation practices adopted by farmers include double cropping, ridge, no-till, chisel on corn stubble, strip contour/contouring, and acreage tilled. Rose and Brownlea found double cropping to be positively associated with farmers decision to adopt conservation practices. Fletcher and Featherstone examined ridge, no-till, and chisel on corn stubble to explain number of good field days. They attempted to explain number of good field days in land preparation and planting periods. They found a positive association for ridge (binary variable) and a negative association for no-till and chisel on corn stubble with number of good field days during land preparation. They also found a negative and significant sign on chisel on corn stubble for planting period. However, coefficients of ridge and no-till variables were although positive, they were non-significant in explaining number of good field days during planting time. Only one study used acreage tilled to explain conservation technology adoption (Lichtenberg et al.). They found a positive and significant relationship between acreage tilled and limited tillage as well as strip contour. Erwin and

Erwin found a negative association between farmers' participation in watershed management and contouring. Given the variations and limited number of studies conducted, no definite conclusions can be drawn from these studies.

Government Programs

Four different programs were found to have been examined in three separate studies. Erwin and Erwin used binary variables to indicate farmers' compliance with Soil Conservation Service (SCS) in acreage reduction and farm plan. The findings from the study suggest statistically non-significant coefficients on SCS variables. Participation in cost-sharing program was examined in two studies (Erwin and Erwin, Noris and Batie). Both studies found positive association between participation in cost-sharing program and adoption variable, but only Erwin and Erwin's study found statistically significant relationship in explaining some of the adoption practices (soil conservation effort and terraces).

Kairumba and Wheelock examined the relationship between participation in price support program and use of price support program. Their result suggest that use of price support program was statistically significant in explaining farmers' decision to participate in CRP. Londhle et al. in their study in Philippines agriculture found a positive association between external technical assistance and adoption of sloping agriculture land technology. To the relevance of U.S. agriculture only two studies provide relevant conclusion stating positive impact of price support and cost sharing programs on technology adoption.

Acreage Allocation

Farmers' crop acreage allocations were used to explain adoption. The empirical evidence led to acreage allocation under four crops--corn, soybean, tobacco, and tree. Five of the eighteen empirical studies reviewed used crop acreage variables. Two studies used acreage under corn (Weaver and Abrahams, Kairumba and Wheelock). Lichtenberg et al. used share of land in corn and Erwin and Erwin used grain farm to represent corn acreage. A negative and significant association between corn acreage variable was reported in all four studies. However, discrepancies in direction of association were also found in this conclusion at least in some of the models estimated. For example, Lichtenberg et al. found a negative association between share of corn acreage and split nutrient application, filter strips, and strip contours. On the other hand, they also found a positive association between share of land in corn and limited tillage, waste storage, water sources, and waterways.

Soybean acreage variable was defined differently in three studies reviewed. One study used a ratio of acres of soybean to corn (Rahm and Huffman). The other two studies defined the variable as share of land in soybean (Lichtenberg et al., Kairumba and Wheelock). In addition, Kairumba and Wheelock also used acres under soybean. All three studies found a positive coefficient on this variable. However, like in corn acreage variable, some of the models had negative coefficients (e.g. in filter strips and strip contour models in Lichtenberg et al. and soybean acres in Kairumba and Wheelock).

Acreage under tobacco was used in two studies (Lichtenberg et al., Noris and Batie). Share of land in tobacco was used by Lichtenberg et al. and area under tobacco was used by Noris and Batie. The first study had positive sign in five models (fertilizer, split application, cover crop, filter strip, and waste storage) and a negative significant association was found in limited tillage model. Noris and Batie also found a negative significant coefficient for tobacco acres in conservation expenditure model and a positive non-significant coefficient in the conservation tillage acreage model. Thus, the empirical evidence is not clear to explain direction of association between tobacco acreage and the adoption variable.

In their study Kairumba and Wheelock examined relationship between tree acres and conservation options -- pasture/tree planting. Their findings suggest a positive and significant relationship between these two variables. No other study reviewed used tree acres to explain adoption behavior.

Environmental Factors

Several environmental factors were considered in different studies to explain adoption. These include precipitation, season, geographical region, slope, number of heating days, consecutive rainless days, and rotation hazard. Three of the eighteen studies reviewed found a consistent sign on rainfall variable (Rahm and Huffman, Belkap and Soupe, Fletcher and Featherstone), but only later two studies had statistically significant results. The results suggest that increase in precipitation is likely to affect technology adoption decision.

Rahm and Huffman also used season variable (defined as average number of growing days between spring and fall dates of less than 50% frost probability). They found a positive but non-significant coefficient on this variable. Their results suggest that adoption of reduced tillage is statistically not affected by "favorable season."

Three studies employed geographical region variable to explain adoption decisions (Lee and Stewart, Lin, and Kinnucan et al.). These three studies were conducted for distinctly different areas. Lin's study examined adoption of hybrid rice variety adoption by Chinese farmers and Kinnucan et al.'s study examined BST adoption by dairy farmers. Only Lee and Stewart's study was relevant to conservation technology adoption. They used dummy variables for different regions and their interaction with "no erosion hazard" to explain adoption decisions for minimum tillage. Their results suggest statistically significant relationship between region and region-no erosion hazard interaction variables and adoption decisions. Delta, Northern Plains, and Southern Plains were likely to have positive impact while Corn Belt, Lake, Northeast, and Southeast were likely to have a negative impact on minimum tillage adoption decisions. Similarly, interactions between no erosion hazard and Appalachian, Delta, and Northeast were likely to have positive impacts and interactions between no erosion hazard and Corn Belt, Northern Plains, and Southeast would have negative impacts on adoption decisions.

In their study on dairy farmers of Southeastern region, Kinnucan et al. found a mixed result on BST adoption. For example, region variables (Georgia, Mississippi, and Florida) were statistically non-significant in most of their models with both positive and negative associations. Only positive and significant signs were found of Georgia in adoption models. The two U.S. studies are not comparable because they have been examined under different context. However, Lee and Stewart's study does reveal some insights into which regions are more likely to adopt minimum tillage.

Two studies used soil type as a variable to explain adoption of technology (Rahm and Huffman, Fletcher and Featherstone). Rahm and Huffman examined different soil types and found that about half of the 21 soil types examined were statistically significant in explaining adoption of reduced tillage practices in Iowa. Fletcher and Featherstone used a soil binary variable and found non-significant association between soil type and number of good field days, both during land preparation and planting periods.

One-third of the studies reviewed used soil erosion variable to explain technology adoption (Bultena and Hoiberg, Lee and Stewart, Belkap and Soupe, Erwin and Erwin, Weaver and Abrahams, and Noris and Batie). All six studies lend support to the hypothesis that soil erosion when perceived as a problem, it would increase likelihood of technology adoption. Erwin and Erwin's study, however, also provides a contradictory result that perceiving erosion as a problem is likely to decrease minimum tillage adoption although it is likely to increase number of practices adopted and soil conservation effort. Lee and Stewart also found that interactions of erosion hazard with region dummies were statistically significant in explaining reduced tillage adoption.

Land slope variable was used in two studies to explain technology adoption (Belkap and Soupe, Lichtenberg et al.). Belkap and Soupe defined land slope as a binary variable indicating steeply sloping/non-sloping cropland to explain adoption of no-till practice. They found a negative coefficient on the slope variable suggesting farms with steeply sloping cropland are less likely to adopt no-till practice which was contrary to their hypothesis. Lichtenberg et al. used two binary variables--3-8% slope and more than 8% slope to explain adoption of several practices. Their results suggest a mixed result. They found that the 3-

8% slope variable was negatively associated with fertilizer use, cover crop, and filter strip. On the other hand, same variable was positively associated with strip contours. The other slope variable, more than 8% slope, was negatively associated with fertilizer, manure and filter strips, and it was positively associated with strop contour, terraces, water sources, and waterways. The empirical evidence suggests that direction of association between cropland slope and adoption varies with the specific practice being examined.

Belkap and Soupe used two additional variables, number of heating degree days and rotation hazard to explain adoption of no till practice. The first variable was negatively associated with the adoption of no-till practice. The second variable, rotation hazard, was positively associated with adoption decision, but it was found to be statistically non-significant.

Fletcher and Featherstone examined role of consecutive rainless days on number of good field days. Their findings reveal a positive association between these two variables, but the relationship was statistically significant in explaining number of good field days in the land preparation model, and not planting period model.

Attitudinal Factors

Various variables related to farmers' perception, attitudes, and beliefs about technological adoption practices are grouped in a broad category "attitudinal factors." These factors are subgrouped into six specific types--risk, profitability, positive externalities, availability of information and technology, role of government, and farm orientation.

Seven of the 18 adoption studies reviewed contained variable associated with risk perception (Bultena and Hoiberg, Belkap and Soupe, Lynne et al., Erwin and Erwin, Kairumba and Wheelock, Weaver and Abrahams, and Noris and Batie). The risk variable in these studies has been defined in different ways. For example, two studies used risk aversion measure (Belkap and Soupe, Erwin and Erwin), one study used risk orientation (Bultena and Hoiberg), one study used family security and farmers' capability of adopting technology (Lynne et al.), one study used planning horizon with farm operator's son to inherit farm (Kairumba and Wheelock), and one study used perception about knowledge of different technological practices (Weaver and Abrahams). The empirical findings are consistent with the hypothesis that risk averse farmers are less likely to adopt technologies and risk loving farmers are more likely to adopt technologies. Similarly, if farmers' kin were to inherit farm or farmers were to keep farm in foreseeable future, then they respond positively to technology adoption and if farmers intend to sell their farm then probability of technology adoption will be smaller. Also, farmers who planned conservation also increased their expenditure on conservation measures.

Five studies used profitability related attitudinal variables (Lynne et al., Erwin and Erwin, Kairumba and Wheelock, Weaver and Abrahams, Noris and Batie). However, these studies used distinctly separate variables. For example, Lynne et al. employed farmers' strength of feeling about present and future profitability. Two studies used off-farm employment/income of farm operator (Erwin and Erwin, Noris and Batie) and another study used farmers' expectation of stability in farm income (Kairumba and Wheelock). Weaver and Abrahams adopted a variable that reflected farmers' perception associated with their belief that financial effects are important factors in conservation adoption.

Lynne et al.'s findings suggest that strength of feeling about current and future profitability was negatively associated with number of conservation practices adopted. However, only coefficient associated with the current profitability was statistically significant. The empirical evidence also suggests that off-farm employment of the farm operator is negatively associates with adoption (Noris and Batie). Farmers who believe that financial factors are important in conservation are not likely to adopt conservation practices (Weaver and Abrahams). The available evidence suggests that farmers who are concerned with short-run profitability are less likely to adopt conservation technologies.

Five studies used perception and belief variables associated with the notion that conservation is good for the society and environment--positive externalities (Bultena and Hoiberg, Rose and Brownlea, Lynne et al., Erwin and Erwin, Weaver and Weaver). All studies reach a consensus in support of the hypothesis, and most of the model estimated have statistically significant coefficients.

Weaver and Abrahams used a several variables related to farmers' perception about the availability of information from various sources, existence of EBPA technology, and role of government in conservation program. Their results suggest that information source from government and NGOs is important in adoption of conservation tillage. Their findings also reveal that farmers who perceive that it is government's responsibility to provide information, finance, and regulate tend not to adopt conservation tillage. Furthermore, farmers who perceive that they need technical training and certification in soil are more likely to adopt conservation tillage.

Three studies used farm orientation related variables to explain adoption decisions (Belkap and Soupe, Erwin and Erwin, Hanen et al.). Belkap and Soupe used two indicator variables--farmers plan to expand acreage and farmers plan to be full-time farmers in next five years. Erwin and Erwin used farm orientation variable to indicate farmers' commitment to farming. Hansen et al. used farmers' orientation to change. The limited empirical evidence suggests that farmers with orientation to change the way they are farming taking into account conservation technology and those who plan to commit to farming by increasing crop acreage and become full-time farmers are more likely to adopt technologies.

Institutional Factors

Institutional factors include farmers' access to and or use of extension service, cooperatives, storage, credit, irrigation, community organization, dairy clubs, conservation agencies, and proximity to input sources and market. Three studies used extension service related variable(s). Daramola in his Nigerian study used number of contacts by farmers with extension workers and Belkap and Soupe employed a binary variable to represent farmers use/non-use of farm institutions. Weaver and Abrahams used a perception variable to represent farmers' belief in usefulness of information obtained from county extension or Penn State specialists. Only later two studies were found to be relevant to the U.S. context. Belkap and Soupe's result suggest a positive relationship between farmers' use of farm institutions and adoption of no-till practice. Weaver and Abrahams study, however, found that belief associated with the role of extension agents was not significant in explaining adoption decisions.

Farmers' membership in cooperative societies and availability of storage facilities and irrigation water were found to be non-significant in explaining technology adoption in Nigeria. Access to credit and proximities to input and output markets, however, were found to be important in explaining adoption decision in that country (Daramola). However, Lin found that credit was not a constraint to hybrid rice variety adoption in china.

Belkap and Soupe examined role of farmers' use of community institutions and found a positive and significant association with adoption of no-till practice. Similarly, Zepeda found that number of dairy organizations a farmer belonged was positively associated with adoption of BST. Farmers frequency of contacts with conservation agencies was found positively related to adoption, but relationship was statistically non-significant.

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