Characteristics of Rural Farm Households that are Efficient in Investing and Have Financially Empowered Women

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Abstract

This article derives a measure of household efficiency and women's empowerment to determine their relationships with household production and consumption characteristics. We use a series of public good games to derive our measures of household efficiency and women's empowerment and match this with survey data from a randomized controlled trial in the Philippines. We use a machine learning algorithm to derive relationships with select household characteristics. We find that the average household efficiency and most common level of efficiency is 50% relative to the most efficient contribution level. We also find that 43% of households have the husband with full bargaining power while 40% have the wife with full bargaining power. We find that households most efficient in investing have husbands that allocate fewer time for leisure activities and an optimal time for farming; wives that allocate more time to social activities and optimal times for cooking and farming; fewer female household members work in crop production; household male workers work in crop production; and have higher z-score of children's height. Households that have wives empowered in decision making have husbands that allocate fewer time to leisure activities and eating, but engage in more farming hours; wives that allocate less time to domestic chores, leisure activities and social activities but more time for dependent care, personal time and more time for cooking; fewer household labor in crop production; higher z-score of children's height and have an optimal amount of rented agricultural land.

Keywords: Women's Empowerment Index; Household Efficiency; Public Goods Game; Machine Learning; Extreme Gradient Boosting; Philippines

JEL Codes: C92, D13, O13, Q12

I. Introduction

Understanding how household decisions are made between its members is crucial in determining the appropriate model of the household. There are two interesting aspects of intra-household decision making that were recently examined with field experiments in developing countries: household efficiency in investment decisions and the influence of women in such decisions. Understanding if households are efficient in different decision-making activities is the foundation for model development. Empirical research has shown that the unitary model of household decision making, where the household head makes most decisions without consultation, do not hold true (Alderman et al. 1995). Instead, interactions between spouses determine household decisions. Such interactions are thought to be cooperative or competitive in nature. A question arises whether such interactions lead to efficient investment decisions or not.

Another aspect of intra-household decision making is the influence of each spouse in final investment decisions, especially the role of women in such decisions. There is a growing literature quantifying the influence of women in household decision making. Such empowerment measures vary based on a variety of factors such as location, culture, household decision and institutional laws of ownership. In Peru, when women lived in locations where land ownership was formally titled to both spouses and not just the husband, women's empowerment index and their ability to contribute to decision making was 15% higher compared to women where this land ownership title was not enforced. Given the potential variety of results across countries, it would be interesting to compare how the Philippines, a country thought of as a relatively matriarchal society (Ashraf 2009), compares with those studied in the literature. We have not come across a study that measures jointly household efficiency and women's financial empowerment along with their relationship on different types of household characteristics.

The objective of this study is to calculate measures of household efficiency and women's empowerment in the Philippines and to determine their correlates with day-to-day rural household decisions. This study is significant because it helps elucidate our understanding of the inter-household decision making process and its effect on investment and consumption decisions. We conduct a series of economic public good games among spouses in farm households to explore measurements of household efficiency and women's empowerment in the household. We match rural household data and results from the public goods game. We contribute to the literature in two ways. First, we derive measures of household efficiency and women's financial empowerment in the Philippines which can be compared to similar studies in developing countries. Second, we derive correlates with our intra-household decision making measures and different types of household decision categories both in the production side as well as the consumption side. This is potentially the first step in a line of research that examines more closely how intra-household decision making complements or substitutes different choices on the production side versus the consumption side of household decisions.

The first set of literature that we contribute to shows the relationship between efficiency in spousal interaction and household decisions. One early work in this literature relates the role of efficiency in decision making to financial investment outcomes in Kenya. Hoel et al. (2015) use a modified dictator game to measure efficiency in decision-making between spouses. They show that this measure of household efficiency is correlated with more information sharing regarding financial use within the family. Schaner (2015) use a field experiment related to opening new bank accounts where the measure of household efficiency relates to savings earned from the type of bank account opened. She shows that household decision makers with relatively similar discount rates are likely to make efficient financial decisions by opening joint accounts that yield higher

savings interest than lowering yielding individual accounts. Couples with mismatched discount rates are more likely to forego savings interest by opening individual accounts instead of joint accounts. Fiala (2017) uses hiding money as a measure of household efficiency in Uganda. When the husband hides money, this is correlated with lower levels of a household economic index composed of household assets, household income and household expenditure. If the wife hides money, the correlation with the same household economic index is positive. This highlights the lack of resource control of women in the household where hiding is their only recourse.

More recent studies go beyond the correlation between household efficiency and financial investment by examining measures of household welfare. Ambler et al. (2020) use the welfare maximizing level in a dictator game to measure household efficiency. In Uganda, this measure of household efficiency is correlated with measure of empowerment such as better marital quality, lower domestic violence index, more access of women to resources and better decision making. In contrast, there was no significant correlation with household efficiency and these similar household welfare measures in Ghana. Zou et al. (2021) measure the exchange rate for spousal earnings using the Becker-DeGroot-Marschak method as a proxy for household efficiency in Burkina Faso. They show that more inefficient household measures correlate with lower household earnings and slower infant growth. Lowes (2022) conducts a public goods game to measure the efficiency between spouses in investment decisions in Sub-Saharan Africa. She finds that matrilineal kinship systems, where inheritance is passed through the women, is correlated with lower investment in the public goods when it is easier to hide money from the spouse. Hoel et al. (2021) has some elements closest to our paper regarding the household efficiency measure which is based on a public goods game in Senegal. Their measure of household efficiency correlates with

smaller gender gaps in milk production. Interestingly, better efficiency measures do not correlate with more cooperation in household decisions.

Our analysis differs from this set of literature in two ways. First, we make a distinction between the correlates of household efficiency on household production versus household consumption activities. Our household production activities relate to labor making decisions along the supply chain of vegetable farming while consumption activities relate to personal expenditure, time use allocation and investment in children's welfare. Second, we use the public goods game measure to derive a measure of female empowerment which we also relate with select household production and consumption activities. Note that since our measure of household efficiency is similar to Hoel et al., it allows us to compare and contrast their measure with our own in a different country context where women are mostly the dominant financial decision makers.

The second literature that we contribute to relates measures of women's empowerment to household welfare. Wiig (2012) identifies five different measures of women's empowerment measures. First, female income and wealth are measures of empowerment. Peterman (2010) shows how female inheritance of land is positively correlated with earnings potential and women's employment. Second is a revealed preference approach that incorporates assumptions regarding gender preferences. Ashraf et al. (2010) show a positive correlation between women's savings and consumption female-preferred commodities. Third are self-reported evaluations of women's rights within the household. Allendorf (2007) show correlations between wives who have the final say in household decisions in Nepal and their ability to own land. Fourth are measures of culture specific indicators that are in the domain of the husband or the wife. Finally, there are results from economic experiments to gauge women's empowerment in the household. Wiig (2012) ran three different games: a public goods game, a risk game and a trade game to derive a measure of

women's empowerment to correlate with land ownership to show that women that are more empowered in the household are more likely to own land in Peru. In our study, we utilize a similar public goods game to derive our measure of women's empowerment as well as our measure of household efficiency. This will allow us to directly compare results with Wiig (2012) from his Peru study and Hoel et al. (2021) from their Senegal study. We expand on the analysis in the women's empowerment literature by examining relationships related to household production practices versus household consumption practices.

Our study site is Laguna, Philippines which has a significant vegetable farmer population. The public goods game yields strikingly similar results regarding the measure of household efficiency in Senegal by Hoel et al. and the women's empowerment measure in Peru by Wiig. We find that 29% of households in our study site contributed to half the efficient level and 42% contributed to more than the average efficiency level. In Senegal, the estimates show that 31% of spousal pairs contributed to half the efficient level and 42% contributed more than average level. About 43% of our households followed the husband's bargaining preference and 40% followed the wife's bargaining preference. The results are similar to Wiig where 42% followed the husband's bargaining preference and 39% was close to the wife's bargaining preference.

We also find interesting relationships between the intra-household decision-making measures with household characteristics using machine learning. We find that households most efficient in investing have husbands that allocate fewer time for leisure activities, personal time, and cooking but work an optimal time in the farm. In the efficient households, wives allocate more time to social activities but have an optimal time for cooking, farming and leisure. In the production side, efficient households have fewer female household members that contribute to farm production but more male workers are in crop production and spend an optimal amount on

herbicides and fertilizers. The children below 5 years old are taller in efficient households. Households that have the wives empowered in decision making have husbands that allocate fewer leisure activities and eating time but engage in more farming minutes; wives that allocate less time to domestic chores, leisure activities and social activities but more dependent care, personal time and more time for cooking. In wife-dominated households, there are fewer workers engaged in crop production, the household has an optimal amount of rented agricultural land and the household efficiency is high.

The remaining sections of our study are as follows: we provide a background on the randomized controlled trial where the economic experiment is conducted Section 2; we give an overview of the experimental methodology in Section 3; we summarize results of the analysis in Section 4 and we conclude and provide implications of the study in the last section.

II. Context of Field Experiment where Lab Experiment is Conducted

We study investment decisions and intra-household decision making process of vegetable farmers in Laguna, Philippines. There is a significant gender gap in the agricultural labor force participation rate in the Philippines where only 28% of workers in the sector are female while the rest are male (ADB, 2013). The lack of technological information and training along with livelihood opportunities within the sector hinder women's participation in the labor force (Gonzalez, 2016). One niche that Gonzalez (2016) found where there is a potential to increase women's participation in the labor force is through organic vegetable production.[1] The development of new organic vegetable technology within Laguna, Philippines presented an

[1] A select group of women from barangays in Los Baños, Laguna were targeted and taught organic vegetable production using various available technologies. The pilot study showed that there is a potential niche for women in such production practice with approximately 85% of farms experiencing a positive net increase in revenue.

opportunity to measure the effect of adopting organic vegetable technology on farmer welfare as well as investigate the intra-household investment decision making process in farmer households.

We conducted a randomized controlled trial to derive the determinants of organic vegetable technology adoption and its impact on farmer household welfare. During the baseline survey, we incorporated a public goods field experiment between farmer couples to derive a measure of intrahousehold investment efficiency and the bargaining power of women. This is the first experiment we are aware of embedded in a randomized controlled trial that measures women's financial empowerment within the household.

The study site is located in the northern portion of the Philippines in the province of Laguna. Households include all vegetable farmers with spouses. We compiled a population list of vegetable farmers in the three largest municipalities in Laguna province – San Pablo, Majayjay and Nagcarlan. From this population list, we randomly selected 600 farmer households. We interviewed 600 households, translating to 1200 individual spouses. During the baseline survey in March 2022, we also conducted a public goods game targeting both spouses. For the experiment to properly work, both spouses were present during the game.

The baseline questionnaire consisted of vegetable production questions such as input use, land allocation and productivity. We also include household and individual consumption, income, expenditure and time use data in the questionnaire. The data allows us to determine relationships with our measures of household investment efficiency and women's empowerment on various individual and household attributes.

III. Experimental Methodology

Our experiment measures two types of intra-household decision making: household efficiency and women's empowerment; and uses them to find relationships with different household decision making choices.

3.1 Measures of Intra-Household Decision Making Using the Public Goods Game

The experiment conducted during the baseline survey is a public goods game between spouses. Each player is allocated 10 tokens. Players are matched to a partner and must choose between keeping the tokens or allocating them to a group pile, to which the partner will also contribute. The value of tokens contributed to the group pile is multiplied by 1.5. Total contributions to the group pile are then divided equally and returned to each partner. Each player is provided with a table of potential returns for each strategy so there is full information available to all participants. The efficient and welfare-maximizing solution is for all players to contribute their entire endowment to the common pool. However, each individual has an incentive to "free ride" and keep their own endowment, while also taking their payout from what others contribute to the common pool. The outcome of interest is how many tokens the individual decides to contribute to the common pool.

Subjects each play four games. In games 1 and 2, subjects are matched to an anonymous partner who is another study participant in the village. The first game is considered a practice round. In game 3, subjects know they are matched to their spouse. In game 4, the spouses make joint decisions and the pair are each matched to an anonymous study participant in the village. After discussion, they must make the same decision.

A key concern in analyzing the decisions made by spouses is that if the decision is not private, it may be influenced by anticipated future bargaining between the spouses (Munro 2017). Therefore, in order to obtain a valid measure of the individual's true preferences in the game, the

decision must be kept private. We accomplish this by introducing randomness into the amount paid out of the common pool. Subjects are informed that in each game, there is a 50% chance that the amount in the common pool will be determined by their decisions, and a 50% chance that it will be determined by a computer. Thus, a player has no way of determining how much the other spouse contributed based on their payout from the common pool, and their own private decisions.

There are two key variables in our analysis. The first is a measure of household investment efficiency. The household investment efficiency, HE, is calculated as,

(1) $HE = MSP + WSP$

where MSP is the man's spousal preference contribution to the pot in Game 3 and WSP is the woman's spousal preference contribution to the pot in Game 3. Maximum efficiency in this scenario occurs when the subjects invest the maximum number of tokens leading to 20 tokens in the group pile. The second is a measure of woman's financial empowerment based on their ability to make investment decisions in the household. We follow Wiig's (2013) formulation of woman's financial empowerment (WP),

(2) $WP = \frac{JP-MIP}{WIP-MIP}$

where JP is the joint preference contribution in Game 4, MIP is the man's individual preference contribution in Game 2 and WIP is the woman's individual preference contribution in Game 2. A large value indicates that the wife's preference is followed more than the husband's preference while a smaller value indicates that the man's preference dominates. A WP equal to 0.5 indicates equal power in household decision-making by both spouses. As a robustness check, we group values into three categories: husband-dominant decision making when there is a value less than 0.5, wife-dominant decision making when there is a value greater than 0.5 and equitable decision-making when the index is 0.5.

Note that there is a possibility for an undefined measure of our women's empowerment index when WIP equals JIP. However, this does not mean that the measure of women's empowerment does not exist in the household. There is still some measure of women's empowerment but our experiment led to an undefined value given our definition of tokens in the game. To determine the women's empowerment index for these households, we impute the values using the K-nearest-neighbors (KNN) algorithm. KNN is a commonly used for imputing missing values in datasets. This technique involves using observations in the neighborhood to impute missing values (Armitage et al., 2020). KNN method has demonstrated robustness to missing data, non-parametric attributes, and fast estimation of missing values, all while accounting for the correlation structure of the data (Suyundikov et al., 2015). The 366 non-missing values were used to train the K-NN algorithm. Then the trained algorithm is used to predict and impute the missing wife's empowerment index. We imputed 221 missing index values.[2]

We hypothesize potential disparities in individual preferences between husband and wife when making preferences in isolation versus when they are paired together. First, the husband and wife may have different preferences when playing with anonymous partners. This is likely to occur if they have different spending and investment priorities within the household. To determine if there are differences in preferences between spouses we run the following model,

(3) $IP_{ig} = \beta_0 + \beta_1 M_{ig} + \beta_3 G2_g + \epsilon_{ig}$

where IP_{ig} is the preference choice of individual i in game g indicating the amount they contributed to the pot, M_{ig} is a dummy if individual i is male in game g, $G2_g$ is a dummy for game 2, β_j are parameters and ϵ_{ig} is a random error term. If men and women have different preferences, we expect

[2] We could not impute one of the observations because of missing covariates.

$\beta_1 \neq 0$ which is interpreted as men and women have different preferences when playing with anonymous partners.

Men and women may have different preferences when paired with each other as opposed to when they are paired with anonymous subjects. This may occur if preferences in financial decisions between individuals are very different and one spousal pair carries more weight in financial decisions than the other. To test this hypothesis, we run the following model,

(4) $SP_i = \beta_0 + \beta_1 M_i + \epsilon_i$

where SP_i is the joint spousal amount contributed to the public good in Game 3 by individual i. If the hypothesis holds, we expect, $\beta_1 \neq 0$ which implies that men and women have different preferences when playing with each other.

3.2 Relating Measures of Intra-household Decision Making to Household Characteristics

We determine relationships with our measures of intra-household decision making across four decision making categorizes: (1) labor decisions in farming, (2) child health characteristics, (3) spending and earning categories and (4) time use allocation. We utilize a machine learning algorithm to determine these relationships.

The machine learning method utilized in this research is a supervised learning algorithm called extreme gradient boosting. This is a class of ensemble methods, used for classification and regression prediction problems. In our application, the ensembles are constructed from decision tree models. “Boosting”, involves adding models (e.g., trees) incrementally into an ensemble, and each model is trained to rectify prediction errors made by the preceding models (Green and White, 2023). Every time a tree is created within the method, the newest tree learns from previous trees’ mistakes and improves its accuracy. This is something that random forest and plain decision trees cannot do. The term “gradient” in gradient boosting refers to the technique of minimizing the

objective loss function such as least squares (Friedman, 2002). Since the goal is to find features (variables) that best predict the gender index, extreme gradient boosting provides feature importance scores (F-scores) to help identify the most relevant features.

The gradient boosting algorithm has its potential weaknesses and strengths. This machine learning method is slower in training because it has many hyperparameters to fine tune, which can take a lot of time. We addressed this issue by conducting a random search for hyperparameter tuning as suggested by Bergstra and Bengio (2012). Also, this method has a potential to overfit the sample so properly training the sample is important. Extreme gradient boosting is a regularized form of gradient boosting that helps prevent overfitting (Chen and Guestrin, 2016) by integrating L1 and L2 regularization to improve the generalization capacity of the model.[3] Furthermore, extreme gradient boosting can process correlated features since it is robust to multicollinearity (Guo et al., 2021). Extreme gradient boosting can accept many different data types at once since it is not sensitive to the scale of features and can accept sparse input data (Dhaliwal et al., 2018). Finally, many researchers prefer extreme gradient boosting, in part, due to its high prediction accuracy and ability to handle missing data (Aydin and Ozturk, 2021).

When a feature is selected to make a prediction, the machine assigns an F-score greater than 0. This represents the number of splits the gradient boosted tree made on the independent variable. More splits imply a more important variable in making a prediction. We estimate Shapley Additive Explanations (SHAP values) to provide a global interpretation of the expected prediction of a machine learning model. The SHAP value is the average marginal contribution of a feature value across all possible groups of variables or coalitions. The relative importance and their actual

[3] L1 regularization, also known as a Lasso regression, eliminates irrelevant features from the model by introducing sparsity to shrink some feature weights to zero (Li et al., 2022). L2 regularization, also known as a ridge regression, mitigates overfitting (Thakkar & Lohiya, 2021).

relationships with the predicted outcome determine the ordering of as presented in a bar plot. Bar plots provide measures of relative importance of each variable in predicting a variable of interest. To determine if the relationship between the variables are positive or negative we present dependence plots which are scatterplots of each SHAP value and their underlying raw value of the features. We conduct predictions using our women's empowerment measure and our measure of household efficiency across 172 independent variables.

IV. Results.

We summarize rural household characteristics from our study site. Then, we present results from a public goods experiment that reflect intra-household decision making capabilities between partners. Finally, we derive relationships with these measures and rural household characteristics.

4.1 Rural Household Characteristics from Study Site

Tables 1 and 2 summarize characteristics of rural households from our randomized controlled trial. We group the characteristics into four categories: time use of each spouse, labor allocation decisions in vegetable production, consumption and expenditure items, and children's health status. Time use allocation were gathered based on the previous day's recall of activities. We distinguish between weekday and weekend time use activities. Some activities had similar time use allocation between spouses such as sleeping, eating and personal time. However, there are defined roles for each spouse such as wives having significantly more time allocated to cooking, dependent care and domestic chores while the husband has significantly more time allocated to farming.

The typical vegetable farm in our sample is small with an average area of 2 hectares (ha). Approximately 54% of farmers own land, while 60% rent land. Additionally, 14% of farmers both own and rent land simultaneously. Given the relatively small size of vegetable farms, the average

number of household farm workers is 1 to 5 during the production process with the planting stage requiring the most workers. Spending on fertilizers and herbicides are important in input production and account for approximately 28% of total income.[4]

Aside from vegetable production, livestock raising is also a significant income source with 41% of farmers in our sample also raising chicken, 14% are involved in raising hogs, and another 14% are involved raising ducks. The most common assets in these households are cellphone, televisions, and watches. The most common expenditures are on food items. Rice and vegetables are common consumption items in the representative household. Approximately 21% of households have children aged 5 and below.

4.2 Intra-household Decision Making Characteristics

Figure 1 shows the individual token contributions of husband and wife when they are paired with strangers. The summary statistics for husband and wife are very similar where the mean, median and mode take the same value. The average token contribution to the pot is 4.7 with a median and mode of 5 out of 10 tokens. We compare these baseline estimates to the intra-household allocation decision measures from the public goods games.

There are two ways in which we elucidate the household decision-making process. First, we examine how couples behave when they are paired with each other to contribute to a common pot to measure household investment efficiency. Figure 2 shows the aggregate contribution to the pot when they know that the other contributor is their spouse. This is a measure of household efficiency where the most efficient investment strategy is to contribute everything, 10, to the pot so that the total contribution is 20. The average contribution is 10.5 with a median and mode of 10. Twenty nine percent of households have an average giving level summing to 10 out of 20

[4] The average expenditure on fertilizers is P16,570 while for herbicides it is P12,354. The average daily wage is P285.19 which is P104,094.35 per year.

tokens and 40% households are able to contribute more than the average. About 2% contribute the optimal amount leading to 20 out of 20 tokens. Our results are remarkably similar to that of Hoel et al. (2021) where they used a voluntary contribution game to measure household investment efficiency in Senegal. They find that 31% of spouse pairs contributed half of the efficient level (similar to 29% for our experiment) while 42% contributed more than the average (similar to the 40% that we found). Unlike our case where we found 2% of households achieving maximum efficiency, the study in Senegal did not find any household achieving the maximum efficient level.

Second, we conduct a game where spouses make a joint decision in contribution against a stranger to calculate our measure of woman's empowerment index. Figure 3 shows that the average investment in the pot based on a joint decision in the household is has a mean of 4.5 and a mode of 5. We estimate equations (3) and (4) to find that the husband has a significantly larger contribution to the pot compared to the wife by about half a token. When we compare contributions to the pot with strangers versus the spouse, we find that the contributions to the pot are significantly larger when the partner is known to be a stranger than their own spouse though the magnitude is only one-fifth of a token. Finally, when the spouses are paired with each other in the game, we find that the husband has a significantly larger contribution to the pot than the wife but it is a small magnitude which is only one-tenth of a token.

We use equation 2 along with results from Figure 1 and Figure 3 to calculate the woman's empowerment index which we show in Figure 4. Out of the 600 households, there are 224 households with an undefined empowerment index which leaves us with 376 observations. An index of 0.5 implies that the joint decision is equally close to each individual decision which implies that each spouse has equal power in bargaining. A value of 1 or greater implies full bargaining power for the wife while a value of 0 or less implies full bargaining power of the

husband.[5] From our sample, there are 25 out of 376 households where the woman's empowerment index is 0.5 which is approximately 7% of our sample. Approximately 43% of households have the husband with full bargaining power while 40% have the wife with full bargaining power. Overall, we have a well distributed sample where almost half the households have husbands controlling more of the bargaining power, while the other half are controlled by the wives. The results are remarkably similar to Wiig (2012) in Peru where 42% followed the husband's bargaining power and 39% was close to the wife's bargaining preference.

4.3 Intra-household Decision Making Characteristics and Household Choices

We estimate relationships between our measures of intra-household decision making and different types of decision making within the household: labor allocation in vegetable production, consumption and expenditure choices, children's health characteristics and time use allocation. Note that in all our analysis with women's empowerment, we incorporate imputed values as discussed in our methodology.

We start by presenting the SHAP values where household efficiency is the dependent variable in Figure 5. Out of the 163 variables, 132 were selected as relevant variables that predicted household efficiency in investment using the extreme gradient boosting algorithm. In the top 25 variables, most were time use variables and labor in agricultural production. There were also a few measures of household asset and consumption indicators. There was only one significant variable within the top 25 that incorporated children's wellbeing, which is the average z-score height of children 5 years and younger.

We also present SHAP values when women's empowerment is our dependent variable and summarize the results in Figure 6. Majority of the top 25 relevant variables predicting women's

[5] We censor the index such that any number greater than 1 is for the wife while any number greater than zero is full bargaining for the husband in order to make the results comparable with Wiig (2012).

empowerment are time use activities. There are two consistent expenditure and consumption measures that are the top two predictors which are the amount of spending on herbicides and fertilizer, two important inputs in production. There are a few measures of household assets and two measures of labor in production. Interestingly, household efficiency is also significant indicator for women's empowerment in the household.

The summary SHAP values only indicate that a particular variable significantly influences our measure of intra-household decision making but it does not indicate the direction in which that variable affects household efficiency or our women's empowerment measures. We identify the relationship of select variables using dependence plots starting with our time use allocation variables followed by labor allocations, child health outcomes and finally expenditure and consumption indicators.

4.3.1 Intra-household Decision Making and Time Use Allocation

We examine how select time use variables are related with household efficiency. The relationship between the SHAP values across different values of the variable of interest determine the relationship of such variables on household efficiency as shown in Figures 7-9. We contrast the relationship between household efficiency and husband and wife activities related to leisure activities in Figure 7. We find a negative relationship between social activities of the husband and household efficiency after approximately 2 hours. In contrast, we find a positive relationship between household efficiency and wife's social activity after 4 hours. The relationship between leisure time and household efficiency for wife peaks at around 3 hours. The household efficiency decreases slightly in leisure then decreases quickly after approximately 3.5 hours for husbands. This implies that for households that efficiently invest their income, we expect to have fewer hours

devoted by the husband to social activities and leisure while wives engage in more social activities and a maximum of 3 hours of leisure.

We examine three basic necessary daily activities that contribute to household efficiency in Figure 8. Personal time for both spouses have a negative relationship. The only significant difference is the change in slope for personal time. The change in household efficiency is much more sensitive to wife's personal time than the husband's. Wife's sleeping time is positive with respect to household efficiency but the household efficiency is higher at the tail ends of husband's sleeping time. We also find that household efficiency is high when eating time is low for the wife and at the tail ends for the husband.

There are some household work-related activities that are significantly related to household efficiency that we highlight in Figure 9. Husband cooking hours is negatively related with household efficiency while an inverted U relationship exists with wife's cooking hours which implies a peak cooking hour level to maximize household efficiency at approximately 1.5 hours. Wife's dependent care is negatively related with household efficiency along with wife's chore time less than 2 hours. Finally, we find an increasing relationship between husband's farming hours and household efficiency peaking at approximately 9 hours before declining. For wives, farming hours peak at approximately 4 hours before declining. Any more than these hours will have a negative effect on household efficiency.

Based on these relationships, we find that households that are most efficient in investing have husbands and wives that work more in the farm (maximum at 9 hours and 4 hours, respectively), husbands allocate fewer time for leisure activities, personal time, and cooking. The household efficiency is higher at the tail ends of husband's eating time. These efficient households

have wives that allocate more time to social activities and sleeping, devote lower time for eating, personal time, chores and dependent care but optimally allocate time for cooking and leisure.

We present dependence plots that relate women's empowerment to select time use variables in Figures 10 to 12. We compare the relationship between our women's empowerment index and husband and wife activities related to leisure activities in Figure 10. There is a negative relationship between the woman's empowerment index and leisure time for both spouses. The relationship between social activities and women's empowerment is the opposite between husbands and wives. Households with higher women's empowerment scores are related with wives engaging in less social activities while husbands engaging in more social activity time.

We show the relationship between select necessary daily time use variables and our measure of women's empowerment in Figure 11. Women's empowerment index and wife's sleeping hours do not show wife's sleeping hours do not show any relationship but there is a positive relationship with husband's sleeping time. Women's empowerment and personal time show positive relationship where the slope is steeper for the wife than the husband. The relationship between women's empowerment and eating hours for the wife has an inverted U shape exists with a peak at around 2 hours. Conversely, for the husband, relationship between women's empowerment and eating hours is generally negative, with small increase around the mean of 2 hours before declining again.

Finally, we relate women's empowerment and work-related household activities in Figure 12. We find that there is a positive relationship between cooking hours and women's empowerment for both husband and wife but it is much steeper for the former. Women's empowerment and dependent care have a positive relationship, but it is decreasing in domestic chores for most

observations. We also find that women's empowerment is slightly decreasing in wife's farming hours but the relationship is increasing in husband's farming hours.

Based on these relationships, we find that households that are most likely to have women as primary decision makers have husbands that allocate fewer leisure activities and eating time but engage in more farming, cooking time, personal time and social activities. These wife-dominated households also have wives that allocate less time to leisure activities and social activities but more time for dependent care, personal and cooking time.

4.3.2. Intra-household Decision Making and Labor Allocation

There are 11 stages in crop production from land preparation until marketing in the dataset and in each stage there are four questions related to labor use – all labor use, male household labor use, female household labor use and hired labor use. We highlight six labor use values related with women's empowerment in Figure 13. In general, more household labor is related with a lower measure of women's empowerment in the household with the exemption of land preparation where an optimal number of male labor is needed to achieve the highest women's power index. This negative relationship holds for planting and harvesting.

We also show select labor use relationships with household efficiency in Figure 14. Overall female labor production is decreasing with household efficiency. In contrast, male household labor during most stages of production is positively related with household efficiency. There are some stages of production where hiring a few workers, instead of using male labor, is positively related with household efficiency such as weeding.

4.3.3 Intra-household Decision Making and Child Health Outcomes

We calculate two measures of children's health under 5 years old: z-score for height and z-score for weight. These z-scores compare the height and weight of children of the same age and sex to classify nutritional status. We also break this measure down by sex.

We find only two relevant measures of children's health outcome as relevant variables related with household efficiency and women's empowerment – the average z-score height and weight for all children. We show the dependence plots for both variables in Figure 15. Household efficiency is positive related with the z-score of children's height but not weight. Similarly, the dependence plot with the SHAP values from women's empowerment with respect to the children's height is positively related but there is no relationship with weight. Health status by sex of the children is not a contributing factor to household efficiency or women's empowerment.

4.3.4 Intra-household Decision Making and Expenditure Activity and Assets

We examine how expenditures and assets are related with household efficiency and our measure of women's empowerment. First, we examine the relationship between household efficiency and select expenditure items in Figure 16. The two most significant expenditure contributors to household efficiency are expenditures on herbicides and pesticides. An optimal amount of herbicides and pesticides are needed in production where too few does significantly increase production and too much does not significantly increase production any further. In general, normal goods such as vegetables and oil are increasing in household efficiency but inferior goods such as rootcrops and fish are decreasing in household efficiency.

Next, we examine household efficiency with assets of the household in Figure 17. In general, we find that normal assets (i.e. assets that increase with income) are positively related with household efficiency such as chickens but they are negatively related with inferior assets such as owning an animal-drawn cart, water buffaloes and horses (in lieu of tractors) and landline

telephones (in lieu of cellphones). Rented agricultural land is negatively related with household efficiency most likely due to owned land as a preference over renting.

We examine the relationship between the women's empowerment measure and spending on herbicides and fertilizers, the top two variables influencing women's empowerment in Figure 18. Similar to the relationship with household efficiency, there is an optimal peak for fertilizer and pesticide use which also leads to an inverse U relationship. Beyond the peak, additional spending on these items rapidly declines women's empowerment.

We summarize the relationship between household assets and women's empowerment in Figure 19. For some assets, such as chickens and telephone landlines, there is an inverse relationship with women's empowerment. However, important assets such as rented agricultural land has an optimal amount (approximately between 1.5 ha and 2 ha). We also find a generally increasing relationship with household efficiency and women's empowerment after a particular point. In this case, very efficient households have women-dominated household.

V. Conclusion

The purpose of this article is to derive a measure of household efficiency and women's empowerment and to determine relationships of these measures to general rural household characteristics. Deriving such relationships will help us characterize different households according to their ability to efficiently use their budget and the weight of women in financial decision making. We use a series of public good games to derive our measures of household efficiency and women's empowerment. We match this data from a survey using a randomized controlled trial using a machine learning with extreme gradient boosting.

We find that the average household efficiency and most common level of efficiency is approximately 50% relative to the most efficient contribution level. The distribution is normal and

is found to be remarkably similar to that of Hoel et al. (2021) in Senegal. We also find that approximately 43% of households have the husband with full bargaining power while 40% have the wife with full bargaining power. The remaining percentage of households have equal bargaining status. The results are remarkably similar to that of Wiig (2012) in terms of household distribution.

Using our machine learning algorithm, we find that households most efficient in investing have husbands that allocate fewer time for leisure activities, personal time, and cooking but devote an optimal time for farming while wives allocate more time to social activities, but allocate an optimal time for cooking, farming and leisure activities. Furthermore, in these households, fewer female household members work in crop production, more male members work in crop production and an optimal amount of money is spent on herbicides and fertilizers. Efficient households also have higher z-score of children's height.

Households that have the wives empowered in decision making have husbands that allocate fewer leisure activities and eating time but engage in more farming hours, cooking time and social activities. In wife-dominated households, wives allocate less time to domestic chores, leisure activities and social activities but more time for dependent care, cooking and personal time. Furthermore, fewer household labor is related with a higher measure of women's empowerment in the household during most stages in production. Important assets such as rented agricultural land has an optimal amount (approximately between 1.5 ha and 2 ha) with women's empowerment. Interestingly, more efficient households are likely to have higher women's empowerment indices.

Our results have potentially important policy implications. By correctly characterizing the relationship between the type of households that are efficient in investing and have women who dominate in decision making, regulators can target such households for policies that can potentially

help improve household welfare. Thus, policies such as cash transfers to the poor or microfinance lending can become more targeted to unobserved efficient households by examining households that embody observable characteristics correlated with household efficiency. Furthermore, understanding if the household is male vs female dominated in decision-making can help policy makers when targeting such households to incentivize the use of particular technologies or policies. For example, if one would try induce the use of organic vegetable technology, then advertising could differ if the wife made investment decisions as opposed to the husband.

There are some extensions of this study. First, our analysis illustrates relationships between variables but these are not causal effects. A future study could potentially determine a causal effect of household efficiency or women's empowerment on a household outcome such as children's health or asset accumulation. Second, our results are specific to the Philippines and cannot be extrapolated to other countries. Even though, we do find similar measures of household efficiency to that of Senegal and women's empowerment to that of Peru, it would be interesting for a future study to conduct similar games in other developing countries to see if the same pattern exists.

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Tables

Table 1. Time Use Allocation by Activity by Partner

Weekday	**Husband**				**Wife**			
Variable	Mean	SD	Min	Max	Mean	SD	Min	Max
Sleeping Minutes	560.39	110.07	135	915	562.89	139.49	60	975
Eating Minutes	101.51	45.49	15	300	109.21	56	0	600
Social Activity Minutes	50.34	120.76	0	825	61.13	120.76	0	780
Leisure Minutes	118.96	115.41	0	705	125.26	122.93	0	555
Personal Minutes	23.07	23.68	0	120	23.29	28.6	0	180
Cooking Minutes	20.89	34.89	0	225	72.82	58.3	0	420
Dependent Care Mins.	7.3	51.23	0	600	54.06	138.71	0	1005
Domestic Chore Mins.	6.66	25.07	0	240	142.21	153.43	0	960
Farming Minutes	463.55	211.94	0	840	144.79	220.92	0	780
Employed Work Mins.	24.92	115.13	0	870	33.9	130.1	0	930
Own Business Work Mins.	36.07	129.29	0	930	85.83	201.54	0	990
Grocery Shopping Mins.	1.59	17.96	0	300	5.57	31.17	0	480
Traveling Mins.	15.18	53.86	0	525	8.52	43.39	0	510
Exercise Mins.	1.04	8.15	0	105	0.95	9.47	0	120
Religious Activity Mins.	1	9.93	0	150	2.72	16.25	0	150
Other Activity Mins.	7.52	58.25	0	600	6.84	48.08	0	645
Weekend								
Sleeping Minutes	569.3	123.36	165	960	565.61	121.01	165	1020
Eating Minutes	99.43	37.15	0	345	106.88	46.7	0	495
Social Activity Minutes	43.89	117.08	0	750	64.16	125.41	0	750
Leisure Minutes	129.08	112.35	0	630	136.99	132.23	0	630
Personal Minutes	22.91	23.54	0	135	24.14	31.98	0	315
Cooking Minutes	12.77	28.12	0	180	71.07	54.69	0	405
Dependent Care Mins.	1.99	18.35	0	255	37.85	122.11	0	735
Domestic Chore Mins.	13.42	59.71	0	525	159.26	155.75	0	900
Farming Minutes	472.79	214.18	0	840	130.9	229.1	0	735
Employed Work Mins.	21.8	92.95	0	570	38.73	133.47	0	630
Own Business Work Mins.	26.02	113.57	0	840	83.85	197.92	0	945
Grocery Shopping Mins.	0.23	3.75	0	60	4.98	26.18	0	240
Traveling Mins.	14.94	38.63	0	240	5.45	23.6	0	180
Exercise Mins.	0.59	6.75	0	90	1.52	19.19	0	300
Religious Activity Mins.	0.06	0.94	0	15	1.29	9.21	0	90
Other Activity Mins.	10.78	77.57	0	690	7.32	51.96	0	570

Note: There are 331 viable Weekday responses related to time use allocation and 256 Weekend responses.

Table 2. Household decisions summary statistics

Variable	Mean	SD	Min	Max
Labor				
All labor used in land preparation	2.3	2.33	0	31
All labor used in planting	3.24	4.29	0	50
All labor used in fertilizing	2.14	1.95	0	18
Hired labor in weeding	1.21	2.53	0	20
All labor used in pruning	2.37	5.7	0	101
Household male labor in harvesting	1.11	0.73	0	5
Household female labor in harvesting	0.32	0.55	0	4
Household male labor in land preparation	0.94	0.69	0	4
Household female labor in land preparation	0.2	0.45	0	3
All female labor in production	1.78	3.2	0	27
All labor used in land preparation	2.3	2.33	0	31
All labor used in land preparation	2.3	2.33	0	31
All labor used in nursery preparation	1.19	1.4	0	10
Hired labor in land preparation	1.15	2.31	0	30
Household male labor in nursery preparation	0.76	0.7	0	4
Household female labor in nursery preparation	0.16	0.44	0	3
Hired labor in nursery preparation	0.27	1.02	0	10
Household male labor in planting	1	0.78	0	5
Household female labor in planting	0.29	0.55	0	3
Hired labor in planting	1.96	4.36	0	50
Household male labor in pruning	0.72	0.75	0	5
Household female labor in pruning	0.18	0.47	0	5
Hired labor in pruning	1.47	5.59	0	100
Household male labor in fertilizing	1.07	0.58	0	4
Household female labor in fertilizing	0.18	0.46	0	3
Hired labor in fertilizing	0.89	2	0	18
Household male labor in pesticide application	0.89	0.62	0	4
Household female labor in pesticide application	0.1	0.37	0	3
Hired labor in pesticide application	0.8	2.44	0	40
Household male labor in irrigation	0.14	0.4	0	4
Household female labor in irrigation	0.02	0.15	0	2
Hired labor in irrigation	0.11	0.76	0	10
Household male labor in weeding	0.92	0.68	0	5
Household female labor in weeding	0.17	0.45	0	4
Hired labor in harvesting	2.33	4.34	0	40
Household male labor in transportation of goods	0.27	0.59	0	4
Household female labor in transportation of goods	0.09	0.33	0	3

Hired labor in transportation of goods	0.44	1.36	0	20
Household male labor in marketing	0.13	0.41	0	4
Household female labor in marketing	0.08	0.32	0	3
Hired labor in marketing	0.04	0.48	0	8
Children				
Height (all)	84.31	20.58	0	118
Weight (all)	13.4	7.61	0	72
Height (boys)	82.56	22.9	0	114
Weight (boys)	13.42	9.06	0	72
Height (girls)	86.17	17.78	37	118
Weight (girls)	13.37	5.73	5	39
Expenditures				
Herbicides	12360.41	24368.47	-99	250000
Fertilizers	18385.65	41650.59	-99	810000
Household consumed vegetables	0.88	0.32	0	1
Household consumed oil	0.51	0.5	0	1
Household consumed rootcrops	0.42	0.49	0	1
Household consumed fish	0.6	0.49	0	1
Household consumed milk byproducts	0.32	0.47	0	1
Household consumed rice or grains	0.97	0.16	0	1
Household consumed fruits	0.68	0.47	0	1
Household consumed organ meat	0.76	0.43	0	1
Household consumed eggs and dairy products	0.61	0.49	0	1
Household consumed beans	0.2	0.4	0	1
Household consumed sugar	0.64	0.48	0	1
Household consumed condiments	0.91	0.28	0	1
Assets				
Household efficiency measure	10.52	3.37	0	20
Main income source is agriculture	0.9	0.3	0	1
Main income source is livestock	0.01	0.1	0	1
Main income source is other	0.05	0.22	0	1
Main income source is remittances	0	0.04	0	1
Main income source is wages	0.04	0.19	0	1
Household has a landline telephone	0.2	0.4	0	1
Household has chickens	0.41	0.49	0	1
Household has a bike	0.21	0.4	0	1
Household has a water buffalo	0.13	0.33	0	1
Household has a horse	0.28	0.45	0	1
Amount of agricultural land owned (Ha)	0.95	1.76	0	15
Amount of agricultural land rented (Ha)	1.15	1.85	0	20

Household has electricity	1	0	1	1
Household has a radio	0.68	0.47	0	1
Household has a television	0.89	0.32	0	1
Household has a computer	0.2	0.4	0	1
Household has a refrigerator	0.72	0.45	0	1
Household has a watch	0.74	0.44	0	1
Household has cellphone	0.96	0.21	0	1
Household has a motorcycle	0.61	0.49	0	1
Household has an animal-drawn cart	0.15	0.35	0	1
Household has a car	0.07	0.26	0	1
Household has a boat	0	0.04	0	1
Household has a tricycle	0.03	0.18	0	1
Household has cattle	0.08	0.27	0	1
Household has goats	0.03	0.18	0	1
Household has chickens	0.03	0.18	0	1
Household has ducks	0.14	0.35	0	1
Household has hogs	0.14	0.35	0	1
Floor material is ceramic tiles	0.26	0.44	0	1
Floor material is bamboo	0.01	0.07	0	1
Floor material is carpet	0.01	0.07	0	1
Floor material is cement	0.46	0.5	0	1
Floor material is soil	0.09	0.29	0	1
Floor material is vinyl	0.16	0.37	0	1
Floor material is wood plank	0.02	0.14	0	1
Roof material is galvanized iron sheets	0.86	0.35	0	1
Roof material is cement	0.06	0.23	0	1
Roof material is finished wood	0.02	0.14	0	1
Roof material is palm leaf	0.02	0.12	0	1
Roof material is shingles	0.04	0.19	0	1
Roof material is tarpaulin	0.01	0.07	0	1
Roof material is wood plank	0.01	0.08	0	1
Main water source is bottled water	0.25	0.44	0	1
Main water source is piped water into dwelling	0.18	0.39	0	1
Main water source is piped water to yard	0.05	0.22	0	1
Main water source is public tap	0.15	0.36	0	1
Main water source is surface water	0	0.04	0	1
Main water source is tube well	0.03	0.18	0	1
Main water source is spring water	0.33	0.47	0	1
Household heads that can read	0.95	0.21	0	1
Household heads that know English	0.09	0.29	0	1

Figures

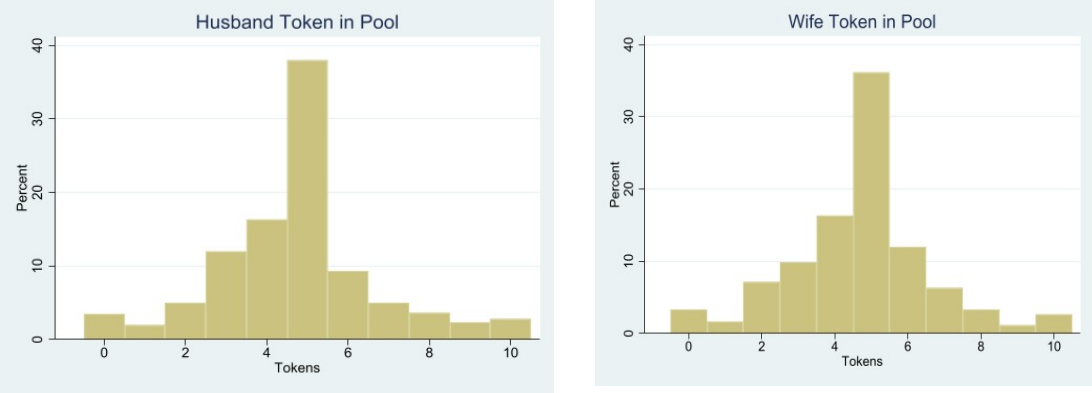

Figure 1. Contribution tokens to the common pot at the individual level

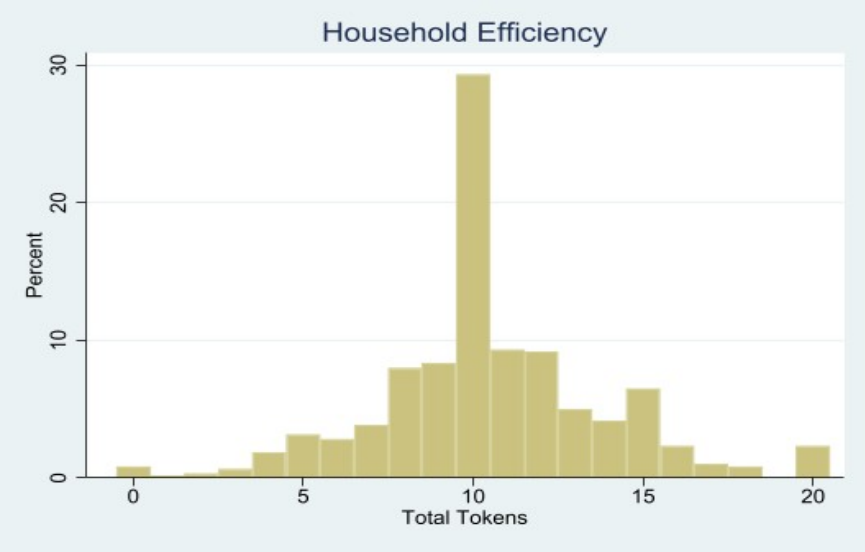

Figure 2. Aggregate contribution to the pot when spouses know they are paired with each other.

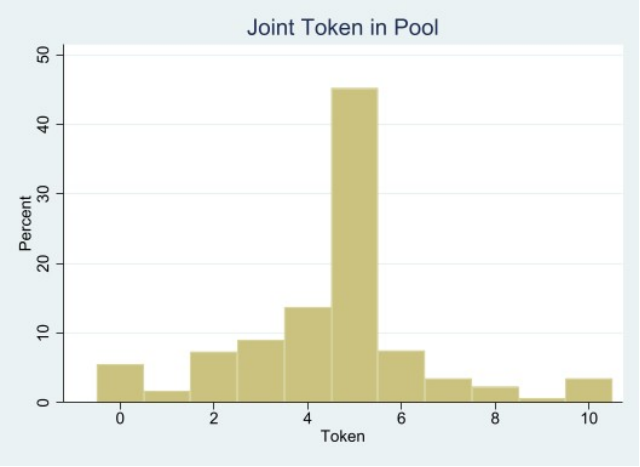

Figure 3. Contribution tokens to the common pot based on a joint household decision

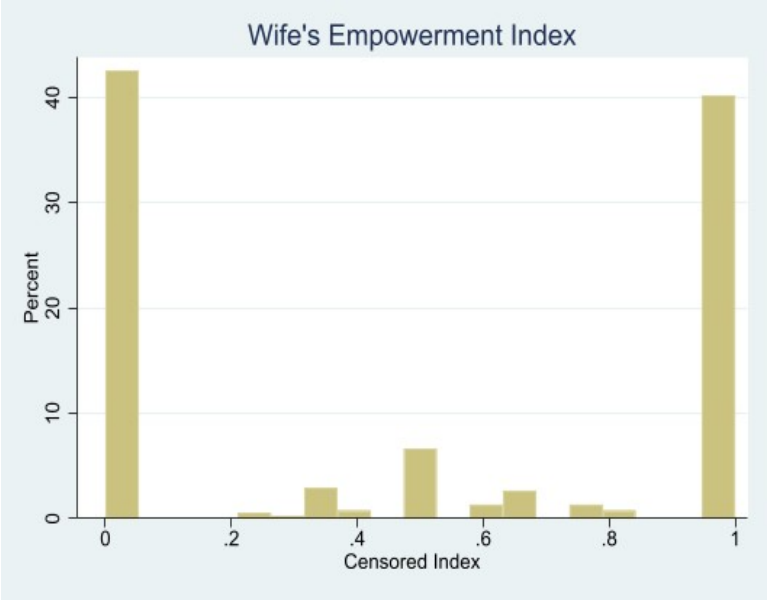

Figure 4. Wife's Empowerment Index

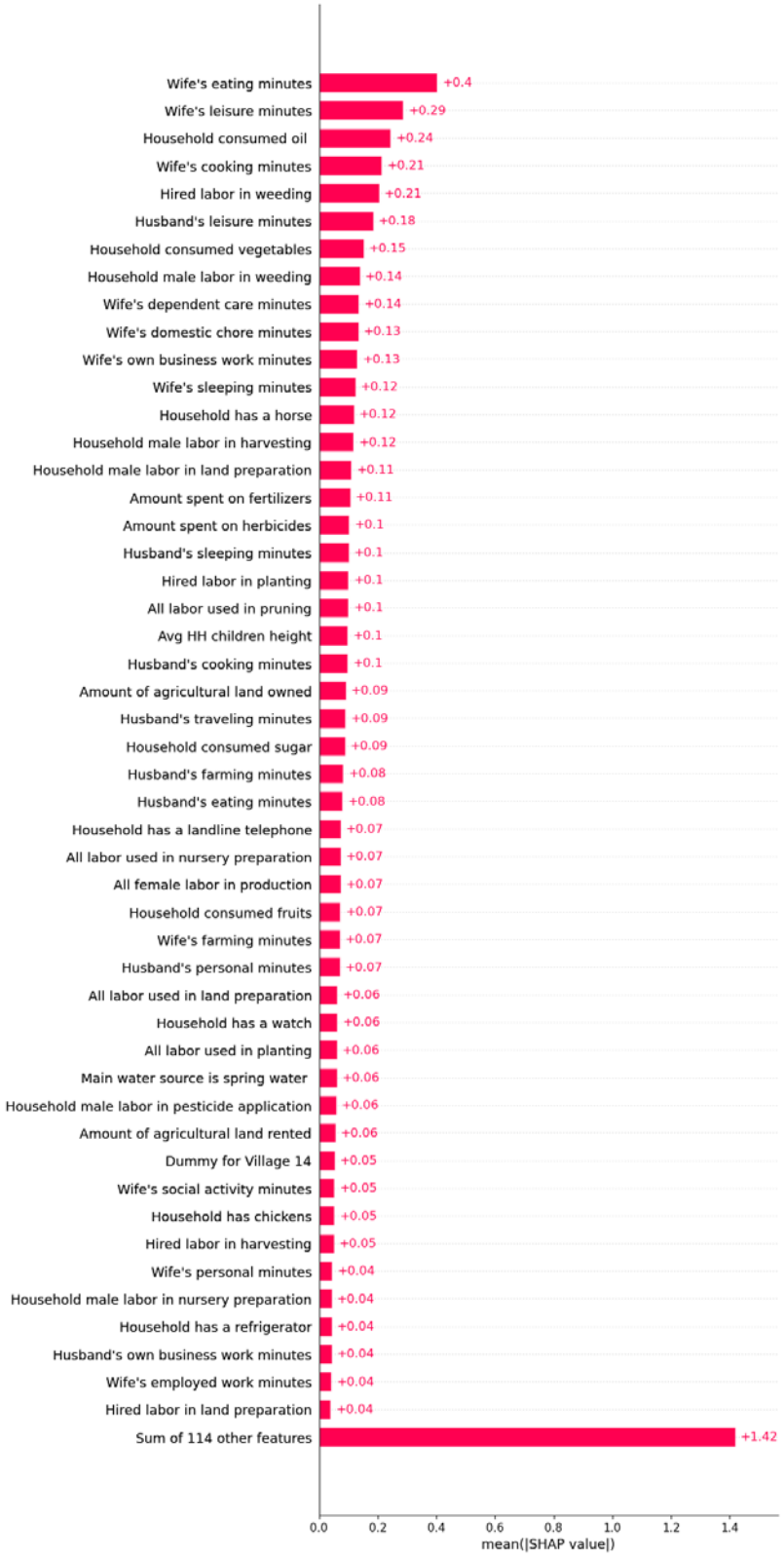

Figure 5. Mean SHAP Values that Predict Household Efficiency

Figure 6. Mean SHAP Values that Predict Women's Empowerment Index

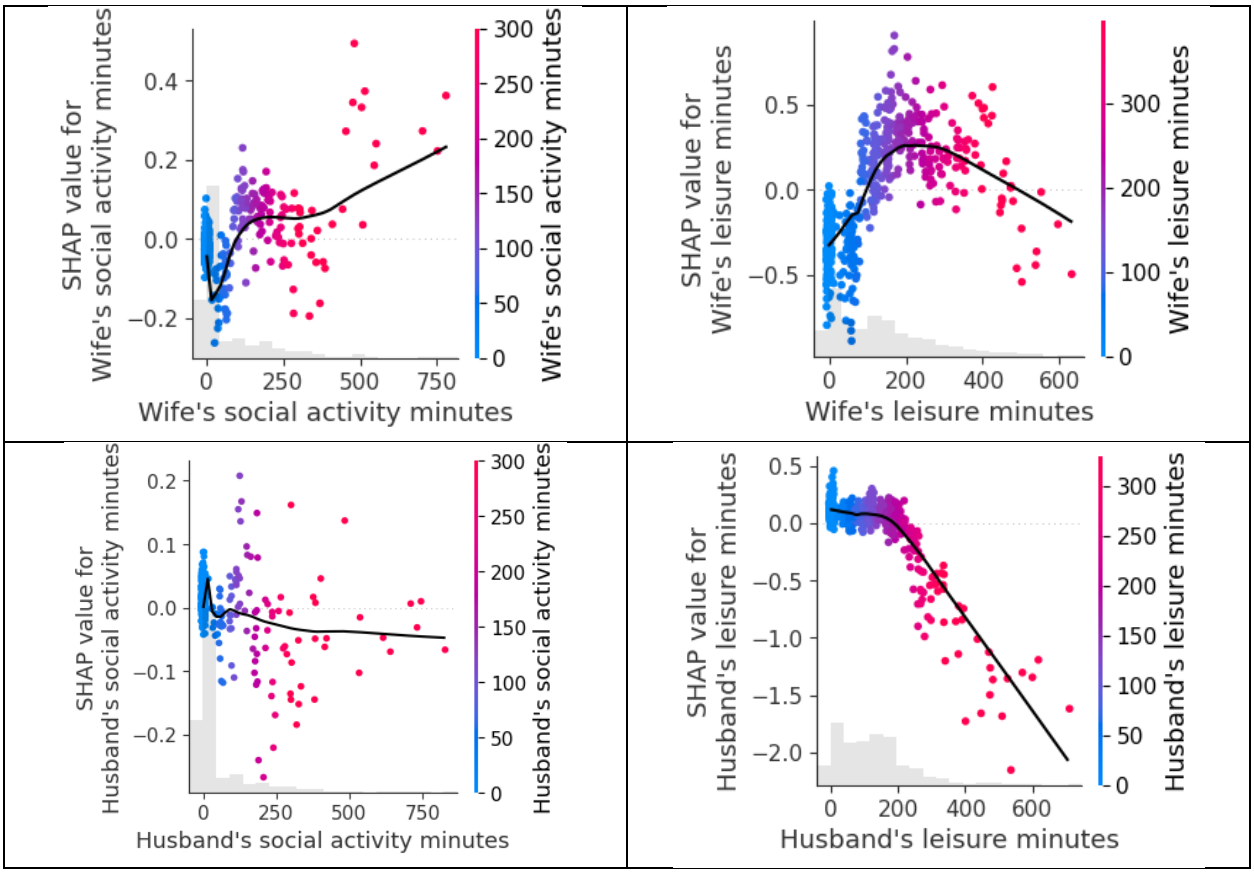

Figure 7. Relating Household Efficiency and Selected Leisure Time Use Variables

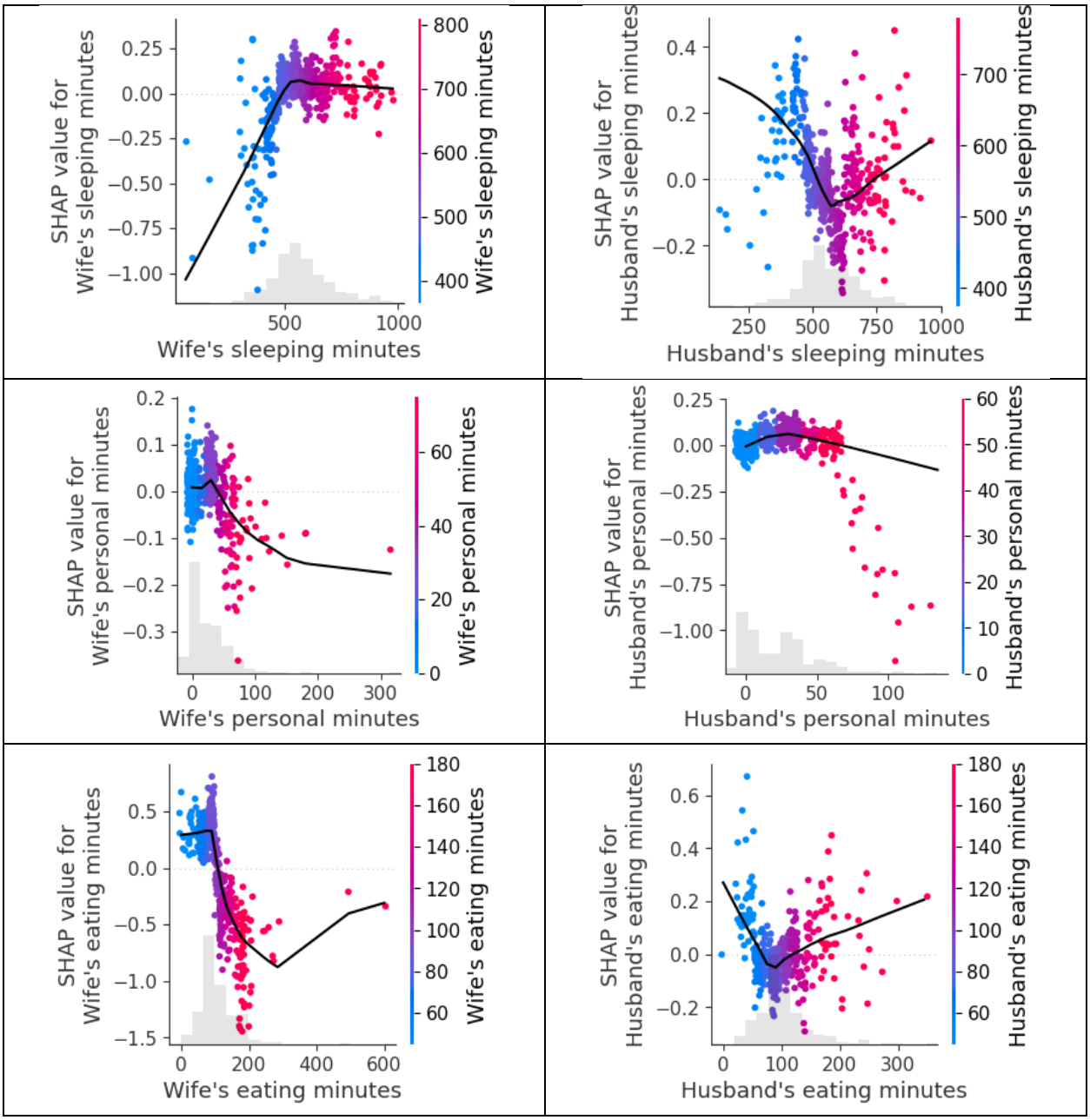

Figure 8. Relating Household Efficiency and Selected Necessary Daily Time Use Variables

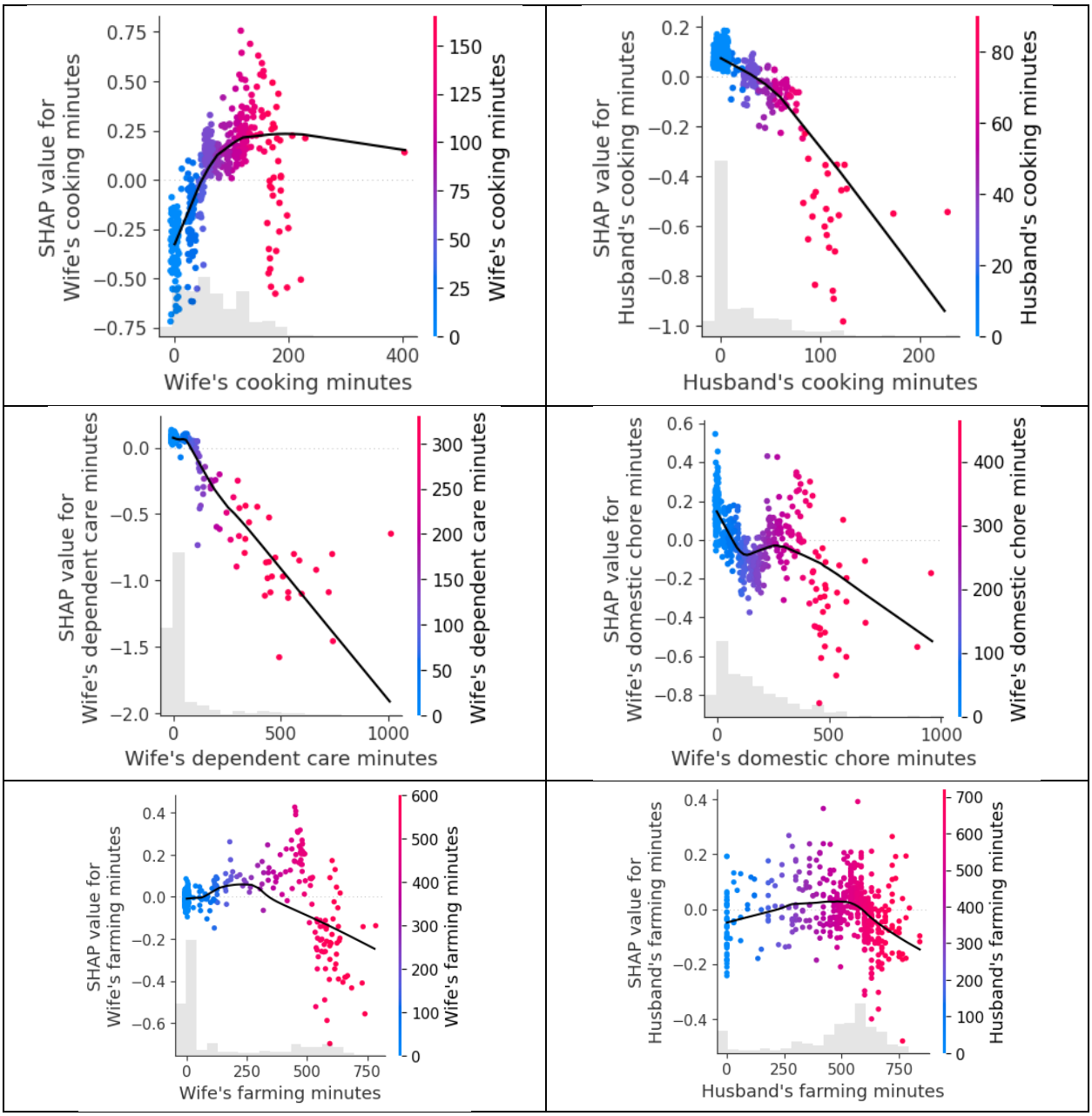

Figure 9. Relating Household Efficiency and Selected Work-Related Time Use Variables

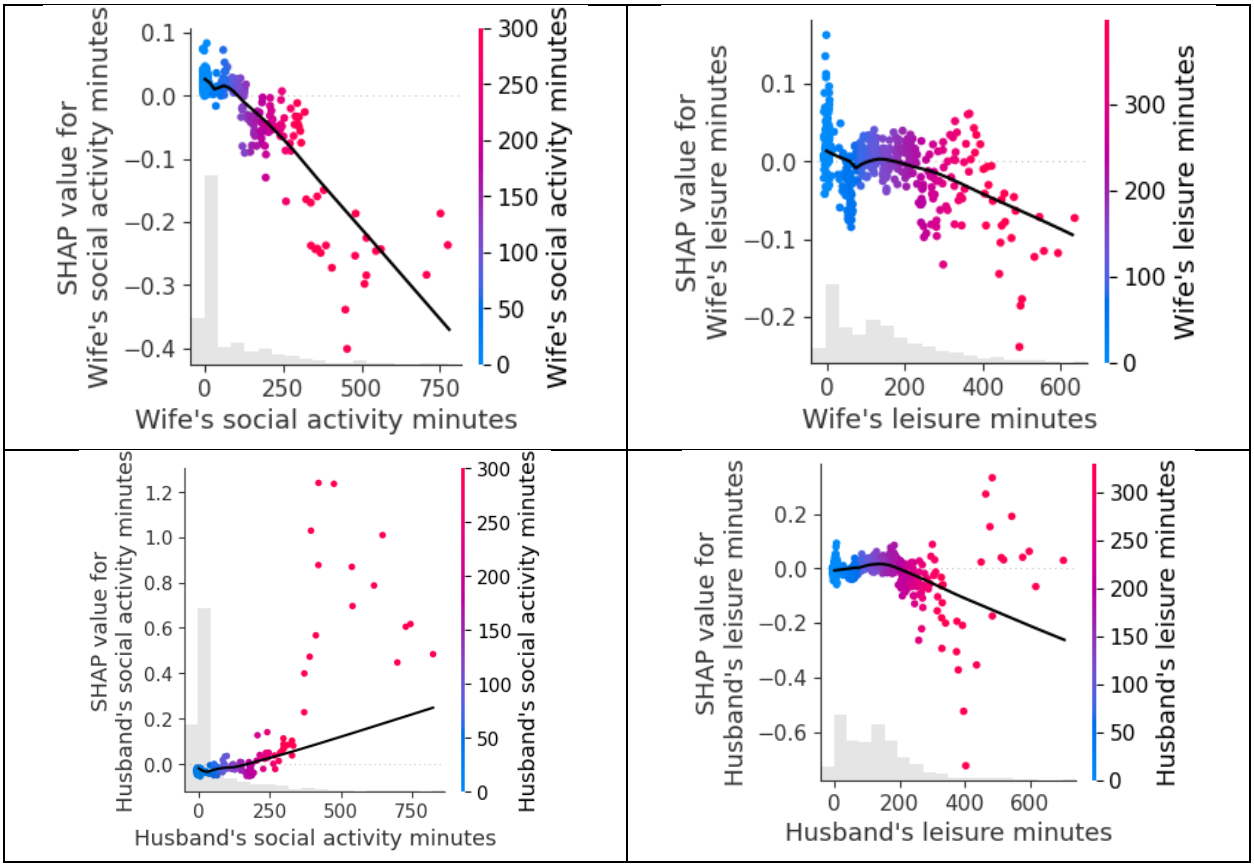

Figure 10. Relating Women's Empowerment Measure and Selected Leisure Time Use Variables

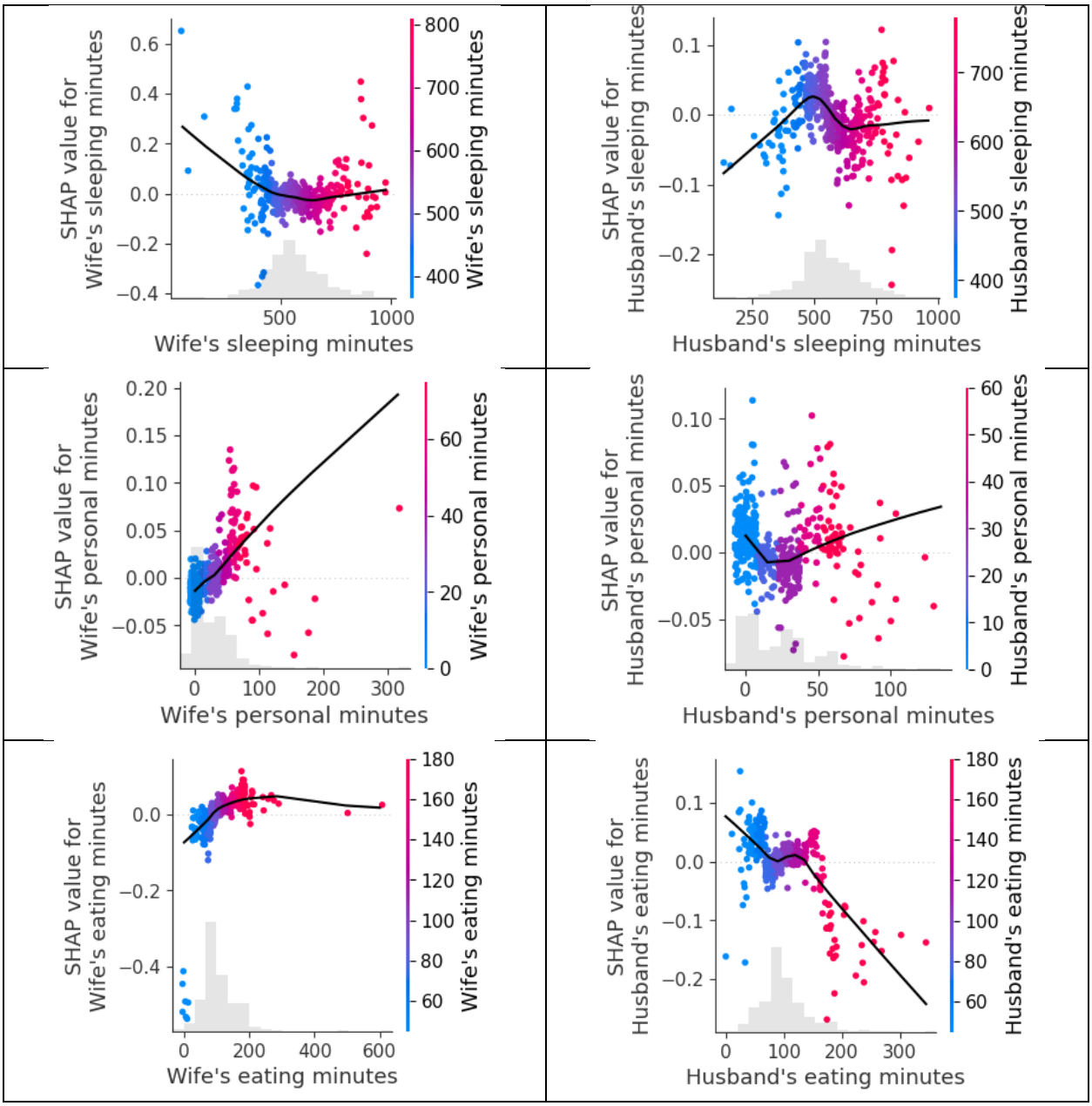

Figure 11. Relating Women's Empowerment Measure and Selected Necessary Daily Time Use Variables

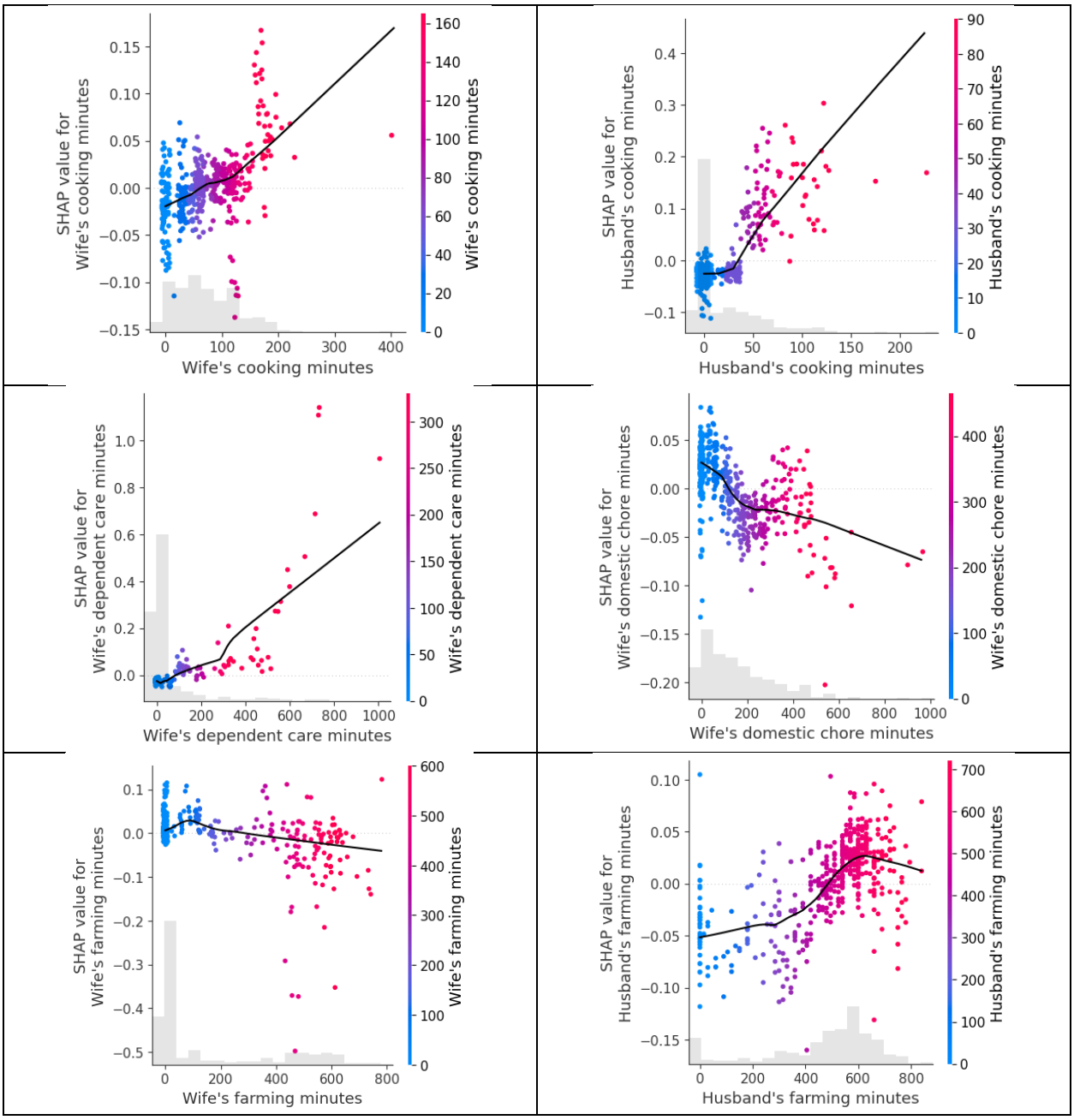

Figure 12. Relating Women's Empowerment Measure and Selected Work-Related Time Use Variables

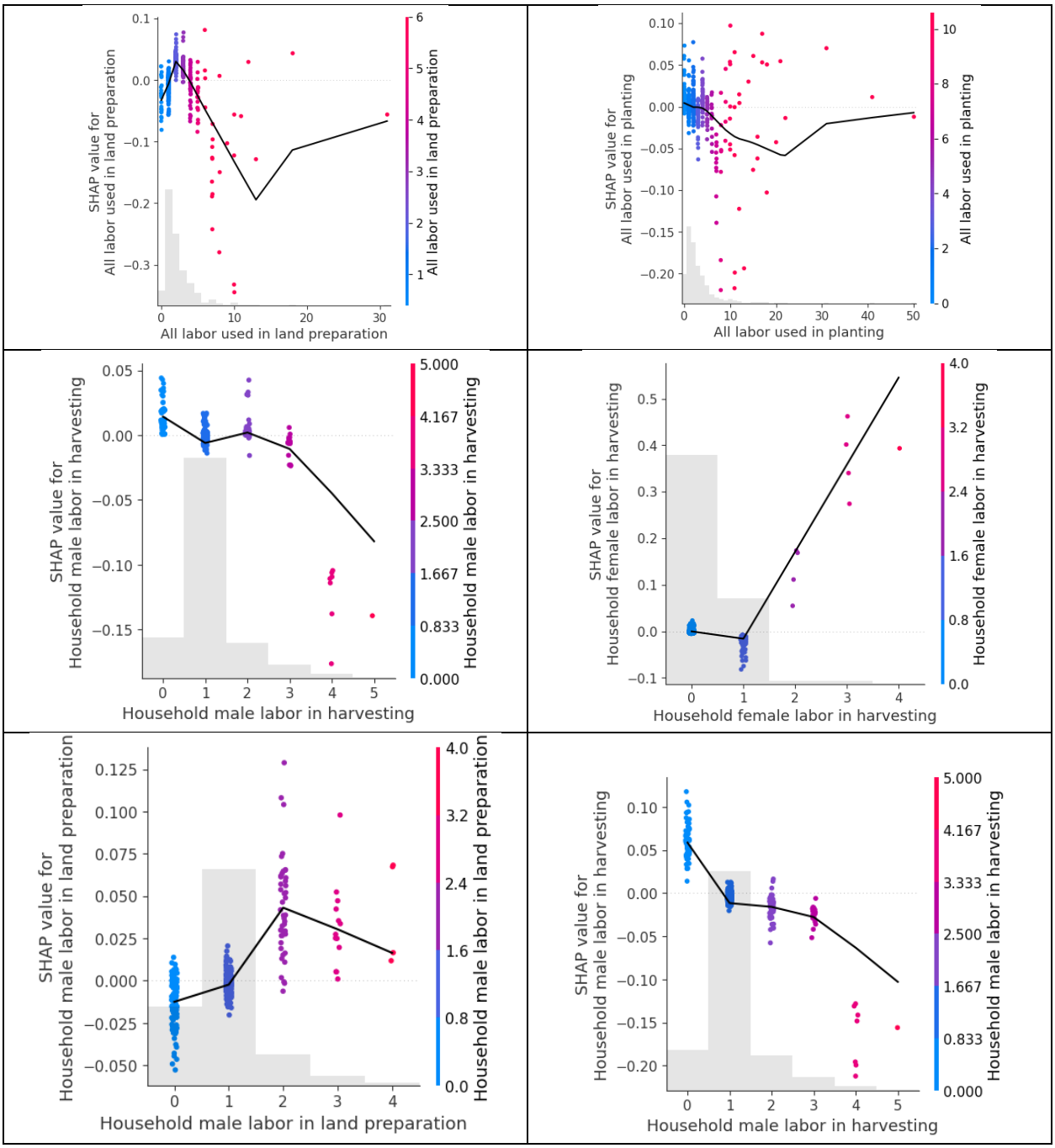

Figure 13. Relating Women's Empowerment Measure and Selected Labor Use Variables

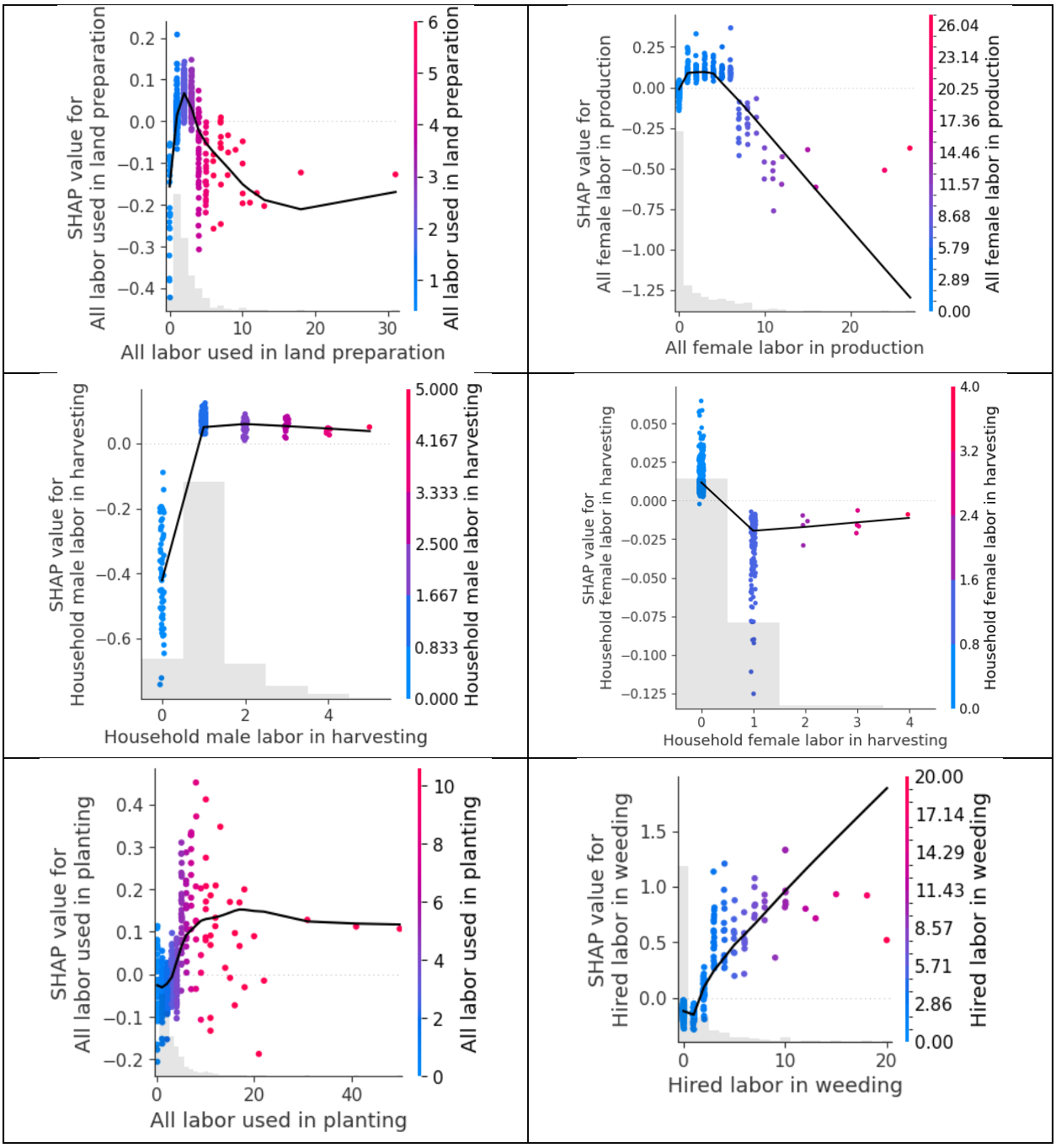

Figure 14. Relating Household Efficiency and Selected Labor Use Variables

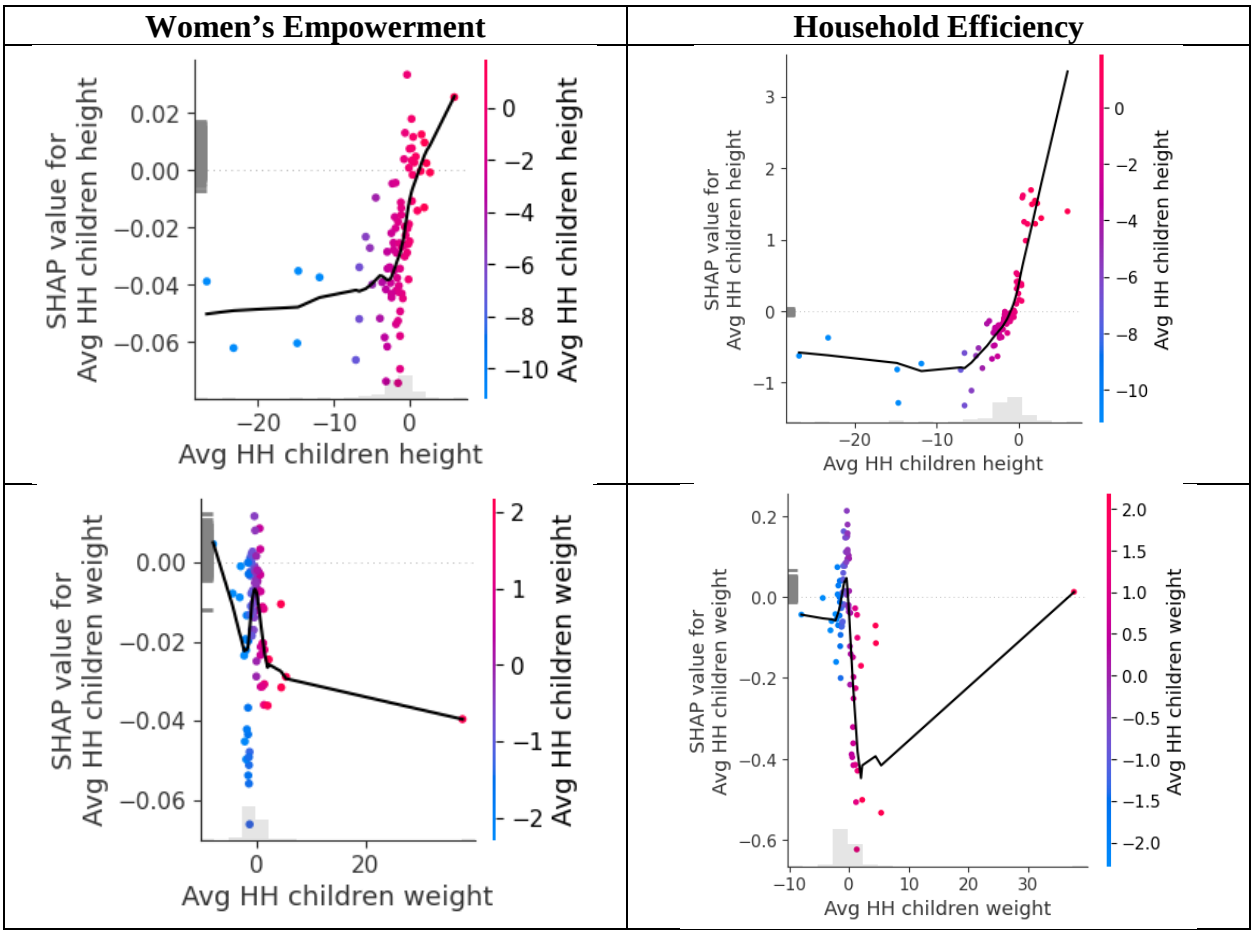

Figure 15. Relating Women's Empowerment and Household Efficiency to Children's Health Outcomes

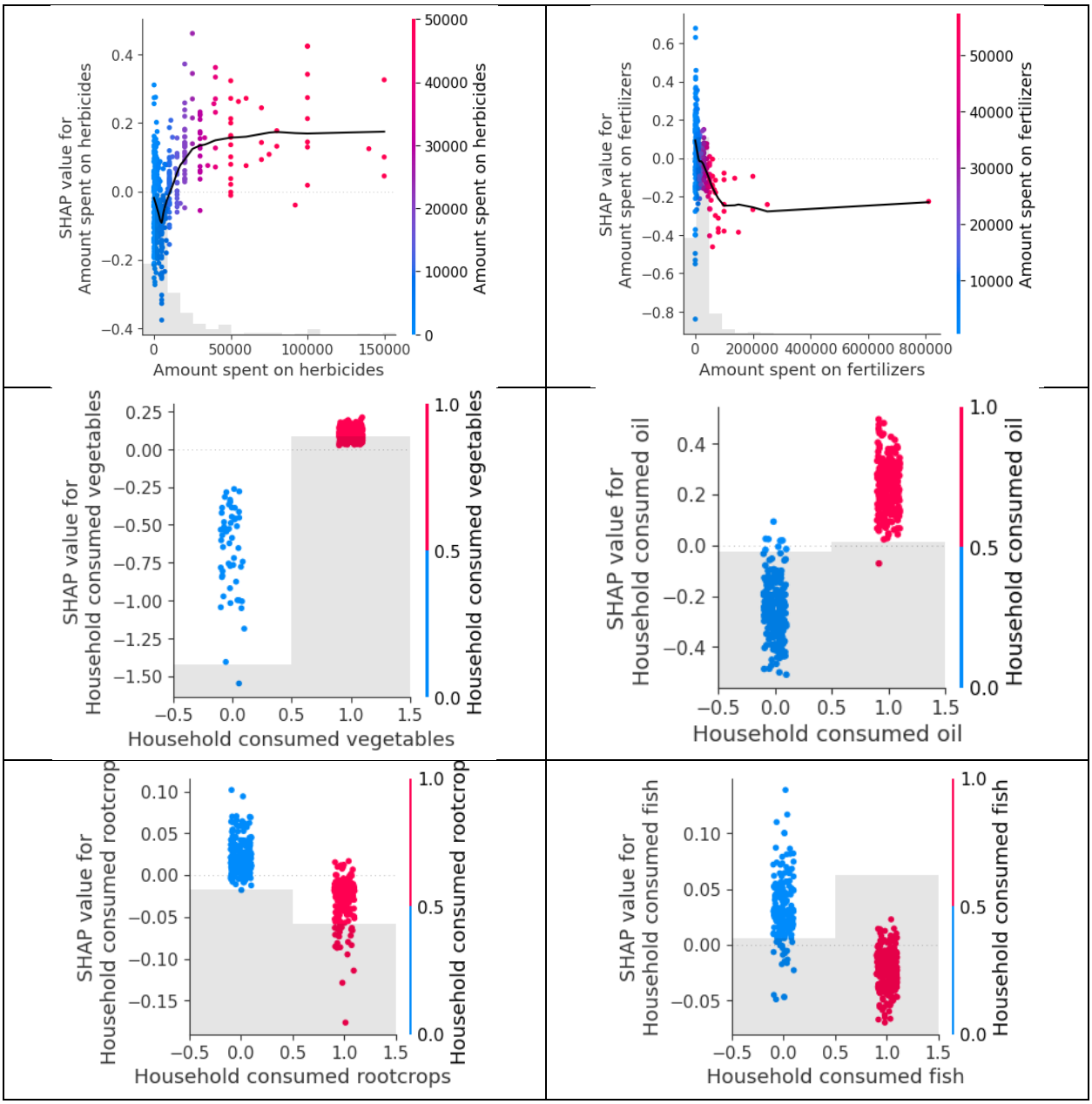

Figure 16. Relating Household Efficiency and Selected Expenditure Variables

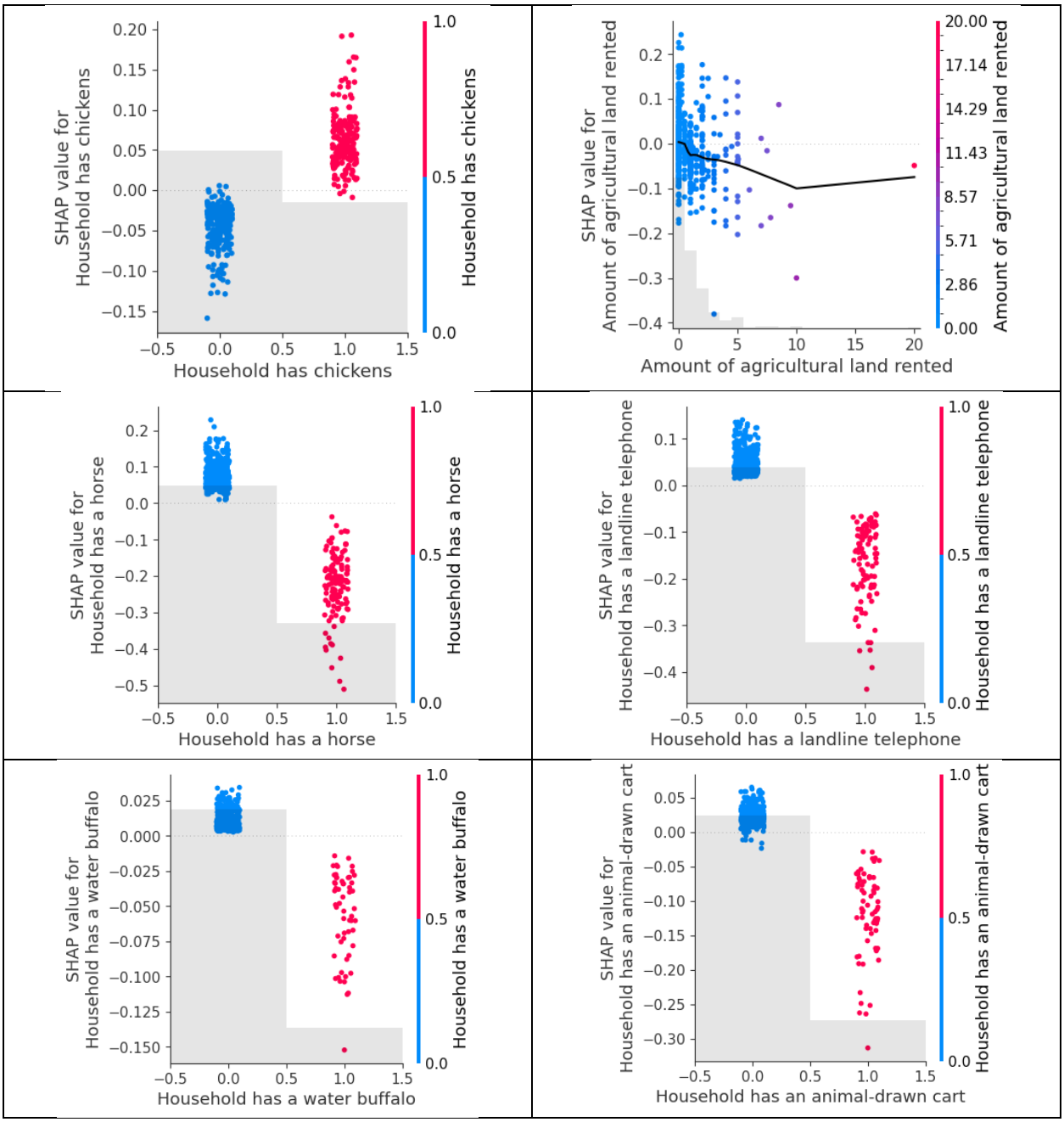

Figure 17. Relating Household Efficiency and Selected Household Assets

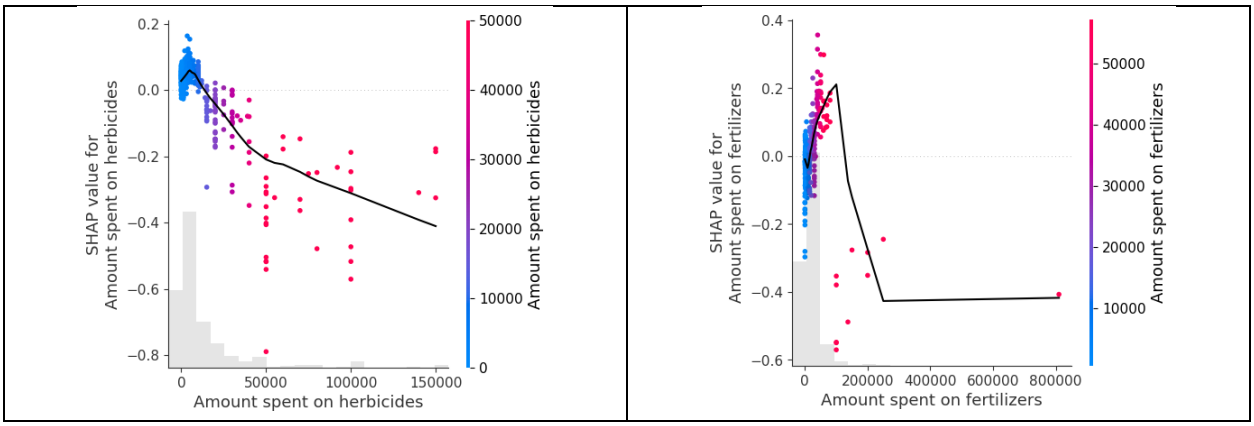

Figure 18. Relating Women's Empowerment and Selected Expenditure Variables

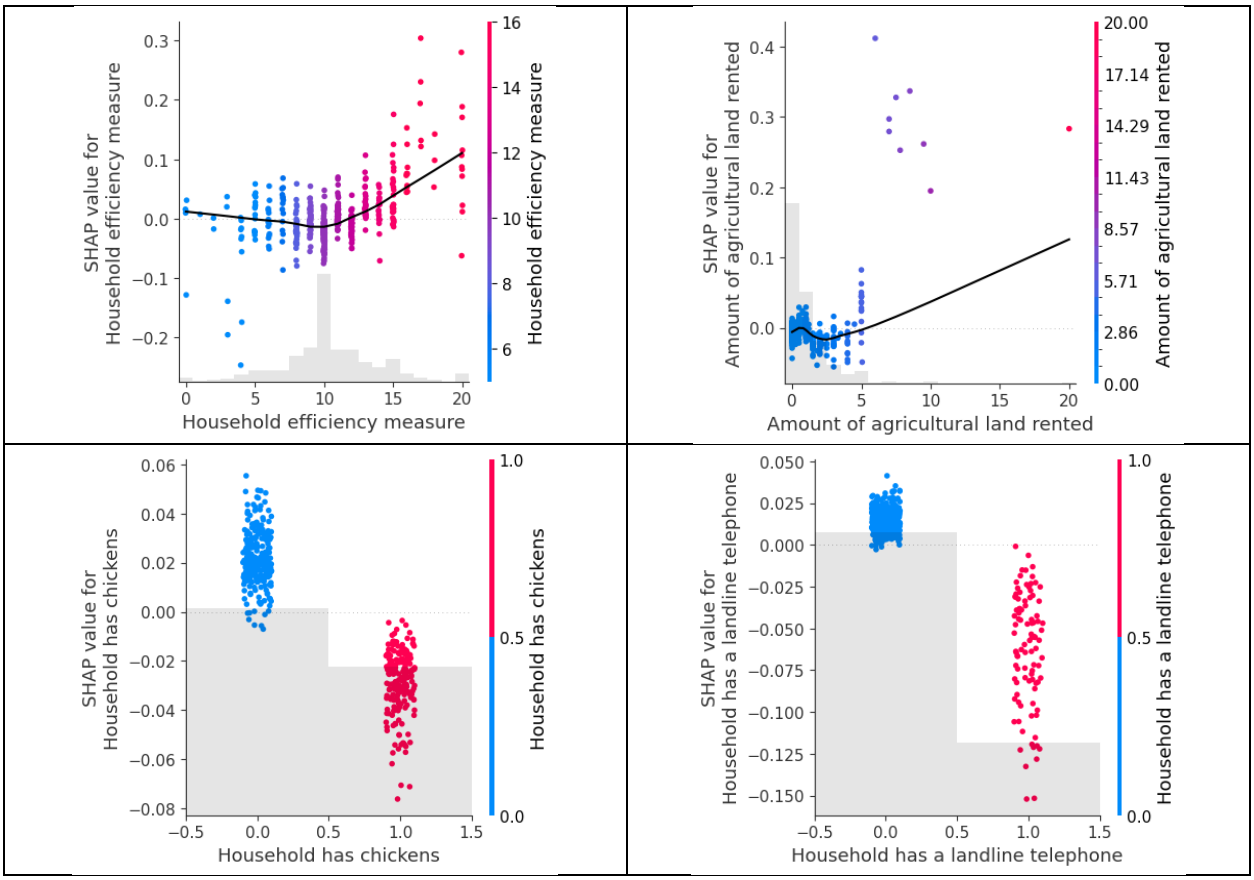

Figure 19. Relating Women's Empowerment and Selected Household Assets