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Determinants of Adoption and Spatial Diversity of Wheat Varieties on Household Farms in Turkey

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International Maize and Wheat Improvement Center

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Executive summery

The Heckman two-stage estimation procedure was used to investigate factors influencing the adoption of modern and/or landrace wheat varieties and spatial diversity of wheat varieties in Turkey. In the first stage, the multinomial logit choice model (MNLM) was used to determine factors influencing farmers' adoption of modern varieties (MVs) and/or landrace varieties (LVs) of wheat. Conditional on the choice of a given wheat variety or combination of MVs and LVs, a Tobit regression model was used to assess the determinants of on-farm spatial diversity of wheat varieties in the second stage. Our empirical approach allows for the analysis of partial adoption decision of wheat varieties and controls for self-selection problem in analyzing the determinants of spatial diversity of wheat varieties. The empirical model was conceptualized based on random utility model (RUM).The analysis was based on cross-sectional survey data collected on 486 sample households in six provinces of Turkey.

Results showed that household size, the number of owned cattle, the number of buildings on farm, farm size, farm land fragmentation, the percentage of irrigable farm plots and regional variations are the important factors in determining the farmers' first-stage choice of wheat variety types. The self-selection problem was significant only in one of the three cases for the landrace wheat varieties. In the second-stage, the farm size and land fragmentation were found to be the key variables influencing the level of on-farm spatial diversity of wheat varieties.

The results showed that considerable spatial wheat genetic diversity was maintained on-farm at the household level, mainly through the simultaneous adoption of modern and traditional wheat varieties. Growing a combination of modern and landrace wheat varieties was observed to yield significantly higher level of spatial diversity of wheat genetic resources as compared to growing modern varieties alone or landrace varieties alone. This result suggests that the modern and landrace wheat varieties can coexist and could still support more on-farm spatial diversity of wheat genetic resources.

This finding has significant implications for future extension, research and policy efforts for on-farm conservation and utilization of wheat genetic resources in Turkey. There is a need for the government and private sector research and extension efforts to support farmers' use of both modern and landrace varieties, for example, in terms of seed supply, provision of extension and credit services and marketing support instead of just giving undue priority to popularization and adoption of modern varieties alone.

1 Introduction

1.1 Background

Wheat (*Triticum spp.)* is one of the most important cereals grown globally. It is found in a wide range of latitudes and altitudes and across many different countries where both very diverse genetic forms of bread and durum types can be found (Curtis et al., 2002; Smale, 1996). Since the Green Revolution, which began in the 1960s and 1970s, many wheat-growing countries have improved overall output considerably. However, this increase has been due, not only to the introduction of modern varieties, but also to increases in external inputs on larger than average farms. Infrastructural improvements, market developments and increased farmer knowledge have also contributed. There is now evidence that the overall rate of productivity growth of cereals is declining in many areas (Dixon et al., 2009) and this has prompted a major reflection on strategies for genetic conservation and whether the agro-biodiversity, nurtured by many farmers in rain-fed and small scale farming systems, could be the basis for crop-breeding programs that lead to longer-term yield stability, productivity and improved rural livelihoods.

Turkey is considered among the primary centres of genetic diversity for durum wheat and major crop species in the world. There are a number of landraces and related wild species of crops grown in the country. However, there is fear that there has been a decline in crop genetic diversity (genetic erosion) in regions and countries such as Turkey which is considered an important centre of crop genetic diversity. Several reasons are given for the loss of crop genetic resources such as the replacement of landrace varieties with modern varieties that have a narrower range of genetic material. The concern over the loss of crop genetic diversity has also increased due to the commercialization of genetically modified crops (Seals and Zietz, 2009).

Losses of crop genetic resources have implications for the livelihood of current as well as future generations (Rubenstein et al., 2005; Rana et al., 2007). First, losses of crop genetic diversity reduces the capacity of farmers to cope with external shocks (weather, diseases and pest outbreaks, market or environmental shocks) and also limit their choice set for consumption goods, thus, affecting their nutritional status. Second, losses of crop genetic resource diversity also limit the potential information and genetic material that could be available for future agricultural research and development in the world.

Recognizing its importance, there has been considerable effort in collecting, characterizing, and conserving crop genetic resources in seed banks through *ex-situ* conservation methods (Jarvis et al. 2007). However, there are several weaknesses of *ex-situ* conservation. For example, it is argued that the *ex-situ* conservation facilities are inadequate in terms of their capacity that preserve the range of useful diversity and in conserving the dynamic process of crop evolution and farmers' knowledge of crop selection and management practices (Jarvis et al. 2007). In general, *ex-situ* conservation is considered static in nature. As a result, over the last two decades, the *in-situ* conservation of genetic resources has also received increasing attention (Jarvis et al. 2007; Di Falco et al., 2007; Bellon, 2003; Meng, 1997; Meng and Brennan, 2009; Brush and Meng, 1998; Meng et al., 1998; Smale, 2006; Tripp, 1996). The collection of germplasm of major food and other crops for *ex-situ* conservation has been complemented by support for *in-situ* conservation of germplasm by farmers and communities (Brush, 1999).

It is observed that *in-situ* conservation approach offers opportunities for sustaining diversity, particularly where productivity increases are likely to have minimal impacts on the profitability of agricultural activities such as in marginal areas. For example, Cavatassi et al. (2011) show that sorghum landraces are more likely to produce under severe drought than improved early maturing sorghum variety in Ethiopia. The drop in crop genetic diversity is also associated with increases in the risks of attack by pathogens (Heal et al., 2004). In this regard, the diversity of crops and varieties are found to be very important means of combating crop losses from pests and diseases (Smale et al., 2008). The planting of diverse crop varieties can also help farmers to increase their productivity (Di Falco et al., 2007).

In general, due to variable economic, social and environmental conditions, small farmers grow more than one variety in order to minimize the risk of crop loss due to growing just one variety under highly variable environment. It is also argued that crop diversification is a deliberate farmer response to the lack of well-developed and efficient markets whereby higher level of crop diversity is associated with remote areas characterized by inefficient markets and lack of marketing infrastructure (Arslan, 2004). In particularly, the market failure problem is most severe in low-income countries where mechanisms for private and social insurance against the risks to agricultural incomes are limited. In such situations, higher levels of biodiversity can improve the mean and decrease the variance of farmers' incomes (Di Falco et al., 2007). The implication of this observation is that as market develops the farmers' private interest in biodiversity might decrease. There might be also a mismatch between farmers' private interest and the public interest in biodiversity. Then, the challenge remains on how to maintain crop diversity while simultaneously ensuring that the farmers benefit from market opportunities and the level of diversity is also beneficial to the society in the long-run.

Proponents of agro-biodiversity conservation have made efforts to raise awareness of the potential links between on-farm conservation, agricultural markets, and livelihood improvement. In a seminal article outlining principles that should govern *in-situ* conservation of crop germplasm, Brush (1991) observed:

> "*Market options are among the least expensive conservation tools because they can rely on existing institutions and on farmer choice. Virtually all farmers in the world are involved in marketing crops and respond to market incentives. In areas of diversity, small amounts of traditional crops reach the market and generally receive premium prices. Income from producing traditional crops as specialty crops, is an incentive to conserve them, and this incentive is available in most areas of diversity*" (1991:163).

Hence, in addition to offering a promising, inexpensive avenue for conserving crop diversity on-farm, market-driven *in-situ* conservation has the potential to improve farmers' livelihoods by raising household income.

Designing policies and marketing strategies which support the on-farm conservation of crop genetic resources conservation requires the understanding of the socioeconomic, cultural and environmental forces driving the losses or conservation of crop genetic diversity in a particular area (Rubenstein et al., 2005). Thus, in order to support farmers' *in-situ* conservation efforts, it is important to identify what factors are influencing farmers' decision to adopt landraces only, modern varieties only, or combination of modern and landrace wheat varieties. In other words, what are the key factors to better understand farmers' wheat varieties adoption decisions and genetic conservation management practices? It is also important to assess the spatial diversity outcomes of various wheat variety adoption decisions: no adoption, partial adoption and complete adoption of improved wheat varieties. The understanding of farmers' variety adoption decisions and its subsequent effect on the level of spatial diversity is important to design incentive mechanisms, inform policy and institutional support (extension and credit service provisions) efforts towards the *in-situ* crop genetic conservation which is financially-profitable and socially-acceptable.

There are several studies which examined the extent of spatial diversity in cereal crops like maize, wheat and rice varieties and its determinants in Turkey (for example, see: Kurizch 2006; Kurizch and Meng, 2006; Meng, 1997) and elsewhere (Gauchan et al., 2005; Smale et al., 2003; Nagarajan et al., 2007; Bellon et al., 2005; Benin et al., 2004). Brush and Meng (1998) carried out a study in three provinces in Western Turkey which are known to be centres of diversity for cereals. The study combined complementary economic and ethno-botanical approaches for examining the value of landraces. The additional information which this approach generated on the factors contributing to the private value that farmers assign to landraces is a contribution to identifying a strategy which ensures the conservation of crop genetic resources which are embodied in landraces. A study was also made in Northeast Turkey of 38 farmers and other stakeholders on agro-biodiversity conservation (Bardsley and Thomas, 2005). Some of the values of the local landrace, *Kirit* were examined in depth and the multiplicity of values that farmers assigned to this material (there were five different types evident) was very different from those values assigned by plant breeders. The farmers valued high grain quality for unleavened bread, a short growing season, low risk in production and a good straw with no awns as livestock feed was important. The landrace was susceptible to lodging under high fertility, to some diseases and was low yielder, but it could be sown at any time of the year.

In many of the aforementioned studies, the spatial diversity of crop varieties was measured using different indices. The determinants of these indices were analyzed. The indices, one way or the other, depended on the number of crop varieties grown and/or land area allocated to different crop varieties. However, there are weaknesses in the previous empirical approaches used to assess the determinants of spatial diversity of crop varieties. This is because these approaches ignored the influence of farm household's first stage variety adoption decision on the second stage decision of the level of spatial diversity.

Farmers' level of on-farm spatial diversity decisions regarding how much area to allocate to different varieties (modern and/or landrace) is second stage decision. Often, this second stage decision is linked to the first stage decision of variety adoption. In situations where the first stage and second stage decisions are related, the parameter estimates for the level of spatial diversity are prone to the problem of self-selection and the parameter estimates of factors influencing special diversity are biased and inconsistent. So in spatial diversity analysis, it is very important to first investigate factors influencing farm households' decision whether or not to adopt modern and/or landrace wheat varieties and to use this information in the analysis of the level of spatial diversity by controlling for the well-known self-selection bias. The self-selection bias may arise from the fact that the sample observations on wheat variety spatial diversity are generated by wheat producers' non-randomly self-selecting themselves into the different wheat variety choices.

This paper builds on the recent studies of spatial diversity analyses for wheat varieties in Turkey by Kurizch (2006) and Kruzich and Meng (2006) and is an attempt to provide an improved empirical approach in analyzing farm households wheat adoption decision making process related to *in-situ* conservation of wheat crop varieties in Turkey which allows obtaining statistically more reliable results regarding the determinants of spatial diversity of wheat varieties.

1.2 Objectives of the study

The major objective of this study was to assess how farm households' wheat crop variety adoption decisions affect the levels of *in-situ* conservation of wheat genetic diversity in Turkey. The specific objectives were:

1. Identify the determinants of farmers' decisions to grow landrace and/or modern varieties of wheat
2. Test whether the adoption of modern varieties negatively affects on-farm spatial diversity of wheat variety
3. Identify other determinants of on-farm spatial diversity of wheat

1.3 Organization of the paper

The next section provides the description of the dataset used in the analyses. The third section outlines the analytical and empirical approaches used for the study. The fourth section presents the results of statistical and econometric analyses. The final section presents the main findings of the study and conclusions and policy implications.

2 Data

This study was based on CIMMYT survey data collected during May to July 1998 involving a sample of 486 farm households from seven provinces in Turkey. The data collected focused on household characteristics for the 1997-98 cropping cycle. Detailed discussions of survey methodology and description of the survey data was given in Kruzich (2006) and Meng and Kruzich (2006). Stratified random sampling method was used. First, seven provinces were selected to ensure regional variations in terms of crop varieties grown, market infrastructure and consumption of wheat. Second, within each province, two districts were selected purposively each to represent high and poor quality market access and infrastructure in terms of availability of market outlets, such as mills. Third, four villages were selected from each district which represent the three agro ecotypes (valley, hillside and mountain). Thus, one village from each valley, hillside and mountain agro ecotypes and one more village from most dominant agro ecotype in the district was selected. Finally, approximately 10 households were randomly selected from each village and interviewed using structured survey questionnaire.

3 Analytical and empirical approach

This section outlines the analytical and empirical approaches used to analyze the factors influencing farm households' choice of wheat varieties in the first stage and the level of spatial diversity of wheat varieties in the second stage. Broadly, wheat varieties grown by the farm households can be classified as modern varieties (MVs) and landrace varieties (LVs). The actual number of MVs and LVs available to wheat producers could vary at a given point in time depending on different factors. Naturally, each wheat variety type has its own advantages and disadvantages, as such no single wheat variety is expected to posses all the attributes desired by the wheat producers. Several studies indicate that single variety does not provide all benefits and different varieties have advantages and disadvantages which entail trade-offs (Bellon et al., 2005; Bellon and Taylor, 1993; Pearles et al., 2003; Brush and Meng, 1998; Brush, 1992). As a result, it can be argued that farmers might adopt multiple wheat varieties in their different fields instead of a single wheat variety. That is, the farmers have to make trade-offs among different wheat varieties due to differences in desirable characteristics among different varieties. For example, with modern inputs, MVs can give higher yield but may be less resistant to drought, diseases, pests, etc. and may lack certain desirable consumption attributes. On the other hand, the LVs have low yield potential but are more adapted to farmers' socioeconomic and climatic conditions and may be more resilient to environmental stresses and low input situations (Seals and Zietz, 2009) and more preferred in certain consumption attributes (Tsegaye and Berg, 2007). The key point is that farmers maintain their LVs even as they adopt MVs. Brush and Meng (1998) argue that farmers' desire for different varietal attributes (yield and quality) and environmental variability and missing markets contributed to the persistence of landraces.

In general, producers' choice set for adoption of wheat varieties can be given based on pair-wise combinations of broadly classified MVs and LVs[1]. Thus, assuming that the farmers are growing at least one wheat variety in a given cropping season, we can define three mutually exclusive and collectively exhaustive wheat variety choice sets, i.e., the producers can choose to adopt MVs only (complete adoption), LVs only (no adoption), or simultaneously both MVs and LVs (partial adoption). As it can be shown from utility maximization theory below, the farmer is assumed to choose only one of the wheat variety choices at a time. There might be farmers who are not growing wheat at all but in this study we are interested in a sample of farmers who are growing at least one wheat variety. Farmers who are not growing wheat at all are not included in our study sample. We are interested in wheat variety choices because we assume that the differences in wheat variety choices also reflect the differences in producers' preferences for levels of *in-situ* conservation of wheat genetic diversity.

The wheat variety choice is assumed to be multinomial discrete choice variable rather than binary discrete choice variable. This means there are more than two choices and there is no natural ordering among the different wheat variety choices. However, it is assumed that the different choices are associated with different levels of utilities for individual wheat producers reflecting their preferences for different wheat variety choices and levels of on-farm wheat variety diversities. Once the producers' choose MVs only, they decide how many of each MV to grow and on what area of land and hence the level of diversity for MVs only. Similarly, if they choose LVs only, they decide how many of each LV to grow and on what area of land. In general, the utility obtained from given wheat variety choice can be defined as:

$$(1) \quad U_{ij},\ j = 0, 1, 2$$

where U_{ij} is the utility of i^{th} wheat producer for wheat variety choice *j, j*=0 denotes modern variety only; *j*=1 denotes landrace variety only and *j*=2 denotes combination of modern and landrace varieties grown simultaneously. As indicated earlier, these variety choices correspond to three possible wheat variety adoption decisions: complete adoption, no adoption and partial adoption of modern wheat varieties, respectively.

The random utility model (RUM) provides the conceptual framework to analyze such discrete multi-choice decisions. The RUM assumes the utility maximizing behaviour by a decision maker under consideration and it ensures that the decision made is consistent with economic theory of optimal decision making by economic agent involved. For example, in the case of wheat variety choice, the RUM indicates that a rational wheat producer chooses a wheat variety or a combination of wheat varieties which provide the greatest utility amongst all wheat variety choices available. In other

[1] As the wheat farmers in Turkey grow several MVs and LVs, the choice set is based on the general classes of MVs and LVs without being specific about specific combinations of MVs or LVs grown.

words, the wheat producer's optimal decision would be to choose one wheat variety choice *j* from a variety choice set containing all three possible alternative wheat variety choices if and only if

$$(2) \quad U_{ij} > U_{ik}, \; for \;\; all \quad k \neq j; \; j = 0,1,2$$

In general, as it is true for any utility function, wheat producers' utilities for different wheat variety choices are not observable. However, wheat producers' choices of wheat varieties and their socioeconomic and demographic characteristics are observable. The utility level obtained from different wheat variety choice is influenced by these observable factors and by other unobservable factors. Thus, the utility function for a given wheat variety choice set is given as a function of various observable explanatory variables and random disturbance term as:

$$(3) \quad U_{ij} = X_i \beta_j + \varepsilon_{ij}, \; for \;\; all \;\; j; \; i = 1,2,..., \; N$$

where X_i is a vector of observable explanatory variables specific to the i^{th} individual wheat producer, ε_{ij} is unobservable random disturbance term affecting wheat variety choice; and β_j is a vector of unknown parameters to be estimated which are specific to the wheat variety choice *j*. The $X_i\beta_j$ is the deterministic component of utility from choice *j* while ε_{ij} is the random component of the utility and hence the name random utility model. The random utility component captures variations in the utilities of wheat variety choices due to omitted variables, measurement errors and other factors which are unobservable. The random component of the utility function also plays an important role in determining the probabilities of choosing different wheat varieties. For example, the probability that wheat producer chooses wheat variety choice *j* from a set of *J+1* choice is given as:

$$(4) \quad P(Y_i = j \mid x) = P(U_{ij} > U_{ik} \mid x) = P(X_i \beta_j + \varepsilon_{ij} > X_i \beta_k + \varepsilon_{ik}), \; for \;\; all \;\; k \neq j$$

Where Y_i is discrete choice variable which indicates the choice made by individual *i* and other variables are defined as before. Rearranging the terms in equation (4) yields to:

$$(5) \quad P(Y_i = j \mid x) \quad = P(\varepsilon_{ij} - \varepsilon_{ik} > X_i \beta_k - X_i \beta_j \mid x), \; for \;\; all \;\; k \neq j$$

Thus, the probability that a particular variety or combination of wheat varieties is chosen depends on the joint distribution of the difference between the two error terms. In general, different choice models are developed based on the assumptions of the distributions for the error terms in the utility functions. For example, under the assumption that the disturbance terms ε_{ij} and ε_{ik} are independently and identically distributed (IID) type-I extreme values, the β parameters are estimated using multinomial logit model (MNLM) (McFadden, 1974). Based on equation (5) the functional form of the MNLM probabilistic response function is given as:

$$(6) \quad P_{ij}(Y_i = j \mid X) \quad = \frac{e^{X_i \beta_j}}{\sum_{j=0}^{2} e^{X_i \beta_j}}$$

Normally, the MNLM given in equation (6) is not identified and its normalization is required in order to obtain unique parameter estimates for variables affecting farmers' wheat variety choice. Normalization involves the choice of reference category and equating the coefficients on the reference category to zeros (Long, 1997; Wooldridge, 2002). The reference category used here is j=0 which is growing MVs only. With normalization, the logistic probability functions given in equation (3.6) results in new logistic probability functions for the three wheat variety choices as follows:

$$(7) \quad P_0(Y_i = 0 \mid x) = \frac{1}{1 + \sum_{j=1}^{2} e^{x_i \beta_j}}, \ for \ j = 0$$

$$(8) \quad P_j(Y_i = j \mid x) = \frac{e^{x_i \beta_j}}{1 + \sum_{j=1}^{2} e^{x_i \beta_j}}, \ for \ j = 1,2$$

In general, the multinomial logit model is considered as a simultaneous estimation of binary logit model for all possible comparisons among alternatives relative to a given selected base category (Long, 1997). Several empirical studies on adoption focused on dichotomous adoption decision in terms of "adoption" or "no adoption" using binary choice model like binary logit or probit models. However, this approach ignores the fact that farm households also adopt technologies partially resulting in incomplete and biased analysis of technology adoption. As opposed to dichotomous adoption decision, the MNLM allows for modelling multiple technology choices: no adoption, partial adoption or complete adoption of technologies. This gives the option to see what explain farmers complete or partial adoption technologies relative to no adoption thus giving clearer picture of improved wheat variety adoption. Partial adoption involves farmers maintaining both MVs and LVS.

In our case, with three types of wheat variety adoption decisions, we simultaneously estimate two binary logits which are given as follows:

$$(9) \quad \ln \Omega_{j/0}(x) = \ln\left(\frac{p_j(Y_i = j \mid x)}{p_0(Y_i = 0 \mid x)} \right) = x\beta_{j/0}, \quad for \quad j = 1, 2; \quad i = 1,2,..., N$$

where $\ln \Omega_{j/0}$ (x) is the natural log of odds ratio of a wheat variety choice j relative to the base or reference ($j=0$) and other variables are defined as before. In general, with J+1 alternatives, only J binary logits need to be estimated. In the above formulations, the two wheat variety choices are compared with the reference. Thus, following Wooldridge (2002) the log likelihood function for MNLM which is used to investigate the factors influencing the farm households' first-stage decision of wheat variety adoption is given as:

$$(10) \quad \ln \ L(\beta \mid x) = \sum_{i=1}^{N} \sum_{j=0}^{J} d_{ij} \ \ln P_j(Y_i = j), \quad j = 0,1, 2; \quad i = 1,2,..., N$$

where N is the sample size, d_{ij} is indicator variable which is equal to 1 if the alternative j is chosen by individual i, and 0 if not, P_j is the probability density function for j^{th} wheat variety portfolio choice observed for i^{th} individual and other variables are defined as before. The MNLM parameter estimates are obtained using maximum likelihood estimation method given in MLOGIT routine for STATA version 11.

One of the major problems with the applications of MNLM is the violation of the independence of irrelevant alternatives (IIA) which results in incorrect probability estimates. The IIA assumption states that the odds of an outcome (P_j/P_k) are determined without reference to the other outcomes that might be available (Long, 1987; Greene, 1993). In other words, the IIA property states that odds ratio is independent of the remaining probabilities. This suggests that the odds ratio between any pair of alternative is unaffected by the existence of other options. The IID condition for the errors allows the IIA assumption to hold. The IIA property is tested using the Hausman and McFadden (1984) test. In other situations, where the IIA assumption is violated the use of other estimation approaches like the multinomial probit model (MNPM) is suggested (Wooldridge, 2002). In the case of MNPM, the error terms are assumed to be identically and independently distributed normal errors. It is also argued that the MNLM should be used in cases where the alternatives are considered to be distinct or different by decision maker. This proposition can be statistically tested using Wald and LR tests. The null hypothesis for combining test is that the independent variables used do not differentiate between choices. The rejection of the null hypothesis indicates the variety choices are not distinguishable and suggests the collapsing or combining of some of the alternatives in order to obtain efficient MNLM parameter estimates.

The other statistical problem with the MNLM is that the collinearity among the independent variables. The problem of collinearity is the situation whereby the high degree of correlation among independent variables makes it difficult to determine which independent variable is actually affecting the dependent variable (Wooldridge, 2002). Therefore, it is very important to test for the presence of collineariy and to take appropriate action if it exists. In general, the presence of collinearity is tested based on the R^2 by regression of a given independent variable on other independent variables and variance inflation factor (VIF) which is given as 1-R^2. The rule of thumb used is that VIF of 10 or higher may indicate the existence of collinearity which is of concern in the estimation of the regression model (Kennedy, 1998).

The performance of MNLM estimates was evaluated using several diagnostic criteria. First, the overall goodness of fit of MNLM was tested using the likelihood ratio test and the McFadden's Pseudo R^2. The null hypothesis for the overall goodness of fit is that all the coefficients except intercepts are zero. Second, the effect of a given independent variable on the choice of wheat variety choice was conducted using the Wald and LR test across all variety choices and using the t-test for individual variety choice. The null hypothesis for the independent variables across the variety choices is that all the parameter estimates associated with given variable(s) for all choices are jointly zero. The rejection of the null hypothesis indicates that a given variable does not have effect on the farm household choice of wheat variety. The usual t-test was also used to see the effects of independent variables on the adoption of different wheat variety separately. Third, the percentage of correct prediction was also computed to see to what extent the MNLM predictions of different variety choices match with the actual or observed choices.

Finally, we follow Heckman-Lee two-stage procedure to investigate factors influencing farmers' spatial diversity of wheat. Heckman's procedure is commonly used for situations where individual decision maker faces two choices (e.g., "adoption" versus "non-adoption"). In our case we extended Heckman approach whereby the farm households are allowed to have three alternative variety choices. In the first stage farmers make choice of wheat varieties among the broad alternative wheat varieties: modern variety only, land race only or both landrace and modern varieties. In the second stage, conditional on choice of wheat variety choice they determine the levels of on-farm spatial diversity. Recently, Edmeades et al. (2008) followed a two-step approach in which first variety choice ("extensive margin") was modelled and then an "intensive margin" decision about the scale of production for each cultivated variety of banana in Uganda was modelled. Van Dusen et al. (2007) used simultaneous estimation approach in modelling farmers' crop choice and crop genetic diversity.

Thus, in the second stage, conditional on the wheat variety choices, we assess the level of farmers' on-farm spatial diversity of wheat varieties. Within RUM framework, we also assume that farm households' optimal land area allocation decision in the second stage is based on their utility maximization behavior given other constraints they face. The values of the various spatial diversity indices (dependent variables) are censored either at zero or one either from below or above[2]. It is indicated that in a situation where the dependent variable is censored the OLS estimators are biased downwards and the use of Tobit regression model is recommended (Wooldridge, 2002). Thus, conditional on wheat variety choice, the determinants of household on-farm spatial diversity of wheat genetic resources in the second stage was investigated using Tobit regression. For example, following Wooldridge (2002), the Tobit regression model for spatial diversity indices censored at zero is given as follows:

$$(11)\quad D_{ij}^{*} = Z'\alpha + v_{ij}\ ;\ j = 0,1,2$$

$$(12)\quad D_{ij} = D^{*}\ \ if\ \ D^{*} \succ 0,\ 0\quad Otherwise$$

where D_{ij}^{*} is the latent variable which represents the desired or optimal level of on-farm spatial diversity for i^{th} household and j^{th} wheat variety choice (j=0 denotes IVs only, j=1 denotes LVs only and j=2 denotes IVs and LVs); which is unobserved if $D_{ij}^{*}$is less than or equal to 0, D_{ij} is the observed value of spatial diversity; Z is a vector of independent variables affecting the level of on-farm spatial diversity of wheat; a is a vector of parameters to be estimated; and v_{ij} is assumed to be independently and normally distributed disturbance term with zero mean and constant standard deviation.

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[2] The formulas used and detailed discussions of various spatial diversity indices are given in Appendix 1.

However, one of the major problems with estimation of determinants of spatial diversity of wheat is that the two-stage decision making processes (choice of variety type in the first-stage and choice of the level of spatial diversity in the second-stage) are not separable due to unmeasured household-level variables affecting both decisions. This situation is known as the selectivity bias where the estimated parameter values on the variables affecting the level of spatial diversity are biased (Wooldridge, 2002). Thus, there is a need to specify a model that corrects for selectivity bias while estimating the determinants of the level of spatial diversity. For this purpose, in the first step, Mills ratio was created from the multinomial logit (MNL) regression. Then, following Heckman (1979) and Lee (1983), the three different probabilities (P_{i0}, P_{i1} and P_{i2}) predicted from the first-stage MNL estimation of wheat variety choices are used to derive selectivity terms (Mill's ratios) which are used as independent variables in the level of spatial diversity equations for different wheat variety choices as shown in equation (13): Hence the Heckman-Lee estimation procedure.

$$(13) \quad D_{ij} = Z'\delta_{ij} - \lambda_{ij} \frac{\phi(\Phi^{-1}(P_{ij}))}{P_{ij}} + \xi_{ij}; \quad j = 0,1,2$$

where δ_{ij} is a vector of parameters to be estimated for j^{th} wheat variety choice; λ_{ij} is the coefficient on the inverse Mills ratio for j^{th} wheat variety choice; ф is standard normal density function; Φ is standard cumulative distribution function; ξ_{ij} is normally distributed disturbance terms with zero mean and standard deviation. Under the null hypothesis of no sample selection bias λ_{ij} is not significantly different from zero. The maximum likelihood Tobit estimation is implemented using STATA econometric software version 11.

4 Empirical results

4.1 Results of descriptive and statistical analyses

The name and frequency distribution of distinct modern and landrace wheat varieties grown by surveyed households in Turkey for the 1998-1999 cropping season are given in Table 1.

Table 1. Name and frequency distribution of distinct modern and landrace wheat varieties reported by farmers in Turkey, 1998/1999.

Modern Variety		Landrace Variety	
Name of Variety	**Percentage of Adopters**	**Name of Variety**	**Percentage of Adopters**
Bezostaya	22.47	Saribas (Saribugday)	8.96
Gerek 79	19.33	Kirik	6.68
Kunduru	6.33	Akçalibasan	3.95
Zeron	5.77	Kobak	3.14
Kirac 66	3.19	Koca bugday	2.07
Izmir 85	2.73	Kulumbur	1.92
Pehlivan	2.58	Akbugday (Beyaz bugday)	1.21
Atay 85 (or Es 7)	1.97	Beyaz kobak (Ak kobak)	1.11
Cumhuriyet 75	1.21	Ari bugday	0.86
Cakmak	1.01	Kirmizi (Kirmizi basak-kizil basak)	0.81
Gemili	0.30	Siyaz	0.35
Valencia	0.25	Ag bugday (Makarnalik)	0.51
Saraybosna (Varesa)	0.20	Yerli bugday (Makarnalik)	0.20
Haymana	0.15	Asire	0.15
Kate	0.05	Çandarli	0.15
Kiziltan	0.05	Gocu	0.10
Topbas	0.05	Karisik	0.10
Sultan 93	0.03		

Source: Household survey conducted in 1998-1999. Note the percentages do not add up to 100 as there could be farmers who grew both MVs and LVs. This frequency distribution was based on results of one season and could vary for different seasons.

A total of 18 modern, 17 landrace wheat varieties were reported across the surveyed households in six provinces of Turkey. However, there were only few dominant varieties both for improved and landrace wheat varieties. For example, Bezostaya and Gerek 79 were the most dominant improved wheat varieties which were grown by 22% and 19% of the farmers, respectively. In general, only four of the improved wheat varieties were grown by more than 5% of the respondents. Similarly, among the most dominant landrace wheat varieties grown by the households only two landrace varieties (Saribas and Kirik) were reported to be grown by more than 5% of the respondents. In general, landrace wheat varieties were grown by small proportion of the households.

In addition to varietal count, the descriptive analysis of wheat variety diversity indices is given in Table 2. The statistical analyses of the indices, in addition to the descriptive analysis of the mean and standard deviation, were also made. One-way analysis of variance (ANOVA) was also used to see whether there is statistically significant difference in spatial diversity of wheat varieties among provinces. Then, pair-wise mean comparisons using the Scheffe least significant difference (LSD) test was used to determine which provinces and which wheat variety choices are statistically significantly different in terms of spatial diversity.

Table 2. Results of one-way analysis of variance of on-farm spatial diversity of wheat varieties by province in Turkey, 1998/1999.

Province	Diversity index				
	Varietal Count	**Margalef**	**Berger-Parker**	**Shannon**	**Simpson**
Eskisehir	1.32[b]	0.08[b]	2.92 [a]	1.33[a]	0.67[a]
Kutahya	1.73[a]	0.18[a]	3.48 [a]	1.48[a]	0.69[a]
Kastamonu	1.85 [a]	0.24[a]	2.86 [a]	1.19[a]	0.61[a]
Malatya	1.21 [b]	0.05[b]	1.91 [b]	0.67[b]	0.38[b]
Kavseri	1.21 [b]	0.04[b]	2.49 [a]	1.00[b]	0.55[a]
Erzurum	1.08 [b]	0.03[b]	1.77 [b]	0.59[b]	0.36[b]
Whole sample	1.40	0.10	2.57	1.04	0.54
F-Value	19.92***	21.76***	18.96***	26.53***	21.96***

Note: Same superscript alphabet along the same column shows there is no statistically significant difference in on-farm wheat spatial diversity indices among the provinces. *** indicates statistical significance of ANOVA model at less than 1%.

The analysis of variance indicated that the impact of province on spatial diversity of wheat genetic resource was statistically significant (Table 2). There was statistically significant difference in varietal count among provinces ($p<0.01$). The average wheat variety count per household was 1.4 and varied from 1.08 to 1.85. In general, the LSD shows that, for varietal count and Margalef Index, provinces Kutahya and Kastamonu had similar levels of spatial diversity and statistically higher levels of spatial diversity as compared to other provinces. For Berger-Parker Index and Simpson Index, Malatya and Erzurum had similar and significantly lower levels of diversity as compared to other provinces.
As discussed earlier, there are three mutually exclusive and collectively exhaustive wheat variety choices for the wheat producers: modern wheat variety only, landrace wheat variety only and both modern and landrace wheat varieties (Table 3). The largest proportion (57%) of sample households was observed to grow modern wheat varieties only. About 27% of the sample households were observed to grow landrace wheat varieties only (no adoption of improved wheat varieties). On the other hand, the percentage of sample households growing modern and landrace wheat varieties simultaneously (partial adoption) was about 15%. Among all provinces, the complete adoption of modern wheat varieties was observed for Kavseri Province. Overall, either singularly or in combination with modern wheat varieties, more than 40% of the sample households were found to grow landrace wheat varieties.

Table 3. Household wheat variety adoption patterns by province in Turkey, 1998/1999.

Province	Wheat Variety Choice (% of respondents)			
	Modern Variety Only	**Landrace Only**	**Both Modern and Landrace Varieties**	**Whole sample**
Eskisehir	88.75	6.25	5.00	16.46
Kutahya	31.71	29.27	39.02	16.87
Kastamonu	40.00	22.50	37.50	16.46
Malatya	58.75	37.50	3.75	16.46
Kavseri	100.00	0.00	0.00	16.87
Erzurum	25.61	67.07	7.32	16.87
Whole sample	57.41	27.16	15.43	100.00

There was statistically significant difference in on-farm spatial wheat diversity among wheat variety choices (Table 4). In terms of varietal richness based on the measures of varietal count and Margalef index, all the choices were significantly different statistically. The simultaneous adoption of MVs and LVs varieties showed significantly the highest diversity among the three alternative wheat variety choices. The MVs only and LVs only were also significantly different from each other, MVs only was found to have higher spatial varietal richness measure value based on both varietal count and Margalef Index. However, the Berger-Parker index, Shannon-Weiner Index and Simpson indices measures of diversity show slightly different pattern. These indices indicate that the difference in levels of spatial diversity between MVs and LVs only was not statistically significant. However, the results of ANOVA of these indices show that the level of diversity for simultaneous choice of MVs and LVs was significantly higher than the MVs only and LVs only in all cases. Thus, on all accounts the combination of MVs and LVs had higher levels of diversity as compared to the MVs only and LVs only choice.

Table 4. Results of one-way analysis of variance of on-farm spatial diversity of wheat varieties by wheat variety choices in Turkey, 1998/1999.

Diversity Index	Diversity index (by wheat Variety choice)			
	Modern Variety Only	Landrace Only	Both Modern and Landrace Varieties	F-Value
Number of wheat varieties (Richness)	1.26[a]	1.09[b]	2.47[c]	195.67***
Margalef index (Richness)	0.06[a]	0.03[b]	0.39[c]	219.62***
Berger-Parker index (Dominance)	2.47[a]	2.29[a]	3.40[b]	15.88***
Shannon index (Richness and evenness)	0.99[a]	0.91[a]	1.47[b]	18.08***
Simpson index (Richness and Evenness)	0.52[a]	0.50[a]	0.71[b]	14.28***

Note: Same superscript alphabet along the same row shows that there is no statistically significant difference in on-farm wheat spatial diversity indices among the wheat variety choices. *** indicates statistical significance of ANOVA model at less than 1% level.

4.2 Results of econometric analyses

4.2.1 Variable description

The definitions, descriptions and summary statistics of independent variables included in the various regression analyses are given in Table 5. The independent variables considered in this analysis can be broadly classified as: household head characteristics, farm characteristics, market access and institutions, agro ecotypes and provincial dummy variables. The household head was characterized based on education, age and farming experience. Educational attainment of household heads was measured in terms of years of school completed by household head. The average education of household heads for sample households was about 5 years. Very similar level of household heads' educational attainment was observed across wheat variety choices. The average age of household head for whole sample was about 49 years and the average age did show significant variations across the wheat variety choices. The average farming experience of household head was about 30 years and similar levels of farming experience was observed across the wheat variety choices. In general, the household head characteristics were very similar for different wheat variety choices.

Several variables were selected to characterize the farms for the sample households. These include: household size; dependency ratio; number of cattle owned; number of buildings on farm; car ownership; farm size, farm fragmentation, percentage of irrigable plots and distance from home to farm plots. On average, there were about 6 people in the household and the household size did not show significant variability across the wheat variety choices. The average dependency ratio was about 65% for the whole sample and some degree of variability was observed among the wheat variety choices in terms of dependency ratio. The lowest dependency ratio of 55% was observed for households with both modern and landrace wheat varieties choices. The highest dependency ratio of 75% was observed for the households with landrace wheat variety only. The average number of cattle owned by the households was about 8 and similar average numbers of cattle were observed across the wheat variety choices.

Table 5. Definition, description and summary statistics of independent variables included in the various regression analyses.

Variable Name	Variable Description	Summary Statistics			All Sample (N=486)
		Modern Varieties Only (n=279)	Landrace Varieties Only (n=132)	Both Modern and Landrace Varieties (n=75)	
Household Head Characteristics					
EDUC	Years of school completed by household head	5.00(2.22)	4.57(2.31)	4.51(2.20)	4.81(2.25)
AGE	Age of household head (years)	48.41(13.27)	49.05(13.59)	50.19(11.59)	48.86(13.11)
FEXPERIENCE	Farming experience of household head (years)	30.03(13.42)	30.12(14.49)	31.28(12.46)	30.25(13.56)
Farm Characteristics					
HSIZE	Household size (numbers)	5.91(2.38)	5.45(2.54)	6.08(2.56)	5.80(2.46)
DPENDRATIO	Dependency ratio (%)	63.03(72.05)	75.37(74.19)	55.19(57.12)	65.15(70.72)
CATTLE	Heads of cattle owned (numbers)	7.07(8.35)	8.58(7.50)	8.29(5.59)	7.67(7.78)
BUILDNO	Number of buildings on farm (numbers)	2.54(1.03)	2.21(0.83)	2.56(0.96)	2.45(0.98)
CAR	Household owns car (dummy)	0.18(0.38)	0.06(0.24)	0.21(0.41)	0.15(0.36)
FSIZE	Farm size owned (decares)	140.18(151.21)	63.19(63.41)	95.47(62.22)	112.37(126.22)
FRAGMEN	Simpson index of farm fragmentation	0.76(0.18)	0.74(0.18)	0.83(0.11)	0.76(0.17)
IRRIG	Percentage of irrigable plots (%)	31.76(78.21)	17.05(39.59)	13.27(35.16)	24.91(64.67)
TIMEPLOT	Walking distance from home to farm plot (minutes)	3.01(3.17)	2.44(2.22)	1.90(1.50)	2.68(2.76)
Market Access and Institutions					
DISTMILL	Distance to the nearest mill from farm (km)	19.16(13.92)	11.66(10.40)	15.18(10.93)	16.63(13.05)
EXTENSION	Farmer had extension contact in 1997 (dummy)	0.17(0.37)	0.07(0.25)	0.11(0.31)	0.13(0.34)
CREDIT	Farmer obtained credit (dummy)	0.32(0.47)	0.20(0.40)	0.29(0.46)	0.28(0.45)
Agro Ecotype					
TOPO_PLAIN	Percentage of plain plots (%)	37.38(40.32)	36.28(41.04)	32.90(33.80)	36.39(39.54)
Province					
Eskisehir	Eskisehir province (%)	88.75	6.25	5.00	16.46
Kutahya	Kutahya province (%)	31.71	29.27	39.02	16.87
Kastamonu	Kastamonu province (%)	40.00	22.50	37.50	16.46
Malatya	Malatya province (%)	58.75	37.50	3.75	16.46
Kavseri	Kavseri province (%)	100.00	0.00	0.00	16.87
Erzurum	Erzurum province (%)	25.61	67.07	7.32	16.87

Note: Figures in parenthesis represent standard deviations.

The number of buildings on the farm and car ownership can be used as a proxy to measure farmers' wealth. The average number of buildings on the farm was 2.45 for the whole sample and similar average number of buildings on farm was observed across the wheat variety choices. The car ownership was about 15% for the whole sample and the lowest ownership of about 6% was

observed for landrace wheat variety only while the car ownership for modern variety only and both modern and landrace wheat varieties was 18% and 21%, respectively.
The average farm size was 112 decares[3] for the whole sample and farm size showed large variability across wheat variety choices. For example, the average farm size for the modern wheat variety only was about 140 decares which is more than double for the landrace wheat variety only. Thus, households with landrace wheat variety only tend to have small farm size as compared to those with modern wheat variety only and those households simultaneously adopting both modern and landrace wheat verities.

Farm fragmentation was also another important variable which was hypothesized to affect the wheat variety choice and spatial diversity. The farm fragmentation was measured using the most commonly used Simpson index of farm fragmentation. The Simpson farm fragmentation is given as the sum of the square of individual plots divided by the square of the area of all plots. This measure overcomes the weakness of using number of plots as a measure of farm fragmentation as number of plots does not take into account the size distribution of plots, for example one plot might account for more than 90% of the total farm size but there might be still many plots. The value of Simpson index varies from 0 to 1, 0 indicates that the household owns just one plot while a value of 1 shows highly fragmented farm. The average Simpson index was 0.76 for the whole sample showing in general there was high level of farm fragmentation among the survey households in Turkey. The level of farm fragmentation was found to be relatively higher for the simultaneous adoption of modern and landrace wheat varieties.

The influence of plot characteristics on the wheat variety choice was captured using two variables: the percentage of irrigable plots and the average walking distance from home to farm plot. The average percentage of irrigable plot was about 25% for the whole sample and variability was observed across different choices in terms of the percentage of irrigable plots. The highest percentage of about 32% irrigable plot was observed for modern wheat variety only while the percentage was the lowest for households with both modern and landrace wheat varieties. The average walking distance from home to farm plot was about 2.7 minutes and the lowest distance was observed for the households with both modern and landrace wheat varieties.

The influence of market access was captured using the proximity of households to the nearest mill while the institutional supports are captured in terms of households' access to extension and credit. The average distance to the nearest mill from farm was 17 kilometers. Contrary to our expectation, it was observed that the households with modern wheat variety only were the furthest away from the mill and the households with landrace wheat variety only were the closest to the mills. In terms of extension service, about 13% of the households had extension contact for the whole sample. The percentage of households with landraces only had the lowest extension contact while the percentage

[3] 1 Hectare is approximately equivalent to –decares.

was the highest for households with modern variety only. The hypothesized relationship between extension contact and household wheat variety choice was that farmers receiving extension advice are more disposed to grow modern wheat varieties. The percentage of households who had obtained credit was about 28% and the percentage was again the lowest for the households with landrace wheat variety only. In general, the level of institutional support was the lowest for the households with landrace wheat variety only. The impact of agro ecotypes on the household's wheat variety choice was captured through percentage of plain plots. The average percentage of plain plots was 36% for the whole sample and similar level of agro ecotype was observed across different wheat variety choices.

4.2.2 Determinants of adoption of wheat varieties

The results of the maximum likelihood estimates of multinomial logit regression coefficients and measures of goodness-of-fit are presented in Table 6. The modern wheat variety only choice was the reference variety choice used. The variety choice specific coefficients of multinomial logit regression estimates for landrace wheat variety only and both modern and landrace wheat varieties are given in column two and three of Table 6, respectively. The respective robust standard errors estimates are given in parenthesis. The χ^2-value statistics for the joint tests of coefficients for a given independent variable across choices is given for likelihood ratio (LR) test and Wald test in columns four and five of Table 6, respectively. The various measures of goodness-of-fit for multinomial logit model are given at the bottom of the left corner of Table 6. Finally, the results of diagnostic tests for MNLM are provided in Appendices 2, 3 and 4.

The overall goodness of fit for the multinomial logit model parameter estimates was assessed based on several criteria. First, the log-likelihood ratio test was applied to assess the overall joint significance of the independent variables in explaining the variations in the household's wheat variety choices. The null hypothesis for the log-likelihood ratio test is that all coefficients except the intercept were jointly zero. The model chi-square tests applying appropriate degrees of freedom indicate that the overall goodness-of-fit of the multinomial logit are statistically significant at a probability of less than 1% (Table 6). This shows that jointly the independent variables included in the multinomial logit regression model explain the variations in the household's probability of choosing different wheat varieties. Second, the McFadden's Pseudo-R^2 was calculated and the obtained value indicates that the independent variables included in the multinomial logit regression explain 46% of the variations in the households' wheat variety choice decisions. Third, the correct prediction rate of the multinomial logit model was obtained for the different wheat variety choices and for the model as a whole. Overall, the multinomial logit model provided 78% correct prediction. It provided 88% and 66% correct prediction for MVs only and LVs only, respectively. However, the multinomial logit model performed relatively poorly in correctly predicting both modern and landrace wheat variety choice whereby it correctly predicted only about 57% of the cases.

Table 6. Maximum likelihood estimates of multinomial logit regression coefficients for wheat variety choice model.

Explanatory variable	**Choice-specific coefficient (*β*) tests**[1]		**Joint tests *of β*s across choices (χ^2-value)**[2]	
	Landrace Wheat Varieties Only	**Both Modern and Landrace Wheat varieties**	**LR Test**	**Wald Test**
EDUC	-0.026(0.094)	0.007(0.086)	0.122	0.122
AGE	0.010(0.026)	0.023(0.026)	0.776	0.774
FEXPERIENCE	0.016(0.025)	-0.002(0.023)	0.644	0.624
HSIZE	-0.242(0.087) ***	-0.103(0.076)	8.786**	7.993
DPENDRATIO	0.003(0.003)	-0.001(0.004)	1.697	1.740
CATTLE	0.105(0.027) ***	0.054(0.029)*	13.380**	14.931***
BUILDNO	-0.188(0.199) **	0.028(0.216)	1.089	1.074
CAR	-0.293(0.587)	0.737(0.464)	2.116	2.102
FSIZE	-0.018(0.006) ***	-0.004(0.003)	23.888***	16.723***
FRAGMEN	4.060(1.530) ***	4.915(1.663)**	15.028***	11.974***
IRRIG	-0.012(0.007)*	-0.019(0.007)**	8.303**	6.944**
TIMEPLOT	-0.015(0.073)	-0.058(0.070)*	0.548	0.500
DISTMILL	0.026(0.021)	0.034(0.021)	3.453	3.365
EXTENSION	-0.474(0.546)	-1.156(0.608)*	3.863	3.585
CREDIT	0.193(0.477)	0.178(0.476)	0.244	0.243
PLAIN	-0.008(0.005)	-0.001(0.005)	2.854	2.731
KUTAHYA	3.767(1.015) ***	4.127(1.016)***	39.286***	26.662***
KASTAMONU	1.808(0.935) *	2.479(0.929) ***	14.251***	11.562***
MALATYA	3.480(1.036) ***	0.854(1.313)	16.342***	12.594***
KAVSERI	-14.489(0.766) ***	-15.627(0.800) ***	10.727***	0.001
ERZURUM	6.395(1.173) ***	3.540(1.349) ***	54.900***	34.798***
CONSTANT	-5.102(2.346) ***	-3.849(1.814)***	NA	NA

Measures of goodness-of-fit for MNL model of wheat variety choice	
Number of observations	385
Log-likelihood value	-199.106
LR χ^2 (42)	336.185
Prob.> χ^2 (42)	0.000
McFadden's Pseudo R^2	0.458
Percent correctly predicted	
MV only	88.44
LV only	66.00
Both MV and LV	56.67
Overall correct prediction	77.66

Note: The dependent variable is discrete multiple choice variable which is wheat variety choice (0=MV only, 1= LV only, and 2=Both MV and LV only) and modern variety only is the base omitted in the MNLM estimation. Robust standard errors are given in parenthesis. [1]Indicates the null hypothesis for choice specific coefficient test is that the β value which is not significantly different from zero for a given choice. [2] indicates that the null hypothesis for joint test of βs is that all the coefficients of a given independent variable for different choices are not jointly significantly different from Zero, respectively. ***, **, and * indicate statistical significance at 1%, 5% and 10% level, respectively. The NA indicates the test is not applicable to the constant.

The violation of IIA assumption was tested using Hausman and McFadden test and the results are given in Appendix 2. The test did not reject the null hypothesis that the odds ratio for a given pair of variety choice alternatives is independent of other alternatives. The results of Wald and LR tests for combining wheat variety choices are given in Appendix 3. The null hypothesis for the Wald and LR tests for combining wheat variety choices is that all the coefficients except intercepts associated with a given pair of choice are 0 (i.e., the variety choices can be combined). The tests indicate that the various wheat choices were distinct and there was no need for collapsing the choices in order to obtain efficient parameter estimates. In other words, the farm households differentiate among alternative wheat variety choices.

The diagnostics for collinearity among the independent variables using the variance inflation factor (VIF) also indicates that the collinearity among the independent variables was within the acceptable range (Appendix 4). The endogeneity is one of the problems affecting the reliability of the MNLM estimates if it exists. However, the limited data did not allow us to test for those potential endogeneity of some of the right-hand variables. In order to overcome this problem, we followed the strategy of estimating the model with and without the potential endogenous variable and examining its effect on the model and individual coefficients. We did not find any major concern. Thus, overall the different measures of goodness-of-fit and the diagnostics tests indicate that the multinomial logit model is quite satisfactory and is reliable in terms of drawing reliable conclusions about the factors influencing the household's adoption of wheat varieties in Turkey. Now, we turn to the discussion of the main findings.

The results of maximum likelihood estimates of multinomial logit regression coefficients are presented in Table 6. The household characteristics such as the education, age and farming experiences of household heads appear to have no significant effect on the household's choice of wheat varieties. Similarly, the effects of farm household characteristics like dependency ratio and number of car ownership on farm household's wheat variety choice was not statistically significant. However, variables which appeared to significantly influencing farm household's wheat variety choice were: household size, number of cattle owned, number of buildings on farm, farm size, farm fragmentation, percentage of irrigable farm plots, and the regional dummy variables. The effects of agro-ecotypes, average walking distance from house to farm plots, distance to the nearest mil, and access to credit and extension contacts on the farm household's choice of wheat variety was found to be not significant at 5%. The joint tests of the effect of a given independent variable across different choices were also confirm the significant effects of household size, number of cattle owned, farm size, farm fragmentation, percentage of irrigable plots and regional dummy variables on the farm household wheat variety choice.

The multinomial coefficient only shows whether a given explanatory variable is significant and does not show the magnitude and direction of the effect of the independent variables on the wheat variety choices. The maximum likelihood estimates of multinomial logit regression marginal effects for wheat variety choice model is given in Table 7. It was found that the household size had statistically significant negative effect on household choice of LVs only. This means as the household size increase the likelihood of choosing LV only relative to the MV only declines. This might be due to the fact that as the household size increase productivity and production from landrace might not be sufficient to meet family food consumption requirements. Therefore, they have to grow more productive modern varieties which allow more production.

It was observed that the number of cattle owned had statistically significant positive effect on-farm household's choice of landrace wheat varieties only. This means the increase in number of cattle owned increases the likelihood of farm household's choice of landrace wheat variety only relative to the reference choice of modern wheat varieties only. For example, a one unit increase in number of cattle appears to increase the probability of choosing landrace wheat varieties only relative to the modern wheat varieties only by about 0.8%. However, the effect of number of cattle owned on the choice of both modern and landrace wheat varieties relative to MV only was not statistically significant.

The number of on-farm buildings was negatively associated with landrace wheat variety only choice; a one unit increase in number of cattle decreases the likelihood of the farm households' choices of landrace wheat varieties only. This indicates that wealthy farm households are less likely to choose landrace wheat varieties only relative to the modern wheat varieties choice. However, the number of farm buildings did not have statistically significant effect on the farm household's choice of both modern and landrace wheat varieties.

The total farm size owned by the farm household was found to have negative and significant influence on the choice of landrace variety only relative to MV only. For example, if the farm size increases by one unit the farm household's likelihood of choosing landrace wheat variety relative to modern wheat varieties only decreases by 0.2%. Thus, as the farm size increases, the likelihood of adopting modern wheat varieties increases.

The effects of farm land fragmentation on the landrace wheat variety only and both modern and landrace wheat varieties were positive but significant only for LVs only. As the land fragmentation increases the likelihood of choosing landrace wheat varieties only increases relative to MVs only. The increase in land fragmentation increases the likelihood of not adopting improved wheat varieties. The percentage of irrigable farm plot had negative and significant effect on the choice of both modern and landrace wheat varieties relative to modern wheat varieties only. However, the effect of percentage irrigable farm plots on the choice of landrace wheat varieties only was statistically not significant.

The effect of time taken from farm house to farm plot on the farm household choice of landrace wheat varieties only relative to modern wheat varieties was not significant. However, it had negative and significant effect on the farm household choice of both modern and landrace wheat varieties. The distance to the nearest mill had no significant effect on the farm household's choice of wheat varieties. Surprisingly, the effects of extension contacts and access to credit were found to be not significant on farm household's choice of wheat varieties. The effects of regional variations as captured by province dummy variables were significant.

4.2.3 Determinants of spatial diversity of wheat varieties

The results of Tobit regression model estimates of the determinants of on-farm spatial diversity of wheat varieties using different diversity indices are given in Tables 8, 9 and 10. The coefficients of Tobit model estimation are given in columns two to five of these tables. These coefficients indicate the effects of independent variables on household on-farm spatial diversity of wheat which can be directly interpreted in similar way to the ordinary least square (OLS) coefficient estimates. The model chi-square for Tobit model regression indicates that the overall goodness-of-fit of the Tobit model were statistically significant at a probability of less than 1% in all cases for modern wheat varieties, in three of four cases for landrace wheat varieties and in three of the four cases for both modern and landrace wheat varieties. This indicates that jointly the variables included in the Tobit model explain the variations in the household's on-farm spatial diversity of modern wheat varieties, landrace varieties and both modern and landrace wheat varieties. Some of the variables which are assumed to affect the wheat variety choice are removed from the diversity regression. These variables include: the number of building owned, dummy for household car ownership, walking distance from house to plot, distance from home to the nearest mill and dummy variable for household extension contacts.

Table 7. Maximum likelihood estimates of marginal effects for multinomial logit regression model for farmers' wheat variety choice.

Variable	Marginal Effect (dy/dx)	
	Landrace wheat varieties only	Both modern and landrace wheat varieties
EDUC	-0.003(0.009)	0.001(0.007)
AGE	-0.000(0.002)	0.002(0.002)
FEXPERIENCE	0.002(0.002)	-0.001(0.002)
HSIZE	-0.020(0.008)**	-0.001(0.007)
DPENDRATIO	0.000(0.000)	-0.000(0.000)
CATTLE	0.008(0.002)***	0.001(0.002)
BUILDNO	-0.019(0.017)	0.009(0.018)
CAR	0.002(0.052)	0.056(0.039)
FSIZE	-0.002(0.001)***	-0.000(0.000)
FRAGMEN	0.252(0.140)**	0.208(0.143)
IRRIG	0.001(0.001)	-0.001(0.001)**
TIMEPLOT	0.003(0.006)	-001(0.006)**
DISTMILL	-0.001(0.002)	0.002(0.002)
EXTENSION	-0.004(0.040)	-0.087(0.052)
CREDIT	0.012(0.042)	0.009(0.039)
PLAIN	0.001(0.001)	0.000(0.001)
KUTAHYA	0.209(0.078) ***	0.393(0.087)***
KASTAMONU	0.080(0.049)	0.222(0.064) ***
MALATYA	0.369(0.076) ***	-0.003(0.054)
KAVSERI	-0.051(0.032)	-0.051(0.034)
ERZURUM	0.684(0.084)***	0.053(0.074)

Note: ***, **, and * indicate statistical significance at 1%, 5% and 10% level, respectively. Modern variety only was the reference wheat variety choice. Robust standard errors are given in parenthesis.

Table 8. Estimates of Tobit regression coefficients for on-farm spatial diversity of modern wheat varieties.

Explanatory variable	Tobit coefficients			
	Margalef Index	Berger-Parker Index	Shannon-Weiner Index	Simpson Index
EDUC	0.005(0.019)	-0.027(0.047) ***	-0.018(0.025)	-0.016(0.011) ***
AGE	-0.001(0.004)	0.001(0.011)	0.001(0.005)	-0.000(0.002)
FEXPERIENCE	0.002(0.004)	0.001(0.011)	0.001(0.005)	0.000(0.002)
HSIZE	0.007(0.013)	0.039(0.049)	0.004(0.022)	-0.004(0.010)
DPENDRATIO	-0.001(0.001) *	-0.001(0.002)	0.000(0.001)	-0.000(0.000)
CATTLE	-0.008(0.005) *	-0.021(0.013)	-0.006(0.006)	-0.001(0.002)
FSIZE	0.000(0.000)	0.002(0.001) ***	0.001(0.000) ***	0.000(0.000) ***
FRAGMEN	1.477(0.433) ***	9.645(1.026) ***	4.757(0.470) ***	1.926(0.204) ***
IRRIG	-0.001(0.001)	-0.002(0.002)	-0.001(0.001)	-0.001(0.000)
CREDIT	-.090(0.082)	0.524(0.204) **	0.231(0.100) **	0.099(0.041) **
PLAIN	0.001(0.001)	0.003(0.002)	0.002(0.001)	0.001(0.001)
PROVINCE	0.201(0.098) **	0.863(0.240) ***	0.391(0.129) ***	0.166(0.059) ***
MILLS RATIO	-0.038(0.094)	-0.044(0.221)	-0.171(0.133)	-0.096(0.063)
CONSTANT	-1.441(0.421)	-5.923(0.987) ***	-3.026(0.478) ***	-0.971(0.203) ***
Measures of goodness-of-fit for Tobit model				
Sigma (σ)	0.362(0.029)	1.174	0.589(0.039)	0.255(0.021)
No. of observations (N)	186	186	186	186
No. of uncensored observations	44	145	145	145
Goodness of fit (Pseudo R^2)	0.181	0.232	0.335	0.656
Log likelihood	-69.92	-251.650	-157.428	-40.688
Model Chi-square	31.062***	152.610***	158.528***	155.241***

Note: † The figures in parenthesis are robust standard error estimates. ***, **, and * indicate statistical significance at 1%, 5% and 10% level, respectively.

Table 9. Estimates of Tobit regression coefficients for on-farm spatial diversity of landrace wheat varieties.

	Tobit coefficients			
Explanatory variable	**Margalef Index**	**Berger-Parker Index**	**Shannon-Weiner Index**	**Simpson Index**
EDUC	-0.231(0.093) **	0.019(0.059)***	-0.003(0.030) ***	0.000(0.016) ***
AGE	-0.004(0.031)	-0.017(0.015)	-0.004(0.007)	-0.002(0.003)
FEXPERIENCE	0.078(0.049)	0.018(0.012)	0.008(0.006)	0.003(0.003)
HSIZE	0.052(0.040)	0.109(0.054) **	0.035(0.024)	0.013(0.011)
DPENDRATIO	0.012(0.004) ***	-0.001(0.001)	-0.000(0.001)	-0.000(0.000)
CATTLE	0.107(0.038) ***	-0.005(0.010)	-0.002(0.006)	-0.002(0.003)
FSIZE	-0.008(0.003) **	0.001(0.003)	0.002(0.001)	0.001(0.001)
FRAGMEN	11.266(6.273) *	8.049(1.523) ***	4.135(0.686) ***	1.967(0.321) ***
IRRIG	-0.050(0.021) **	-0.014(0.003) ***	-0.008(0.002) ***	-0.004(0.001) ***
CREDIT	-1.125(0.541) **	-0.122(0.218)	-0.006(0.094)	0.017(0.041)
PLAIN	0.027(0.013) **	0.001(0.002)	0.001(0.001)	0.001(0.001)
PROVINCE	-1.684(0.544) **	0.164(0.368)	0.047(0.157)	0.000(0.070)
MILLS RATIO	2.085(0.770) ***	0.119(0.310)	0.039(0.156)	-0.028(0.078)
CONSTANT	-15.280(6.944) **	-4.296(1.228) ***	-2.501(0.547) ***	-1.046(0.265) ***
Measures of goodness-of-fit for Tobit model				
Sigma (σ)	0.408(0.107)	0.864(0.092)	0.431(0.053)	0.207(0.030)
No. of observations (N)	100	100	100	100
No. of uncensored observations	5	77	77	77
Goodness of fit (Pseudo R^2)	0.592	0.320	0.495	0.907
Log likelihood	-8.056	-109.144	-59.110	-5.689
Model Chi-square	23.392	102.562***	115.915***	111.027***

Note: † The figures in parenthesis are robust standard error estimates. ***, **, and * indicate statistical significance at 1%, 5% and 10% level, respectively.

Table 10. Estimates of Tobit regression coefficients for on-farm spatial diversity of modern and landrace wheat varieties.

	Tobit coefficients			
Explanatory variable	**Margalef Index**	**Berger-Parker Index**	**Shannon-Weiner Index**	**Simpson Index**
EDUC	-0.006(0.007)	-0.028(0.094) ***	0.008(0.024) ***	0.006(0.007) ***
AGE	-0.001(0.003)	0.010(0.022)	-0.003(0.006)	-0.001(0.002)
FEXPERIENCE	0.001(0.002)	0.019(0.020)	0.007(0.005)	0.001(0.002)
HSIZE	0.009(0.010)	0.200(0.080) **	0.055(0.025) **	0.013(0.006)
DPENDRATIO	0.000(0.000)	-0.000(0.004)	-0.001(0.001)	-0.000(0.000)
CATTLE	-0.003(0.004)	0.005(0.045)	0.003(0.010)	0.001(0.002)
FSIZE	0.000(0.000)	0.001(0.005)	0.001(0.001)	0.000(0.000)
FRAGMEN	0.191(0.160)	8.962(2.046) ***	3.000(0.448) ***	1.101(0.142)
IRRIG	-0.001(0.001)	-0.013(0.10)	-0.004(0.003)	-0.002(0.002)
CREDIT	0.019(0.047)	0.389(0.496)	0.278(0.116) **	0.052(0.026)
PLAIN	0.001(0.001)	0.000(0.005)	0.003(0.001) *	0.001(0.000)
PROVINCE	0.122(0.078)	0.028(1.040)	0.135(0.280)	0.049(0.083)
MILLS RATIO	0.003(0.078)	-0.081(0.944)	-0.111(0.233)	-0.023(0.066)
CONSTANT	0.099(0.305)	-6.267(3.655) *	-1.677(0.899) *	-0.386(0.267)
Measures of goodness-of-fit for Tobit model				
Sigma (σ)	0.141(0.013)	1.342(0.118)	0.363(0.028)	0.095(0.010)
No. of observations (N)	60	60	60	60
No. of uncensored observations	0	60	60	60
Goodness of fit (Pseudo R^2)	-0.245	0.124	0.509	-1.272
Log likelihood	32.464	-102.803	-24.338	56.041
Model Chi-square	12.790	29.012***	50.497***	62.744***

Note: † The figures in parenthesis are robust standard error estimates. ***, **, and * indicate statistical significance at 1%, 5% and 10% level, respectively.

4.2.4 Spatial diversity of modern wheat varieties

The results of Tobit regression model estimates of the determinants of on-farm spatial diversity of modern wheat varieties using different diversity indices are given in Table 8. The coefficient on Mill's ratio was not significant in all cases for modern wheat varieties only indicating that there was no sample selection problem. The effects of household head characteristics except education were found to be statistically not significant at a probability of less than 5%. The education of household had negative effect on wheat spatial diversity in three of four regressions and the effect was statistically significant in two of the cases. This indicates as the education of household head increases, the spatial diversity of modern wheat varieties decrease. They grew fewer modern wheat varieties. On the other hand, other variables like household size, dependence ratio, and number of cattle owned and percentage of plain plots also did not have statistically significant effect on the on-farm spatial diversity of modern wheat varieties at a probability of less than 5%.

However, it was observed that the farm size, land fragmentation, access to credit and regional variations were found to be the key variables explaining the variations in the household's on-farm spatial diversity of improved wheat varieties. The farm size was positively associated with on-farm diversity of improved wheat varieties in three of four regressions while land fragmentation is positively associated with diversity of improved varieties in all of the regressions. The effect of province was positive and statistically significant indicating regional variations in spatial diversity of improved wheat varieties. In general, it was observed that there was very strong and positive relationship between the variables farm size and land fragmentation and the spatial diversity of modern wheat varieties. The increase in farm size and land fragmentation increases the spatial diversity of modern wheat varieties.

4.2.5 Spatial diversity of landrace wheat varieties

The results of Tobit regression model estimates of the determinants of on-farm spatial diversity of landrace wheat varieties in Turkey are given in Table 9. The coefficient on Mill's ratio was significant only in one of the four cases for landrace wheat varieties indicating that there was no sample selection problem in most of the cases. The effect of selectivity bias was positive and significant for Margalef index which measures the on-farm genetic diversity based on the concept of richness. The effects of household head characteristics except education were found to be statistically not significant at a probability of less than 5%. However, the education of household had mixed effects on landrace wheat spatial diversity; its effect is negative in two cases and positive in two cases of the four cases. This indicates the increase in education of household head either increases or decreases the spatial diversity of landrace wheat varieties. The farm size was negatively associated with the Margalef index and its effect was statistically significant at 5% while the effect was positive for other indices but statistically not significant. The farm fragmentation was positively associated with on-farm diversity of landrace varieties in three of four regressions. The percentage of irrigable land was negatively associated with the spatial diversity of wheat varieties. The effects were statistically significant in all cases. The increase in land fragmentation increases the spatial diversity of landrace wheat varieties. This might indicate the fact that the productivity levels for landraces does not provide enough for the farmers to grow it under intensive input and management practices such as the use of irrigation water. The effect of province was positive and negative and statistically significant indicating regional variations in spatial diversity of landrace wheat varieties.

4.2.6 Spatial diversity of modern and landrace wheat varieties

The results of Tobit regression model estimates of the determinants of on-farm spatial diversity of modern and landrace wheat varieties in Turkey are given in Table 10. The coefficient on Mill's ratio was not significant in all cases indicating that there was no sample selection problem. The effects of household head characteristics except education were found to be statistically not significant at a probability of less than 5%. However, similar to the landrace wheat varieties, the education of household had mixed effects on spatial diversity of modern and landrace wheat varieties. Its effect was positive in two cases and negative in one case. On the other hand, other variables except household size, land fragmentation and access to credit did not have statistically significant effect on the on-farm spatial diversity of modern and landrace wheat varieties at a probability of less than 5%. The effect of household size was positive and statistically significant in two of four cases.

The land fragmentation was positively associated with diversity of improved and landrace varieties in all of the regressions and the effects were statistically significant in two of four cases. In general, all regressions, it is observed that there was very strong and positive relationship between land fragmentation and the spatial diversity of wheat varieties. The increase in land fragmentation increases the spatial diversity of wheat varieties.

5 Conclusion and implications

This paper makes a methodological contribution to on-farm spatial diversity analysis by applying the Heckman-Lee two-stage estimation procedure. By controlling for selectivity bias, this methodology allows to obtain unbiased and consistent estimates of the effects of various variables on on-farm spatial diversity. We have applied this method to investigate the factors influencing the wheat variety adoption and the determinants of the levels of on-farm spatial diversity of wheat varieties in Turkey. The analysis was based on cross-sectional survey data collected during May to July 1998 on 486 sample households in six provinces of Turkey. The results show that the single most important factor influencing the on-farm spatial diversity of wheat variety was farm fragmentation. Farm fragmentation was positively associated with on-farm spatial diversity of wheat varieties. This implies that wheat improvement strategies and polices that aim to reduce farm fragmentation may need to find a judicious balance between the advantages and disadvantages of farm fragmentation.
It was also observed that considerable spatial wheat genetic diversity was maintained on-farm at the household level, mainly through the simultaneous adoption of IVs and LVs. Growing of a combination of modern and landrace wheat varieties was observed to yield significantly higher level of spatial diversity of wheat genetic resources as compared to growing modern varieties alone or landrace varieties alone. This finding contradicts the conventional view held (the replacement hypothesis) that the replacement of landrace varieties by modern varieties was one of the main causes of crop genetic resource losses. The results suggest that the modern and landrace wheat varieties can coexist and could still support more spatial diversity of wheat genetic resources. This finding has significant implication for future extension, research and policy efforts for on-farm genetic conservation and utilization of wheat genetic resources in Turkey and elsewhere with similar situations and other centers of crop diversity. There is a need for government and private sector research and extension efforts to support both modern and landrace varieties, for example, in terms of seed supply, provision of extension and credit services and marketing support instead of just giving undue priority to popularization of modern varieties alone.

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Appendix 1 Spatial diversity indices

Commonly, crop species diversity information is captured qualitatively using a list of names of varieties grown. This is often considered inadequate to capture the full extent of species diversity over space and time. As a result, there are several non-parametric indices which are used to provide quantitative measures of species spatial diversity. The detailed discussion of conceptual and mathematical derivation of the various qualitative measures and indices used in measuring spatial and temporal diversity of crop genetic resources and their application is found in Smale et al (2003). The various indices are constructed in such as way to show diversity even though they are based different concepts: richness, dominance and evenness. The non-parametric measures of diversity used in measuring the spatial diversity of wheat varieties are derived based on the combination of all or some of the information on number of wheat varieties grown by farmers (*S*), proportion of wheat area under each wheat variety (p_i) and the total wheat area (*A*). For example, the Margalef Index of diversity is derived as follows:

(1) $MDI = (S-1)/\ln A$

The lower limit for Margalef Index is zero when the household grows only one variety. The Margalef Index of species diversity is based on species richness and it increases as the value of Margalef index increases. The Berger-Parker index is derived based on the concept of species dominance. It is given as:

(2) $BPDI = 1/p_{i\max}$

Where $P_{i\,max}$ is the maximum wheat area share occupied by any single wheat variety. The lower limit for Berger-Parker index is 1 when only one variety is grown by the household. From the formula, the spatial diversity increases with value of Berger-Parker Index.

Both the Simpson's Index and the Shannon-Wiener indices are derived based on species richness and species evenness information. For example, the Simpson's index of diversity is given as:

(3) $SDI = 1 - \sum_{i}^{s} (P_i)^2$

The Simpson's index ranges from 0 (lowest spatial diversity) to almost 1 (highest diversity). Thus, the spatial diversity increases with increase in the value of Simpson's index. Similarly, the Shannon-Wiener Index is also derived using the information about the number of wheat varieties grown and proportion of wheat area under each wheat variety and is given as:

(4) $SWDI = \sum_{i=1}^{s} (P_i)(\log\ p_i)$

As it can be seen from the formula, the value of *SWDI* is greater or equal to zero. The lower limit for *SWDI* is obtained when only one variety is grown. The *SWDI* measure also increases with the number of wheat varieties grown by the households and theoretically it can take larger values. In general, higher values of the various indices discussed represent greater species diversity.

Appendix 2 Hausman and McFadden tests for IIA assumptions for multinomial logit model (N=346)

Omitted variety choice	Hausman-McFadden Test		
	χ^2	$P>\chi^2$	Evidence
LV only	3.292	1.00	For H_0
Both MV and LV	0.000	1.00	For H_0

Note: H_0: Odds for a given pair are independent of other alternatives.

Appendix 3 Wald and LR tests for combining wheat variety choices (N=346)

Alternatives	Wald Test			LR Test		
	χ^2	$P>\chi^2$	Evidence	χ^2	$P>\chi^2$	Evidence
LV only ←→ Both MV and LV	49.262	0.00	For H_0	88.640	0.00	For H_0
LV only ←→ MV only	67.224	0.00	For H_0	223.910	0.00	For H_0
Bothe MV ←→ LV Vs. MV only	47.625	0.00	For H_0	131.083	0.00	For H_0

Note: H_0: All coefficients except intercepts associated with a given pair of alternatives are 0 (i.e., the alternatives can be combined).

Appendix 4 Diagnostics for collinearity among independent variables used in MNL model estimation

Variable	VIF	Square root of VIF	Tolerance	R-Squared
EDUC	1.29	1.14	0.776	0.224
AGE	3.14	1.77	0.318	0.681
HSIZE	1.14	1.07	0.879	0.121
FEXPERIENCE	2.99	1.73	0.334	0.666
DPENDRATIO	1.15	1.07	0.866	0.134
CATTLE	1.31	1.15	0.760	0.239
BUILDNO	1.17	1.08	0.853	0.147
CAR	1.20	1.10	0.830	0.170
FSIZE	1.32	1.15	0.760	0.240
FRAGMEN	1.21	1.10	0.829	0.171
IRRIG	1.47	1.21	0.682	0.318
TIMEPLOT	1.13	1.06	0.886	0.114
DISTMILL	1.72	1.31	0.582	0.418
EXTENSION	1.15	1.07	0.868	0.132
CREDIT	1.19	1.09	0.841	0.159
PLAIN	1.28	1.13	0.779	0.221

Note: The mean variance inflation factor (VIF) is 1.70. The rule of thumb is that the VIF greater than 10 indicates the level of collinearity is of concern. Tolerance or ($1-R^2$) tells what proportion of an x variable is independent of all other ***x*** variables.