Diversification Across Crops and Land in Small-Holder Agriculture in Ethiopia: The Case of Shewa Administrative Region[1]

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Abstract

The opportunities available for consumption smoothing can be expected to influence the ways in which rural households respond to income risks and thereby impact on the degree of diversification and adoption of risky activities. By assuming that diversification is a risk reduction mechanism, this paper deals with the diversification across crops and plots in Ethiopian small-holder agriculture. Specifically, the incidence and levels of land fragmentation and cereal crop diversification is analyzed in relation to the households' consumption security provided by liquid asset stocks (livestock). It is hypothesized that more endowments, specifically in terms of livestock assets will lead to less diversification (more specialization). A four year rotating panel data from the "Rural Integrated Household Survey Program" of the Ethiopian Central Statistical Authority (CSA) collected during 1988 to 1991 in Shewa, Ethiopia is employed. Contrary to the expectation of a safer strategy, land fragmentation was found to have a positive relationship with the level of asset ownership (though insignificant) and land holdings. This result, coupled with the positive relationship between population density and fragmentation, and the absence of land markets in rural Ethiopia, suggests that farmers were supply constrained. When the rural population is growing faster than the number of off-farm jobs, agriculture is the only career option for many. As more people try to make a living from a limited land base, pressure to divide and sub-divide farms and fields will increase. This calls for measures to ease barriers to land transactions which may then induce greater consolidation of plots thereby setting in motion a wide range of social and economic benefits. It also calls for enhancing the attempts being made to facilitate the introduction of appropriate technology, to create off-farm employment, and to curb

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population growth. On the other hand, it was found that, apart from climatic and agronomic factors, there is a systematic bias towards more crop diversification as the level of asset ownership and land holdings decline. Households with higher levels of livestock asset ownership and/or farm size have relatively lower levels of crop diversification. Thus, households with the ability to bear more risk (through their asset position) are found to have greater concentration on fewer cereal crops. The traditionally developed strategy of closely integrating crop and livestock enterprises to buffer against uncertainty in peasant agriculture is under threat due to the ever expanding cultivation of crops into grazing land, feed shortages, and overgrazing of existing pasture. This limits the possibility of poorer households entering into livestock rearing and those who have already done so may be forced to give it up.

Keywords: Ethiopia, Smallholder agriculture, Risk response, Liquid assets, Land fragmentation, Crop diversification

1. Introduction

Ethiopia, one of the poorest countries in the world with very low per capita income (100 USD per annum in 2003) and high population growth rate (2.7 percent in 2003), has an enormous food and nutrition problems at its forefront. Agriculture is the main economic activity contributing about 45 percent of GDP with some 80 percent of the population earning a living directly or indirectly from it. The very low levels of agricultural growth and productivity coupled with the prevalent high population growth are, therefore, at the crux of the country's economic malaise. Among other things, the overwhelming dependence on rainfed agriculture, increasingly reduced access to land, declining farm size, and lack of basic infrastructure for intensive land use have undermined agricultural growth and productivity.

Since 1993, Ethiopia has embarked on a development strategy based on agricultural development-led industrialization (ADLI) which made agricultural growth central to overall economic development aimed at creating more favorable conditions for significant productivity improvements in the agricultural sector in general and small-holder agriculture in particular. The liberalization of the economy, the large increase in modern input availability, the drive to build rural roads and storage facilities have already created a favorable response from farmers in terms of increased productivity and marketed output.

Appropriate government economic policies and institutions are essential in creating a climate conducive to tackling the above mentioned problems. However, ultimately it is the response of peasant farmers to these policies which will make the difference. The basis of peasant households' decision-making should be a critical factor in the formulation of agricultural policy in developing countries. If farmers operate efficiently, implying that profits are maximized, then incomes can only be increased by introducing improved methods of production. On the other hand if farmers do not act efficiently, it may be desirable to reallocate resources within traditional agriculture. So far, knowledge about the behavior and choice of activities on small farms in Ethiopia, what governs these choices, their resource constraints and their potential for the overall development of agriculture is limited. Such information is not only indispensable for general assessment and improvement of the well-being of the low-income families, but it is also essential for designing efficient agricultural and rural development projects.

The objective of this paper is to analyse whether resource-induced risk aversion hampers crop specialisation and land consolidation, thus worsening the relative - and possibly absolute - income position of poorer households. Asset ownership, in terms of livestock, as an insurance mechanism in Ethiopian peasant economy is examined. By assuming that diversification is a risk reduction mechanism, the relation is tested between the degree of diversification across space and crops, and the level of endowments, particularly livestock ownership in Ethiopia's predominantly subsistence peasant households. Specifically, the incidence and levels of land fragmentation and cereal crop diversification is analyzed in relation to the households' consumption security provided by liquid asset stocks (livestock), controlling for the possible effects of idiosyncratic differences, the direct inputs available (land, oxen and family size), the experience of the household head (proxied in terms of age), and rainfall.

This paper is expected to contribute to the understanding of the behavior of small-holder rural households and the empirical analysis and results are expected to benefit the on-going discussions on Ethiopian rural land policy that have a critical bearing on economic development and poverty reduction. It also highlights the importance of livestock in Ethiopian agriculture not only through their direct benefits in providing milk, meat and draught power but also in influencing the production decision of farmers through their role of being a security and buffer if and when income shocks occur. In the absence of adequate credit and insurance markets this role is very essential in peasant agriculture. It is particularly important, at this juncture, to understand this role because of the ever increasing transformation of grazing land into crop cultivation. This means that it is only a small number of households with large landholdings which are able to keep livestock, thereby concentrating innovative activities to these households. Without proper policies and adequate credit facilities this may result in the development of poverty traps with permanently low incomes for the majority of rural households.

The analysis in this paper is based on agricultural household survey data for the years 1988-1991during which interventionist policies were in operation. The centrally planned policy environment within which the farmers were operating is no longer functional due to the change in government in 1991. The liberalization of the economy and the emphasis in agricultural growth since the current Ethiopian Government took power is having some positive impact on the resources available to peasant households, hence affecting the activity choices they make. However, the predominantly subsistence nature of the Ethiopian peasant sector, with limited participation in the market, and the overwhelming dependence on livestock as both productive input and store of wealth implies that, despite the data being relatively old, results and conclusions from this study have contemporary policy implications.

2. Literature review[3]

Economic theory rests on and takes as its starting point the assumption that each economic subject tries to maximize his individual gain, and that profit motivation governs the behavior of producers. Theoretical constructions based upon this assumption have been more successful in explaining the behavior of the non-agricultural sector of economies than that of the agricultural. This is more so in backward economies like Ethiopia where risk looms large and factor and product markets are, at best, imperfect. Risk has long been recognized as an important feature of the environment facing the farmer. A decision is said to be risky when its precise outcome is not known at the time when the decision must be taken. In farm management, such decisions are pervasive and often inescapable. Crops are planted without perfect knowledge of the weather or markets, unpredictable economic and political events may occur, yet a decision must be taken. This situation is particularly burdensome to the peasant farmers who, with their rudimentary technology, are faced with non-existent or imperfect credit, insurance and other factor markets. In order to investigate the impact of risk on decision making, a distinction is usually made between: 1) farmers' attitudes towards risk taking, i.e. the possibility that they are unwilling to take risks and to invest in risky but profitable activities, causing an overall

[3] For an extended review and discussion see Stefan Dercon 2004, *Risk, Insurance, and Poverty: A Review.* In Stefan Dercon (ed.), *Insurance Against Poverty* Oxford University Press. And Marcel Fafchamps 1999, *Rural poverty, risk and development.* FAO Economic and Social Development Paper 144.

underinvestment in agricultural inputs and misallocation of resources and/or; 2) the farmers' inability to invest in risky activities because of limited risk-taking capacity, leading to an unequal distribution of benefits derived from profitable activities, such as new technology, among the rich and poor strata of rural households. The latter, known as farmers' behavior towards risk, is the subject of this paper.

The volatility of states of nature, particularly in predominantly rainfed subsistence agriculture, can result in fluctuations in the income process which in turn results in consumption fluctuations. Such income uncertainties results in considerable welfare costs and is particularly burdensome to peasant households in poor countries like Ethiopia who, with their rudimentary technology, are faced with non-existent or imperfect credit, insurance and other factor markets. The standard theoretical and empirical analysis of the cost of risk and instability (Newbery and Stiglitz 1981) assumes incomplete markets: credit and insurance markets are absent. Their absence can be explained by problems of asymmetric information between lender and borrower, causing incentive problems such as moral hazard and adverse selection, as well as by the covariance of risks in agricultural societies that limit the scope for risk trading. Similar problems limit the use of community-based informal insurance systems (Townsend 1994, Alderman and Paxson 1992).

In the absence of these markets, rural households devise strategies to cope with income uncertainty. A common strategy is to alter the income risk they face through diversifying their income sources and skewing the risk distribution by focusing on low-risk income sources. Risk-averse households are willing to trade lower incomes for lower variability of incomes. They can achieve lower variability in incomes in a variety of ways: by diversifying crops and plots, using traditional and familiar inputs, finding employment off-farm, and through migration to other rural areas, or to the town.

The extent to which a household might choose lower but less variable income activities depends on its preferences towards risk, on the technology available and its ability to smooth consumption, given a particular level of income. The opportunities available for consumption smoothing can be expected to influence the ways in which households respond to income risks and thereby impact on the degree of diversification and adoption of risky activities. Where households have adequate means of risk diffusion, risk averse attitudes are not necessarily translated into risk averse behavior in the choice of income earning activities. Empirical studies in India found that the wealth of the household increased the riskiness of the portfolio of activities to which productive assets were allocated (Rosenzweig and Binswanger 1993) and also that liquidity constraints affected the degree of diversification and the adoption of risky activities (Morduch 1990).

Diversification across crops and fields probably represents the single most important weapon in the farmer's management arsenal to combat crop income instability (Walker et al 1983). Crop diversification is an important feature in the agricultural systems of less developed countries, where futures and insurance markets are not well developed. Small farms diversify to reduce costs associated with income variability. In this sense, crop diversification may be thought of as a form of portfolio management with the objective of minimizing income variation or of avoiding an absolute minimum income threshold. In this context, factors affecting the degree of crop diversity might include the farmer's wealth, the share of income which the farmer derives from crops as opposed to alternative sources of income, and access to consumption smoothing facilities such as insurance, or formal or informal credit facilities.

These traditional risk management actions are effective if they impart stability to net crop income and at the same time do not greatly reduce mean crop income. If diversification across land (land fragmentation) affords risk protection, then it will be privately more difficult and socially less desirable to enact consolidation reforms. Similarly, if crop diversification is effective there would be less incentive for farmers to participate in government-sponsored crop insurance programs.

Livestock is the traditional liquid store of wealth in highland Ethiopia. Many studies in Ethiopia have shown that the accumulation and depletion of livestock is mainly used in mitigating the consumption consequences of income fluctuations (Dessalegn 1987, Webb *et al*. 1992, Mohammed 1994, Dagnew 1994). Ninety five percent of the households in this study have mixed crop and livestock production. This is true for much of the highland parts of Ethiopia. The role of livestock is closely related to crop production and household consumption, providing draught power, milk and farmyard manure, supplementing crop income, and more importantly as a safety net for bad years.

It is important to note at this point that keeping livestock itself can also be risky. Disease, death, or thefts of animals are common. This may affect the role of livestock as a buffer, particularly if returns are covariate with crop income. However, the probability that these losses occur simultaneously with crop damage is not likely to be high or frequent except for extreme events such as drought and severe floods.

To summarize, it follows from the above discussion that income risk combined with credit constraints provide incentives for consumption smoothing through the use of liquid savings (livestock in this case). And it also follows that households with more livestock are willing to take more risks because of their ability to withstand the consequences of income shocks. The opportunities that are available for consumption smoothing can be expected to influence the ways in which households respond to income risk (Alderman and Paxon 1992). In short, liquidity constraints affect the degree of diversification and the adoption of risky activities. This study aims to test for the above proposition in the Ethiopian context. Livestock as a store of wealth are expected to encourage increased concentration and limit diversification.

Land fragmentation

Agricultural land fragmentation - also known as pulverization (Clout 1972), morcellment (de Vries 1974), parcellisation (Roche 1956) - is the type of land ownership pattern where "a single farm consists of numerous discrete parcels, often scattered over a wide area" (Binns 1950). In other words it exists when a number of non-contiguous plots (or "parcels") of land are farmed as a single production unit. The existence of fragmented landholdings is an important feature in less-developed agricultural systems. The alleged costs of fragmentation include increased traveling time between fields (hence higher transport costs for inputs and outputs), negative externalities (such as reduced scope for irrigation and soil conserving investments as well as the loss of land for boundaries and access routes), and greater potential for disputes between neighbors.

In Ethiopia, some empirical studies suggest that the level of fragmentation is quite high given the small size of land holdings (Fassil 1980, Yohannes 1989). In the years prior to the 1975 land reform, one of the root causes of fragmentation of agricultural land was inheritance. Often, land areas of different fertility levels or located in different villages were shared among brothers and sisters. It was also possible for a married couple to obtain inheritance of land from parents of both husband and wife. In the regions where tenancy prevailed, it was often imperative for a tenant to cultivate parcels of land wherever they were available.

The land reform in 1975 put an end to the transfer of land through sale, lease, inheritance (except to minors and widows), or other means. [4] There is no other way of acquiring it except through peasant associations. But there is evidence suggesting that the magnitude of fragmentation has increased since the land reform in 1975. As Dessalegn noted "plot consolidation was not a goal in many peasant associations, the goal rather was equality as conceived by peasants. The distribution of land and the

[4] A good deal of research was carried out on the land issue in Ethiopia. For a recent work and bibliography see Tesfaye Teklu 2003, *Rural Lands and Evolving Tenure Arrangements in Ethiopia: Issues, Evidence and Policies*. FSS Discussion Paper No. 10, Forum for Social Studies, Addis Ababa.

curtailment of the free movement of people due to the land reform accentuated the problem of subdivision and fragmentation" (Dessalegn 1984 P.31). Land distribution was made to accommodate the landless, newly married couples, and increase in family size. These have become the main causes of fragmentation since the land reform (Dessalegn, 1984; Fassil 1980, Mengistu 1986). The 1975 land reform program in Ethiopia gave the opportunity to the poor and underprivileged to acquire land. However, it also transferred all land to public ownership, prohibiting all forms of private ownership, thereby replacing landlords by the state. [5]

The factors affecting agricultural land fragmentation can be broadly classified into socio-cultural, economic (operational), physical and political (King and Burton, 1982). The socio-cultural factors include increasing population pressure, shortage of gainful non-farm employment, and inheritance institutions which lead to the division of the land property among heirs (Igbozurike, 1970). Other socio-cultural factors include competition between different land use interests, deterioration or lack of marketing opportunities (assuming the farmer was able and willing to raise a saleable surplus by working a larger area), and absence of an effective agricultural education and extension services (Igbozurike, 1970).

Natural and man made features such as broken topography, railroads, highways and irrigation channels contribute to agricultural land fragmentation. The operational factors include the switch from an extensive to intensive tillage. Land fragmentation is also accentuated by land distribution schemes, as was the case in Ethiopia in the study period, which take land from the large and average land owners and divide it out among the landless and small peasant producers.

The above explanations of the factors affecting land fragmentation can, more formally, be classified into two broad categories (McPherson 1982, Bently 1987). The first, consisting of what can be described as "supply-side" explanations, treats fragmentation as an exogenous imposition on farmers. The second views fragmentation as primarily a choice variable for farmers and can therefore be described as "demand-side" explanations. Supply-side explanations invariably conclude that fragmentation has adverse effects on agricultural production. Demand-side explanations presume that farmers will, given free choice, choose levels of

[5] The current constitution of the Federal Democratic Republic of Ethiopia (1995), guarantees free access of land to rural households who seek and are able to cultivate in their place of residence. Such access through the official channel is conditional on proof of permanent physical residence, ability to farm continuously, and meet administrative dues and obligations. Qualified farmers have open-ended usufruct rights to land. These use rights are inheritable but the constitution bars any other forms of land transfer including land rental.

fragmentation that are beneficial. Imperfections in factor or commodity markets play a key role in both types of arguments.

Supply-side explanations of land fragmentation

Several factors have been widely cited as causing or contributing to involuntary fragmentation. The most frequently cited are partible inheritance and population pressure resulting in land scarcity (Anthony *et al.* 1979, Binns 1950, Holmberg and Dobyns 1969, World Bank 1978). Many authors argue that partible inheritance logically leads to fragmentation when farmers desire to provide each of several heirs with land of similar quality. Likewise extreme land scarcity may lead to fragmentation as farmers in quest of additional land will tend to accept any available parcel of land within reasonable distance of their house (Farmer 1960).

As McCloskey (1975) points out, the above mentioned factors explain why a young farmer might begin with fragmented holding but they do not explain the persistence of fragmentation in the face of economic incentives for consolidation. Such persistence indicates significant imperfections in the land market and it is claimed that land markets themselves are highly fragmented, with few willing sellers (Lipton 1968, Sargent 1952). Dorner (1977) cites multiple interests over parcels as restricting the potential supply of land, because unanimous agreement to sell is difficult to achieve. McKinnon (1973) stresses incomplete credit markets and the resulting inability of many farmers to finance land acquisitions.

Another supply-side factor is the breakdown of common property systems under the pressure of population growth. This breakdown has led to increased fragmentation in, for example, Kenya (King 1977) and Eastern Nigeria (Udo 1965). Rapid population growth in South Asia has, through inheritance, caused decreasing farm size and more fragmentation (Singh 1979). A number of authors have demonstrated that fragmentation in certain areas is a consequence of egalitarian objectives on the part of the communal authority (Dahlman 1980, Georgescu-Roegen 1969, Grigg 1970, Quiggin 1988). State laws that restrict land transactions also limit possibilities for land consolidation. Finally, nature itself may limit the boundaries of arable parcels (for example, waterways and wastelands) so that expansion of farm size requires the acquisition of separate pieces of land.

The supply-side explanations, while plausible, are not sufficient to explain fragmentation in all the areas in which it is found. First, even where land markets afford farmers opportunities for consolidation, fragmentation persists (for example, Rwanda and Ghana [Blarel *et al.* 1992]). Second, fragmentation has developed in the absence of land scarcity (for example, in areas of

Kenya, Zambia, and The Gambia [McPherson 1982]). Third, ancestors continue to bestow heirs with scattered holdings, a practice that would seemingly be halted if fragmentation was largely detrimental (Douglass 1969, Leach 1968). The argument that partible inheritance is designed for equity reasons runs into difficulty when it is observed that subdivision and fragmentation levels are eventually "checked" after reaching specific levels (noted in India by Hopper 1965, in Mexico by Downing 1977, and in Sri Lanka by Leach 1968). These facts suggest that other factors may be important in explaining fragmentation.

Demand-side explanations of land fragmentation

Demand-side explanations presume that the private benefits of fragmentation exceed its private costs. That fragmentation might benefit farmers follows from the realization that land is not homogenous. Parcels differ with respect to soil type, water retention capability, slope, altitude, and agro-climatic location. Recognizing this, Buck (1964) and Johnson and Barlow (1954) were among the first to note that by operating parcels in different locations, farmers are able to reduce risk by reducing the variance of total output and hence final consumption. This is partly because the scattering of parcels reduces the risk of total loss from flood, drought, fire, and other perils and also because farmers can more efficiently diversify their cropping mixtures across different growing conditions.[6] Other risk-spreading mechanisms, such as insurance, storage, or credit, also reduce variations in household consumption. Therefore, fragmentation for risk reduction should persist only if these alternatives are either not available or are more costly (Charlesworth 1983, Fenoaltea 1976, Ilbery 1984, Walker et al. 1983).

Another explanation for fragmentation was developed by Fenoaltea (1976) for medieval England. He argued that because of transaction costs in labor markets, the scattering of parcels enabled farmers to better fulfill their seasonal labor requirements and consequently to obtain higher yields. If the labor market does not work at all, labor supply is fixed by household size, and the need for temporally spreading labor requirements is great. Even if labor markets exist, the costs of supervision may induce farmers to scatter parcels and supervise a small number of workers at a time, rather than watch over a large number of hired workers on a consolidated holding at peak periods. This approach is most effective when different types of land are suitable for different crops (hence, when fragmentation facilitates crop diversification)

[6] The realisation of these advantages may require that the fragmented farms are scattered over a wide area. Studies in several parts of Ethiopia have shown that more than a quarter of fragmented parcels lie at a distance of more than 5 km from the dwellings (Fassil 1980, Yibeltal 1994).

or when different parcels of land offer sufficient diversity in climatic conditions that the same crop can be staggered over a wider range of planting dates.

Commodity market failures may also cause fragmentation to have a positive impact on productivity. When such failures occur, a subsistence mode may be adopted in which several products are raised for household consumption, rather than purchased with the proceeds of crop sales. If different land types or eco-zones are suitable for cultivating different crops, then the required diversity can best be obtained from fragmented landholding (Netting 1972).

3. Empirical approach

3.1 The setting and the data

The area considered in this study is Shewa, in central Ethiopia, divided into five regions during the study period (1988-1991).[7] The cultivated area under food crops in Shewa, accounted for almost 23 percent of that of Ethiopia (CSA 1987) and on average, cereals accounted for more than 90 percent of total cultivated area under annual crops. *Teff*, maize, wheat, sorghum, barley, are the most important crops in the region. These five cereals accounted for over 80 percent of all crop area. Livestock is an important component of the region's agriculture with rural households maintaining a few heads of livestock along with their farming practices. In this system, livestock provides draught power for cultivation, a source of additional income and self insurance, and home consumption. Available reports on regional estimates of livestock in the mixed agricultural (excluding nomadic) areas show that Shewa province had the highest proportion of livestock of all categories. In all about 26 percent of cattle, 28 percent of sheep, 21 percent of goats, and 33 percent of beasts of burden were found in the province (CSA 1984).

The household data used for analysis in this study are from the Ethiopian Central Statistical Authority (CSA). The CSA launched the "Rural Integrated Household

[7] The regional divisions of Ethiopia underwent several changes. Until 1987 there were 14 provinces of which Shewa was one. In 1988, with the formation of the Peoples Democratic Republic of Ethiopia (PDRE) by the former Military Regime, the provinces were devolved into regions and autonomous regions but most of the sub-divisions within provinces were still intact. For example Shewa was divided into 5 regions (North Shewa, South Shewa, East Shewa, West Shewa and Central or Addis Ababa). Currently, with the formation of the Federal Democratic Republic of Ethiopia, the country is divided into nine ethnically-based administrative regions and 2 chartered cities. Hence, the former Shewa province is divided between four of these newly formed regions.

Survey Program" (RIHSP) in 1980 with the objective of conducting sample surveys on a wide range of subjects in rural areas. The major part of this survey was the integrated food and agricultural statistics, while as part of the program the Authority conducted monthly surveys of retail and producers' prices in the rural areas for both crops and livestock and produced quarterly average prices. More than 20,000 households across the country were interviewed every year. From each zone (*Awraja)* a number of Peasant Associations (PAs) were selected at random and used for several years). [8] In all some 860 PAs were included in the sample (of which 170 were in Shewa). In each PA 25 households were selected by simple random sampling to conduct the survey.

The rainfall data are from the National Meteorological Services Authority. The data are reported on a monthly basis and are available for major towns throughout the province. For each PA in this study, data from the nearest meteorological station are employed. The unavailability of data on the distribution of rainfall within a month, which could be crucial for agricultural production, and for each PA calls for some caution in interpreting the empirical results.

3.2 Econometric method used

Most of the panel data models are based on the assumption that each cross-sectional unit is observed for the same time periods. However, in the context of sampling survey data from a population of households, the assumption of observing each of them over the same period is unrealistic. An alternative to this is to use a 'rotating sample' scheme. Rotation of a sample of households over time may deliberately be pursued by the data-collecting agency because the agency can neither force nor persuade a randomly selected individual to report more than once or twice (depending on how time consuming the reporting is). Thus the main purpose of rotating is to reduce the degree of non-response. The rotation principle also improves the quality of data collected by maintaining the representativeness of the sample, especially when the structure of the population is continuously changing.

The structure of the sample selection of individuals in a rotating design is as follows: Let all individuals in the population be numbered consecutively. The sample in period 1 consists of N_1 individuals. In period 2, a fraction, $m_{e1}(\sum m_{e1} \sum N_1)$ of the sample in

[8] Farmers are organized in peasant associations (PAs) within an officially demarcated physical area that does not exceed 800-hectare. The PAs were the basis for administering land-use directives from the government, administering and conserving public property and settling land cases.

period 1 is replaced by m_{i2} new individuals from the population. Thus the sample size in period 2 is N_2=N_2-m_{e1}+m_{i2}. In period 3 another fraction of the sample in the previous period, m_{e2} individuals ($\sum m_{e2} \sum N_2$) are replaced by m_{i3} new individuals and so on. The procedure of dropping m_{et-1} individuals selected in the previous period and replacing them by m_{it} individuals from the population (in period t) is called a rotating sampling. The total number of observations and individuals observed are $\sum_{t=1} N_t$ and $N_1 + \sum_{t=2} m_{it}$, respectively.

The sampling design outlined above generates several special cases. Firstly, the completely overlapping sample (m_{it}=m_{et}=0) where the units are observed in every period (the regular panel data case). Secondly, partly overlapping sample ($\sum m_{it}, m_{et} \sum N_t$). Thirdly, the incomplete non-overlapping sample (m_{it}=m_{et}=N_t), where the units are observed only once and the whole sample is replaced after one period. The data used here are of the second type where it is a partly overlapping sample.

Statistical methods developed for analyzing complete panel data can be extended in a straightforward manner to analyze rotating samples if the error terms are assumed to be independently distributed across cross-sectional units (Biorn *et al.* 1982, Hsiao 1986, Kumbhakar 1992). Apart from the minor modifications, the estimation technique is basically of the same form as for the complete panel data (Baltaji 1995).[9] The econometric estimation was carried out using LIMDEP computer package (Greene 1991) which has developed special estimation programs for rotating or incomplete panel data sets (unbalanced panel data).

Panel data sets for economic research possess several major advantages over conventional cross-sectional or time-series data sets. They usually give a large number of data points, increasing the degrees of freedom and reducing the collinearity among explanatory variables - hence improving the efficiency of econometric estimates. The problem, when using panel data to estimate a relationship, is to specify a model that will adequately allow for differences in behavior over cross-sectional units as well as any differences in behavior over time for a given cross-sectional unit. One of the early uses of panel data in economics was in the context of estimating production functions where allowance had to be made for unobserved effects specific to each production unit. This is referred to as the 'fixed effects' model and is given by:

[9] Panel data estimation techniques and their extension to rotating or incomplete panel data sets are discussed in Hsiao (1986) and Baltaji (1995).

$$y_{it} = \alpha_i + \beta' X_{it} + U_{it} \qquad i = 1,2,\ldots,N \quad t = 1,2,\ldots,T \qquad \textbf{[3.1]}$$

Where y_{it} is the output and X_{it} the vectors of inputs for the i-th farm in the t-th period; α_i captures the farm specific unobserved inputs assumed to be constant over time, and U_{it} is the error term with mean zero, $E(U_{it}) = 0$, and constant variance, $E(U_{it}^2) = \sigma_u^2$.[10]

The next important step was the 'random effects' model where α_i in equation (3.1) are treated as random variables just like U_{it}. Denoting $\bar{y}_i = \frac{1}{T} \sum y_{it}$ and $\bar{y} = \frac{1}{N} \sum \bar{y}_i$ it is possible to decompose the total sum of squares $T_{yy} = \sum (y_{it} - \bar{y})^2$ into two components as:

$$T_{yy} = \sum (y_{it} - \bar{y})^2 = \sum (y_{it} - \bar{y}_i)^2 + \sum (\bar{y}_i - \bar{y})^2 = W_{yy} + B_{yy}$$

W_{yy} measures within group variation, and B_{yy} measures between group variation in y. Using similar decomposition for all the variances and covariances, it is possible to get the estimator of β from equation (3.1) as $\hat{\beta} = W_{xx}^{-1} W_{xy}$. This is known as the 'within group estimator'. Assuming $\alpha_i \approx \text{iid}(0, \sigma_\alpha^2)$ and $U_{it} \approx \text{iid}(0, \sigma^2)$, the generalized least squares estimator of β is found in the random effects model as:

$$\hat{\beta}_{GLS} = (W_{xx} + \theta B_{xx})^{-1} (W_{xy} + \theta B_{xy}) \qquad \textbf{[3.2]}$$

where $\theta = \sigma^2 / (\sigma^2 + T\sigma_\alpha^2)$.

This is the same as using the ordinary least squares estimation with the transformed data:

$$y_{it} - \lambda \bar{y}_i \quad \text{and} \quad X_{it} - \lambda \bar{X}_i \qquad \text{where} \quad \lambda = 1 - \sqrt{\theta} \qquad \textbf{[3.3]}$$

An inevitable question is, which should be used? From a purely practical standpoint, the fixed effects approach is costly in terms of degrees of freedom lost, and in a wide, longitudinal data set, the random effects model has some intuitive appeal. On the other hand, the fixed effects approach has one considerable virtue. There is no

[10] In LIMDEP parameters for fixed effects are estimated as follows: a) estimate β in (1) by regression of (y_{it} - $\bar{y}_{i.}$) on (X_{it} - $\bar{X}_{i.}$) (with no constant term), b) estimate α_i with $\bar{y}_i$ - b' $\bar{X}_i$. Estimates of the standard errors of a_is are obtained by : Est.Var[a_i] = s^2/T + ' $\bar{X}_{i.}$'Est.Var[b]' $\bar{X}_{i.}$. For rotating or incomplete data sets subscript t and T are replaced by t_i and T_i respectively, denoting the first and the last periods during which the i^{th} individual was observed.

justification for treating the individual effects as uncorrelated with the other regressors, as is assumed in the random effects model. The random effects treatment, therefore, may suffer from the inconsistency due to omitted variables (Green 1993). Furthermore, the fixed effects specification will control for the risk preferences of individual households.

The fixed effects specification was used in this paper after the Hauseman test rejected the random effects specification (under the null hypothesis that the random effects model is the correct specification, the hypothesis that the error term and the explanatory variables are uncorrelated was tested).

4. Descriptive statistics

4.1 Description of land fragmentation in the surveyed households

In measuring fragmentation, most researchers use, as proxies, the number of fields per household (Evenson and Binswanger 1984) or the number of fields per unit area (Bardhan 1973). Both of these measures are usually highly correlated with farm size. To measure fragmentation properly, one needs information on three attributes: 1) the number of non-contiguous fields in the holding, 2) the area of each field, and 3) the location of each field with reference to every other field in the same holding and to the village homestead (Walker and Ryan 1990).

Data are available on the first two attributes for the surveyed households. Information on the number of non-contiguous fields per holding and the size of each field can be readily combined into a land fragmentation index by relying on measures of economic concentration or statistical diversity. In measuring fragmentation, the land fragmentation index is primarily used in this study. It is defined as one minus the Simpson index of diversity (Patil and Taillie 1982). The index F is calculated for each household i for cropping year t and represents one minus the sum of the squared proportional area of each field:

$$F_{it} = 1 - \sum (W_{ijt})^2$$

Where W_{ijt} equals the proportional area of parcel j to gross cropped area planted by household i in year t. The index equals zero for a holding containing one field, approaches one for an extremely fragmented holding and, unlike the measures cited earlier, is independent of farm size (Walker and Ryan 1990).

***Farm size, livestock asset and fragmentation*[11]**

Farms in Shewa are small and often fragmented. There is, however, some variation in the average farm size between the regions of Shewa as shown in Table 4.1. The average size is smallest in South Shewa while largest in East Shewa. The fragmentation index is found to be positively and significantly correlated with farm size in all regions of Shewa, with the highest correlation in East Shewa (0.461), and the lowest in South Shewa (0.241). In all regions, a higher level of fragmentation is associated with lower average parcel sizes.

Table 4.1 Shewa: Fragmentation and characteristics of surveyed households (1988-1991)

Regions of Shewa	Population Density (person/ha)*	Mean				Number of Observation
		Farm Size (ha)	**Number of parcels**	**Fragmentation Index**	**House hold size**	
North	0.95	1.08	3.20	0.51	5.22	962
Central	0.94	1.63	3.16	0.52	5.44	1,311
West	1.18	1.27	2.74	0.43	5.41	1,250
South	2.40	0.80	2.05	0.37	5.75	1,564
East	0.87	1.80	3.30	0.50	5.40	1,282
All	**1.33**	**1.31**	**2.83**	**0.47**	**5.47**	**6,369**

*The population density is based on *Woreda* (district) level data

Table 4.2, below, indicates that about 50 percent of households in Shewa had less than one hectare, with an average of around 0.6 ha. Both the number of parcels and the fragmentation index suggest that fragmentation increases with farm size, the larger land holdings are the more fragmented they are.

[11] "Livestock Asset" represents the total monetary value of livestock (cattle, sheep, goats, donkeys, mules, horses and camels) owned by each household.

Table 4.2 Shewa: Farm size and levels of fragmentation in surveyed households (1988-1991)

Category of Farm Size	% of Households	Mean		
		Farm Size (ha)	Number of Parcels	Fragmentation Index
Small Farms (less than one ha)	48.2	0.56	2.08	0.37
Medium Farms (one to two ha)	32.3	1.43	3.11	0.53
Large Farms (greater than two ha)	19.5	2.93	4.22	0.60
All	**100.0**	**1.31**	**2.83**	**0.47**

The same is true for the different asset size categories as shown in Table 4.3. The average number of parcels and the fragmentation index steadily increase for the higher asset ownership category. The above results taken together indicate that the level of household endowments in terms of farm size and asset ownership, if at all, have a positive relationship with the level of fragmentation. This is contrary to the idea that fragmentation is demand driven in response to the risky environment within which they operate.

Table 4.3 Shewa: Livestock and fragmentation in surveyed households (1988-1991)

Category of Livestock Ownership	% of Households	Mean		
		Livestock Value (Birr)*	Number of Parcels	Fragmentation Index
Small Farms (less than 1000 Birr)	40.9	451	2.45	0.41
Medium Farms (1000 to 2000 Birr)	32.7	1,457	2.91	0.49
Large Farms (Greater than 2000 Birr)	26.4	3,085	3.32	0.52
All	**100.0**	**1,541**	**2.83**	**0.47**

* The official exchange rate of the Ethiopian currency "Birr" was fixed under the former military government at Birr 2.07:US $1. Following the change in government, the official rate was initially devalued in October 1992 and followed a gradual devaluation since. At the beginning of 2006 the rate stood at about Birr9: US$1.

Population density and fragmentation

Population growth generally leads to further land fragmentation in rural areas (Blarel *et al*. 1992). Based on the review in earlier sections, it can be expected that fragmentation in areas of low population density will be driven primarily by demand. Demand in these areas, while originating from imperfections in the credit, labor, or food markets, will depend on the extent of soil and agro-climatic diversity within the community and hence on the possibilities of diversifying into different crops. In regions where land is scarce, however, supply-side factors could also come into play, especially where land markets, as in Ethiopia, are almost non-existent to permit desired levels of farm consolidation. Other things being equal, it is expected that fragmentation is greater in more highly populated areas.

The data confirm a positive correlation between population density and the fragmentation index for most of the regions (North Shewa (0.28), Central Shewa (0.29), South Shewa (0.21), East Shewa (0.21)). West Shewa was the exception with a negative correlation of (-0.124). However, taken together, the population density for all observations in Shewa is positively correlated with fragmentation (0.14). A positive relation between population density and fragmentation together with the absence of land markets suggests that fragmentation is a supply constraint.

Table 4.4 Shewa: Percentage distribution of households by measures of fragmentation (1988-1991)

Measure	**Regions of Shewa**					
Fragmentation Index	North	Central	West	South	East	All
0.0-0.2	13.0	12.0	15.2	25.6	14.2	16.6
0.2-0.6	7.2	7.3	12.5	15.3	6.9	10.2
0.4-0.6	37.3	39.1	40.3	39.6	36.7	38.7
0.6-0.8	39.3	38.4	29.5	19.5	36.3	31.6
0.8-1.0	3.2	3.2	2.5	0.0	5.9	3.0
Mean*	0.51	0.52	0.43	0.37	0.50	0.47
Median*	0.57	0.58	0.49	0.44	0.58	0.50
Number of Parcels						
1	14.2	16.2	18.0	37.1	15.7	21.3
2-3	54.1	54.5	57.0	53.6	50.6	54.0
4-5	21.5	21.4	17.6	8.3	21.6	17.5
6-7	7.0	5.4	5.2	0.8	9.8	5.3
8 or more	3.2	2.3	2.4	0.1	2.4	1.8
Mean*	3.20	3.16	2.74	2.05	3.30	2.83
Median*	3.00	3.00	2.00	2.00	3.00	2.00
(Range)*	(1-18)	(1-16)	(1-16)	(1-11)	(1-17)	(1-14)

*Expressed in relevant units, not percentages.

However, the evidence reported in Table 4.1 and Table 4.4 indicates that farm holdings in West Shewa and South Shewa are the least fragmented while densely populated. The median number of parcels is 2.0 each, and the median value of the fragmentation index is 0.49 and 0.44 respectively. On the other hand, Table 4.1 shows that the average *Woreda* population density of these two regions is 1.18 and 2.4 persons per hectare, respectively, showing that they are the most densely populated regions of Shewa. Furthermore, Table 4.4 shows that more than 37 percent of farmers in South Shewa operate only one parcel, while 90.7 percent operate three or fewer parcels. The fragmentation index is correspondingly low.

If farm fragmentation in the highly populated regions is not purely driven by supply, then its prevalence may not reduce average productivity of land. Moreover, the effect on productivity will depend on the degree of heterogeneity in soil and agro-climatic conditions, and hence the possibilities for efficient crop diversification or the staggering of labor tasks.

4.2 Description of crop diversification in the surveyed households

The concept of crop diversity is illusory because it incorporates two distinct ideas. First, crop diversity is assumed to increase with the number of different crops. In the case of Ethiopia, farms may be expected to have large number of different crops, particularly in the homestead gardens. However, a second concept relates to the relative importance of each crop in production. A more diversified farm is one which does not depend too heavily on any single crop.

The measure of crop diversification which evaluates the number of crops produced and the evenness of production share across crops is entitled the *diversification index (C).* This index is similar to the fragmentation index used in the previous section, except in this case area under each crop is used as the numerator. It is defined as:

$$C = 1 - \sum ((a_i)^2/A^2)$$

where a_i = area devoted to a particular crop in a given year, and
A = total annual cultivated area (equal to the sum of all cropped areas in each season).

The diversification index varies between zero and one, with more diverse farms approaching one. Thus, for example, a farmer who produces only one crop would have an index value of zero, while the index of a farmer with an infinite number of crops, each covering the same area, would have an index value of one.

The average number of crops and level of diversification in all the regions of Shewa had a more or less similar pattern, ranging from 2.06 and 0.38 in Central Shewa to 2.75 and 0.45 in West Shewa respectively (Table 4.5). The reported correlation coefficients between crop diversification and fragmentation in Table 4.5 are all significant at the 1 percent level of significance. This may indicate that different parcels have different land types (slopes) or quality which are suitable for cultivating different crops. In particular, a household with more spatially separated fragments is more likely to have a higher level of diversification than a household with fewer parcels of land.

Table 4.5 Shewa: Percentage distribution of households by levels of crop diversification (1988-1991)

Measure	Regions of Shewa					All
Crop Diversification Index	North	Central	West	South	East	
0.0-0.2	17.5	19.8	11.8	14.0	15.1	15.5
0.2-0.6	11.4	8.2	8.7	10.8	11.4	10.1
0.4-0.6	56.4	57.0	55.3	51.6	55.8	55.0
0.6-0.8	13.6	14.4	22.2	22.7	17.0	18.4
0.8-1.0	1.0	0.5	2.1	0.9	0.7	1.0
Mean*	0.40	0.38	0.45	0.43	0.41	0.41
Median*	0.42	0.42	0.43	0.42	0.44	0.42
Number of Crops						
1	17.4	22.1	13.3	14.5	14.7	16.3
2-3	79.2	74.2	68.3	74.8	76.7	74.5
4-5	3.2	3.6	12.6	10.5	8.7	8.1
6 or more	0.0	0.0	5.8	0.2	0.0	1.0
Mean*	2.16	2.06	2.75	2.33	2.31	2.33
Median*	2.00	2.00	2.36	2.36	2.00	2.36
(Range)*	(1-4)	(1-5)	(1-8)	(1-6)	(1-5)	(1-8)
Correlation between Crop Diversification and Fragmentation	**0.49**	**0.39**	**0.37**	**0.45**	**0.53**	**0.41**

*Expressed in relevant units, not percentages.

Farm size, livestock asset ownership and crop diversification

Table 4.6 documents the percentage of households, number of crops and crop diversification index by farm size. The results suggest that both the number of crops and the index increase with increasing farm size though at a decreasing rate.

Table 4.6 Shewa: Farm size and levels of crop diversification (1988-1991)

Category of Farm Size	% of Households	Mean		
		Farm Size (ha)	Number of Crops	Crop Diversification Index
Small Farms (less than one ha)	48.2	0.56	2.07	0.37
Medium Farms (one to two ha)	32.3	1.43	2.51	0.46
Large Farms (greater than two ha)	19.5	2.93	2.75	0.49
All	**100.0**	**1.31**	**2.33**	**0.41**

On the other hand, in Table 4.7, the diversification index suggests that diversity declines after a certain level of livestock ownership. This result indicates that the share of area devoted to multiple crops is less evenly distributed at the higher level of ownership of livestock assets than at the lower ones. An explanation of this could be that farmers with a large enough asset ownership are more likely to grow some crops for the market, devoting more land to them, because they are less constrained by subsistence needs.

Table 4.7 Shewa: Livestock asset and crop diversification (1998-1991)

Category (Livestock Value)	% of Households	Mean		
		Livestock Value (Birr)	Number of Crops	Crop Diversification Index
Small Farms (less than 1000 Birr)	40.9	451	2.16	0.45
Medium Farms (1000 to 2000 Birr)	32.7	1,457	2.42	0.49
Large Farms (Greater than 2000 Birr)	26.4	3,085	2.43	0.38
All	**100.0**	**1,541**	**2.33**	**0.41**

5. Discussion of results

The estimating equations for land fragmentation and crop diversification are given below. For land fragmentation, the following linear fixed effects equation was used:[12]

[12] Logarithmic and semi-logarithmic type of functions were also estimated but the linear type was chosen because it had a better fit and all of the coefficients were more significant.

$F_{it} = b_0 + b_1 FARMSIZE_{it} + b_2 OXEN_{it} + b_3 ASSET_{it} + b_4 AGE_{it} + b_5 HHSIZE_{it} + b_6 POPDEN_{kt} + \mathbf{b}_7 V_i + \mathbf{b}_8 T_t + e_{it}$ **[5.1]**

where F_{it} is either the number of parcels or the fragmentation index of household i in year t; FARMSIZE is total farm size owned by a household (in hectares); OXEN is the number of oxen owned by a household; ASSET is the monetary value of livestock owned by each household (in '000 Birr); AGE is age of the household head; HHSIZE is the number of household members; POPDEN is population density for *Woreda* k in year t; V_i is a binary variable for each individual i; T_t is a binary variable for each year t; b_0 – b_6 are parameters and $\mathbf{b}_7$ and $\mathbf{b}_8$ are vectors of parameters to be estimated; and e_{it} is an error term.

Similarly, the determinants of crop diversification could be extended from the formulation given above. The main difference is the inclusion of the fragmentation index and the amount of sowing season rainfall as explanatory variables, and the exclusion of population density in the crop diversification equation. The inclusion of the fragmentation index is because the characteristics of different parcels may give rise to the cultivation of different crops. This gives rise to the problem of endogeniety because both crop diversification and land fragmentation are determined by the same household and village level variables. Therefore, the fitted value of fragmentation ($\hat{F}$) is used in the crop diversification equation which is given below:[13]

$C_{it} = b_0 + b_1 FARMSIZE_{it} + b_2 OXEN_{it} + b_3 ASSET_{it} + b_4 AGE_{it} + b_5 HHSIZE_{it} + b_6 RF_{rt} + b_7 \hat{F}_{it} + \mathbf{b}_8 V_i + \mathbf{b}_9 T_t + e_{it}$ **[5.2]**

where C_{it} is either the number of crops or the diversification index of household i in year t; RF_{rt} is the amount of sowing season rainfall for *Woreda* r in year t; $\hat{F}_{it}$ is the fitted value of the fragmentation index. All others are defined above.

5.1 Explanatory variables and expected relationships:

- Farm size is the total operated area belonging to a household. It is one of the major factors differentiating households in terms of production. It is expected that households with larger farms are less diversified and specializing in limited

[13] The exclusion of population density was necessitated because the inclusion of the fitted value of fragmentation captures the effect of population pressure on crop diversity. The fitted value was derived without population density.

number of crops because of their ability to produce more than the families' needs which they can exchange for the products they did not produce.

- Oxen are the main source of traction power and therefore a significant input in agricultural production. This variable captures the technological differences that exist between the households. Therefore, households with more oxen are expected to have less diversified pattern of production.
- The asset variable is the monetary value (in thousand Birr) of all livestock owned by a household. This variable captures the insurance available to a household. Households with more asset value are expected to be less diversified because of their ability to absorb negative shocks if and when bad harvests are encountered.
- Family size is the total number of household members. It proxies the amount of labor available to a household. Due to lack of data no attempt was made to distinguish the consumer units from the work units. This creates a problem on the expected relationship between family size and diversification. If the dependency ratio is high, more food crops for household consumption are likely to dominate. And if the adult ratio is high, certain high value crops are likely to dominate.
- Age of the household head can be seen as a proxy for the experience and familiarity with some cultivation techniques. Older household heads are expected to be more conservative and risk averse. This means that age is expected to have a positive relationship with diversification.
- Population density is calculated at the *Woreda* level and proxies the pressure on land. It is expected that higher population density will encourage the sub-division of land and hence fragmentation.
- The amount of the sowing season rainfall is derived by simply adding the amount of rainfall for the months of April-July. These months encompass the sowing season for the different crops. One limitation of the rainfall variable is the lack of the rainfall distribution within a month. The rainfall distribution is important because most farmers change the land allocation to the different crops throughout the sowing season depending on the amount and distribution of rainfall. In any case, a higher amount of rainfall is expected to reduce the level of crop diversification because it means less risk.

5.2 Econometric results

Table 5.8 below presents the regression results for the fragmentation index and the number of parcels. The variation in fragmentation explained by the variables taken together is significant, as indicated by the F-statistics. However, none of the equations is very successful in explaining fragmentation by either measure as indicated by adjusted R-squared of 0.16 and 0.19 (fixed effects) for the fragmentation index and the number of parcels respectively.

Although this is not uncommon for cross-section/panel data, the fixed effects specification did not improve much of the results indicating that unobserved household variables have little influence on the level of fragmentation. An example of such variables are managerial ability and risk preferences in a household. However, the joint significance test rejected the null hypothesis that the intercepts are homogeneous, thus rejecting the specification without fixed effects.

Table 5.8 Shewa: Determinants of land fragmentation (1988-1991)

Explanatory Variables	Dependent Variable			
	Fragmentation Index		Number of Parcels	
	without fixed effects	with fixed effects	without fixed effects	with fixed effects
FarmSize	0.09 (10.37)***	0.10 (8.21)***	0.18 (12.37)***	0.21 (11.89)***
Oxen	0.01 (1.41)	0.01 (1.37)	0.08 (1.47)	0.05 (1.21)
Livestock Asset	0.001 (0.98)	0.001 (1.28)	0.01 (1.08)	0.02 (1.56)
Age	- 0.004 (2.26)**	- 0.001 (3.39)***	- 0.003 (2.97)***	- 0.006 (5.23)***
Household Size	0.007 (1.85)*	0.005 (1.63)*	0.01 (1.69)*	0.03 (1.71)*
Population Density	0.07 (2.43)**	0.08 (3.39)***	0.15 (2.33)**	0.17 (4.68)***
T_2		-0.001 (0.23)		-0.02 (0.56)
T_3		0.002 (1.02)		0.01 (1.34)
T_4		0.001 (0.29)		0.01 (0.43)
Constant	0.34 (19.17)***	0.29 (10.13)***	1.99 (24.96)***	1.51 (9.28)***
AdjustedR^2	0.12	0.16	0.11	0.19
F-statistic	134.49***	156.98***	165.93***	172.14***
Joint-F Test	7.89***		9.45***	
N	6,369	6,369	6,369	6,369

Note: Figures in parentheses are t-statistics.
*** Significant at 1 percent ** significant at 5 percent * Significant at 10 percent
N = Number of observations

All considered variables, except for the age of the household head, have positive relationships with the level of fragmentation. The coefficients for farm size and population density are positive and statistically significant while for age it is negative and statistically significant. Population pressure is seen to be one of the main factors exacerbating fragmentation. On the other hand as farmers get older they tend to have less fragmented land which may indicate that their land is redistributed to new households or that younger farmers had no option but to accept more fragmented holdings. Household size is also significant (at 10 percent). This may indicate the relatively larger allocation of land (though fragmented) to larger families by the peasant associations. The other variables (oxen, and assets), though positive, are statistically insignificant. The time dummies are also insignificant indicating that the level of fragmentation did not change much in the years considered.

The positive significant effect related to farm size is unexpected as far as fragmentation is considered to be a risk management strategy and hence a choice variable. This result coupled with the insignificant effect of assets on the level of fragmentation indicates that households are supply constrained and have no control on the level of fragmentation they would like to have. The land holding and distribution pattern that was practiced during the study period may explain this result. Land was distributed in such a way that takes the different land types and qualities, in a peasant association, into consideration. This means that larger farm sizes can only be attained through additional parcels of land.

Table 5.9 presents the regression results for crop diversification. The introduction of fixed effects substantially raised the explanatory power of both equations (the adjusted R^2 rose to o.47 for the crop index and 0.38 for the number of crops equations). The joint-F test also rejected the homogeneity of the intrecept term. Most included variables are statistically significant and their level of significance rose with the fixed effects specification.

Significant positive effects can be observed on household size, and fragmentation for the crop index equation, while farm size is also positive and significant for the number of crops equation.[14] On the other hand, significant negative effects are observed for

[14] For comparison both equations were estimated without the fragmentation index as an explanatory variable. In both cases farm size became positive and significant, while assets became positive but not significant. The inclusion of the fragmentation index controls for cultivating different crops on different parcels of land due to differences of, say, soil quality.

farm size, number of oxen and the level of assets. The variables related to the age of the household head and amount of rainfall are not significant. However, as may be expected, the rainfall variable has negative effect on diversification.

Table 5.9 Shewa: Determinants of crop diversification (1988-1991)

Explanatory Variables	Dependent Variable			
	Crop Index		Number of Crops	
	without fixed effects	with fixed effects	without fixed effects	with fixed effects
Farm Size	-0.02	-0.01	0.21	0.25
	(2.61)**	(2.85)***	(3.72)***	(3.83)***
Oxen	-0.03	-0.02	-0.05	-0.05
	(3.88)***	(3.71)***	(2.15)**	(2.11)**
Livestock Asset	-0.05	-0.07	-0.02	-0.01
	(3.05)***	(3.22)***	(3.34)***	(3.58)***
Age	0.001	0.001	0.002	0.003
	(0.80)	(0.96)	(1.06)	(1.09)
Household Size	0.006	0.005	0.02	0.03
	(5.40)***	(5.02)***	(1.69)***	(3.78)***
Fragmentation	0.38	0.42	0.87	0.96
	(11.67)***	(12.39)***	(16.49)***	(17.26)***
Rainfall	-0.001	-0.001	-0.006	-0.005
	(1.23)	(1.33)	(1.07)	(1.27)
T_2		-0.004		0.01
		(1.32)		(0.98)
T_3		-0.01		0.02
		(1.72)*		(1.64)
T_4		-0.03		-0.01
		(2.05)**		(0.87)
Constant	0.15	0.11	1.24	1.07
	(10.19)***	(5.36)***	(20.64)***	(8.28)***
AdjustedR^2	0.22	0.47	0.17	0.38
F-statistic	152.95***	205.12***	116.17***	206.16***
Joint-F Test	11.52***		12.12***	
N	6,369	6,369	6,369	6,369

Note: Figures in parentheses are t-statistics.
*** Significant at 1 percent ** significant at 5 percent * Significant at 1 percent
N = Number of observations

It is interesting to note that both measures of crop diversification are positively and strongly influenced by the level of fragmentation. At the mean level of fragmentation, holdings have 48 percent more crop diversification than consolidated ones. The results on asset, farm size and oxen (in the crop index equation) are consistent with the predictions: higher endowments discourage diversification (or encourage specialization) in crops. Even though larger farms tend to grow more crops, the proportion of area under the crops is less evenly distributed, meaning that certain crops get the lion's share.

The time dummies indicate an increasing and statistically significant decline in the crop diversification index, while the change in the number of crops is not significant. This means that farmers were less evenly allocating land to the different crops (allocating more land to some crops) in 1989-1991 compared to 1988 while not changing much the number of crops they were cultivating.

6. Conclusion

Results in this paper throw some light on land fragmentation and crop diversification, important features characterizing traditional farming systems. The results indicate that peasant households in Ethiopia produce many crops and cultivate fragmented holdings. The number of crops which farmers produce increases with farm size, but the crop diversification index declines with farm size because the distribution of land among crops becomes more skewed as farm size increases. This pattern implies that the larger the farms, the more land they allocate to fewer crops. Higher levels of livestock asset holdings are also associated with more specialization. By contrast, farmers with no or small level of assets allocate land more evenly, possibly to assure self-sufficiency first, because the risk of depending on and selling one crop to purchase another, where markets are poorly integrated, are greater than any gains from specialization. Rural households with limited sources of income and financial security will be forced to engage in higher degree of crop diversification.

The level of land fragmentation, on the other hand, increases with farm size and population density but does not seem to respond to the asset levels. These results, coupled with the non-existence of land markets in Ethiopia, imply that rural households are supply constrained. A higher level of fragmentation also leads to a more diversified cropping pattern. This can be beneficial for risk reduction, reducing peaks and troughs in labor demand and enhancing household food security and diversity. But the indication that fragmentation is a supply constraint implies that it may have adverse effects on productivity.

Measures are needed to reduce the costs of fragmentation on agricultural production. The ability of farmers to adjust optimally the extent of fragmentation (or consolidation) of their holdings over time is limited due to the absence of land markets. When the rural population is growing faster than the number of off-farm jobs, agriculture is the only career option for many. As more people try to make a living from a limited land base, pressure to divide and sub-divide farms and fields will increase. This calls for measures to ease barriers to land transactions which may then induce greater consolidation of plots thereby setting in motion a wide range of social and economic benefits. It also calls for enhancing the attempts being made to facilitate the introduction of appropriate technology, to create off-farm employment, and to curb population growth.

The traditionally developed strategy of closely integrating crop and livestock enterprises to buffer against the uncertainty of rainfed crop production in the Ethiopian peasant agriculture is under threat due to the ever expanding cultivation of crops into grazing land, feed shortages, and overgrazing of existing pasture. This limits the possibility of poorer households entering into livestock rearing and those who have already done so may be forced to give it up. Countering the increasing severity of shortages in animal feed calls for strategic measures that should give due attention to the conservation of quality of those types of forage which grow on residual moisture. The promotion of deep rooting species would make forage available into the dry season without the need for supplementary irrigation. In the final analysis, an important means of reducing resource induced risk aversion is to increase the ability of farmers to take risks - for instance by improving credit facilities in rural areas, among other things.

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