Demand for Agricultural Biodiversity: The case of home gardens in Hungary

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Abstract:

This paper argues that there are clear micro-economic foundations of individual decision making, which can contribute to our understanding of the relationship between economic development and agricultural biodiversity. It unravels these foundations by analysing the impact of markets on the aggregate demand for agricultural biodiversity on remote farming communities. It shows that in non-integrated settings, in which farmers do not have access to markets and/or markets do not exist, the returns on the agricultural activities are correlated and access to assets are restricted. Under these circumstances, the small size of the market or lack of thereof translates and amplifies the riskiness of natural variation in agricultural yields with respect to household income. This has to be balanced on a farm level by a much wider portfolio of agricultural activities undertaken. Market creation and/or integration removes this motivation for supplying a diverse stock of agricultural biodiversity, while allowing individual farmers to pursue much less constrained forms of agriculture. These unconstrained forms of agriculture generate much improved returns for farmers, but imply a much-reduced portfolio agricultural activities, hence a much reduced level of agricultural biodiversity thereby contributing to the loss of agricultural biodiversity maintained on farms.

Keywords: Agricultural biodiversity, Market Integration, Development, Choice Experiments

JEL-Classification: O13, Q32, Q12, Q18, Q26

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1. Introduction

Agricultural biodiversity is the variety and variability of agro-ecosystems, animals, plants and micro-organisms on earth, that are used directly or indirectly for agricultural and food production. Each and every component agricultural biodiversity encompasses is essential to sustain key functions of agricultural ecosystems, their structure and processes for, and in support of, food production and food security. It provides the basis of the food security and livelihood security of billions of people and the future development of all food production, both for industrial agriculture and for the biotechnology industries. Agricultural biodiversity, therefore, in all of its components, is one of the most crucial environmental resources (FAO and SCBD, 1999). As vital as for our existence this environmental resource is it has been left to erode in an unprecedented rate throughout the 20th century. For example, of the about 7,000 plant species that have been cultivated and collected for food by humans since agriculture began 12,000 years ago, only about 15 plant species and 8 animal species supply 90% of our food consumption today (CBD). The erosion of this resource is regarded by ecologists as one of the most fundamental aspects of the problem of biodiversity loss (Oldfield, 1990). It is frequently cited as an example of the loss of an important form of naturally supplied insurance and a potential threat to entire civilisations, past and present.

This unprecedented rate of loss of agricultural biodiversity during the past century has been attributed to several interlinked and intertwined reasons, including population growth, wrong development policies, failure to recognise the value of agricultural biodiversity, but mainly to specific changes in agricultural practices that have come about with economic development. The majority of observers have traced recent erosion of agricultural biodiversity to the rapid diffusion and expansion of Green Revolution agriculture, which consists of cultivation of relatively few, high yielding varieties of crops in monocultures and intensive livestock production in a limited number of high yielding breeds of animals (Pretty, 1995; Fowler and Mooney, 1990; Shiva, 1991; Scarpa, 2003a). Other analysts, such as Porceddu *et al*. (1988), argue that loss of agricultural biodiversity is a result of the “industrialisation of agriculture”.

It was preceded by a similar erosive process, which resulted from the advent of new technologies and crops in modern agriculture in the form of intensive farming practices in the nineteenth century. Whatever the precise cause of this perceived resource loss, there is a widespread belief in diffusion of modern agriculture causing the loss of agricultural biodiversity. Consequently, public policies for conservation and sustainable use of agricultural biodiversity for global agriculture have been advocated (Cooper *et al.,* 1992; FAO 1996; FAO, 1999; CBD).

The overall impact of economic development on demand for agricultural biodiversity, however, is not straightforward to assess. This is not only due to the complexity and impossibility of defining and measuring agricultural biodiversity (see, e.g. Weitzman 1993) but also due to the difficulty of separating and pinpointing to the factor(s) that cause loss of agricultural biodiversity. As Smale (1997) concludes that "a causal relationship between genetic erosion … and the Green Revolution cannot be established, because of the difficulties in defining and measuring genetic erosion and proving causality with multiple intervening factors".

This paper attempts to separate out some of the "multiple intervening factors" in the chain of causation between development and agricultural biodiversity, by investigating the impact of economic development, in the form of market development, on farmers' demand for agricultural biodiversity on farms. The motivations of this study are twofold. The first is the theoretical studies that investigate the relationship between markets and farmers' choices of production technology, which in turn specifies the level of agricultural biodiversity on farms (e.g. Fafchamps, 1992; de Janvry, Fafchamps and Sadoulet, 1991). Fafchamps (1992) demonstrates that when markets are thin and isolated and/or farmers cannot participate in the markets due to high transaction costs, food prices become stochastic and especially for smaller farmers a large covariance between price and income exists. Consequently, farmers, especially smaller ones who are more risk averse due to their inability to rely on alternative insurance mechanisms, choose to be self-sufficient in food production in order to insure themselves against price and income, and hence consumption risks. Thus farmers allocate farm resources (e.g. land or household time endowment) to production of food crops implicating higher levels of agricultural biodiversity rather than cash crops implicating loss of agricultural biodiversity. Fafchamps further demonstrates that as markets get integrated price risks decline, agricultural productivity increases and transaction costs fall. Consequently, the need to become self-sufficient in food production diminish, freeing farm resources to be used in production of cash crops, thereby causing loss of agricultural biodiversity, other things remaining equal.

The second motivation of this study is the empirical research that investigate the relationship between farmers' access to and availability of markets and agricultural biodiversity that is found on farms (e.g. Brush, Taylor and Bellon, 1992; Meng, 1997; Van Dusen 2000, Smale, Bellon and Aguirre Gómez, 2001). Brush, Taylor and Bellon (1992) find that among others, one of the important reasons of continued cultivation of traditional varieties of potatoes on farms in Peru is for compensation for market imperfections in satisfying household demands for diversity in consumption. Moreover, they cite market access, along with insurance and financial resources, as one of the requirements for farmers' adoption of modern production technologies. Meng (1997) and Meng, Taylor and Brush (1998) find the level of market integration as well as farmers' attitudes towards risk, measured by off farm income availability, to be determinants of varietal diversity of wheat on Turkish farms. Van Dusen (2000) also investigates the impact of the extent of market integration on demand for agricultural biodiversity and finds that imperfect markets result in higher levels of within and between species diversity maintained in the Milpa systems on farms in Mexico. Finally, Smale, Bellon and Aguirre Gómez (2001), who investigate the demand of farmers for traditional varieties of maize in Mexico, observe a negative relationship between infrastructure, such as transportation, communication and education, and inter species diversity, signifying diminishing levels of agricultural biodiversity as farmers gain access to markets. The common finding of these studies is that market integration is one of the causes of agricultural biodiversity loss on farms.

Building up on these motivations, the aim of this paper is to investigate both theoretically and empirically the relationship between market development and farmers' demand for agricultural biodiversity. The theoretical part of this study demonstrates that as markets develop and become integrated, the environment of farmers' decision-making is effected in such a way that causes farmers' demand for agricultural biodiversity on farm, both as an input into production and as a consumption good, to decrease. A simple model is developed, which considers integration of output and input markets within farmers' communities and across broader markets with more heterogeneous natural environments, as the fundamental force driving this modification. The model demonstrates that the benefits from market integration arise as a result of relaxation of a constraint, which coincidentally produced a greater farm household demand for agricultural diversity. The reason is that when markets are absent, thin, or non-integrated, agricultural biodiversity on farms is often the only instrument available for farm households to efficiently manage risks in price and income and hence in consumption. The model shows that markets and access to thereof render more effective risk management tools available, reducing demand for agricultural biodiversity on farms for purposes of risk management.

This paper also attempts to establish an empirical relationship between market development and farmers' demand for agricultural biodiversity. Differently to empirical studies that investigated this relationship previously by use of revealed preference data in the form of farm household surveys (e.g. Brush, Taylor and Bellon, 1992; Meng, 1997; Van Dusen 2000, Smale, Bellon and Aguirre Gómez, 2001), this paper adopts a stated preference approach, namely a choice experiment. The choice experiment method, which is capable of estimating the demand for an environmental good as well as the demand for multiple attributes of the good, is suitable to analysis of demand for agricultural biodiversity, an environmental good with multiple attributes in the form of functions, services and outputs. There have been a few choice experiment studies investigating the demand for certain components of agricultural biodiversity. These include demand for agricultural products obtained with specific production techniques (e.g. organic, non-GMO eggs in Kontoleon *et al*. 2002 and Kontoleon, 2003; and demand for beef produced with hormones in Lusk *et al*., 2003) and demand for animal genetic resources (e.g. pig landraces in Mexico in Scarpa *et al*., 2003a, and cattle landraces in Kenya in Scarpa, *et al*., 2003b). This study is a first in investigation of demand for an agro-ecosystem and for its components that make up agricultural biodiversity. The case study in this paper is one on farmers' demand for traditional Hungarian home gardens and for the agricultural biodiversity therein, defined in terms of intra and inter-species diversity, agro-diversity, genetic diversity in landraces, and in organic production methods. The survey is carried out in three regions of Hungary, that are distinct in terms of market availability, market access as well as several other development characteristics, including infrastructure and off farm employment opportunities. The results of the case study are in tune with the theoretical model and well as other empirical studies on this issue, as the results reveal that farmers' demand for agricultural biodiversity, in all of its components, decline as they become more integrated into markets.

The remainder of this paper will firstly investigate theoretically the impact of economic development, in the form of market development, on farmers' demand for agricultural biodiversity on their farms, based on a simple model of a semi-subsistence small farm who operates in an isolated farming community and experiences the first moves toward integrated markets. Then the impact of markets and other of economic development indicators on farmers' demand for agricultural biodiversity will be demonstrated analytically with the use of a choice experiment, which was specifically designed to investigate the demand of Hungarian semi-subsistence small farmers for agricultural biodiversity and its specific components. The final part of the paper will investigate policy options, such as farmers' contracts, for conservation of agricultural biodiversity on farms as economies develop and markets get integrated, as in the case of Hungary, which prepares to join the EU.

2. Theoretical Framework

2.1 Demand for agricultural biodiversity in Non-Integrated Agricultural Economies

Firstly the manner in which a farm household diversifies its activities, in the forms of intra and inter-species crops it cultivates and livestock production it engages in hence spread risks when agricultural biodiversity is conceived of as a productive asset is investigated. In this setting farm household make choices constrained by lack of a market and/or lack of accessibility to the market.

2.1.1 The Setting

Consider a semi-subsistence small farm household with limited access to markets due to high transaction costs the household faces. Further consider that the farming community in which this farm household is located does not have a fully developed community markets and the community is isolated and far from any regional or national markets. In this non-integrated market setting, this farm household and others, which are identical to this one in terms of resources endowments and preferences, rarely trade inputs and outputs only amongst themselves in isolated, thin and mostly informal community market (e.g. a farming community in a remote mountain region). The farm household chooses a set of activities to undertake, such as a set of crops to grow from a set of all varieties known to the community. The household bases this decision on a common information set regarding each crop within this set: the yield distribution (including known mean and variance for each variety)[2] and the covariance between crop yields[3]. The farmer household then allocates its resources (e.g. plots of its land and/or total household time) to each activity to maximise its overall expected utility, which is assumed to be linear in expected income[4].

We define this situation as a *non-integrated farm household in a non-integrated agricultural economy*, and identify its essential characteristics as:

(1) Environmental risk that derives from exogenous local environmental factors that affect crop yields and variability. This risk has a plot-specific component (yield variance), and a component that is positively correlated with the increasing use of a given plant variety across the farmers' total land (positive covariance). It is local in the sense that it will affect every plot planted in the same crop in the same way (while it may not do so for plots planted in the same crop in other locations).

[2] The information on yields is assumed to take the form of a normal distribution, with known individual mean and variability (cf. Appendix). The actual yield outcome will depend upon the stochastic environmental events that transpire in that particular location in that particular year.

[3] The information on the covariance matrix is that it is made up of positive elements on the diagonal, and zeros elsewhere. This means that decisions to plant the same crop on different plots on the same farm will imply linked outcomes at these sites in that they respond to the same environmental events in like manner.

[4] This implies that the farmers are not averse to yield variability in itself as equation (2) in the Appendix shows (as they would if the individual utility function was specified in mean-variance terms). In the discussion section we will relax this assumption. For now we merely wish to demonstrate that development and diversity are inversely related, even under the most stringent assumptions.

(2) Interaction in a thin product market with a small number of identical agents. Prices, and hence incomes, in this imperfect market are endogenously determined as a function of aggregate output decisions.[5]

(3) Instruments for risk management, which are limited to the farm households' choice of an aggregate portfolio of activities (e.g. plant and animal varieties) from the set of those known to the community.[6]

2.1.2 Implications

These three assumptions capture the essence of an agricultural economy where the costs of transactions with other farmers, villages and regions are prohibitively high. The first provides the exogenous flow of uncertainty that makes insurance desirable. Its spatial uniformity renders risk management via pooling instruments unsuitable (Binswanger and Rosenzweig 1986). The second assumption states that the scope of the product market matches that of the environmental risk. Since these farmers do not exchange goods outside their economy, all of their produce must be exchanged locally, in thin community level markets. This implies that market outcomes will reflect the same correlation present within the environment. Hence, the thin market adds to the naturally conditioned correlation of outcomes and - instead of enabling the spread of risks - exacerbates the unavailability of insurance mechanisms. The third assumption delimits the farm household's choice of insurance mechanisms explicitly to activity selection. The only means available for addressing these risks is to diversify its activities and to be self-sufficient in food production. In effect the input and asset markets are also contiguous with the zone of environmental risk. That is, thin markets make matters worse by correlating outcomes. Even if some surplus output can be sold in the markets, the thinness of those emphasises unavailability of insurance. In short, the only insurance mechanism that the farm household can use for hedging against risk is by diversifying its activities, thereby bringing about agricultural biodiversity.

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[5] This is similar to the statement that "markets for raw agricultural products are spatial markets, an arena where imperfect competition is almost certain"(Sexton 1994).

[6] This refers to impacts related to the "breadth" of the market, and echoes the literature which has analysed the problem of positive risk-correlation in agricultural communities, both empirically (Binswanger and Rosenzweig 1986, Hazell et al. 1986) and theoretically in the context of development economics (Dasgupta 1993).

Under these conditions the private incentives are at their most extreme for the use of the instrument of agricultural biodiversity for risk management. Farm households will be attempting to cope with all of the risk arriving from the environment and the resulting variability in yield and market outcomes, through the single instrument of portfolio broadening in farm activities.

2.2 Market Integration and Demand for Agricultural Biodiversity

In this section we analyse the impacts that the first steps toward market integration have on the outcome of the decision making over farm activity diversification, which implies the level of agricultural biodiversity managed on farms, in farm households. Market integration is viewed here as a process that either broadens the markets in terms of market participants, or broadens the market in terms of the types of goods and assets traded. In both instances, an increase in market integration will result in reduced aggregate diversity within the farm household's activity portfolio. The Appendix to the paper specifies the model fully, and demonstrates the proofs for the propositions set forth here in general terms.[7]

2.2.1 Demand for Agricultural Biodiversity with Product Market Integration

In this part we will examine farmers' behaviour in regard to activity diversification when integration across the output market takes place.[8] In a non-integrated agricultural economy the farmers will select a relatively broad portfolio of activities, in order to reduce the effects of co-variability on their expected returns, and to increase overall output and to enable diversity in the household's diet. They will know the relative ranking of the various crop varieties and animal breeds, based upon the mean return of the activities, nutritional contents, and household's preferences. They will further know that increasing intensity in the use of a given activity will

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[7] We occasionally refer to equations in the appendix for clarification.

[8] Our context provides the circumstances under which the usual outcome of portfolio invariance does not inhere. Under the usual assumptions of the Capital Asset Pricing Model, this process would not result in a decrease in the aggregate number of assets held since the composition of the efficient frontier of assets is assumed to be independent of environmental parameters and the number of market participants is assumed to be sufficiently great that changes in individual portfolio decisions have a negligible impact on prices. However, this independence is not valid in our model as critical characteristics of the asset, notably its expected return, change with the structure and size of the market (cf. equation (5) in the Appendix).

impact upon its expected returns - by reason of increasing correlation, increasing variability in yields and decreasing revenues. The farm households will respond by means of including within their portfolio lower yielding varieties and breeds, in order to reduce the intensity of use of the higher yielding activities (see Proposition 0). Even though neo-classical theory suggests that for profit maximisation specialisation in the activity with the highest return is required, this does not happen in this context.

Now assume that there exist other farms and farmers whose outcome from the undertaking of any activity is less correlated with this farmer household's yields.[9] In either case, the point is that the farm is one whose outcomes are less closely correlated with the non-integrated farm household in the non-integrated agricultural economy. If this farmer is integrated within the pre-existing economy, then this provides another option for hedging against the risk of increased activity intensity, other than the expanded use of lower yielding activities. The community now has access to the pooling effects that spatial separation affords. For this reason, the integration of a single "distinct" farm household will make a difference in the portfolio of diversity retained by the previously non-integrated farm household in the non-integrated agricultural community.[10] This provides us with Proposition 1. Market integration enables integration with a less correlated farm household and this implies hedging against risk.

Proposition 1*: The overall level of agricultural biodiversity that is managed on farm by a non-integrated farm household in a non-integrated agricultural economy decreases as the farm household starts to interact with other farm households with sufficiently non-correlated farm yields.*

Proof: See Appendix.

In effect, market integration removes constraints on individual decision making that enable the election of preferred production techniques.[11] In this context the main

[9] This would be attributable to the existence of distinct micro-agricultural ecosystems, with distinct exogenous forces determining yield outcomes (e.g. independently determined pest and pathogen invasions, precipitation patterns etc).

[10] In this context, "distinctness" refers to the characteristics (e.g. distance in space) that result in reduced correlation of impacts from environmental events.

[11] This result is of course well known in respect to the role of market integration in the development of agricultural economies, by means of ushering in the specialisation process with all its attendant benefits (Fafchamps 1992). Our point is simply that these constraints conferred important social benefits as

consequence is the substitution of higher yielding activities for the lower yielding one included in the portfolio to reduce activity intensity that is necessary for risk hedging. The importance of risk management in activity portfolio selection is reduced with each step towards integration, and this favours activities with higher expected yields.

2.2.2 Demand for Agricultural Biodiversity with Other Assets

Market integration may occur by many means other than the integration of communities or product markets. All that is necessary is for the non-integrated agricultural economy to be able to transact in other "distinct" markets, irrespective of the type or nature of that market. Examples would include improved access to markets for wage labour, agricultural inputs, or even financial markets. All that is necessary is that the market be one that is sufficiently uncorrelated with the outcomes prevailing within the previously non-integrated farm household in the non-integrated agricultural economy. We will show that these forms of integration also remove incentives for broadened farm activity portfolios by substituting newly accessible instruments for risk management.

Proposition 2*: The overall level of agricultural biodiversity that is managed by a farm non-integrated farm household in a non-integrated agricultural economy decreases as risk free assets (e.g. off farm wage employment) become available to the farm household.*
Proof: See Appendix.

The reason for this effect is that any market can function as an instrument for risk management, if its outcomes are sufficiently uncorrelated with those in the non-integrated household in the non-integrated economy. This is because it allows resources to be invested in sectors of the economy that are uncorrelated with agriculture, thus diversifying away from the market-induced variabilities. Consider for example a relatively well clearing labour market within reachable distance from a previously non-integrated agricultural economy. This market would enable farm labour to be allocated between the relatively risky agricultural sector and the

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well, but not ones appreciated primarily at the local level. Market integration results in development of agricultural economies as a result of specialisation.

relatively riskless wage labour sector. Whatever balance of risk and return that was desired could be achieved by means of allocation of labour between these two sectors. There would be no further role for farm activity diversification in the management of agricultural/environmental risks.

3. The Case Study on Demand for Agricultural Biodiversity on Hungarian Semi-Subsistence Small Farms

3.1 The Background

This case study was undertaken with the objective to investigate farmers' demand for semi-subsistence small farms and for specific attributes of these farms in three environmentally sensitive areas (ESAs) of Hungary. Hungarian semi subsistence small farms in their present forms, evolved out of the small plots[12] near the dwellings[13] that the households were allowed to cultivate privately during the period in which agriculture was collectivised and state owned (1960-1989) (Kovách, 1999; Meurs, 2001). Throughout that period these home gardens played a significant role in meeting the subsistence needs of many rural households. Since village level food markets have always been lacking or thin in rural Hungary, as a result of high transaction costs and/or historical discouragement of food and labour market formation, rural households became to depend on the level as well as diversity of their own home garden production for food consumption. Consequently, home gardens became instruments of insurance against consumption, price and income risks. Even today, with about 800 000 home gardens in various sizes up to 1 ha and with 33% of the Hungarian population reported engaged in auxiliary agricultural work, part time agricultural activity and home garden production continue to play a crucial role in the livelihoods of Hungarian households (Hungarian Statistical Monitor, 2000; Simon, 2000; Már, 2002).

Production in home gardens has been accomplished with family labour, using traditional, labour intensive farming practices and ancestral crop varieties and livestock breeds and generally with limited use of purchased inputs. Consequently,

[12] Average size of a home garden in Hungary is estimated to be 0.5 ha (Már, 2002)
[13] Hence the semi-subsistence small farms are also called home gardens interchangeably.

home gardens became to be ‘small repositories of agricultural biodiversity’ (Már, 2002) as micro- agricultural ecosystems that are rich in intra and inter-species diversity, including crop genetic resources in landraces, and other micro-organisms on earth. In addition to their function as havens for agricultural biodiversity, home gardens also supply several other benefits including conservation of Hungarian cultural heritage in traditional varieties of crops and animals they contain and in traditional farming methods embedded in them. Further, they also provide food security for farmers, food safety and quality in landraces and their possible uses in the future for plant breeding purposes and in possible niche markets. And finally, home garden production also contributes to protection of rural settlements and rural life by keeping the rural population on the countryside.

Continued cultivation of these ‘small repositories of agricultural biodiversity’ depends very much on the present and future national and EU agri-environmental policies. Hungary’s agricultural policy at the moment is one that encourages multifunctionality in agriculture[14]. Hence it is in line with the 2078/92 EU agri-environmental regulation on the support of agricultural production methods that are environmentally friendly and aim at the preservation of the rural areas, which is one of the several community legislations Hungary has accepted to apply as a prerequisite for accession. Under this EU agri-environmental regulation each EU member country, including those that are preparing to become full members in 2004, is expected to encourage production of public good aspects of agriculture with development of a National Agri-Environmental Programme (NAEP).

In preparation for its entry into the EU therefore, Hungary has developed a NAEP (Juhász, 1999), which was accepted by the Ministry of Agriculture and Regional Development in 2000 and was experimentally launched in 2001. NAEP calls for emphasis on multifunctionality in Hungarian agricultural sector and proposes that degree of intensity of agricultural production in a region should depend on its natural and human resources. Under this programme, several areas of Hungary with low agricultural productivity but high environmental value are designated as

[14] Multifunctional agriculture can be defined as agricultural production, in addition to the private goods it supplies (e.g. food and fibre), it also provides a bundle of public goods, including rural settlement

environmentally sensitive areas, and the main aim of NAEP is to protect these areas that are habitats for endangered plant and animal species. The strategy used to promote conservation in areas designated as environmentally sensitive areas consists of direct payments, training programmes and technical assistance to the farmers, who are willing to participate in several agri-environmental schemes which promote use of specified farming methods[15]. Participation in these agri-environmental schemes is voluntary and is based on a 5 year contract, according to which the farmer is bound to comply with the rules of production for the scheme in question as defined in the contract. In return the farmer is rewarded by an annual support payment for the contracted period on a hectare or livestock basis. These payments are designed to cover the possible loss of income due to the measures applied and contains a further 20% incentive to make the scheme attractive and the environmentally friendly farming practices competitive among the farmers. Hungarian NAEP has calculated the amounts of these payments according to the EU support calculation methodology.

The Hungarian NAEP recognises that extensive agricultural methods are the most suitable ones for conservation of agricultural biodiversity, and for provision of multifunctional agriculture (Juhász, 1999), but has not yet included home gardens in the schemes proposed. In addition proposed EU policies for countries that are to become members in 2004 (i.e. Special Accession Programme for Agriculture and Rural Development, SAPARD) fail to recognise the multifunctional agriculture values that may be generated through cultivation of traditional home gardens. SAPARD considers the dual structure of agriculture[16] that exists in several of the accession states as inefficiencies and proposes subsidies for transformation of semi-subsistence small farms to commercial farms. Alternatively, SAPARD also proposes direct payments to land-holdings larger than 0.3 ha on the condition that there is no obligations to produce but land has to be managed in a way compatible with

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and economic activity, food security, safety and quality, biodiversity, cultural heritage and amenity and recreational values (Romstad *et al.*, 2000; Lankoski, 2000)

[15] Schemes under NAEP include agri-environment basic scheme, integrated production scheme, organic production scheme, grassland scheme and wetland scheme. In addition to these schemes, NAEP also has several zonal objective programmes in environmentally sensitive areas, which include integrated, nature protection, landscape protection, soil protection and water protection schemes (Juhász, 1999)

[16] The dual structure of Hungarian, as well as Polish and Slovenian, agriculture consists of large, mass produced, industrialised, mechanised farms alongside subsistence or semi-subsistence small-scale farms[16] produced with traditional, labour intensive methods

protection of the environment, as suggested by the NAEP of the member country (Commission of the European Communities, 2002). These policies imply that as long as Hungarian NAEP does not include home gardens as a method that supports multifunctional agriculture, and as long as farmers' incentives to cultivate home gardens are shifted towards other forms of agriculture (e.g. commercial, or large scale organic production) home garden production might cease to exist.

As it has been already listed above Hungarian home gardens supply several functions and services, all of which comply with the essence of multifunctional agriculture. All of these benefits home gardens generate firstly accrue to the farmers that cultivate them and to their communities. These benefits, however, are not limited to the farmers only, as they are also local, regional, national and global in nature. Therefore this failure of exclusion of home gardens from any agri-environmental policy that supports multifunctional agriculture could in fact result in various environmental problems (e.g. agricultural biodiversity loss) as well as economic inefficiencies. Therefore, as an extension to its primary aim of investigation of farmers' demand for home gardens and for their multiple attributes, this study also expects to capture the values of these home gardens to farmers so as to justify their integration in the Hungarian NAEP.

3.2 Description of the Environmentally Sensitive Areas

The three study sites are located in the buffer zones of ESAs of Hungary and were purposively selected to represent contrasting levels of market integration and agro-ecological characteristics, which are associated with different farming systems and land-use intensity. The design enables tests of hypotheses about the impact of economic change on the demand for agricultural biodiversity on semi subsistence small farms in Hungary. The three regions include

1. *Dévaványa region.* This region is located in the centre of the Hungarian Great Plain. The landscape is flat and consists of a mosaic of cultivated lands and grasslands. Soil and climatic conditions of this region are well suited to intensive agricultural production. Dévaványa region is the most urbanised region among the three selected sites, with the most developed road and other infrastructure and

food markets, mainly due to its proximity to the centre of the country and to its higher population density. Unlike the other two sites selected, here migration is not an important problem and the number of inhabitants is stagnating (Gyovai, 2002). However, the unemployment rate is slightly higher than Hungarian average at 12.4% (National Labour Centre, 2000).

2. *Őrség-Vendvidék region*. Őrség-Vendvidék region is located in the southeast of Hungary and supports a heterogeneous agricultural landscape with knolls, valleys, forests, grasslands and arable lands. Poor soil conditions render intensive agricultural production methods impossible. Villages in this region are very small both in size and population. Population in Őrség-Vendvidék is also declining and ageing. Most of the villages are far from towns and road density is very low (Gyovai, 2002). However, this regions has one of the lowest unemployment rates in the country, with 4.8 % (National Labour Centre, 2000).

3. *Szatmár-Bereg region:* Szatmár-Bereg region is at the northeast part of the country, and has a diverse landscape with a mosaic of grasslands, forests, arable lands and moors. This region consists of settlements, which are small both in terms of area and population. The main economic problem of this region is its declining and aging population, which is a result of lack of investment in this isolated region that is also distant from the economic centre of the country (Gyovai, 2002). Consequently, this region supports low quality roads and high rates of unemployment reaching to 19% (National Labour Centre, 2000).

A total of 300 households were interviewed for the choice experiment survey (See Birol, 2003 for details of the sampling framework). Observations with missing choice and socio-economic data were excluded from the sample hence the final number of households that answered the choice experiment survey came out to be 277.

3.3 The Choice experiment Method

Most of the outputs, functions and services that home gardens generate are not traded in the markets. Consequently, non-market valuation methods are suitable to determine the values of the benefits of home garden production. As a result of nonmarketability of most of the products of home gardens, agricultural biodiversity that is residing in these home gardens have been shaped mainly by the consumption and production preferences of home garden farmers. In other words, these benefits primarily accrue to home garden producer-consumers. Therefore, any study on investigation and conservation of agricultural biodiversity on Hungarian semi-subsistence small farms must identify and characterise the preferences of home garden producer-consumers and determine the implicit values these farmers attach to home gardens and their attributes (Scarpa *et al*., Forthcoming). The choice experiment method has been used to measure the implicit values of home gardens and of the agricultural biodiversity therein. This method is most appropriate in valuation of a good, such as home gardens, which encompass multiple attributes, since this method allows for derivation of benefit value of each attribute. Further, this method also enables comparison of values between different regions, as well as characterisation of value attributes on the basis of household composition, showing how multi-attribute valuation can vary according to the household socio-economic characteristics and regional impacts.

The choice experiment method is a new and budding addition to the portfolio of stated preference methods for environmental valuation. Unlike other stated preference methods it enables estimation of not only the value of the environmental asset as a whole, but also the implicit marginal values of its attributes (Hanley *et al*., 1998a; Bateman *et al*., 2003). The method is based on Lancaster's characteristics theory of consumer choice (Lancaster, 1966), which states that consumers derive utility not from the goods themselves but from the bundle of attributes and levels of the attributes they provide. The choice experiment method is also based on the random utility theory (Luce, 1958, McFadden 1973), which demonstrates that utility an individual derives from a good consists of two parts, an observable part and an unobservable, since it is almost impossible to completely describe any good in terms of its attributes, and it is possible to make errors in measuring attributes and respondents' subjective preferences. (Hanley *et al*., 1998a; Bateman *et al*., 2003)

A choice experiment is a 'structured method of data generation' (Hanley *et al*., 1998a), as it relies on carefully designed tasks or "experiments" to reveal the factors that influence choice. It works by creating several profiles of the environmental good in questions, in terms of its attributes and levels of these attributes, and by asking respondents repeatedly which profile of the good they prefer, given the other alternative profiles. For this choice experiment, therefore, the Hungarian home garden had to be defined in terms of its attributes, i.e. functions, services and outputs it encompasses, and levels these attributes take. After several informal interviews and focus groups with the farmers in all three regions and with consultations with NAEP and agricultural sciences experts, the final set of attributes and levels were determined to reflect agri-environmental as well as socio-economic values of home gardens. The attributes and levels chosen are presented in Table 1.

Table 1. Home garden attributes and attribute levels used in the choice experiment

Home garden attribute	Definition	Attribute levels
Crop Species Diversity	The total number of crops that are grown in the garden. A count index of richness of crop species or inter-specific crop diversity.	6 13 20 25
Agro-diversity	Mixed crop and livestock production, representing diversity in agricultural management system	Mixed crop and livestock production vs. Specialised crop production
Organic Production	Whether or not industrially produced and marketed chemical inputs are applied in farm production.	Organic production vs. Non-organic production
Landrace	Whether or not the home garden contains a landraces ("ancestral crop variety" or "traditional variety") that has been passed down from the previous generation and/or has not been purchased from a commercial seed supplier. An indicator of crop intra-specific (within crop) diversity.	Home garden contains a landrace vs. Home garden does not contain a landrace
Self-sufficiency	The percentage of annual household food consumption that it is expected the home garden will supply. This variable is a proxy for the monetary attribute that is needed for welfare estimations.	15% 45% 60% 75%

A large number of unique home garden descriptions (combinations of attributes) could be constructed from this number or attributes and levels[17]. Using the orthogonalisation procedure in SPSS an experimental design was undertaken to investigate only the main effects. This resulted in a total number of 32 pair wise

[17] Number of home gardens that can be constructed from 5 attributes, 2 with 4 levels and the remaining 3 with 2 levels is $4^2 * 2^3 = 128$

comparisons of home garden profiles, which were then randomly blocked to 6 different versions, two with 6 choice sets and the remaining four with 5 choice sets. The choice experiment survey took place in Summer 2002. During each experiment the respondent was presented with 5 or 6 choice sets, each with two home gardens and an option to select neither garden, should they prefer neither of the home garden profiles presented to them. The respondents were personally interviewed and were almost all the time those responsible for home garden production decision-making. An introductory section explained to the respondents the context in which choices were to be made, described each attribute[18] and explained that the key attributes of home gardens had been selected as a result of prior research and combined artificially in the choice sets. Respondents were informed that completion of the exercise would help agricultural policy makers. Overall, a total of 1480 choices were obtained from 277 interviewees.

3.4 The Analysis and Results

3.4.1. Pooled Model for Home Garden Farmers

The basic multinomial logit model is used to analyse the data (See Birol, 2003 for a detailed description of this model)[19] using LIMDEP 7.0 NLOGIT 2.0. This model is used to estimate the attribute values for the entire population represented by the sample and to test whether or not the demand for each attribute is significant and to compare the implied, relative values of attributes. The choice experiment is designed with the assumption that the observable utility function would follow a strictly additive form. Model specifications (with logarithmic forms for variables with 4 levels) are compared according to higher log-likelihood value criterion. The model is

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[18] Even though the respondents are all home garden producers and hence are all familiar with the good that is being valued (home gardens) each attribute was described by the enumerator so as to enable uniformity in understanding of the attributes among farmers. Furthermore, each home garden profile was fixed in size at 0.5 ha.

[19] The data (both the pool and each ESA subsamples) were also analysed using the random parameter logit model. The estimates of this model resulted in insignificant derived standard deviations indicating that data does not support any choice specific unconditional unobserved heterogeneity. Moreover, whether or not random parameter logit model is an improvement over multinomial logit model was tested with a Swait-Louviere Log Likelihood Ratio Test. The results of the test cannot reject the null hypothesis that the random parameter logit model is equal to multinomial logit model and hence there is no improvement in the model fit. On the basis of this test it can be concluded that the multinomial logit model is sufficient for analysis of this data set.

specified so that the probability of selecting a particular alternative is a function of attributes of the alternatives and of the alternative specific constant. The highest value of the log-likelihood function is found for the specification with the diversity variable in logarithmic form, indicating that the marginal willingness to accept compensation for this attribute is diminishing. Indirect utility received by the home garden attributes take the form

$$V_{ij} = \beta + \beta_1 \ln(Z_{diversity}) + \beta_2 (Z_{agro-diversity}) + \beta_3 (Z_{organic}) + \beta_4 (Z_{landrace}) + \beta_5 (Z_{selfsufficiency}) \quad (1)$$

where β refers to the alternative specific constant and β_{1-5} refers to the vector of coefficients associated with the vector of attributes describing home garden characteristics. The results of the estimated basic multinomial logit model for the pool are presented in Table 2.

Table 2. Demand of the pool for home gardens and their attributes

Attribute	Coeff.	s.e.	t-stat
Constant	-0.6805	0.2458	-2.768
Crop Species Diversity	0.1790	0.0739	2.423
Agro-Diversity	0.3993	0.0416	9.592
Organic Production	0.1923	0.0423	4.543
Landrace	0.1639	0.0385	4.258
Self-sufficiency	0.0216	0.0020	10.945
Sample size		1480	
ρ^2		0.12717	
Log likelihood		-1419.1764	

All of the home garden attributes are statistically significant at 5% level and any single attribute increases the probability that a home garden is selected, other things remaining equal. Since the underlying sample is statistical, these parameters represent preference estimates of home garden producers-consumers for home garden attributes in three environmentally sensitive areas of Hungary. When the self-sufficiency attribute is used as the normalising variable, it can be seen that the most important attribute among these producer-consumers is agro-diversity (mixed crop and livestock production). This is followed by organic farming methods and crop (inter- and intra-specific) diversity variables, all of which are similar and about half as important as the agro-diversity variable[20]. The negative sign on the ASC coefficient implies that respondents are highly responsive to changes in choice set quality and they make decisions that are closer both to rational choice theory and the behaviour observed in reality (Kontoleon, 2003). The overall fit of the model as measured by McFadden's ρ^2 is reasonable by conventional standards used to describe probabilistic discrete choice models[21] (Ben-Akiva and Lerman, 1985). Furthermore, the IIA property of this model is tested using a procedure suggested by Hausman and McFadden (1994) and contained within LIMDEP 7.0 NLOGIT 2.0. It was found that the IIA property is not violated implying that the multinomial logit estimates do not hold any bias that could have resulted from inclusion of the 'neither' option.

3.4.2 Comparison of Preferences in Three ESAs

Farmers in different ESAs may face different trade-offs in production of home gardens and consumption of home garden outputs, and capturing of these differences, should they exist, may have relevant consequences in efficient policy design. It is therefore crucial to investigate whether and in which direction the regional characteristics, such as market integration, infrastructure quality, agro-ecological conditions, affect farmers' demand for home gardens and for their attributes. Hence whether or not the set of parameter estimates of the pooled model are shared across the three distinct regions must be tested. Consequently, separate multinomial logit estimates are obtained for each region and the following test is carried out to investigate whether or not preferences differ across environmentally sensitive areas,

$$H_0 : \beta_{pool} = \beta_{Dev} = \beta_{Orseg} = \beta_{Sz-B}$$

[20] Note that the coefficients and standard errors for crop species diversity and self-sufficiency appear lower than the other coefficients because actual values (6, 13, 20, 25) and (15, 45, 60, 75) were used respectively.

where β_x are the multinomial logit parameter vectors as estimated in (1). Rejection of the null-hypothesis would imply that farmers in different regions have different demand models for home gardens and their attributes. This test can be done with Swait-Louviere log likelihood ratio test. The test statistic is asymptotically distributed as χ^2 and is expressed as

$$\chi^2 = -2(LL_1 - LL_2)$$

where LL_x refers to the log likelihood statistics for the different models.

The demand for home gardens and their attributes per region can be seen in Table 3.

Table 3. Demand for home garden attributes in each ESA

	Dévaványa környéke			Őrség-Vendvidék			Szatmár-Bereg		
Attribute	Coeff.	s.e.	t-stat	Coeff.	s.e.	t-stat	Coeff.	s.e.	t-stat
Constant	0.050	0.399	0.126	-1.475	0.450	-3.281	-0.685	-1.544	0.123
Crop Species Diversity	-0.031	0.123	-0.248	0.284	0.135	2.106	0.295	0.130	2.277
Agro-diversity	0.504	0.070	7.245	0.256	0.077	3.327	0.414	0.073	5.647
Organic Production	0.293	0.072	4.070	0.116	0.077	1.507	0.158	0.073	2.162
Landrace	0.085	0.065	1.310	0.241	0.071	3.393	0.174	0.067	2.615
Self-sufficiency	0.014	0.003	4.401	0.029	0.004	7.714	0.024	0.035	6.825
Sample size	533			455			499		
ρ^2	0.10915			0.12533			0.18471		
Log likelihood	-521.6492			-430.4925			-446.9454		

Swait-Louviere log likelihood ratio test rejects the null hypothesis that the regression parameters are equal.[22] Producer-consumers have distinct preferences for home gardens and their attributes in each of the regions compared to the pool. When the same test is carried out to make pairwise comparisons it is seen that each of the regions' parameters are different from each other[23]. Therefore, it can be concluded

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[21] The ρ^2 value in multinomial logit models is similar to R^2 in conventional analysis, except that significance occurs at lower levels. Hensher and Johnson (1981) comment that values of ρ^2 between 0.2 and 0.4 are considered to be extremely good fits.

[22] LR= -2[-1419.18-(-521.65+-430.49+-446.95)]=40.18, which is larger than 18.55, the critical value of chi square distribution at 6degrees of freedom at 0.5% significance.

[23] Comparison of demand estimates for Dévaványa vs. Őrség-Vendvidék is LR= -2[-521.65+ 430.49]=182, Dévaványa vs. Szatmár-Bereg is LR= -2[-521.65+-446.95]=149 and for Szatmár-Bereg vs. Őrség-Vendvidék it is LR= -2[-446.95+430.49]=32 all larger than 18.55, the critical value of chi square distribution at 6degrees of freedom at 0.5% significance.

that respondents in each region have different preferences for home gardens and their attributes.

Investigation of the results per region reveals that the findings of the study are strikingly in line with those as predicted by economic theory. In Dévaványa region, where food markets as well as road infrastructure are fully developed, farmers' demand for crop species diversity is negative and insignificant and demand for a home garden with a landrace is insignificant although positive. In this region agro-diversity variable is significant and positive, owing to the complementarity between intensive agricultural production, especially of maize and animal husbandry. In the isolated region of Őrség-Vendvidék, where community level food markets are lacking, distance to the nearest towns are large and road density are low, crop species diversity and landraces are significantly and positively demanded by the farmers. The poor soil quality of this region results in insignificant demand for organic production methods. And the results are similar to those in Őrség-Vendvidék for home garden farmers in the isolated region of Szatmár-Bereg region, where community level food markets are also lacking and road quality as well as transportation quality to the nearest towns are low. Here farmers demand crop species diversity positively and significantly and home gardens with a landrace are also positively and strongly significantly demanded. Finally, farmers in this region consider agro-diversity as a very important home garden attribute, perhaps due to the fact that high unemployment levels in this region render labour intensive animal husbandry practices less costly in terms of opportunity cost of time of the farmers.

3.4.3. Willingness to Accept Compensation for each Attribute per ESA

Using secondary data from Hungarian Central Statistical Office (HCSO, 2002) on the annual expenditure of average Hungarian household on food consumption, the indirect monetary variable of food self sufficiency obtained from food production in the home garden was converted into monetary units. Differently than many choice experiment studies undertaken so far, which estimate WTP values for environmental goods and their attributes, the values estimated in this study reflect willingness to accept (WTA) compensation for these attributes. This is because the monetary attribute was asked as a benefit rather than cost since the property rights of the home gardens and of their outputs and functions reside with the farmers who were being interviewed (Freeman, 1993). The WTA compensation for each of the home garden attributes was found by finding the part-worth

$$W = -1\left(\frac{\beta_{attribute}}{\beta_{monetary\,variable}}\right) \qquad (2)$$

which represents the marginal rate of substitution between income change and the attribute in question. The results of the part-worth of each attribute for the pool and per region can be observed in Table 4.

Table 4. WTA estimates for each home garden attribute per ESA

Attribute	Pool	Dévaványa	Őrség-Vendvidék	Szatmár-Bereg
Crop Species Diversity	-28 085.35	6550.16*	-29 784.68	-37 648.52
Agro-diversity	-55 948.82	-108 104.59	-26 884.27	-52 903.40
Organic Production	-29 935. 25	-62 904.69	-12 126.04*	-20 235.31
Landrace	-22 959.06	-18 212.96*	-25 364.53	-22 287.01

Figures in Hungarian Forints (HUF) (1 € = 245.6 HUF, March 2003)

** Demand for the attribute is insignificant at 0.5% significance level.*

The values home garden producer-consumers attach to home gardens and their attributes can be seen from the WTA compensation value estimates as reported in Table 4. Information as such on the differing demand levels and rankings for home gardens and their attributes in each region is critical to the design of appropriate policies that aim promotion of multifunctional agriculture in environmentally sensitive areas and conservation of agricultural biodiversity on Hungarian semi-subsistence small farms. As it is reported in Table 4, farmers in Őrség-Vendvidék and Szatmár-Bereg regions attach the highest and strongly significant values to inter and intra species crop diversity as well as significant and substantial values to agro-diversity. Therefore it should be expected that these regions would be the ones to target for least cost conservation programmes, such as incentive contracting to encourage continued cultivation of home gardens and hence on farm conservation of agricultural biodiversity therein.

4. Discussions and Conclusions

The principal aim of this paper was to unravel one of the many complex interlinkages between the process of development and the decline of agricultural biodiversity. It has set forth and demonstrated, both empirically and theoretically, what seems to us to be a very plausible line of argument about the way in which relatively isolated farmers and agricultural communities would have managed risk through activity diversification, i.e. by keeping high levels of agricultural biodiversity. Further the paper established the way in which market integration removes the reasons for isolated farmers and agricultural communities to be managing risk in this manner.

The secondary aim of this paper was to value the benefits from home gardens and their attributes, and particularly those associated with the use values of agricultural biodiversity. A sample design that includes three environmentally sensitive areas of Hungary with distinct economic and agro-ecological features enabled the testing of hypotheses about the possible effects of economic change on the value of these attributes to producer-consumers. The choice experiment method was applied to investigate how farmers' demand for agricultural biodiversity changed with changing economic conditions such as market integration. Findings support the overall hypothesis that home garden attributes and home garden production itself significantly and positively contribute to the utility of producer-consumers in environmentally sensitive areas of Hungary. To the extent that the findings are representative of other areas in Hungary, they confirm that home gardens continue to be a vital institution for Hungarian farmers[24]. The reasons as to why Hungarians value these gardens and the relative importance of their attributes clearly differs according to the social, demographic, agro-ecological and economic characteristics of the region in which respondents live. In this study a cross-section of regions shows that farmers in regions that are more integrated into markets demand lower levels of agricultural biodiversity compared to those that are not integrated into markets.

[24] The value estimates for benefits of home gardens and their attributes are obtained only from home garden producers. Hence these values can be considered as lower bounds since only the private values were estimated, as they accrue to the farmers. If the social (regional, national or global) values that these home gardens generate were also taken into account, this value would be expected to be higher. Considering landraces, for example, as Smale, Bellon and Aguirre Gomez (2001a) note ' In addition to the private value they [landraces] generate for the farmers who grow them, landraces have social value because plant breeders use them as sources of novel alleles (gene types) or gene combinations to improve the crops that produce the food, feed and fibre on which societies depend.'

Therefore the most important result of the study is that market integration and development, do affect the demand of farmers for agricultural biodiversity negatively, as found by several empirical studies that preceded this one (e.g. Van Dusen, 2000; Meng, 1997). Hence it can be concluded that market development is one of the causes of agricultural biodiversity loss.

Information obtained from this choice experiment case study can be used when designing policies that aim to encourage continued cultivation of home garden systems to conserve the agricultural biodiversity as well as other multifunctional agriculture values that are embedded in them. Since this study reveals the regions in which farmers are most likely to cultivate home gardens and value each attribute the most, incentives for continued cultivation of home gardens can be targeted at these regions at the least cost. In other words, since values placed on home gardens and their attributes are overall significant and substantial in certain regions (e.g. those that are not integrated into markets) than others (those integrated into markets), identification of those regions would lead to realisation of cost effective on farm conservation strategy. This is because these farmers in these regions would need minimal incentives and interventions to continue management of home gardens in a way that conserves the agricultural biodiversity therein (Meng, 1997) and the least cost conservation strategies must be ranked the highest for conservation policies (Brown, 1991).

In short there is evidence of on farm conservation of agricultural biodiversity, and of its components, found in Hungary as well as in other locations (Brush, 1992; Meng, 1997; Van Dusen, 2000; Smale et. al., 2001). In the face of changing economic environment, however, there is insufficient assurance that society can indefinitely rely on farm households to conserve these resources. In other words, even though there is evidence that farmers demand agricultural biodiversity on their home gardens at the moment, there should dynamic concerns due to Hungary's ever-changing economic conditions. Hungary is a transitional economy that is about to become an EU member hence development of markets in these isolated regions and integration of these isolated regions into the rest of the country and of Hungary into rest of Europe is inevitable. Hence a long-term viable framework for on farm conservation of these agricultural biodiversity rich systems needs to be established.

EU agri-environmental policies and Hungarian NAEP must therefore step in to ensure continued cultivation of home gardens and thereby on farm conservation of the agricultural biodiversity therein by creation of agri-environmental contracts for home garden cultivation. Justification of their values in terms of multifunctional agricultural benefits they provide confirms the necessity of their inclusion in NAEP. Results on of different values being attached to different attributes of home gardens in different regions enrich information content for policy design, revealing which regions to target at least cost.

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6. Appendix

Definitions and Assumptions:

Crops or more generally home garden activities, *d=1,2,...* are ranked by mean output, or more generally mean return, and the return of activity *d* is $y_d \sim N(Y_d, \sigma_d^2)$. Co-variance between or returns of the same activity carried out on different plots of land in the home garden is denoted by *z*.[25] There are *N* plots *j=1,2,...,N* in the home garden. There is perfect information and the rationality of all players is common knowledge. Demand for *d* is linear in supply such that (subscripts omitted)

$$p = A - B\sum_{n} y$$

(A.1)

where *n* indicates the number of plots in which the farmer has chosen to carry out activity *d*. We will refer to n_d repeatedly as the "intensity" of a activity *d*. We assume that $Y_1 < A/2B$ and *A>>B*.[26] Input price variability is excluded in this analysis in order to keep the exposition simple.[27] We are interested in the resultant aggregate demand for crop or activity diversity as a function of risk correlation.

Farmer's Problem:

The individual farmer's problem is to maximise utility, which is linear in expected income, and therefore linear in expected revenues (assuming inputs at zero cost). Choice is restricted to selecting one activity per plot such that the problem for the farmer is to maximise utility for each plot. That is the problem for the farmers for plot *j* is to

$$\max U_j = E\left(R_{d_j}\right) = E\left(p_d \cdot y_d\right)$$

(A.2)

by choosing *d*. Expected revenues are a function of the mean output of the chosen activity and the expected price. Using (1),

$$E(R) = E\left[y_j\left(A - B\sum_{k=1}^{n} y_k\right)\right]$$

(A.3)

[25] For simplicity, we disregard co-variances between yields of different crops. Since we assume that crops are not substitutes in consumption, omitting co-variances between yields of different crops has no implications within the model. If this assumption is relaxed, the static demand for aggregate diversity will lie in most circumstances above the level derived here, although there are specific combinations involving strong negative covariances for which it is below. The conclusions derived from the comparative statics used in propositions 1 and 2 will not be substantially affected, however.

[26] Hence, issues of demand saturation do not confound the analysis and outputs of the activities are assumed not to be substitutes in consumption.

[27] Variability of input prices is likely to contribute to the demand for insurance unless input and output prices are negatively correlated. We are grateful to an anonymous referee for stressing this aspect of farm household behaviour.

Expanding the revenue term and taking expected values, we get

$$E(R) = AY - B \cdot \left\{ \sum_{k=1}^{n} \left(Y^2 + Cov\left(y_k , y_j \right) \right) \right\} \tag{A.4}$$

where Y denotes the mean output which is identical for all plots in the home garden. Since the co-variance between returns on different plots on the home garden is z and the own variance of the activity is σ^2, we can simplify (4) into

$$E\left(R(n) \right) = AY - B\left[nY^2 + (n-1)z + \sigma^2 \right]$$
(A.5)

Equation (5) defines for each activity a family of functions. These functions are the expected returns on the activity which increase in Y,[28] but decrease in n, σ^2, and z. Equation (5) shows the extent to which the small or thin markets translate the natural correlation of home garden plot yields into income risk for the individual household.

Varying over the set of activities and n generates a set of possible returns RS. The nature of RS depends critically on the relative distribution of returns among activities: Great differences in performance favour concentration of choice. But in reality, cultivar performance does not differ that widely in terms of yields (Smale and McBride 1996). We assume therefore that

$$E\left[R_d(n) \right] - E\left[R_{d+1}(n) \right] < E\left[R_d(n) \right] - E\left[R_d(n+1) \right] \quad \text{for all} \quad n<n^*$$
(A.6)

Equilibrium:

We are interested in the nature of the set of activities chosen by the home garden farmers. The equilibrium we want to examine here is the correlated equilibrium of this N-player game (cf. Brandenburger and Dekel 1987, Aumann 1974). The appeal of this equilibrium concept for the given problem is that it enables farmers to reach the efficient frontier of returns contained in RS without having to assume that farmers sign binding contracts (Barany 1987). What is required for the community to reach this equilibrium is that they co-ordinate their crop choices through some publicly observable random signal. We conjecture that there exists a correlated equilibrium that generates a "recommendation" for each farmer which it has an incentive to obey in order to maximise individual payoff.

In order to characterise the equilibrium it is necessary to give some definitions: Define F as the set of activities that generates $FS \subset RS$ and fulfils the following two conditions: (1) The home garden farmer can allocate some activity, which is in an element of F, to each plot (although the plot may not be the only one on which this activity is carried out). (2) No element of $RS \backslash FS$ has a payoff higher than the lowest

[28] Remember that the analysis deals with the increasing part of the logistic revenue curve since demand saturation is not of relevance in this context.

payoff in *FS*. Call *F* the "efficient set" of activities. Define n_d^* as the highest intensity of activity $d \in F$ for which *d* is still included in the efficient set.

DEFINITION: (Fudenberg and Tirole 1993, 2.4B) A correlated equilibrium is a probability distribution *p(·)* over the pure strategies $F_1 \times F_2 \times \cdots \times F_N$ for which for every player *j* and every s_j with $p(s_j)>0$,

$$\sum_{s_{-j} \in F_{-j}} p\left(s_{-i} \middle| s_j\right) U_j\left(s_j, s_{-j}\right) \geq \sum_{s_{-j} \in F_{-j}} p\left(s_{-i} \middle| s_j\right) U_j\left(s'_j, s_{-j}\right) \quad \forall s'_j \in F_j$$

(A.7)

Our conjecture is that some device that generates a probability distribution *p(·)* which allocates each activity *d* to exactly n_d^* plots is sufficient for a correlated equilibrium. A candidate for this probability distribution is one for which the farmer chooses to employ activity *d* in each plot with probability n_d^*/N. Call this candidate *p(d)*.

PROPOSITION 0: *p(d)* is a correlated equilibrium.
PROOF: Assume an information set which recommends farmer choose activity *d* for plot *j* if the event *Q* has occurred (i.e. the realisation of the randomised device). Assume *Q* occurred. Then for *p(d)* to be a correlated equilibrium, (7) must hold. Given payoff function (5), (7) becomes

$$\frac{n_d^* - 1}{N}\left[AY_p - B\left(n_d^* Y_d^2 + \left(n_d^* - 1\right)z + \sigma_d^2\right)\right] \geq \frac{n_d^* - 1}{N}\left[AY_e - B\left(\left(n_e^* + 1\right)Y_e^2 + n_e^* z + \sigma_e^2\right)\right] \quad \forall e \in F$$

This inequality must hold since the farmer now chooses to employ activity *e* on $n_e^* + 1$ plots. But since n_e^* is the highest intensity for which *e* is an element of *F*, $n_e^* + 1$ is not an element of *FS* and its associated payoff is therefore smaller than that of *d* at n_d^*. *p(d)* is therefore a correlated equilibrium. ■

Intuition: In order to establish that our candidate solution is a correlated equilibrium, we have to show that there is no incentive for the farmer to deviate any of its plots from the activity he/she has been recommended to employ given that for every other plot he/she owns the farmer observes its recommendation. Comparing the payoffs from conforming with the recommendation and from deviating when everyone else conforms, the proof establishes that deviation is not preferred.

The set of activities chosen by the farm household is therefore the efficient frontier of activities contained in RS, in other words the efficient set *F*. This set, which arises in equilibrium, has the following structure:

$F = \{1,2,\ldots,T\}$ and $n_d^* \geq n_{d+1}^*$

This means that the efficient set includes activities in descending order of mean output, starting with the activity of rank 1 down to the last activity included, which is denoted by rank *T*. The optimal intensity is overall decreasing in the rank of activities such that activity 1 will be employed with the highest intensity of all crops included in F.[29]

The Effects of Market Integration:

This section establishes the core propositions of the paper regarding the effect of market integration on F. For the purpose of proving proposition 1, a Lemma is in order.

LEMMA 1: In equilibrium, activity T is not employed on more than one plot.

PROOF: Assume T was employed on two plots. This implies that $E[R_T(2)] > E[R_{T+1}(1)]$ since otherwise $E[R_{T+1}(1)] \in FS$, i.e. $T+1$ would have been selected into F. But from (6), $E[R_T(1)] - E[R_{T+1}(1)] < E[R_T(1)] - E[R_T(2)]$ from which follows that $E[R_T(2)] - E[R_{T+1}(1)] < 0$ which contradicts $E[R_T(2)] > E[R_{T+1}(1)]$. T can therefore not have been employed on two plots. For $n>2$, the proof works analogously. ■

Lemma 1 states that the activity with the lowest return contained in the portfolio is carried out on not more than one plot. Call this activity the "marginal activity".

Proof of Proposition 1:

PROPOSITION A1: If the *(N+1)*th plot, which becomes available as a result of a food market creation, contributes covariance $g<z$, activity T is removed from F.

PROOF: From Lemma 1, $n_T^*=1$. Unless $S=T-1$ and with (5) holding, the *(N+1)*th plot contributing covariance g results in $n_{S+1}^*=2$. Therefore, for all activities e with $n_e^*=2$, $E(R(n=2)) = AY - B\left[2Y^2 + \frac{S-P-1}{S-P}z + \frac{1}{S-P}g + \sigma^2\right]$ such that if $g < z - (S-P)\left[z + 2Y_{S-P}^2 - Y_T^2 + A/B\,(Y_T - Y_{S-p})\right]$, then $E[R_{S-P}(2)] > E[R_T(1)]$ and consequently $T \notin F$ since $\sum_d n_d^* = N+1$ for all $d \in F$. ■

Intuition: We look for the conditions on g, which give the farmer who employs the marginal activity on one of its plots the incentive to switch to another activity employed on one of its other plots. The *(N+1)*th plot that becomes available as a results of food market accessibility, will add an activity to the set of those employed by the farmer unless this would mean adding T. The effect of this is that there is a positive probability for every plot owned by the farmer that it will be paired with the farmer who tends the *(N+1)*th plot by choosing an activity of the set *(P, P+1,..., S)*. If the return of the *(N+1)*th plot has covariance g which is sufficiently uncorrelated with other plot returns, this results in a general increase in expected revenue for all activities undertaken on more than one plot by decreasing expected covariance. For g sufficiently small (and potentially negative) this effect offers $N+1$ returns that exceed the expected revenue of undertaking activity T. The farmer, who employs the

[29] We assume here at N is sufficiently big such that crop 1 is at least grown on two plots. Otherwise, the correct statement is that the optimal intensity is non-increasing in the rank of crops.

marginal activity on one of its plots will switch to an activity of rank *S+2*, hence *T* will be removed from *F*.[30]

Proposition A1 states that the marginal activity *T* will be removed from the set chosen by the farmer as soon as the farmer interacts with farmers whose home garden outputs are sufficiently uncorrelated with those of the farmer. This means that at most activities with a higher mean returns than that of activity *T* remain to be undertaken. This proves proposition 1 in the main text.

Proof of Proposition 2:
Assume that there is now an asset available that generates a risk-free return $w<AY$, such as off farm employment and that the farm household can allocate its resource endowment freely between the risk-free asset and home garden production.

PROPOSITION A2: With an asset with risk-free return available to farmers, *F* does not contain *T*.
PROOF: For *a* denoting the relative share of the resource of household time allocated to home garden production, the household income is

$$I=(1-a)w+E\left[R(a)\right]=(1-a)w+E\left[A-B\left(\sum_j a_j n\cdot y\right)a_i y_i\right] \qquad \text{(A.8)}$$

and $a^*=\arg\max I$ such that $a^*=\dfrac{AY-w}{2B\left(nY^2+(n-1)z+\sigma^2\right)}$ for intensity *n*. As we would expect, $\partial a^*/\partial w<0$, i.e. the amount of resources devoted to home garden production decreases with the return on the risk-free asset. We want to show that the farmer will consequently select a portfolio consisting of a smaller number of activities, i.e. there will be more activities carried out on more than one plot.[31] If returns along the intensity dimension *n* become densely distributed more rapidly than the distribution of returns along the output dimension when a labour market exists, then increasing the intensity of activities with higher returns relative to switching to an activity of lower return rank incurs a smaller sacrifice in expected revenues than in the absence of a risk-free asset. It is therefore sufficient to show that

$$\frac{-\dfrac{\partial E[R_L]}{\partial Y}}{\dfrac{\partial E[R_L]}{\partial n}}<\frac{-\dfrac{\partial E[R]}{\partial Y}}{\dfrac{\partial E[R]}{\partial n}}$$
(A.9)

[30] This is the most stringent test for removing *T* since if there are other activities of higher rank undertaken on more than two plots, returns associated with activities of higher rank, e.g. *P+1*, may exceed that of *S+2* and consequently that of the marginal activity *T* at levels of correlation higher than *g*.
[31] To prove proposition 2, it would be sufficient to show that farmer switches at least the marginal plot (see Lemma 1).

with $E[R_L] = \dfrac{A^2Y^2 - w^2}{4B\left[nY^2 + (n-1)z + \sigma^2\right]}$ given a^*.

(A.10)

where subscript L indicates revenues when a labour market exists.

Differentiating (10) and (3) with respect to Y and n to get (9) and re-arranging results in

$$(A - 2nBY)\left(AY^2 - w^2\right)\left(Y^2 + z\right) < 2Y\left(BY^2 + z\right)\left[A\left(\sigma^2 + (n-1)z\right) + nw^2\right]$$

(A.11)

Inspecting (11), the RHS is clearly greater than the LHS and the gap is increasing in n.[32] Thus (10) and (3) fulfils (9). ■

Intuition: The idea behind the proof is that when a finite set of the N highest revenue streams is selected for employment, there must be proportionately more activities undertaken on more than one plot than previously since the density of these streams has increased relatively. Since the set must serve an identical number of plots, the number of activities undertaken by less than two plots must decrease.

It should be clear that proposition A2 is not more than an identical way of expressing proposition 2 on the basis of the notation established in the appendix. We have therefore proven proposition 2.

[32] Since the RHS is greater than the LHS for $n=1$, it must be greater then the LHS for all $n>1$, since the RHS is increasing in n and the LHS is decreasing in n.