

# **Economic Reforms and Soil Degradation in the Ethiopian Highlands: A Micro CGE Model with Transaction Costs**

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## **Abstract**

*The model is developed for a rural economy in the Ethiopian highlands. The economy is characterized by transaction costs in the internal markets as well as in the markets linking the economy to the external world. The model contains a representation of the crop-livestock system in the area through nested constant elasticity of substitution (CES) production functions with realistic elasticities of substitution, multiple inputs and multiple outputs. Imperfections in the local markets are captured through market specific transaction costs and price bands for some commodities and factors, and missing markets for others. Market imperfections cause commodity and factor prices to be household group specific and implies that production and consumption decisions are non-separable for each household group. The model also captures the environmental externality related to land degradation. The simulations indicate that both output price increase (tax reduction) and fertiliser subsidy removal may have caused an increase in the negative environmental externality in form of more rapid decline in land productivity. A combination of a tax on marketed surplus of agricultural commodities and a fertilizer subsidy appears to reduce the land degradation externality. Such a policy affects household groups differently as it leads to a welfare improvement for the wealthiest households and a welfare reduction for the poorest households.*

# 1. Introduction

Typically macro economy-wide models incorporate the agricultural sector as a pure producer sector, while the consumption side has been kept separate (pure consumers). Production and consumption are closely linked in typical rural economies in low-income countries, and may be better captured by separable or non-separable agricultural household models (Singh *et al.* 1986). Farm households appear to be an extremely robust and dominant decision-making unit in relation to production, natural resource management and consumption in rural economies in Africa. Farm household modules that represent groups of farm households with common characteristics are therefore cornerstones of village economy models.

The links between macro policy changes and rural micro economies and the environment may be complex. The main links between the economy and the environment in agriculture-based poor rural economies go through the agricultural production activities of farm households. Natural resources are depleted in the production process, reducing the production potential of the agroecosystem unless a sufficient amount of productivity-raising investments are carried out. The production and investment decisions of farm households are endogenous responses to exogenous changes in policies and other external factors, conditioned by household and farm characteristics.

Rural economies in developing countries are characterized by significant transactions costs and imperfect information (Hoff *et al.* 1993, Sadoulet and de Janvry 1995). The resulting gap between (higher) buying prices and (lower) selling prices induce farm households to be only partially integrated into markets. Missing markets or non-participation in markets may cause production decisions of farm households to become non-separable from consumption decisions (Strauss 1986; de Janvry *et al.* 1991). Transaction costs cause isolation of markets and inter-spatial and inter-temporal price variation.

Holden *et al.* (1998a) developed a typology of village economies and village economy models (Figure 2) based on the size of transaction costs in relation to trade and the degree of differentiation in asset ownership within villages. The typology indicates that it is relevant to use village CGE models only when significant transaction costs lead to endogenous price determination in village markets. Some differentiation is required in order for farm households to have incentives to trade with each other given that there are transaction costs related to local trade as well. Holden *et al.* (1998) found that a remote Zambian village, in which local trade was insignificant, could be modelled as a number of non-separable farm household models. Taylor and Adelman (1996) modelled village economies as consisting of a number of separable farm household models. Lofgren and Robinson (1999) developed a CGE model that is written in a mixed-complementary format and where households, in the presence of transactions costs, endogenously choose between participation and non-participation in markets.

The most serious environmental problem in Ethiopia is land degradation, primarily due to soil erosion and nutrient depletion. This leads to on-site and off-site external effects. The on-site external effects are external because of high discount rates due to market

imperfections, poverty, and insecure or unspecified private property rights (Holden *et al.* 1998b). One consequence of imperfections in markets and tenure regimes is land degradation, manifested in declining productivity, as users lack incentives to make sufficient investments in the land that they operate. Such degradation may be irreversible. The net present value of this permanent productivity loss, which may be called an inter-temporal externality (Holden and Shiferaw 2002), may be considerable. In this study we estimate the size of this externality and assess how it is affected by various policy reforms. More specifically, in our model crop choice and the level of fertilizer use in one year is permitted to influence land productivity in the following year.

Removal of policy distortions has been an important step in the right direction to make the Ethiopian economy more dynamic. However, that does not necessarily mean that all taxes and subsidies always are bad for an economy. The environmental and poverty impacts of the changes in output tax and input subsidy policies have not been carefully analysed. We therefore, in the spirit of Pigou (1924), assess whether such taxes and subsidies alone or in combination could help reduce the land degradation externality related to agricultural production in Ethiopia. Before we have used this model to assess the impacts of such subsidies and taxes independently (Holden and Lofgren 2005). Here we also look at the combined effects of agricultural output taxes and fertiliser subsidies. Sterner (2003, p. 103) considers combining policy instruments for environmental and natural resource management a fertile area. Such a tax may be used to fund a subsidy. The tax could also be targeted at specially land degrading crops or activities while the subsidy is used to stimulate ameliorating activities.

We have developed a micro CGE model for three villages for a high agricultural potential area with relatively good market access in the Ethiopian highlands. We assess the impact of a) an output price increase of 5% (reduction in output tax due to decontrol of prices), b) removal of fertiliser subsidies, c) combining a) and b) and d) increasing the fertiliser subsidy from 20 to 40% in combination with an additional tax of 5% on agricultural output (Pigouvian tax and subsidy). We assess the impacts of these simulations on household welfare for different household groups, on production, marketed surplus, fertiliser demand, import of other goods, and the land degradation externality.

We present a brief background on the economic policy reforms in Ethiopia in part 2, describe the case study area in part 3, and provide a model description with emphasis on the unique characteristics of this model in part 4. The simulation results are presented and discussed in part 5 and some conclusions are derived in part 6.

## **2. Economic policy reforms in Ethiopia**

Market imperfections are common in rural markets in Ethiopia. This may partly be due to historical factors since economic policy only recently (in 1991) was changed from a socialist, top-down planning system to a more market-friendly regime. It may take time before more efficient markets develop. The poor infrastructure also causes transaction costs to be high. Ethiopian land reform in 1975 resulted in an egalitarian distribution of land among farm households. While all land is state-owned, user rights have been allocated to individual households through the land reform in 1975 and several land

redistributions in the years that followed. Land sales are illegal but there are active land rental markets. The distribution of other rural assets, most importantly livestock, is less egalitarian and this creates incentives for trade within villages, including the renting of land and oxen.

With the regime change in 1991 and its replacement by a more market-friendly government, Ethiopia embarked on structural adjustment policy reforms. These reforms included devaluation of the exchange rate, removal of fertiliser subsidies, removal of price controls for agricultural commodities (pan-territorial pricing), and privatisation of public enterprises.

The development strategy, called 'Agricultural Development-Led Industrialisation,' is focused on the development of labour-intensive industries that rely heavily on domestic raw materials and inputs from smallholder agriculture. The new strategy aims to stimulate market development, competition, and efficiency. Consequently, the Government has dissolved producer cooperatives, reduced the role of state farms, abolished compulsory food grain quotas, and removed price controls on agricultural commodities and domestic trade restrictions.

Like in many African countries, Ethiopia followed a pan-territorial fertiliser pricing policy and provided subsidies to smallholder farmers. These subsidies are often blamed for creating wrong incentives to farmers although the universality of this claim has been questioned (Holden and Shanmugaratnam, 1995). The fertiliser subsidy in Ethiopia was 15% in 1993, 20% in 1994, 30% in 1995, and 20% in 1996. Following the devaluation in 1992, fertiliser prices increased sharply, causing a decline in fertiliser consumption in that year. Fertiliser subsidies were therefore introduced, but later reduced and then eliminated starting from 1997. Fertiliser use has remained low in Ethiopia after the reforms. In terms of nutrients the average rate of fertiliser application is 7 kg/ha in Ethiopia against 9 kg/ha for SSA, and 65 kg/ha worldwide. A new fertiliser distribution policy was introduced in 1997. It called for elimination of fertiliser subsidies and pan-territorial pricing system for fertiliser. The involvement of the private sector in importation and distribution of fertilisers was also stimulated.

Although dependence on rain-fed agriculture and frequent droughts continue to pose serious concerns, most macro indicators suggest that economic performance has been strengthened since the introduction of the reforms. On average, growth seems to have accelerated, both in agriculture and other parts of the economy, while overall inflation has remained moderate. Both exports and imports have grown much more rapidly than gross domestic product (GDP), thus drastically increasing the openness of the economy.

### **3. Case study area**

The study area consists of the Hidi, Hora Kilole and Borer Guda peasant associations in the Ada-Liben district in Showa region in the central highlands of Ethiopia. This area is favourably located approximately 20 km from Debre Zeit, which is near the main highway and only 50 km east of the capital, Addis Ababa. In addition to good market

access, the area enjoys a high agricultural potential. Ada-Liben district is a surplus producer of teff (*Eragrostis teff*), the main crop (both in terms of consumption and market sales) and the preferred cereal among Ethiopian consumers. The production system is an integrated crop–livestock system where oxen provide traction power for land cultivation, and straw from grain production is the main source of animal fodder. Very little communal land exists as most of the land has been distributed to individual households.

Land rental markets are active, particularly given that land cannot be sold or purchased. Usually, fixed-rent contracts are used. Livestock, most importantly oxen, are the most important privately owned asset in the study area. The distribution of this resource is less egalitarian and is a good indicator of household wealth. Oxen ownership is also an important indicator of farming capacity due to the crucial role of oxen. Rental markets for oxen are less important because of moral hazard problems in relation to oxen management and because proper timing of ploughing is crucial on the dominant heavy black soils in the area. In this setting, characterised by a non-egalitarian distribution of oxen and impediments to oxen rental, households without oxen rent out much of their land. Typically, households with two or more oxen rent in land as they have excess ploughing capacity. Households with one ox tend to exchange oxen with other one-ox households as a pair of oxen is needed for ploughing. Average household and farm characteristics for different oxen ownership groups of households are presented in Table 1. In 1993/94, 25% of the households had no oxen, 17% had one ox, 34% had two oxen and 24% had more than two.

The local economy is highly agriculturally oriented, as the diversification into non-farm activities is limited. However the area is a net importer of unskilled labour (seasonal demand in crop production) but exports some skilled labour.

Holden *et al.* (1998a) found that the subjective discount rates of farm households in the study villages were high and that they were influenced by wealth as poorer households had higher subjective discount rates. This indicates that households are credit constrained and that poorer households suffer most. Credit in kind (in the form of fertiliser), was provided in the area but this credit also appeared to be rationed during our first survey round in 1993-94 but credit access had improved in the two later survey rounds in 1997 and 2000.

Holden and Shiferaw (2002) estimated the farm households' willingness to pay (WTP) to sustain land productivity in the area as almost all farm households stated that land productivity was declining over time. They also estimated farmers' perceived average rates of land productivity decline. Shiferaw and Holden (1999) used the Universal Soil Loss Equation adapted to Ethiopian conditions to estimate soil erosion in the area, and production functions adapted from experimental studies at other locations in Ethiopia to estimate the impact of erosion on crop yields. The resulting estimates of average rates of land productivity decline were about twice as high as those estimated based on farmers' judgements.

## 4. Model description

### 4.1. General model structure

As the starting point for our village CGE model, we use a standard CGE model developed by Lofgren *et al.* (2002). The model has been applied to a large number of countries. Its flexibility is based on two main features: a. It separates the model from the database, making it easier to apply to model to new settings, and b. It permits the user to choose among alternative assumptions for how factor markets and macro constraints operate (Lofgren *et al.*, 2002).

The modelling structure has also been adapted for village-level analysis. The general structure of the modelling system is kept separate from the specific structure and inputs needed for a specific economy to be modelled. Relatively few changes are therefore needed in its general structure. The specific structure is entered through an input file or database containing most of the relevant elements and quantitative inputs for modelling the specific economy. One important distinction for a village model from a country model is that a village does not have a separate currency with an exchange rate and this has implications for how the interactions of the village with the surrounding economy are balanced. Another distinction is that ‘the rest of the world’, export, import, and ‘foreign’ have different meanings in village and country models. For the village model these terms refer to outside the village, be it inside or outside the country.

The database of the model consists of the SAM, elasticity data for production, consumption and trade, and possibly physical factor quantities. A simplified picture of the model and its building blocks is provided in Figure 1 (Lofgren *et al.*, 2002). Vi refer to Lofgren *et al.* (2002) for a detailed mathematical description of the standard CGE model.

### 4.2. Specific model structure

The general model was modified to accommodate the characteristics of the economy in the study area. These modifications included fitting a village SAM to the requirements of the CGE model. Market imperfections (in markets for: land, labour, oxen ploughing services, manure, crop residues, and crop outputs) in the study area caused production and consumption-decisions of households to be non-separable. The prices for land and oxen services became endogenous to villages (closed village market only). Shadow prices for non-traded factors (crop residues and manure) became endogenous to each of the household groups. Transaction costs in the local factor markets caused household group specific factor prices for factors traded within the village to depend on whether the household group was a net seller or net buyer of the factor in the village market. Household group specific and general commodity accounts were used to capture transaction costs in relation to local and external trade.

As discussed earlier, oxen ownership is a good wealth indicator and is used as a basis for household group classification. One additional reason for this is that oxen ownership tends to drive the participation in land rental markets. In the CGE model and the

underlying village SAM, the households were therefore divided into three groups on the basis of oxen ownership. Households with two oxen or more were pooled into one group, while households with zero and one ox were kept as separate groups.

The modelling structure is quite flexible and this has been further developed in order to handle a relatively complex farming system (crop–livestock system) and market imperfections induced by transactions costs. Households typically produce a variety of crops and livestock types. Agricultural production activities may have multiple inputs and multiple outputs. Outputs from one activity may be inputs in another activity. Typically crop residues are used as livestock fodder, while oxen are used for land preparation, and animal manure is used as fuel. Production technology is captured by nested, two-level CES-production functions, allowing substitution elasticities to be different at different levels of the nest (Figure 3). At the bottom level, substitution elasticities between oxen, land, capital and labour may be quite low ( $\sigma = 0.2$ ) relative to the elasticities between land and fertilisers at the higher level of the nest ( $\sigma = 0.9$ ). This reflects the relatively fixed relationship between land, oxen, capital and labour in relation to land preparation and the much higher flexibility that exists in relation to fertiliser application.

As a result of transaction costs, selling prices are typically lower than buying prices. In the base year, each household group is a net seller, self-sufficient, or a net buyer of various factors of production (inputs) and commodities. This also determines the choice of price when value added is imputed to the different factors in the SAM. Markets for crop residues and manure are missing. Manure is used for fuel (an input into the chores activity, representing miscellaneous tasks carried out inside the households). SAM cell values for manure are based on the nutrient contribution of manure and the cost of nutrients if they were bought as fertiliser (for nitrogen and phosphorus). The values of crop residues and fodder from grazing land were determined residually after subtracting the value of labour and animal stock from the value of livestock production.

A village SAM that was structured to match the requirements of the CGE model was constructed. The SAM is based on a survey of the economy in 1993, carried out in 1994. The basic structure of the village SAM is presented in Table 2. Transaction costs in relation to village exports and imports are captured by separate accounts while transaction costs in relation to internal village trade are primarily represented by the labour time needed to carry out the transactions. This implies a considerable expansion in the number of rows and columns in the SAM, making it too big for reproduction here (a copy of the SAM used in this case study can be obtained from the authors upon request).

Land productivity declines have been estimated for the area for different types of soils and crops (Shiferaw and Holden, 1999). Information about farmers' perceptions on the rates of land degradation is available from Holden and Shiferaw (2002). The rate of productivity decline is reduced by the use of fertilisers that replace lost nutrients. The model is calibrated such that the estimated rates of productivity decline (annual mean, 1.1%) are taken as an indicator of the rate of productivity decline when no fertilisers are used, while the average rate of fertiliser use in the area is assumed to reduce the rate of productivity decline to the rate that farmers perceived (annual mean, 0.55%).

Some of the equations that capture the link between the land productivity and land degradation are described below. The land productivity decline per unit of land is a function of land-type ( $A$ ), crop choice ( $C$ ), household type ( $H$ ) such that:

$$\psi_{ach} = \psi(F_{ach}, \psi_{MAX}(A, C)) = \psi_{MAX}(A, C) / (100(1 + \beta F_{ach} / Q_{ach})) \quad (1)$$

where  $F_{ach}$  is the household, land and crop specific fertiliser use,  $\psi_{MAX}$  is the maximum land productivity decline that takes place when no fertiliser ( $F$ ) is added to the land,  $Q_{ach}$  is the current output of crop type  $c$ , on land type  $a$  by household type  $h$ , and  $\beta$  is a calibration parameter. The rate of productivity decline without fertiliser use is specified at two levels – high and low. The actual values used for  $\psi_{MAX}(A, C)$  for different crop types and land types in the model are given in Table 3. The intensity of fertiliser use ( $F_{ach}$ ) is household group ( $H$ ) specific and depends on the price of fertiliser ( $P_F$ ), crop choice ( $C$ ), crop price ( $P_C$ ) and land type ( $A$ );

$$F_{ach} = F(H, P_F, P_C, C, A,) \quad (2)$$

while the fertiliser price ( $P_F$ ) depends on the import price (including transportation costs), ( $P_{FI}$ ), and the level of subsidy ( $S_F$ );

$$P_F = P_{FI} - S_F \quad (3)$$

Optimal fertiliser use is determined through the first-order conditions for the production functions, implicit in equation (2). The first order conditions equate marginal value products to the prices of the respective inputs. An output price change will similarly affect the first- order conditions and affect both input use and output supply. Other things remaining the same, reduction in the fertiliser subsidy will cause the fertiliser price to increase, the level of fertiliser use to go down, and the level of productivity loss from land degradation to increase. This land degradation externality ( $LDEXT$ ) is aggregated across areas ( $L_{ach}$ ) of different land types, crop types, and household groups, assuming that the process is irreversible,<sup>1</sup> with a social discount rate  $\delta$  and that land use and output prices ( $P_{Qc}$ ) are constant over time:

$$LDEXT = \sum_H \sum_A \sum_C \psi_{ach} L_{ach} P_{Qc} / \delta \quad (4)$$

Household consumption is captured by a Stone-Geary Linear Expenditure System which can handle broad commodity groups. Leisure is one of the commodities that is included in the model, consistent with theoretical household models but unlike typical macro CGE models. Agricultural production for home consumption is also included in the

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<sup>1</sup> Although some soil degradation may be reversible to some degree, soil formation is a slow process and erosion rates have been found to be more than 10 times higher than the soil formation rates in Ethiopia.

expenditure system. All household groups are net sellers of agricultural commodities, indicating the importance of the area as a surplus producer of food grains. The agricultural production activities are given in Table 5.

## **5. Policy simulation results**

For each simulation experiment, in the following sections we present the impacts on household welfare, crop and livestock production, village exports, fertiliser use, and environmental externality, see Tables 4 to 10.

Because of the influence of market imperfections, the impacts of specific policies vary by land type, crop type and household group. This is a consequence of the non-separability of production and consumption decisions, making land use and land degradation a function of household characteristics. This has been one of the major limitations of many of the standard CGE models, which assume that production decisions are unaffected by poverty or equity. The model developed here demonstrates how this assumption can be relaxed to make CGE models capture poverty–NRM linkages more effectively.

### **5.1. Increase in output prices (output tax reduction).**

The results from a 5% increase in the prices for all agricultural outputs (reduction of output taxation) are examined first. The real income effects for the different household groups are shown in Table 4. The 5% price increase leads to an increase in household real incomes of 1.4–3.6% for the different household groups. The poorest group benefited more (3.6%) from the output price increase than any other group. This is mainly because the price increase makes production more profitable thereby allowing them to cultivate more of their land themselves (rent out less). This is supplemented by increased fertiliser use and livestock production. The impacts on production activities are shown in Table 5. An increase in output prices has a positive impact on production of most commodities although there is some variation across commodities and household groups. The price policy had a stronger effect on production of lowland cereals (wheat and barley). The lion's share of the production comes from households who own at least a pair of oxen, but the largest % increase in production was for the poorest household group.

Perhaps a surprising result is the impact on marketed surplus from the village (Tables 6 and 10). The output price increase reduced the marketed surplus of grains because the income effect increased the demand for self-consumption more than it stimulated local production. The profit effect (Singh et al. 1986) and a relatively high income-elasticity for food consumption among the poor households explain the increase in food consumption. Market imperfections and low elasticities of substitution for inputs may also explain this low supply response. Similar results have been found by Bardhan (1970) and de Janvry and Kumar (1981) in parts of India, and by Dorward et al.(2004) in Malawi.

The effect of output price changes on fertiliser demand is shown in Table 7. The price increase led to increased fertiliser use for cereal crops. At the aggregate level a 10% price change led to an almost equivalent (9.7%) increase in fertiliser demand.

## **5.2. Removal of fertiliser subsidies**

We simulated the effects of a removal of the 20% subsidy on fertiliser that was present up to 1997. Table 4 shows that the reduction in fertiliser subsidy reduced household incomes by 1.6–2.3%. The strongest relative change was for the wealthiest household group (2.3%). This is opposite to the distributional impact of output price changes. The wealthiest benefited relatively more from fertiliser price subsidies, while output price increase seemed to be more pro-poor.

Table 5 shows that the removal of fertiliser subsidy caused a reduction in cereal production in most cases, while it had mainly positive effect on the growing of pulses (legumes). This is mainly because the price hike causes a shift to crops that are less fertiliser-intensive or encourage planting of legumes usually grown without fertilisers. The subsidy removal also had a negative effect on livestock production because fodder production (crop residues) became more costly. The reduction in fertiliser subsidy caused a decrease in the marketed surplus (export from the village) of teff and an increase in the export of other cereals and of pulses (Table 6) while overall exports were reduced (1.3%). There was a small reduction in the export of livestock products and an increase in out-migration and outputs from small businesses.

The removal of fertiliser subsidy caused a fall by 18-24% in the demand for fertiliser in the different cereal production activities (Table 7). The aggregate demand decreased by 20%. The village import of other commodities was also reduced (Table 8) and overall import was reduced by 6.3%. We see from Table 9 that the land degradation externality increased when the fertiliser subsidy was removed. It increased more than it did due to the 5% output price increase, 6.7% for subsidy removal vs. 3.7% for output price increase, see Table 10, in the case of low level of land degradation and low discount rate (3%).

The results are also consistent with the findings of Croppenstedt et al. (2003) who found that fertiliser demand stagnated in Ethiopia after the fertiliser subsidy removal even though credit availability was improved. Our own panel data from the study area for this model confirm the same; increased access to credit for farm inputs did not lead to an increase in fertiliser use from 1994 to 2001 (Holden et al. 2005). Our panel data also confirm a declining trend in marketed surplus that may be due to land degradation and population increase.

## **5.3. Combining output price increase and fertiliser subsidy removal**

This is in essence what happened based on the strong pressures to reduce taxation of the agricultural sector (Krueger et al. 1991) and based on many arguments against fertiliser subsidies (e.g. reviewed by Holden and Shanmugartnam 1995). We see from Table 4 that the effects of this policy have mixed effects on the different household groups. The

poorest household group benefited (2.0%) while the wealthiest group lost (-1.0%) and the overall effect was negative but small (-0.6%). We see also that the effects on production were diverse but with a reduction in teff exports (-4.1%), an increase in exports of pulses (+15%) and other cereals than teff (+1%), see Tables 5 and 6.

The effects on fertiliser demand for the different crops were negative and in the range –12% to –18% with an overall reduction of –16.1% (Table 7). There was also a small increase in imports of labour and agricultural commodities.

When it comes to the environmental externality we found that it increased by 10.9% that is more than the sum of the effects of output price increase and fertiliser subsidy introduced separately (3.7% and 6.7%), see Table 10. We see the overall effects in Table 10, including a reduction in overall private consumption, exports from and imports to the village economy. This gives reasons to question the benefits of this policy.

#### **5.4. Combination of increased fertiliser subsidy and an output tax**

This is an opposite (“mirror”) experiment of the previous one and implies an increase in the fertiliser subsidy from 20% to 40% and an increase in the tax on agricultural exports from the village of 5%. The results are not exactly opposite of the previous experiment, however, due to the non-linearity of many relationships.

We see from Table 4 that the main beneficiaries of this policy would be the wealthiest household group that has a pair of oxen or more while the group without oxen will be worse off. One of the reasons for this is the effect on the local land rental market where wealthier households rent in more land from the poorer households as a response to the policy change.

Production effects are diverse due to the various responses in input demand and substitutions among crops (Table 5) but village export of teff will increase by 4.9% and export of other cereals and pulses decline by 1.8% and 16.5% but the base values of these are much lower than that of teff. The overall effect on export of livestock products was very small and negative while livestock production increased (Tables 6 and 5).

The responses in fertiliser demand range from 19% to 29% across cereal crops with an overall increase of 25.2% (Table 7) while there were small changes in other imports.

The most interesting result is that the negative environmental externality was reduced by 11.9% with this combination of output tax and input subsidy when the externality is assumed to be low and we use a low social discount rate (3%). The overall effects on the village economy were increased private consumption, increased village exports and imports.

## 6. Conclusions

We have developed a micro CGE model that captures essential structures of a low-income natural resource based rural economy. Such an economy is characterised by substantial transaction costs that affect the functioning of internal and external markets. The basic decision-making units are farm households that are both producers and consumers and market imperfections cause their production and consumption decisions to be interdependent. To capture the social differentiation of the economy farm households are grouped in homogenous producer-consumer households. This basic structural difference as compared to standard CGE models may lead to household price responses that may go even in opposite direction of those of pure producers and pure consumers (Singh et al. 1986; de Janvry et al. 1991). Our simulations demonstrate such effects.

Our model simulations for a village economy with high agricultural potential and fairly good market access in the Ethiopian highlands indicate that both the output price increase and the removal of fertiliser subsidies that were implemented in the late 1990s lead to more rapid land degradation.

The blanket recommendation that all input subsidies are bad may not always hold. The environmental economics policy perspective, drawing on Pigou, may be worth considering in relation to environmental externalities. We have looked at the case of a village economy in Ethiopia where agricultural production, as currently practiced, has a negative effect on future land productivity. Fertiliser use may counteract the negative effects of nutrient depletion and soil erosion. Imposing blindly a “polluter pays principle” through an output tax may be questioned, however, as it would enhance poverty. The innovative idea here is to impose a tax on agricultural output that may be ploughed back into the economy to stimulate fertiliser use. Such a policy is shown to both have a less negative effect on poverty and a stronger positive effect on the negative land degradation externality. Still, we found that such a policy may have a negative effect on the poorest household group without oxen.

We have to state that this kind of policy is insufficient to deal with the land degradation and poverty problems in the Ethiopian highlands. There is in addition an urgent need for an “Organic Green Revolution” that stimulates adoption of productivity-enhancing conservation methods like reduced tillage, water harvesting and conservation, improved fodder crops, intercropping of legumes and cereals, cover crops, and fodder trees in combination with improved cattle and animal management systems (cut and carry system).

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**Table 1. Basic farm household characteristics in the survey area of Ethiopia, 1993**

Variable	Household category by number of oxen				
	0	1	2	>2	All
Share of population (%)	25	17	34	24	100
Female headed households (%)	27	7	7	3	11
Farm size (kert) <sup>a</sup>	4.48	7.4	8.18	11.25	7.83
Total income (Birr) <sup>b</sup>	2 992	4 893	5 792	12 279	6 489
Male work force (adult equivalents)	0.71	1.34	1.57	2.84	1.62
Female work force (adult equivalents)	0.91	1.01	1.12	1.68	1.18
Consumer units (adult equivalents)	2.47	3.76	4.12	6.47	4.2
Tropical Livestock Units	0.31	2.46	4.46	9.12	4.09

**Table 2. A stylized SAM for the village economy**

	Activities	Commodities	Factors	Households	Enterprises	Government	Savings- Investment	Transaction costs	Rest of the World	TOTAL
Activities		outputs								activity income (gross output)
Commodities	intermediate inputs			private consumption		government consumption	investment	Transaction costs	exports	demand
Factors	value-added transaction costs								factor income from RoW	factor income
Households			factor income to households		surplus to households	transfers to households			transfers to households from RoW	household income
Enterprises			factor income to enterprises			transfers to enterprises			transfers to enterprises from RoW	enterprise income
Government	producer taxes, value-added tax	sales taxes	factor income to government, factor taxes	transfers to government, direct household taxes	surplus to government, direct enterprise taxes				transfers to government from RoW	government income
Savings- Investment				household savings	enterprise savings	government savings			foreign savings	savings
Transaction costs		Transaction costs								Transaction costs
Rest of the World (RoW)		imports	factor income to RoW		surplus to RoW	government transfers to RoW				foreign exchange outflow
TOTAL	activity expenditures	supply	factor expenditures	household expenditures	enterprise expenditures	government expenditures	investment	Transaction costs	foreign exchange inflow	

**Table 3. Maximum land productivity decline rates used in the model<sup>a</sup>**

Land and crop type	Level of land degradation, annual % yield decline	
	High	Low
Upland, teff	4.1	1.2
Lowland, teff	0.38	0.25
Upland, other cereals	3.5	0.9
Lowland, other cereals	0.3	0.1
Upland, pulses	3.5	0.5
Lowland, pulses	0	0

<sup>a</sup>Based on Shiferaw and Holden (1999, 2000) and Holden and Shiferaw (2002).

**Table 4. The impact of alternative policies on real household incomes by household group<sup>a</sup>**

Household group	Base results	Output price +5%	Fertiliser subsidy Removal -20%	Combine	Fertiliser subsidy +20%
		(a)	(b)	(a)+(b)	Output price -5%
Without oxen (H0)	263.4	3.6	-1.6	2.0	-1.8
With one ox (H1)	281.1	2.5	-2.0	0.5	-0.3
With two or more oxen (H2)	2972.1	1.4	-2.3	-1.0	1.4
<b>Total</b>	<b>3516.5</b>	<b>1.6</b>	<b>-2.2</b>	<b>-0.6</b>	<b>1.0</b>

<sup>a</sup>Base results in '000 Ethiopian Birr ; non-base simulation results as % change from base results.

**Table 5. The impact of alternative policies on land use and crop and livestock production activities for the three household groups<sup>a</sup> defined in Table 13.3.**

Production activities by household group	Base results	Output price +5% (a)	Fertiliser subsidy Removal -20% (b)	Combine (a)+(b)	Fertiliser subsidy +20% Output price -5%
<b>Upland teff</b>					
H0	36.5	2.9	-2.7	0.2	0.1
H1	99.5	0.8	-4.3	-3.4	4.3
H2	1098.7	0.6	-3.3	-2.6	3.3
<b>Lowland teff</b>					
H0	30.2	2.9	-2.5	0.4	-0.1
H1	52.0	-0.4	-4.8	-5.0	6.2
H2	823.9	0.4	-3.0	-2.5	3.1
<b>Upland other cereals</b>					
H0	8.5	1.6	0.2	1.7	-2.0
H1	19.8	0.8	0.3	1.0	-1.3
H2	193.9	0.3	-1.0	-0.7	0.8
<b>Lowland other cereals</b>					
H0	5.6	4.0	-4.9	-0.7	1.5
H1	7.4	3.4	-6.5	-3.0	4.0
H2	53.2	3.8	-7.5	-3.9	5.5
<b>Upland pulses</b>					
H0	2.9	0.9	4.3	5.3	-5.8
H1	9.5	-1.3	6.6	4.8	-5.2
H2	108.6	1.1	-0.5	0.5	-0.2
<b>Lowland pulses</b>					
H0	6.2	1.1	1.1	1.9	-2.1
H1	12.5	-0.2	6.6	5.9	-6.2
H2	147.9	0.0	1.1	1.0	-0.9
<b>Livestock</b>					
H0	8.2	2.3	-1.7	0.6	-0.4
H1	53.0	0.7	-1.4	-0.7	0.8
H2	622.3	0.5	-0.9	-0.4	0.4

<sup>a</sup> Base results in '000 Ethiopian Birr; non-base simulation results as % change from base results.

**Table 6. The impact of alternative policies on village exports <sup>a</sup>**

Factor/ trade/ activity	Base results	Output price +5%  (a)	Fertiliser subsidy Removal -20% (b)	Combine  (a)+(b)	Fertiliser subsidy +20% Output price -5%
Teff	794.9	-0.5	-3.8	-4.1	4.9
Other cereals	9.7	-1.5	2.3	1.0	-1.8
Pulses	34.4	-4.5	20.5	15.0	-16.5
Livestock	211.4	0.4	-0.7	-0.1	-0.1
Business	113.7	-7.0	3.8	-3.2	3.0
Skilled labour	13.8	-36.5	45.6	-5.3	1.1

<sup>a</sup>Base results in '000 Ethiopian Birr; non-base simulation results as % change from base results.

**Table 7. The impact of alternative policies on fertiliser use by production activity and household group<sup>a</sup>**

Production activities by household group	Base results	Output price +5% (a)	Fertiliser subsidy Removal -20% (b)	Combine (a)+(b)	Fertiliser subsidy +20% Output price -5%
Upland teff					
H0	5.5	7.6	-19.0	-12.8	19.9
H1	14.9	5.2	-20.5	-16.2	25.6
H2	161.4	4.8	-20.1	-16.2	25.4
Lowland teff					
H0	4.6	7.6	-18.8	-12.6	19.7
H1	7.7	4.0	-21.0	-17.7	27.9
H2	121.8	4.6	-19.8	-16.1	25.1
Upland other cereals					
H0	0.7	6.6	-17.9	-12.6	19.3
H1	1.5	5.7	-18.3	-13.7	21.0
H2	14.4	4.9	-19.6	-15.7	24.5
Lowland other cereals					
H0	0.8	8.4	-21.4	-14.5	23.1
H1	1.0	8.0	-22.7	-16.2	25.8
H2	6.7	8.0	-23.9	-17.8	28.9
Aggregate change	341.0	4.9	-20.0	-16.1	25.2

<sup>a</sup> Base results in '000 Ethiopian Birr; non-base simulation results as % change from base results.

**Table 8. The impact of alternative policies on village import of labour and commodities<sup>a</sup>**

Commodity	Base results	Output price	Fertiliser	Combine	Fertiliser
		+5%	subsidy		subsidy
		(a)	Removal		+20%
			-20%		Output price
			(b)	(a)+(b)	-5%
Unskilled labour	91.4	1.4	-0.5	1.0	-0.9
Fertiliser	341.1	4.9	-20.0	-16.1	25.2
Agricultural commodities	246.9	3.6	-2.3	1.2	-0.9
Other commodities	1031.3	1.8	-1.7	0	0.2

<sup>a</sup>Base results in '000 Ethiopian Birr; non-base simulation results as % change from base results.

**Table 9. Sensitivity analysis of the impact of alternative policies on the village-wide land degradation externality<sup>a</sup>**

Policies	Level of land degradation and social discount rates					
	High			Low		
	3%	5%	10%	3%	5%	10%
Base results	1227.0	736.2	368.1	353.1	211.8	105.9
Output price increase 5% (a)	1272.2	763.3	381.7	365.4	219.2	109.6
Fertiliser subsidy removal (b)	1309.6	785.7	392.9	378.9	227.3	113.7
Combine: (a) + (b)	1360.4	816.2	408.1	393.0	235.8	117.9
Combine: -(a) - (b)	1080.6	648.4	324.2	309.0	185.4	92.7

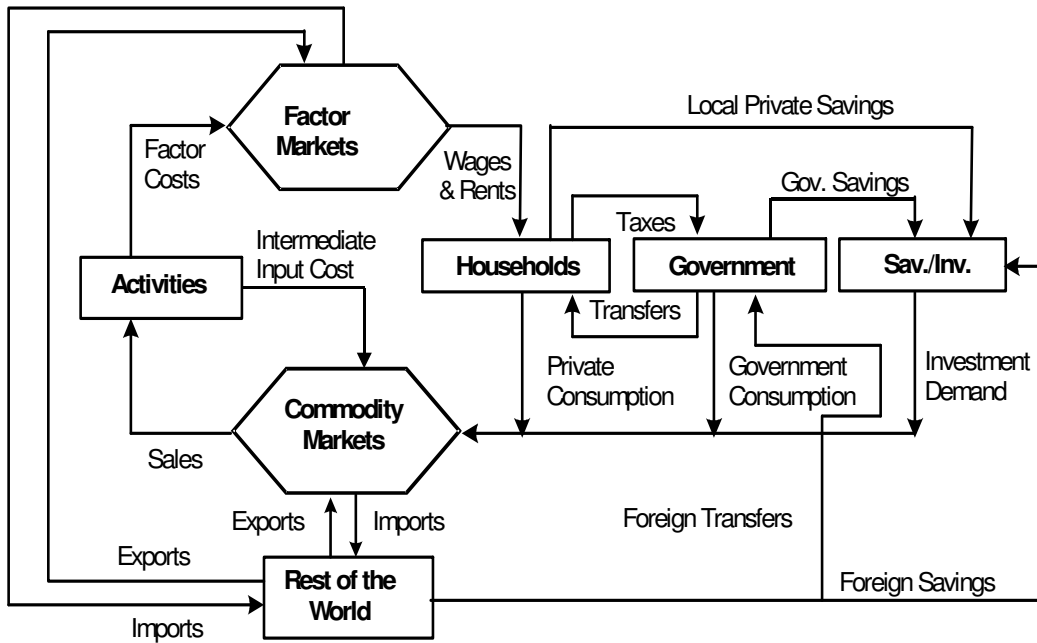
<sup>a</sup>In '000 Ethiopian Birr.

**Table 10. Aggregate indicators for the economy**

Commodity	Base results	Output price	Fertiliser	Combine	Fertiliser
		+5%	subsidy		subsidy
		(a)	Removal		+20%
			-20%		Output price
			(b)	(a)+(b)	-5%
Absorption	4262.1	1.4	-1.8	-0.5	0.8
Private consumption	3516.5	1.6	-2.2	-0.6	1.0
Marketed surplus ("export")	1481.1	-1.4	-1.3	-2.7	3.1
"Imports"	-1725.1	2.8	-6.3	-3.8	6.2
Externality, low, 3% disc.rate	353.1	3.7	6.7	10.9	-11.9

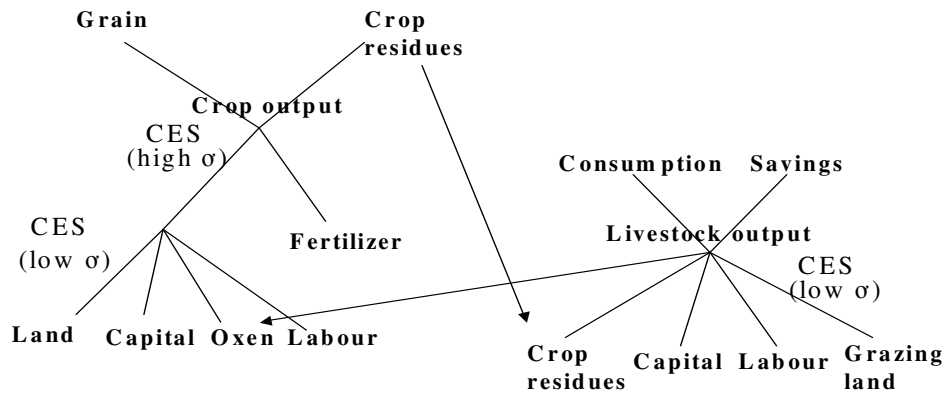
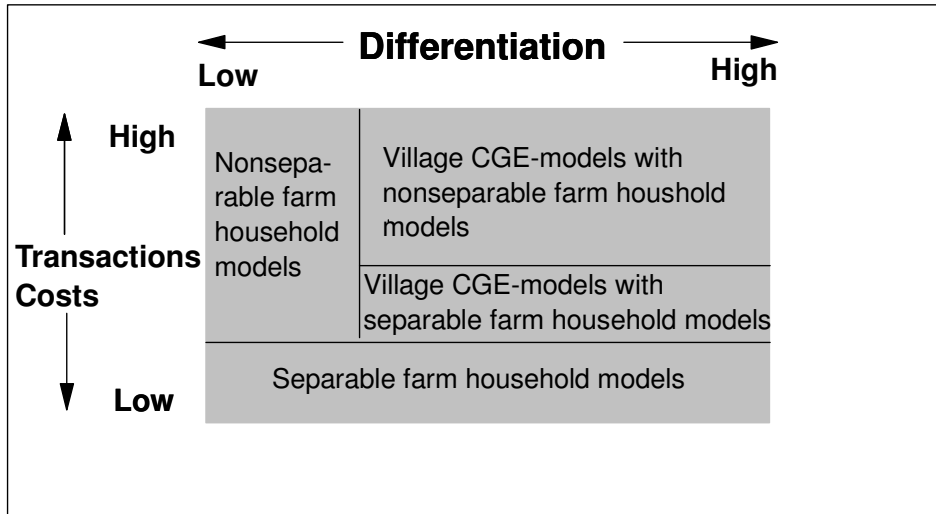
<sup>a</sup>Base results in '000 Ethiopian Birr; non-base simulation results as % change from base results.

Figure 1. Structure of Payment Flows in the Standard CGE model.



Source: Lofgren *et al.* (2002).

**Figure 2. Typology of village economy models**



**Figure 3. Technology tree in crop and livestock production**

