ISBN 978-82-575-0760-2
ISSN 1503-1667

Norwegian University of Life Sciences
NO–1432 Aas, Norway
Phone +47 64 96 50 00
www.umb.no, e-mail: postmottak@umb.no

Adane Tuffa Debela

Philosophiae Doctor (PhD) Thesis 2007:39

Norwegian University of Life Sciences • Universitetet for miljø- og biovitenskap
Department of Economics and Resource Management
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Policy Reforms, Soil Fertility Management, Cash Cropping and Agricultural Productivity in Ethiopia

Politiske Reformer, Gjødselbruk, Cash Cropping og Landbruksproduktivitet i Etiopia

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Avhandling nr 2007: 39

Dissertation no. 2007: 39

Errata

Table 2 (page 86) should read as follows:

Table 2 Site level information on soil fertility management practices and input use

Village (number)	Manure (%)	Fert Use (%)	Average Total land holding (Timad per consumer unit)*	Average Operated Land holding (Timad per consumer unit)*	Average Oxen ownership (number)	average TLU	Average Fert. Use (Birr per timad)*
1	88.2	79.4	0.40	0.3	0.5	2.8	15.9
2	18.7	9.4	2.1	1.9	1.7	7.3	3.5
3	0	100	1.1	1.0	1.1	4.5	42.1
4	16.66	100	1.0	1.0	1.1	4.9	38.6
5	88.23	38.2	0.3	0.3	0.1	3.9	8.6
6	88.97	48.6	0.5	0.4	0.3	5.1	6.3
7	18.2	18.2	0.6	0.5	0.4	2.4	11.8
8	3	84.8	3.4	2.8	2.1	6.7	48.4
9	97.1	97.1	1.8	1.7	2.7	4.7	110.5
10	0	70.6	2.8	2.6	3.0	5.2	11.8
11	100	60.7	0.8	0.6	1.0	4.2	10.9
12	100	79.4	0.7	0.6	0.9	4.6	20.3
13	97.1	80	0.3	0.3	0.6	2.7	20.7
14	94.3	100	1.5	1.4	1.5	5.6	24.2
15	2.8	100	7.9?	1.6	3.0	6.4	105.3
total	55	71.4	1.3	1.2	1.3	4.7	32.4

*Note: Timad is a local unit (1 timad=0.25 hectare)

Errata (continued)

Table 3 (page 87) should read as follows:

Table 3 Definition and summary of variables

Variable name	description	mean	Std dev	Expected sign		
				Manure	Fertilizer use probability	Fertilizer use intensity
a. Endogenous Var.						
man	1=uses manure as fertilizer, 0=otherwise	.55	.498		?	?
fertyn	1=applies fertilizer, 0=otherwise	.71	.452			
fertamop	Amount of fertilizer applied per Operated land holding	32.46	51.007			
b. exogenous exp. Var.						
olszocu	Operated land holding per consumer unit	1.16	1.045	?	?	?
sex	1=male, 0=female	.95	.222	?	?	?
age	Age of household head in years	44.56	13.824	?	?	?
edu	Number of household members with education up to grade six	.57	1.035	?	?	?
Eduto6	Number of household members with education above grade six	2.21	1.964	+	+	+
wfolsz	Number of worker unit per operated holding	4.17	2.003	+		
irrg	1=has irrigated land, 0=otherwise	.09	.295	+	+	+
rrl	Ratio of rented in to total operated holding	.06	.135	-		-
cwr	Ratio of consumer unit to worker unit	1.65	.310	?	?	?
tluolsz	Total Livestock unit per operated land holding	.99	.910	+		
oxolsz	Number of oxen per operated land holding	.19	.22	+	+	+
Walk	1=if household only walks to market, 0 otherwise-reference transport	.714	0.452			
Publict2	1=if household uses public transport to the market, 0 otherwise	0.096	0.29		+	+
Cartt3	1=if household uses cart, 0 otherwise	0.026	0.159		+	+
mktdist	Distance of household from market	66.01	80.736		?	?
manfuel	1=if household uses manure as fuel and 0 otherwise	0.53	0.499	-		
lvarname	Variable transformed to logarithm					

Footnote to Tables 3 and 4 (Pp. 152-154):

Note: a, b, and c indicate significance level at or less than 1, 5 and 10% significance levels.

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Acknowledgement

Many people **h**ave contributed to the realization of this thesis in one way or another. My parents, brothers and sisters deserve thanks for their assistance and encouragement, without which I could not be where I am now. I would like to thank my supervisor, Ragnar Øygard, for his tremendous help He provided constructive comments and advice in all my works. I always felt free to discuss all kinds of problems with him and his assistance has been genuine. I had all the freedom to work on topics and analytical tools of my choice. I would also like to thank Professor Almas Heshmati of the University of Kurdistan for his help with one of my papers. He provided useful comments, which increased the quality of the paper.

Thanks also go to Prof. Stein Holden, who was the first person in the department I talked to about the possibility of pursuing the PhD program at UMB while I was still doing my masters program. I would not have gotten this chance if it had not been for his advice and information on how to go about starting the application process. I have also discussed many issues with him since and his ideas have been useful. Arild Angelsen has been helpful in many of administrative matters, especially financial ones for seminars and courses.I extend my heart-felt thanks to him. I would also like to thank Mette Wik to whom I talked and got assistances on several occasions during my stay.

I am indebted to Hawassa University for allowing me to use their data for parts of my research works. I am thankful to Charles Jumbe for reading my paper and providing useful comments. I extend thanks to Worku Tessema, Jeetendra Aryal, Baikuntha Aryal, Fitsum Hagos, Yalew Tarekegn, Mehari Okbasillassie, Million Tadesse and Ronnie Babigumira for their friendship and encouragement. Each of them has been instrumental in my work in one way or another. Jeetendra aryal is a close friend with whom I discussed academic problems and otherwise. I am indebted to my friend in Ethiopia, Taye Mamo, for taking care of my personal affairs and family back home while I am here. He has been my real friend and therefore has a special place in my life

My friends, Ayana Angassa, Gutu Olana, Chaltu Dula, Itana Debela, Boku Tache, Ajebu Nurfeta and Hussien Jema deserve special thanks for their encouragement and close friendship beyond academic matters. Finally I would like to thank the UMB libraries for their efficient and unreserved services

Adane Tuffa Debela

Ås, May 2007

Summary of the thesis

This thesis consists of an introduction and four independent papers. The papers aim at investigating agricultural productivity and factors that affect the performance of agriculture and food security directly or indirectly. Paper I analyses the impacts of economic policies on the productivity and efficency of crop production Results suggest that inefficiency increased after the introduction of policies while technical progress stagnated. As a result, total factor productivity declined during the same period. Paper II deals with fators influencing soil fertility management practices, the use of animal manure and chemical fertilizer, in the highlands of Ethiopia. Results indicate that adoption of chemical fertilizer is positively influenced by animal manure and farm and household characteristics. The results further indicate that adoption of manure and the intensity of use of chemical fertilizer are influenced by farm and household characteristics. Paper III concerns the impacts of perennial cash crops on food crop production and productivity in southern Ethiopia. The food crops are divided into enset and other food crops. Results show that more intensive chat production is associated with lower production and productivity of other food crops while more coffee production is associated with more intensive production of enset. On the other hand, more intensive sugarcane production is associated with reduced production and productivity of other food crops. However, production of coffee has no significant impact on food crops. Paper IV concerns the impact of market liberalizations on prices of crops and livestock. Results suggest that market liberalizations have mixed impacts on prices of grain, cash crop and livestock. Prices have increased in some markets and decreased in others both for crops and livestock. Moreover, grain market liberalization has increased price volatility in price levels and price spreads overall.

Introduction

Introduction

Meeting the increasing demands for food is a pressing challenge facing Ethiopia today. This will require increased agricultural production. Increasing cultivated area has been the traditional way of increasing agricultural production. However, increasing population pressure and the limits of area expansion means that future increases in production have to come from increased use of productivity-enhancing inputs and practices. Yet agricultural production faces many constraints. These constraints include land degradation, institutional constraints and unfavourable policy environments, all affecting agricultural productivity directly or indirectly.

Land degradation is one of the major constraints facing agricultural production and food security efforts. The expanding population in the highlands of Ethiopia has not only eliminated the possibility of increasing production through the expansion of cultivated land but it also reduced the productivity of land under cultivation through continuous cultivation without supplementary inputs, since it eliminates the practices of fallowing and shifting cultivation (Shiferaw and Holden, 1999). As population grows, new and marginal lands are brought under cultivation and livestock grazing (e.g., Grepperud, 1996; Foeli et al., 2003; Kruseman, 2006; Keerthisinghe et al., 2003). These marginal lands are easily eroded.

Land degradation, resulting from soil erosion and nutrient depletion, causes significant losses in agricultural production (e.g., Shiferaw, et al, 1999; Berry, 2003; Pender, 2001; Holden et al. 2005; UNDP, 2002; Ruttan, 2004) and other environmental hard-to-quantify damages (Berry, 2003), posing serious threat to food security.

Sustainable provision of increasing food supply requires the use of productivity-enhancing inputs, soil conservation investments and improved agricultural practices. However, the use of these inputs and agricultural practices is limited due to many constraints facing farmers. These include limited liquidity, price policies, risks, subsistence constraints and resource constraints (e.g., Pagiola, 1996; Shiferaw et al., 1999; Reardon and Vosti, 1995; LaFrance, 1992).

During the Dergue regime government intervention in agricultural market imposed pan-territorial and pan-seasonal price control system on agricultural products. This intervention also included fixing the value of Birr against US dollars. These interventions adversely affected the performance of agricultural sector (e.g., Franzel, et al., 1989; Dadi et al., 1992; Kherallah et al., 2000). Since 1991 policy reforms have been undertaken by the Ethiopian government. Proponents of reforms argue that removing these distortions created by government interventions would raise efficiency in agricultural production and provide incentives to farmers to use inputs or make investments that raise productivity (e.g., Brauw, 2000).

Imperfection in credit markets is another constraint on agricultural productivity. In countries where government credit institutions and government-led food crop intensification cannot fit the demands of farmers, there should be a reliable source of income to finance the purchase of inputs during planting periods. Studies from Africa show that cash crops provide cash income to farmers to meet these demands (e.g., Goetz, 1993). Cash crops can also increase farmers' credit worthiness with village money lenders. Moreover, perennial cash crops reduce soil erosion (Hailesellasie et al., 2005). All these can contribute to increasing the productivity of food crops and thus ensure food security.

This thesis deals with the above issues. With the central theme being agricultural productivity, the thesis explores these different conditions, as they affect agricultural production and productivity. The main research questions addressed in the thesis are:

- **Have policy reforms improved agricultural productivity and efficiency?**
- **What factors affect farmers' use of productivity enhancing inputs and short-term investments?**
- **Do cash crops affect production and productivity of food crops?**
- **Have policy reforms increased agricultural commodity prices?**

While the first question addresses agricultural productivity and efficiency, the other questions deal with factors that are related to agricultural productivity directly or indirectly. The thesis consists of four papers. Each of the above questions is answered in separate papers that constitute the thesis. The titles of the papers are:

Paper I: An evaluation of the impact of economic reforms on performance of agriculture in Ethiopia.

Paper II: Soil fertility management strategies of smallholder farmers in Ethiopia: a simultaneous equations analysis.

Paper III: Impacts of perennial cash crops on food crop production and productivity.

Paper IV: The effect of market liberalization on agricultural commodity prices in Ethiopia

The rest of this introductory part is organized as follows. First, discussions of theoretical models used in the papers, estimation methods, data used in the studies and empirical topics are provided. The second part provides summaries of the papers.

Theoretical models

Theoretical models used in the papers are based on the neoclassical theory of households, except paper IV, which is a reduced form of equilibrium food price levels. Farm household models are important tools for studying household decision-making processes because one can integrate production, consumption and labour supply decisions into household models (Sadoulet and de Janvry, 1995; Singh et al., 1986). Farm households are both producers and consumers of their own products and have to make decisions regarding production, consumption and labour supply. When there are market failures, these decisions become inseparable and have to be made simultaneously (Sadoulet and de Janvry, 1995; Singh et al., 1986; de Janvry et al., 1991).

Market failures are pervasive in developing countries like Ethiopia (Heltberg, 1998; Holden et al., 1998; Barham et al., 1996). This may include output, input (labour, land), credit and insurance markets (de Janvry et al., 1991). Market imperfections exist due to high transaction costs and imperfect information, and may take the form of missing markets, seasonally missing markets, rationing, and imperfect competition (thin markets) (Holden et al., 1998).

The Ethiopian experience shows that credit and insurance market imperfections are binding at least for poorer households. Credit rationing in formal credit markets may be explained by adverse selection and moral hazard (Stiglitz and Weiss, 1981). Informal credit markets are characterized by very high interest rates and are rationed. Lack of credit for consumption smoothing indicate high rate of time preferences (Holden et al., 1998), which, for example, adversely affects investments in agricultural production. Moreover, there is no insurance market for farmers. Formal credit is available only through commodity specific (fertilizer) arrangements at 10-12% interest rates (Holden et al., 1998).

Imperfect information and high transaction costs may also lead to interlinkage of markets (e.g., share tenancy) (e.g., Stiglitz, 1974), while asymmetric information may lead to problems with adverse selection in credit and commodity markets (Rochland and Stiglitz, 1974) and moral hazard, for example, in land and credit markets (Arrow, 1963). A market is considered to fail for a particular household, when it faces a wide price band between the (low) price at which it could sell the product or factor, and the (high) price at which it could buy it (Sadoulet and de Janvry, 1995, Chap. 6). Thus markets may fail for some households, but not for others (Heerink e al., 2001). The impact of market failures is that separability of production and consumption decisions does not hold and household characteristics in consumption affect production decisions (de Janvry et al., 1991; Sadoulet and de Janvry, 1995). In this case the traditional analysis of farm output supply and input demand using the theory of the firm will not yield the same results as fully specified agricultural household models, and there is a need for the latter (Singh, et al., 1986).

In our study sites there are input and output markets. However, since markets may fail for some but not for others, it is difficult to know if one or more of these markets fail for some or all of the households in the sample. Therefore, rather than modelling the farm households explicitly including all market failures for inputs and outputs (except for those markets which are evident to fail and are important to address questions raised in a particular paper), we include household characteristics in the empirical models of production and input decisions. If the household characteristics are statistically significantly different from zero in the regressions, it means that market failures exist and affect the decisions. Thus, the choice of explanatory variables is based on these settings, previous studies and field observations.

Paper I applies theory of household production using a reduced form household production function derived from farm household utility maximization. The model is specified as a stochastic frontier production function (Aigner et al., 1977; Meeusen and van den Broeck, 1977). This model has been applied by Battese and Coelli (1995), Coelli and Battese (1996), among others. The concept of frontier defines the existence of an unobservable function, the production function frontier, that corresponds to the set of maximum attainable output levels for a given level and combination of inputs.

Paper II applies a fully specified neoclassical household mode1- a two-period household utility maximization model. The model shows how manure adoption decisions differ from fertilizer adoption decisions due to carry over effects. The model allows for the absence of market for manure and the results of the model show that tenure insecurity and time preference can affect short-term investments in land.

Paper III also applies a fully specified neoclassical household model, explicitly incorporating a credit constraint. The model framework shows that farmers with cash crops are better off in situations where credit constraints are binding. This model modifies the previous models used to analyse the impact of cash crops on food crop productivity (e.g., Govereh and Jayne, 2003) to show that cash crops can relax liquidity constraints, in addition to their benefits with interlinked markets through which they attract inputs to be used for food crops. The model suggests the impact of cash crops on liquidity through two links. One link is that cash crops make relatively stable cash income available. The other link is that cash crops increase credit worthiness of households with money lenders.

Paper IV is based on a reduced form of equations for equilibrium prices. The model is a meso-level economic model to investigate the impact of economic policy reforms on equilibrium prices of agricultural commodities. This is an alternative to structural models since there is no sufficient data for the estimation of structural equations. The advantage of this model is its relative simplicity and lesser restriction in terms of excluding variables for identification (e.g. Tomek and Myers, 1993).

Empirical specification and estimation methods

The main focus of the thesis is the application of economic theory and econometric methods to the Ethiopian agricultural problems. All papers use econometric tools to address the main questions raised. In paper I, a Cobb-Douglas (C-D) functional form is used to specify the production function. Following Battese and Coelli (1995), we express the inefficiency effects as a linear function of farm specific explanatory variables. We estimate the farm specific inefficiency and factors explaining inefficiency differentials among farmers in a single step. This procedure helps avoid the bias arising from the two-step estimation procedure (Wang and Schmidt, 2002). The estimation of total factor productivity (TFP) growth is based on regression-based growth accounting technique and the non-parametric TFP index number (Coelli et al., 1998). This allows the comparison of the two results and ensures reliability.

In paper II, I apply a simultaneous system of equations estimation technique. Fertilizer and manure adoption equations are specified as probit while fertilizer use intensity equation is specified as linear model with selectivity. The probit models of fertilizer and manure adoptions were estimated as a biprobit maximum likelihood (Greene, 2000) while the fertilizer use intensity model was estimated with a two-stage probit (2STP) procedure (e.g., Hassan, 1996), which also involves the Heckman two-stage technique (Heckman, 1979).

Paper III specifies the model of the value of food crop production as a C-D functional form. The cash crop and enset production are indexed either as total number of plants divided by total operated holding or size of area planted to the cash crop or enset divided by total operated holding. Based on the result that the exogeneity of the cash crop and enset indices could not be rejected, the equations were estimated in one step. Ordinary least squares estimation technique is used for food crop and enset since the dependent variables are continuous while tobit models are used to estimate the cash crop indices owing to the presence of many zero-valued observations.

In paper IV equations of inflation-adjusted equilibrium crop and livestock prices in different markets for a single commodity were estimated as seemingly unrelated regressions (SUR) since shocks that hit one market are likely to hit other markets at the same time. The policy reform variables were represented by dummy variables, taking values of zero before the reforms and one after the reforms. Lags of prices were included based on statistical tests (Akaike, 1973, 1974) to account for historical price correlations.

Summary and contributions of papers

Paper I: An evaluation of the impacts of economic reforms on performance of agriculture in Ethiopia

Objectives

The objective of this paper is to investigate the impact of agricultural policy reforms (especially the removal of fertilizer subsidies) on the performance of agriculture in terms of efficiency and productivity. We measure the impact of the reforms on economic efficiency of crop production and total factor productivity.

Theoretical model

Reduced form stochastic frontier production function is used to estimate the inefficiency effects of household crop production. This production function is then used to generate the TFP growth of the crop production sector. In addition, the non-parametric TFP index is used to measure TFP growth between the time before and after the reforms.

Empirical approach

Maximum likelihood estimators of the C-D function, the inefficiency effects and parameters of the inefficiency effects model were obtained in one step using Frontier 4.1 (Coelli, 1996). This approach enabled us that while we specify the inefficiency effects model and the frontier production function separately the estimation is carried out in one step, avoiding the problems associated with two-step estimation.

Data

The data used in this study come from a sample survey of smallholder farmers located in two peasant associations in central highlands of Ethiopia. There were two surveys of the same households in 1993/94 and 2000/2001, producing a short panel data. The dependent variable in the production function is the aggregate value of all food crops and the inputs are the values of different categories of inputs used on the farms for crop production. The data on food crops do not include high value crops such as coffee since they are not produced in sample areas.

Main findings

The results of the model show that there are inefficiencies among farm households; technical progress has stagnated during the period; and inefficiency has increased. They further indicate that inefficiencies are influenced by location, i.e., farmers close to market areas are less inefficient; farmers with larger number of oxen are less inefficient; and older farmers are more inefficient. Results from the regression-based and index number-based measures of TFP are very similar, both suggesting that technical progress has stagnated during the period and TFP declined as a result The results generally indicate that reforms have not achieved the results expected of them although total output has increased slightly. The implication is that more has to be done in the areas of the reforms; marketing infrastructure; provision of information to farmers and market participants; and extension and research.

Main contributions

The paper is the first to assess the impact of reforms on efficiency and technical change since the reforms using primary data and econometric methods. Previous studies on the performance of agriculture used data from forecasts of economic indicators and the analysis based on descriptive statistics. These types of study show only whether forecasted productions are up or down, thus having no indication whether efficiency and productivity have changed. This study showed, using different approaches, that inefficiency has increased and TFP has declined

Paper II: Soil fertility management strategies of smallholder farmers in Ethiopia: a simultaneous equations analysis.

Objectives

The objective of this paper is to investigate factors affecting the adoption of manure and chemical fertilizer and the intensity of use of chemical fertilizer and the strategy farmers adopt in applying the two inputs. Identifying these factors can help solve the problems of declining productivity and design effective extension packages that can assist farmers to use the two inputs in an optimal way.

Theoretical model

The paper uses a two-period farm household model that takes into account the carry-over effects of manure. The model is based on household utility maximization subject to budget, technological and manure availability constraints. The production function in the budget constraint is constructed in such a way that there is a non-zero probability of losing part or all of the rented in land during the second year and that this affects the expected value of production due to the risk associated with losing the land. This further affects the use of manure, which is a short-term investment in land quality.

Empirical approach

The models of manure and chemical fertilizer adoption and intensity of use of the latter were estimated as a system of simultaneous equations where manure adoption decision enters the chemical fertilizer adoption and use intensity equations. The adoption equations were specified as probit and the use intensity equation was specified as a linear model. The two probit equations were then estimated by maximum likelihood as biprobit while fertilizer use intensity equation was estimated by probit two-stage procedure with selectivity because there are households which did not use fertilizer.

Data

Data used in this study were collected from 15 different sites across the central highlands of Ethiopia using a household survey questionnaire in 1999. The different sites were selected to take into account the major agro-ecological areas within the central highlands. Thirty to 35 households were randomly selected from each site, constituting 505 households in total. The sites differ in the concentration of crops grown, access to markets and population density. Five hundred households were used in the final analysis with the rest dropped due to incomplete data.

Main findings

The results from the study show that after controlling for other factors, adoption of chemical fertilizer is positively associated with adoption of manure while there is no significant correlation between manure adoption and use intensity of chemical fertilizer. Household and farm characteristics also affect the adoption of chemical fertilizer. Contrary to the long-held belief that tenure insecurity resulting from informal land contract arrangements discourage investment decisions in land, this result shows that farmers with larger share of rented-in land are more likely to invest in land in the form of manure. Besides, manure adoption decision is affected by other household and farm characteristics. The results further indicate that factors that influence adoption of an input does not necessarily influence intensity of use of the input-evident from chemical fertilizer adoption and use intensity regressions.

Main contributions

This paper has two main contributions. First, unlike previous studies (e.g. Omamo et al., 2002), this study treats manure differently from chemical fertilizer, extending the model of manure adoption. Second, it estimates manure and chemical fertilizer equations simultaneously in a recursive manner. It also contributes to the existing literature that land renting does not always mean insecure tenure.

Paper III: Impacts of perennial cash crops on food crop production and productivity

Objectives

To investigate the impact of perennial cash crops

Such as coffee, chat and sugar cane and a perennial food crop, enset, on other major food crop production and productivity and the impact of the cash crops on enset production. We hypothesize that in addition to the provision of cash income to the household in general, cash crops can increase the liquidity of farmers through the regular flow of cash income and increasing farmers' credit worthiness, which in turn relax farmers' credit constraints. This can help farmers buy inputs for production of food crops, thereby raising production and productivity. Perennial cash crops also reduce soil erosion and food crops intercropped with the cash crops can be more productive.

Theoretical model

A fully specified household model is used to specify the theoretical framework. The household is assumed to maximize household utility subject budget, credit, and production technology constraints. Borrowing and own cash incomes are specified as functions of cash crop production and this produces a testable hypothesis about the impact of cash crops on food crop production and productivity.

Empirical approach

Cash crop and enset productions were represented either as number of plants per total operated holding or area planted to them divided by total operated holding indices. Endogeneity tests showed that the cash crop and enset indices are exogenous in the food crop production models. With no endogeneity problems, we used the indices in the C-D production function of the food crop production equations and enset production indices. The models for food crops were then estimated with ordinary least squares (OLS) with selectivity since some of the observations were zero. Enset production had only insignificant number of zeros and was thus estimated with OLS.

Data

Data used in this study were collected in 1999 from Wondo Genet area located in the southern part of Ethiopia. One hundred and fifty sample households were randomly selected from two peasant associations, Wesha and Chuko. The area is characterized by mixed crop-livestock production system and is well known for its cash crop and enset production. The two peasant associations differ in their intensity of cash crop production.

Main Findings

The study shows that higher chat production is associated with reduced productivity and production of food crops while higher sugarcane production is associated with increased value of food crop production and productivity. On the other hand, coffee production is associated with more intensive enset production. Production of coffee does not have significant influence on food crop and enset production. Similarly, enset production does not have any significant impact on other food crop production and productivity. Household characteristics, wealth variables and input levels also influence food crop production and productivity.

Main contributions

This is the first study to investigate the impact of cash crops on food crop production and productivity in the absence of market inter-linkages. The study shades light on the arguments about the impact of cash crops on food security. The results show that cash crops do not necessarily jeopardize food security and that market inter-linkages are not necessary for cash crops to contribute to food crop production and food security.

Paper IV: the effect of market liberalization on agricultural commodity prices.

Objectives

To investigate the impacts of policy reforms, i.e., grain market liberalization, removal of fertilizer subsidy and devaluation of Ethiopian currency on the levels and spreads of crop and livestock prices.

Theoretical model

The paper uses a reduced form model of equilibrium prices. This model is an alternative to structural models when we have limited data to construct structural equations that involve many market agents. In addition, it is simpler in that it involves minimal restrictions on the model while we can include variables of interest.

Empirical approach

Inflation-adjusted real prices were used to estimate the impacts of the reforms. Market reforms were represented by dummy variables. Prices of a commodity in different markets were estimated using a seemingly unrelated regression (SUR) procedure. Historical price correlations were summarized using lagged values of prices based on statistical tests. In addition, we estimated one equation to see if prices of crops and livestock have any correlations, as the two commodities have complex relationships in the farming system.

Data

Data used in the study were collected from five markets in different areas by the Central Statistical authority (CSA) of Ethiopia. One of the markets is a central market (Addis Ababa) and the others are regional markets. The data are market prices corrected for inflation (deflation) using general food price indices. The commodities include teff, maize, coffee, sheep and oxen. The locations of the markets differ in distances from the central market and in the concentration of the types of crops and livestock they produce. Some of the regions are known for their cash crops (e.g., coffee) and others are known for maize, teff and livestock production. All markets are accessible by asphalt road from the central market.

Main findings

Grain market reforms have increased grain and livestock prices in some areas (both deficit and surplus areas). Fertilizer market liberalization has also been associated with increases in grain and livestock prices in some markets. Currency devaluation is associated with decreased teff and maize prices. Volatility in price levels and price spreads has increased after grain market liberalization, raising concerns about its impact on production.

Main contributions

Based on our literature search no, previous study has investigated the impacts of policy reforms on grain, cash crop and livestock prices at the same time. Cash crops and livestock prices have been neglected in similar previous studies. Livestock and crop prices are closely related in many ways and it is therefore difficult to assume that policies designed for one sub-sector do not affect prices of other sub-sectors. Results of this study can guide future policy formulations to take into account the impacts of the reforms on agricultural sector at large.

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Paper I

An evaluation of the impacts of economic reform on performance of agriculture in Ethiopia

Adane Tuffa Debela[a,] , Almas Heshmati[b], and Ragnar Øygard[a]

[a] Department of Economics and Resource Management, Norwegian University of Life Sciences, P.O. Box 5003, 1432 Ås, Norway.

[b] Prof. of Economics, Techno-Economics & Policy Program, College of Engineering, Seoul National University, Bldg # 38, Room 410, San 56-1, Shinlim-dong, Kwanak-gu, Seoul 151-742, Korea.

Abstract

In an effort to boost agricultural productivity the Ethiopian government has since 1991 implemented policy reforms. Assessing the performance of the sector after the introduction of these policies can help to evaluate the impact of the reforms on agricultural productivity and to design future policy reforms or take corrective measures. We employ the stochastic frontier production function, which incorporates a model for the inefficiency effects to examine technical inefficiency in crop production using farm level data from 1993/94 and 2000/01 production years from of a sample of households in the central highlands of Ethiopia. In addition, we measure and decompose the growth in the value of agricultural production to examine the contributions of the changes in efficiency, technical progress and inputs to the total factor productivity (TFP) change in agriculture. Results show that there are inefficiencies attributable to household and farm characteristics and the policy environment. Technical progress stagnated while inefficiency increased during the period. As a result TFP has declined during the period.

Keywords: policy reforms; growth accounting; efficiency; frontier production function; Ethiopia

JEL Classification Numbers: C23; D13; D24; O13; Q12

1. Introduction

Despite the fact that the Ethiopian economy is dominated by agriculture, accounting for over 50 percent of the GDP, 90 percent of export earnings, and 88 percent of the labour force (FAO, 1995), the performance of the sector has been rather disappointing over the last three decades. On the other hand, the population grew at an annual rate of 2.46% (MeDAC). With fluctuating agricultural production levels leading to frequent negative annual growth rates, it has become difficult to feed the increasing number of people, leading to dependence on food aid (Afrint, 2003) (Table A2). If the problem of food insecurity is to be resolved, production should grow faster than the population. Increase in agricultural production can be achieved either through expanding the cultivated area or through intensification, i.e., increasing productivity of cultivated land.

Since there may be small room for increasing the size of cultivated land, most of the production increase must come from increased productivity, either through technical progress, or technical efficiency, or increased use of high-yielding inputs (such as fertilizer), or a combination of all of these. Moreover, increasing allocative efficiency can increase the net income that farmers can receive from the given level of input use.

In an effort to raise production and productivity several economic policy reforms have been undertaken by the Ethiopian government over the last decade. The economic reform program, which was initiated in 1991, took the form of a structural adjustment program under the auspices of the International Monetary Fund (IMF) and the World Bank.

The major components of the policy reforms designed to assist agriculture include removal of grain price controls; devaluation of the Ethiopian currency; introduction and then removal of fertilizer subsidies; abolition of forced delivery of grain to the government grain trading parastatal at predetermined low prices; and privatisation of large state-owned farms (MeDAC, 1999). There is also establishment of export promotion institutions designed to encourage foreign trade.

The actual performance of the Ethiopian economy in general, and the agricultural sector in particular after the reform, has been uneven. Growth rates of total GDP and of the agricultural sector between 1993/94 and 2000/01 are shown in Table A2. Agricultural GDP growth rates fluctuated more than total GDP during the period mainly because of its reliance on variable rainfall.

When fluctuations in rainfall have such dominating effect on short-term changes in output, a longer-term perspective is needed to assess effects of changes in policies on the sector. Yet, production fluctuates even during non-drought years and in areas where drought incidence is minimal. In order to evaluate the effects of current policy reforms for corrective measures or alternative policies, it is necessary to identify the factors causing changes in the performance of agriculture. Yet such empirical studies are lacking in Ethiopia. There are also very few studies on farm efficiency in Ethiopia. Studies by Gavian and Ehui (1999), Asfaw and Admassie (1996) and Seyoum et al. (1998) are the only studies we have found on agricultural efficiency in Ethiopia. The few studies that are available were either done prior to some of the relevant policy reforms for agriculture (e.g. removal of fertilizer subsidies) or for various reasons they were not appropriate to evaluate the effects of such policy reforms.

The objective of this study is to analyse how the economic reforms have affected the performance of agriculture in terms of technical change and technical efficiency (which may be influenced by allocative efficiency) of the farmers, using data covering both the period before and after the reforms. In doing so, we identify factors explaining these efficiency differences and account for agricultural production growth between 1993/94 and 2000/01 using the growth accounting method. Technical efficiency (TE) is defined as the ability of a farm to achieve maximum possible output with available resources, given the current best practice technology, while allocative efficiency (AE) refers to the ability of a farm to use the inputs in optimal proportions, given the input prices and their production technology. In other words, AE refers to the ability to contrive an optimal allocation of inputs given resources by equating the ratio of marginal products of inputs with input price ratios. The two measures, TE and AE, are then combined to provide a measure of economic (overall) efficiency. On the other hand, technical change (Hicks-neutral technological change) refers to a shift in the production possibility frontier over time. In growth accounting the change in the value of output is broken down into its underlying components, namely changes in input use and changes in total factor productivity growth. Productivity reflects the current state of technology in agriculture represented by production frontier. Farms in the industry operate either on that frontier (efficient) or beneath the frontier if they are not technically efficient.

The paper is organized as follows: In section two we present an overview of economic policy reforms in Ethiopia. Section three describes the performance of the economy after the reforms. The methodological framework of the study is presented in section four. In section five we describe the study area and data collection. Section six presents empirical models and estimation methods and discussion of the results. The paper concludes with section seven.

2. Overview of Economic Policy Reforms

After the overthrow of the socialist government (Derg) in 1991, the current government of Ethiopia, in collaboration with the international financial organizations, has taken steps to implement economic policy reforms, which are in-line with a free market economy to enhance economic development. The overall objectives of these reforms were to bring about economic development through the Agricultural Development Led Industrialization (ADLI) strategy. In this strategy technical progress has been considered as the primary tool to sustain high growth rates and commercialization of agriculture. This aims at raising the productivity and efficiency of agriculture, which enables the sector to release resources for the industrial sector and the gradual decline of the share of agriculture in GDP. Measures have been taken to reduce the role of the public sector in agriculture and other productive sectors through rationalization and divestiture of parastatals[1]. Other measures include devaluation of the Ethiopian Birr in 1993 from Birr 2.07 to Birr 5.00 against one US $; removal of fertilizer subsidies and the pan-territorial pricing system in 1997; involvement of private traders in the supply

[1] See Aredo (1990) for the complete review of rural policy reforms in Ethiopia.

of fertilizers to farmers; abolition of price controls on agricultural commodities; and privatisation of public companies. Cooperative farms were dismantled completely with the fall of the Derg regime and the number of state owned and state managed farms has been reduced. All taxes and subsidies on exports were eliminated and state exporting enterprises are required to compete with private enterprises.

Land, fertilizer and seed are the main components of agricultural policy in both the pre- and post-reform periods. Land in Ethiopia is owned by the state and farmers have only user right (usufruct) to land.

To facilitate external trade, several domestic support institutions were also involved in the implementation of the reform policies. These support institutions, mainly the Ethiopian Export Promotion Agency, are engaged in the provision of information on international markets, training, and conducting studies of exportable products. There are also policy reform measures in the livestock sub-sector of agriculture.

A new marketing system was designed for fertilizer in 1992 with the main objective of liberalizing the fertilizer market and creating a multi-channel distribution system. This liberalization permitted the private sector to engage in the importation and distribution of fertilizer, hence ending the monopoly power of the state-owned Agricultural Input Supply Corporation (AISCO). In 1994 a new National Fertilizer Policy was introduced. This policy calls for the gradual elimination of fertilizer subsidies and the current system of pan-territorial pricing, the expansion the private sector’s role in the fertilizer trade and the establishment of the National Fertilizer Industry Agency (NFIA) to serve as a major instrument for the fertilizer sector. In 1996/97 fertilizer subsidies and the pan-territorial pricing system were completely removed. However, although liberalization has removed pan-territorial pricing and allowed private sector participation, fertilizer prices have remained high owing to an inefficient procurement and distribution system. Importers and distributors face considerable uncertainty and high costs due to problems related to timely unavailability and size of foreign currency obtained from foreign loans and grants to purchase fertilizer. These funds are obtained at unspecified time of the year (Demeke, 1999). In addition, these funds are granted with restrictive conditions regarding the sources of fertilizer supply, in effect raising the costs of fertilizer. The study by Demeke (1999) also indicates that despite the reform, fertilizer distribution is marked by regional monopolies and lack of leve-playing field. Local companies in some regions of the country limited market shares to importers and companies that have close links with the government (owned by parties and local governments). The regional governments control fertilizer loan and limit credit sales to preferred companies, making the market less competitive and unpredictable, which raised fertilizer prices in these regions compared to others.

Improved seeds are provided together with fertilizer on credit basis, whereas consultation and advisory services (extension services) are provided by the Ministry of Agriculture through Participatory Agricultural Demonstration and Extension System (PADETES). While farmers can seek advice from agricultural office workers assigned by the Ministry of Agriculture, full consultation and advisory services are provided only if the household is selected to participate in the PADETES for demonstrating the extension package of inputs (mainly fertilizer and seeds). These farmers have little influence in the way the PADETES is organized or the package is designed, as far as the plots allocated for demonstration are concerned. Afrint (2003) reports that the number of families participating in this extension program expanded from 32,047 in 1995 to 3,793,164 in 2001 countrywide. Problems related to output marketing, weak input distribution systems, and inadequate investment in research are cited to be among the factors contributing to the weakness of technology transfer (Kuma, 2002; Afrint, 2003).

3. Performance of the Economy after the Introduction of Policy Reforms

Studies have reported both negative and positive growth rates after the implementation of the reforms in 1990s. Afrint (2003) reported that real GDP grew annually on average by nearly 6% between 1992/93 and 2000/2001 while agricultural GDP grew by 3.5% per annum during the same period. Agricultural GDP growth fluctuated more than the overall GDP between 1993/94 and 2000/01 because of its dependence on weather.

Years with negative growth rates due to bad weather are usually followed by recovery and strong growth the following year, as can be seen from Table A2.

As a result of currency devaluation, fertilizer prices increased dramatically in 1993 and this caused a decline in fertilizer consumption in the following years. The situation forced the government to introduce fertilizer subsidies. The subsidies were later reduced and finally eliminated altogether in 1997. The complete removal of the subsidy resulted in a persistent low level of fertilizer usage in farming and subsequent productivity decline.

Investment on extension and fertilizer has expanded in recent years. Nevertheless, inadequate research capacity and lack of location specific research results have limited the contribution of new technology. Following bumper production since 1995/96, prices fell significantly (Kuma, 2002). Thus, more efficient markets are necessary to reduce price fluctuations and price risk to producers (Gabre-Madhin et al., 2002; Kuma, 2002; Gabre-Madhin, 2002; Amha, 2002; Afrint, 2003). Fertilizer consumption reached a record level of 297,907 tons in 2000 and then declined thereafter, probably due to the decline in producer prices (Table A1). Distribution of fertilizer has not been optimal due to delays caused by late import, transportation problems, loan repayment difficulties, and lack of credit availability. This has adverse impacts on the contribution of fertilizer to productivity.

The majority of farmers in Ethiopia do not use improved seeds. The multiplication system is poor and is dominated by a single parastatal, the Ethiopian Seed Enterprise. There has not been any significant increase in seed production in Ethiopia since 1991 (Afrint, 2003). The total sale of improved seeds has fallen since the reform. The quality of improved seed in Ethiopia is low due to low genetic quality, long period of repeated use, and inadequate storage facilities. The yield levels of cereals, pulses and oil seed have stagnated or even tended to decline in some cases. Among the major food crops, only maize yields have shown some yield improvement (Table A1).

Overall, grain production has increased steadily since 1993/94 except during some drought years (Afrint, 2003; Kuma, 2002). The result of the increasing production was that grain prices fell dramatically in 1995/96 and continued to fluctuate highly afterwards. While the price fluctuations vary across the regions, there have been general declining trends in producer prices, especially during the bumper production years (Table A2). Price fluctuations also vary across crops. Thus prices of teff fluctuate less than maize prices.

Although urban consumers and net buyer households may benefit when prices fall, and farmers gain when prices are high, fluctuations in grain prices have adverse impacts on farmers' income and productivity. Inter-annual price uncertainty can lead to inefficient allocation of resources in agricultural activities distorting allocative efficiency (Gabre-Madhin et al., 2002; Fan, 1999). Price risk also discourages adoption of yield-increasing technologies, thereby hampering technological change (Kim et al., 1992; Gabre-Madhin et al., 2002).

4. Methodological Framework

4.1 Technical Efficiency

The model of a stochastic frontier production function was first proposed by Aigner et al. (1977) and Meeusen and van den Broeck (1977) and then applied by Battese and Coelli (1995), Coelli and Battese (1996), Bravo-Ureta and Pinheiro (1997), Heshmati (1998), Grazhdaninova and Lerman (2005), Shu and Lee (2003) and others. The concept of a frontier defines the existence of an unobservable function, the production frontier, that corresponds to the set of maximum attainable output levels for a given level and combination of inputs.

While the use of stochastic profit function models enables us to estimate combination of the concepts of technical and allocative efficiencies directly, it requires that input prices vary among farmers since the prices are used as explanatory variables in the frontier profit function (Coelli, et al, 1998). However, households in our study area face the same input and output prices. Coelli et al (1998) indicate that estimation of frontier production function is appropriate when farmers maximize expected (rather than actual) profit. This leads to the application of stochastic frontier production function model to estimate farm specific efficiency (e.g. Battese and Coelli, 1995; Coelli and Battese, 1996; Liu, 2000).

A number of studies of efficiency measurement have adopted a two-stage approach to explain the inefficiency effects, in which the first stage involves the specification and estimation of the stochastic frontier function and the prediction of either the inefficiency effects or the efficiency scores of the firm involved. In the second stage the regression model is specified for the predicted inefficiency effects in terms of various explanatory variables and an additive random error generally using the ordinary least squares regression. Examples of these studies include Bravo-Uretha and Pinheiro (1997). This two-stage estimation approach is, however, criticized for its inconsistency in its assumptions regarding the independence of the inefficiency effects in the two stages of estimation (Battese and Coelli, 1995; Coelli, 1996; Rahman, 2003)[2]. Wang and Schmidt (2002) also show that the first-step of the two-stage procedure is biased for the regression parameters if the explanatory variables in the first-step and those in the second step are correlated. In addition, even if the two sets of the explanatory variables are independent, the second-step estimate is biased downward. Battese and Coelli (1995) suggested that the inefficiency effects could be expressed as a linear function of farm-specific explanatory variables. This extended stochastic frontier production model has the advantage of allowing the estimation of the farm specific inefficiency and the factors explaining inefficiency differentials among farmers in a single stage estimation procedure. Other studies, which adopted this single-stage procedure, include Coelli and Battese (1996), and Rahman, (2003). The Battese and Coelli (1995) model also permits the use of panel data and estimation of time-varying inefficiency effects. In this paper we utilize the Battese and Coelli (1995) single-stage model by postulating a stochastic

[2] In the two-stage estimation procedure, the first stage uses the assumption that the inefficiency effects (u_i) are identically distributed with one-sided error terms to estimate the stochastic frontier production function and predict the inefficiency terms. The second stage involves the regression of the predicted inefficiency effects on firm specific factors, which contradicts with the assumption of the identically distributed one-sided error term in the first stage. (Battese and Coelli, 1995)

frontier production function. To fix the idea consider the stochastic frontier production function with panel data:

$$(1)\, Y_{it} = f(X_{it};\beta)\exp(\varepsilon_{it})$$

such that $\varepsilon_{it} = v_{it} - u_{it}$ and where Y_{it} denotes an aggregate output value index for the ith farm (i=1, 2, …N) observed in period *t*; $f(.)$ represents the production function technology common to all farms; X_{it} is a vector of inputs and other explanatory variables; and β is a vector of unknown parameters to be estimated.

The error term, ε_{it}, is composed of two components, v_{it} and u_{it}. The component v_{it} are errors similar to those in the traditional regression model assumed to be N($0, \sigma_v^2$), while u_{it} are nonnegative random variables, to account for the existence of technical inefficiency in production and are assumed to be independently distributed, such that u_{it} is obtained by truncation (at zero) of the normal distribution with mean $z_{it}\delta$ and variance σ_u^2 (Battese and Coelli, 1995); z_{it} is a vector of explanatory variables explaining technical inefficiency of production of farms over time, assuming the inefficiency effects are stochastic; and δ is a vector of unknown coefficients. If all elements of the δ-vector are equal to zero, then the technical inefficiency effects are not related to the z-variables and so the half-normal distribution originally specified in Aigner et al. (1977) is obtained (Battese and Coelli, 1995). The model for the technical inefficiency effect, u_{it}, can be specified as:

$$(2)\; u_{it} = z_{it}\delta + w_{it}$$

The random variable, w_{it}, is defined by the truncation (at $-z_{it}\delta$) of the normal distribution with zero mean and variance σ_w^2.

The method of maximum likelihood (MLE) is used to estimate the unknown parameters of the stochastic frontier production function and the technical inefficiency model simultaneously. The likelihood function is expressed in terms of the variance parameters $\sigma_s^2 = \sigma_v^2 + \sigma_u^2$ and $\gamma = \frac{\sigma_u^2}{\sigma_u^2 + \sigma_v^2}$.

The technical efficiency of production for the i^{th} farm at time t (TE_{it}) is defined by:

(3) $$TE_{it} = \exp(-u_{it}) = \exp(-z_{it} - w_{it})$$

Technical efficiencies are predicted based on the conditional expectation of u_{it} upon the observed values of ε_{it}.

4.2 Measuring Total Factor Productivity Growth

4.2.1 Growth Accounting

Since efficiency is only one source of productivity, identifying other sources of output change allows the targeting of the most important sources of output change. The objective of this section is to examine total factor productivity (TFP) growth, technological progress and technical efficiency change in post reform agriculture of Ethiopia.

Estimation of TFP growth requires estimation of the frontier production function in (1). The model in logarithmic form is written as:

(4) $$\ln Y_{it} = \beta_0 + \beta_t t_t + \sum_{j=1}^{k} \beta_j \ln X_{ijt} + v_{it} - u_{it}$$

where β_j (j=1,2,…,k) are the elasticities of output with respect to changes in input *j*; β_0 is the intercept; β_t is the rate of technological progress, or neutral shift in the output over time; $\ln Y_{it}$ and $\ln X_{ijt}$ are the values of output and inputs of the *i*th farm in period *t*; and v_{it} and u_{it} are as described previously. As specified earlier, the degree of technical efficiency is given by:

(5) $$TE_{it} = Y_{it} / Y_{it}^F = e^{-u_{it}}$$

where Y_{it} is the observed level of aggregate value of output for farm *i* in period *t* and Y_{it}^F is the sample frontier (maximum) output. Manipulating (4) and (5) gives the growth accounting equation:

(6) $\dot{Y}_{it} = \beta_t + \sum_{j=1}^{k} \beta_j \dot{X}_{ijt} + \dot{T}E_{it}$

where the over-dots indicate percentage changes (with respect to time). According to equation (6) growth of output during a certain period can be decomposed into three components: technological progress (β_t); growth rate of inputs $\left(\sum_{j=1}^{k} \beta_j \dot{X}_{ijt}\right)$; and change in technical efficiency $\left(\dot{T}E_{it}\right)$. From equation (6) the growth rate of total factor productivity (*TFP*) can be calculated as:

(7) $T\dot{F}P = \beta_t + \dot{T}E_{it}$.

In this paper we use the residual left over after accounting for technological progress and input growth as a measure of technical efficiency change ($\dot{T}E_{it}$) for the growth accounting purpose (Liu and Zhuang, 200). This measure of technical efficiency change includes both the explained and unexplained parts of the *TE* change.

4.2.2 TFP Index

To support our regression-based TFP growth obtained in the previous section, we calculate the non-parametric TFP index number for the purpose of comparison. A TFP index measures a change in the value of total output relative to changes in the usage of all inputs between two time periods (Coelli et al., 1998; Gavian and Ehui, 1999). Thus the TFP index (in its logarithmic form) for two periods, s and t, can be defined as:

(8) $\ln TFP_{st} = \ln(\frac{output\ index_{st}}{input\ index_{st}}) = \ln(output\ index_{st}) - \ln(input\ index_{st})$

where $\ln TFP_{st}$ is a fixed-base TFP index for current period t with s as the base period; ln is the natural logarithm; $output\ index_{st}$ and $input\ index_{st}$ are output and input indices, respectively, for current period t.

The *output index*$_{st}$ and *input index*$_{st}$ numbers are calculated using the indirect measure of quantity changes, which uses the basic idea that price and quantity changes are two components that make up the value change over the periods s and t:

(9) $v_{st} = p_{st} Q_{st}$

where v_{st}, p_{st} and Q_{st} are, respectively, value, price and quantity index numbers between two periods, s and t. Since v_{st} is defined from data directly as the ratio of values in periods s and t, we can obtain Q_{st} as[3]:

$$(10)\ Q_{st} = \frac{v_{st}}{p_{st}} = \frac{\sum_{i=1}^{K} p_{sit} q_{it}}{\sum_{i=1}^{K} p_{is} q_{is}} / p_{st} = \frac{\sum_{i=1}^{K} p_{it} q_{it} / p_{st}}{\sum_{i=1}^{K} p_{is} q_{is}}$$

$$= \frac{value\ \ in\ \ period\ \ t(at\ \ constant\ \ s\ \ prices)}{value\ \ in\ \ period\ \ s(at\ \ period\ \ s\ \ prices)}$$

where p_{is} and p_{it} are prices of i^{th} (i=1, …, K) input or output, at s and t periods and q_{is} and q_{it} represent quantities of i^{th} input or output at s and t. p_{st} are consumer price indices obtained from the Ethiopian Central Statistical Agency (ECSA).

This approach states that quantity indices can be obtained from ratios of values, aggregated after removing the effect of price movements over the period under consideration.

5. The Data and the Study Area

The data set used in this study comes from a sample survey of small farmers located in the two peasant associations (administrative units) of the Ada-Liben district of the central highlands of Ethiopia, 45 km east of the capital, Addis Ababa. The surveys were conducted in 1993/94 and 2000/01.

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[3] The same formula (10) is used to calculate the output and input quantity index numbers, Q_{st} . The ECSA uses the Laspeyres formula to calculate p_{st} .

The area has good market access, high agricultural potential and it is a major teff[4] producing area. In addition to its good market access, the area enjoys one of the highest rainfalls in the country, which makes it one of the least prone areas to drought. This makes it appropriate for this kind of study because of the relatively low probability of random shock resulting from drought, and as a result much of the yield variation can be explained in terms of other non-random variables related to environmental, farm and farmer characteristics.

Land redistribution has ceased, except in a few regions, since the current government took over power. Because of this, young-headed households who were not eligible during the first and successive land distributions are mostly landless, except the informally contracted lands such as fixed contracts, sharecropping and, in some cases, some patches of land are shared voluntarily with their parents. The informal contract pattern is shifting from sharecropping to fixed rent contract. Only a few households reported that they had cultivated land under sharecropping contract.

Oxen are used in pairs for ploughing. Households with only one ox exchange oxen with another household having an odd number of oxen. Labour is imported to the area especially during peak seasons. But skilled labour is exported to urban areas.

The use of modern inputs in the area is limited. Most of the households use fertilizer only for production of teff, wheat and barely and sometimes maize, with the rate of application usually falling far below the recommended rates. The use of improved seeds is also very limited. However, there is an increasing trend in input use between the two survey years (Table 1). Fertilizer is provided on credit basis to farmers at 12% interest rate. Failure to repay the credit is followed by fines and being denied the next season's credit. Fertilizer and seed credit is the only formal credit available to farmers, which is also the case in other parts of the country.

[4] Teff (Eragrostis tef.) is a staple cereal crop in Ethiopia

There have been frequent delays in fertilizer provision, with farmers failing to meet the recommended dates and rates of application. There are two main reasons for fertilizer rates to be below optimal. First, credit is either rationed or there is problem of indivisibility in fertilizer supply. Suppliers often supply only a certain package, for instance, 100 kg of DAP plus 50kg of UREA, and only the integer multiples of this package is supplied to a farmer in the area. Thus, farmers who need less than this amount cannot get fertilizer on credit. Land degradation is one of the main agricultural problems in the area (Holden et al, 2003).

The data sets from 1993/1994 and 2000/2001 cover the same 80 households observed during both survey years, 40 households were randomly selected in 1993/94 from each of the two peasant associations. Teff, wheat, barley and beans are the main crops grown in the areas. Cropping patterns of the sample farmers are provided in Table A3. In this study we include teff, wheat, barley, maize, peas, beans, chickpea, lentil and common vetch. There are no high value crops in the area, which would have made aggregation of products difficult.

The two peasant associations do not have basic differences in terms of weather, and soil fertility. The difference, though, is that one association (Hidi) is closer to the market area than the other (Hora) and may have better proximity to input supply and off-farm income opportunities. These two associations are found to be representative of farming conditions within the region. But as they are not representatives of the whole country, we would not want to generalize our conclusions to the Ethiopian agriculture in general. In light of the large fluctuations from year to year in agricultural production due to weather variations, any analysis of the impact of policy reforms on the performance of agricultural production must utilize data collected over some time. Panel data collected with a larger gap between surveys is more advantageous than with shorter gap since policies take time to have their effect (Deaton, 1997). It would, however, have been preferable to have more observations in our data set, both in terms of number of cross sections and rounds of the survey.

The results of the regression-based growth accounting model will be supplemented with the TFP index result to see if the two results are comparable since the panel data from two isolated years is more appropriate for TFP index construction.[5]

Out of the sample of 80 households during the two survey years, 19 households were dropped because of incomplete data and outlier observations, probably due to measurement errors in the data. There was no attrition between the two rounds of the survey. Table 1 presents descriptive statistics for variables used to estimate production function and inefficiency effects models.

6. Empirical Model and Estimation Results

6.1 Specification of the Frontier Production Model

The Cobb-Douglass (C-D) functional form is used to specify the stochastic frontier production function in (1).[6] This functional form has been widely used in farm efficiency analysis. Furthermore, since there are a large number of inputs, by using a simple functional form, the risk of multicollinearity due to inclusion of interaction and square terms of the explanatory variables is avoided. The empirical specification of (1) is given by:

$$(11)\quad \begin{aligned} \ln Y_{it} &= \beta_0 + \beta_1 \ln(fertilizer_{it}) + \beta_2 \ln(seed_{it}) + \beta_3 \ln(cash \ \ \exp_{it}) + \beta_4 \ln(land_{it}) \\ &+ \beta_5 \ln(labour_{it}) + \beta_6 \ln(oxen_{it}) + \beta_7 (year_{it}) + v_{it} - u_{it} \end{aligned}$$

And the technical inefficiency effects are defined as

$$(12)\quad \begin{aligned} u_{it} &= \delta_0 + \delta_1 (land_{it}) + \delta_2 (locadum_{it}) + \delta_3 (oxen_{it}) + \delta_4 (age_{it}) + \delta_5 (price_{it}) \\ &+ \delta_6 (workforce_{it}) + \delta_7 (edu_{it}) + \delta_8 (rent_{it}) + \delta_9 (year_{it}) + w_{it} \end{aligned}$$

where ln denotes the natural logarithm; y_{it} is aggregate value of crop output for farm i (i=1,…, 61) in period t (t=1, 2). Coelli and Battesse (1996) state that when the output variable in the stochastic frontier production function is aggregate value of total outputs,

[5] Examples of studies which use data from two isolated years' surveys include Rosenzweig et al. (1986) and Pitt et al. (1993).

[6] We tried the translog functional form but only very few terms were significant at 10%.

the measure of technical efficiency obtained becomes a measure of the total economic efficiencies of the farmers since it is influenced by allocative inefficiency. Hence, the u_{it} are hereafter referred to as "inefficiency effects" rather than technical inefficiency effects in this study.

Descriptions and expected signs of all variables used in stochastic frontier production function and the inefficiency effects model are given in Table 1. All values in 2000/01 are given in 1993/94 constant prices (real values) by deflating them with consumer price indices[7] to remove the effects of inflation over the period under consideration.

The inefficiency frontier model (11)-(12) accounts for both technical change (β_7) and time-varying inefficiency effects (δ_9). The year variable in the stochastic frontier (11) accounts for Hicks-neutral technological change while the year variable in the inefficiency model specifies that the inefficiency effects may change linearly with respect to time (Battese and Coelli, 1995). The maximum likelihood estimates (MLE) of the parameters of the stochastic frontier (11) given the specification for the inefficiency effects (12) were obtained using Frontier 4.1 (Coelli, 1996). These estimates are given in the upper part of Table 2.

6.2 Results and Discussions

6.2.1 Descriptive Statistis

In this section we provide a brief discussion of descriptive statistics of our data provided in Table 1 as a prelude to the discussion of econometric results. The aggregate value of crop output is slightly higher in the second year. We will provide the breakdown of the increase in the growth accounting section. Land and labour inputs have declined during the period. While the decline in operated holding could be due to renting out or land sharing with relatives, the decline in labour use could be associated with the decrease in

[7] Price indices were obtained from the Ethiopian Central Statistical Agency (ECSA) (1994-2001). Since there are no producer price indices produced in Ethiopia, we use the food consumer price index for outputs and seed inputs and the general consumer price index for other inputs.

operated holding and the shift to other non-farm activities. Other inputs have increased during the period. The increase in cash income is especially notable. This may point out the increasing shift of labour from farm activities probably due to the fall in grain prices. Weighted average primary market grain prices have declined slightly over the period. Generally this decline is less than the average price decline for Ethiopia as a whole.

6.2.2 Stochastic Frontier Production Function Results

We base our discussion in this section on the MLE (Model II of Table 2). All variables have the expected signs and, with the exception of seed and fertilizer, are statistically significant. The inclusion of seed in the regression is based on the ground that farmers in Ethiopia do not use seed in a fixed proportion and this may affect production.[8] The insignificant coefficient of seed could be because of the fact that there are not many improved seeds in use. Farmers are mostly using the same traditional seeds or, if they have ever used improved seeds, they use it repeatedly and the productivity of the seed deteriorates over time as a result. Therefore, variations of seed costs across farmers and over time are more likely to be the result of differing amounts of traditional seeds, rather than the result of some farmers using more costly improved seeds. The coefficient of fertilizer is not significant at 10% level of significance. This may be because of its late application due to delays in fertilizer provision or insufficient quantity.

The elasticity of aggregate value of output with respect to land is the most elastic and highly significant. The elasticity of output value with respect to oxen days is the second biggest. The elasticity of output value with respect to labour comes next to oxen days. Table 2 shows the difference, in parameter size, between the two groups of inputs (fertilizer, cash expenditure, and seed) and (oxen days, labour, land). Generally, the first group has lower elasticities and are less significant than the second group, suggesting that the variation in this first group of inputs does not necessarily mean similar variation in outputs. The effect depends on how these variables are used in production. For

[8] Rahman (2003) noted the same situation in Bangladesh and included seed cost as an explanatory variable in his regression of frontier profit function.

instance, the time of fertilizer application, the actual use of cash spent, and the seed type and rates matter.

This calls for more efficient ways of delivering the inputs to the farmers

The estimated coefficient of the time variable is positive but not significant, indicating that there was no significant technical progress. This may suggest that there have not been significant improvements in the quality of inputs used, information, skills of farmers and other factors that lead to technical progress. Low grain prices might have also discouraged farmers from investing in improved farm inputs. The damages to agricultural land in terms of soil degradation (erosion and nutrient depletion) may also counteract the investments in extension and use of fertilizers.

Returns to scale (RTS) which measures the change in output resulting from a proportional changes in all variable inputs, is obtained by summing the input coefficients since we used the double-log transformation. The estimated value of the function coefficient is 0.9813 suggesting decreasing returns to scale, but statistically not different from constant returns to scale (Table 2).

6.2.3 Inefficiency Model Results

Determinants of inefficiency

For policy purposes, it is useful to identify sources of production inefficiency. The land coefficient is positive which indicates that larger farms tend to be more inefficient, probably due to imperfections in labour market (Heltberg, 1998). The dummy variable for location has a negative sign as hypothesized and is significant indicating that farmers close to towns and markets (in Hidi) have better access to inputs and information than those in Hora. The number of oxen owned by households has an expected negative sign and is significant. We hypothesized that the number of oxen determines the capacity of farmers to plough land timely. This means that farmers with larger number of oxen are expected to be more efficient. The age coefficient is positive and significant indicating that older farmers are more inefficient. The time coefficient is also positive and significant, which indicates that inefficiency has increased over time.

We also have included weighted average prices of crops as an explanatory variable in the inefficiency model on the ground that price can influence inefficiency. Price varies only between the two years. The coefficient on price is positive and insignificant. Size of total workforce available to the household has a positive sign but it is insignificant. We expected that larger labour force reduce inefficiency in the face of labour market imperfections.

Education is another variable with unexpected positive but insignificant coefficient. The hypothesis was that more educated decision makers are less inefficient. This result can be explained by the possibility that more educated people are more probable to be employed off farm and have less time for farm management especially when farm income falls due to price fall.

The share of rented-in land in total operated holding was also included in the model to control for the possible inefficiency associated with land rental contracts. However, the coefficient of the variable has unexpected negative and insignificant coefficient that farms with larger share of rented-in land tended to be less inefficient. Possible explanation is that most households with rented in land have lack of land relative to their counterparts and this enables them to operate their farm more efficiently. This explanation makes sense because the coefficient of land size is positive. In addition, land rental contracts are mostly fixed rental and hence we do not expect the Marshalian inefficiency introduced by share cropping to contribute to the inefficiency effects.

Patterns of inefficiency

The results of testing the hypotheses that the inefficiency effects are not simply random errors are reported in the lower part of Table 2. The estimate of the variance ratio parameter, γ, is close to one, indicating that the inefficiency effects are likely to be highly significant in the analysis of the value of output of the farmers. γ is bounded between 0 and 1. If γ=0, inefficiency is not stochastic, and if γ=1, there is no random noise.[9] In Table 3 we present generalized likelihood ratio test[10] of the null hypotheses that the inefficiency effects are absent or that they have simpler distributions. The first null hypothesis that the inefficiency effects are absent from the model is strongly rejected (at 5% level). The second null hypothesis, which specifies that the inefficiency effects are not stochastic, is also rejected at 5% significance level. The third hypothesis specifies that the inefficiency effects are not a linear function of the variables included in the model. This hypothesis is also rejected, indicating that the joint effects of the nine variables on the inefficiency of production are significant although the individual effects of some of the variables are not significant. This shows that this model, which includes the inefficiency effects in the stochastic frontier, is better than that which does not include the model for inefficiency effects.

Measures of efficiency

Based on the technical inefficiency effect derived from the stochastic production frontier (Model II of Table 2), we calculate *TE* (equation 3). The mean of efficiency by various size measures and over time is reported in Table 4.

The results show that technical efficiency index range from 29.0% to 96.9% in 1993/94 and from 14.0% to 86.0% in 2000/2001. The mean efficiency for 1993/94 and 2000/01 are 59.8% and 36.0%, respectively. It decreases significantly over time. The low mean of the efficiency scores indicates that the inefficiency effects are influenced by the allocative inefficiency in addition to technical inefficiency and hence are a measure of overall economic efficiency. Due to the stochastic nature of the model, no farmer is fully efficient in the sample. Average efficiency for the sample is 47.9%. Accordingly, if the average farmer in the sample was to achieve the efficiency of its most efficient

[9] If γ is not significantly different from zero, the variance of the inefficiency effects is zero and the model reduces to a mean response function in which the inefficiency variables enter the production function directly (Battese and Coelli, 1995).

[10] The likelihood ratio test statistic, $\lambda = -2\{\log[likelihood(H_0)] - \log[likelihood(H_{1})]\}$ has approximately chi-square distribution with degrees of freedom equal to the number of parameters assumed to be zero in the null hypothesis, H_0, provided H_0 is true. All critical values of the χ^2 involving the tests for γ are taken from Kode and Palm (1986; Table 1).

counterpart, then the average farmer could realize a 50.01% cost saving, i.e. [1-(47.9/96.0)]. A similar calculation for the most technically inefficient farmer reveals a cost saving of 85.4% [1-(14.0/96.0)].

These cost savings can alternatively be interpreted as equivalent potential increase for output values for given input use in production by using the best practice production technology.

6.2.4 Results of TFP Measurement

Growth Accounting

In this section, we attempt to identify the sources of a change in the value of agricultural production based on methodological approach outlined in section 4.2.1. To accomplish this we use the estimation results of our stochastic frontier production function reported in Model III of Table 2. This estimation omits seed, fertilizer and the year dummy, the coefficients of which are not significant in the stochastic frontier model reported in Model II of Table 2.

The sources of value of output change between the two periods as shown in equation (6) are divided into three components: changes in conventional inputs; technological progress; and a change in efficiency. The first component is divided into different conventional inputs. However, due to the fact that the year variable is not significantly different from zero in Model II we assume there is no technological progress contribution in the growth accounting (Model III).

The percentage growth in the value of output and inputs between the two periods is used to arrive at the growth accounting results. In Table 5 we report the percentage changes in the output and inputs while Table 6 reports growth accounting results. Between 1993/94 and 2000/01, aggregate value of production increased by 7.95%. During the period aggregate value of production increased by 13.8 percent due to the increase in conventional inputs. The most important source of increase in output was the increase due to oxen-days (24.93%), followed by cash expenditure (3.4%). However, these positive contributions have been offset by the decline in other inputs. Declines in land and labour inputs led to declines in the aggregate value of output by 8.95% and 5.85%, respectively.

Although cash expenditure increased by 62.5% during the period, its contribution to the total output value growth was only 3.4%. This is due to its low elasticity. The increase in oxen days is the biggest contributor to the total output value increase due to its high elasticity (0.45). Technological progress, although positive, has not contributed significantly to output value growth. There could be many factors to which this result could be attributed. One possible reason is that there may not be enough investment in agricultural productivity-enhancing packages by farmers due to lack of incentives attributable to low agricultural prices. Low rate of generation of yield enhancing technologies by the research service could be another problem affecting technological change. Soil degradation could also be another factor counteracting productivity. A recent study by Holden et al. (2003) which used computable general equilibrium (CGE) model to simulate the impact of different policy measures on soil degradation indicate that these policy measures tended to increase land degradation (measured by its impact on land productivity).

Having accounted for input change, and assuming zero technical progress, the remaining residual is attributed to a change in technical efficiency, since technical efficiency is a residual concept (Liu and Zhuang, 2000; Lin, 1992). The change in the aggregate value of production due to efficiency reported in Table 6 is about –5.85%. This result is clear from the inefficiency effects model as explained by the year variable, which is positive and significant indicating efficiency declined from the first to the second year. Following the convention of growth accounting, the TFP growth $\left(T\dot{F}P\right)$ reported in Table 6 is –5.85%. This study shows that the change in efficiency is the only part constituting TFP change, as technical change is not significant. This shows that the production frontier remained the same while the gap between standard practice and the best practice grew.

TFP Index

The non-parametric TFP index is calculated using aggregate output and input value indices reported in Table 5 and the TFP index is reported in the last row of Table 6. This result is –6.0%, which is very close to the parametric growth accounting TFP measure. Given that the former includes all inputs unlike the regression-based TFP measure, which excludes the inputs, which are insignificant in the regression, the two results are almost identical suggesting the validity of our methods.

7. Summary and Conclusions

This paper attempts to analyse the performance of agriculture in post reform Ethiopia by investigating several performance measures such as inefficiency and TFP growth. We used stochastic frontier production function with inefficiency effects to obtain estimates of the above performance measures. In addition, we calculated the non-parametric TFP index based on output and input value indices. The production frontier is specified by using the inputs of land, fertilizer, seed, labour, oxen and costs of other inputs. In addition, we include a time variable to proxy the influence of technical change. All the estimates have the expected signs.

The model for inefficiency effects in the production frontier includes seven farm specific variables, price and the time variables to proxy the change of inefficiency over time. A number of tests of hypotheses are conducted to assess the relative influence of these factors and other random effects on inefficiency in production. The results indicate that there is evidence of significant inefficiencies among the farmers and that the factors have a significant influence on the size of inefficiencies of farmers in the area.

The number of oxen and being close to the market locations decrease inefficiency, while age and time trend increase inefficiency. From the findings, there is evidence that inefficiency has increased in production over the period. Our frontier model enabled us to separately estimate technical change and change in the inefficiency effects over time. Location has implications on how fast and well inputs and outputs are taken from and brought to the village, affecting inefficiency.

Following the convention of growth accounting, the rate of total factor productivity growth is found to be negative. Increased fertilizer use and other inputs in the form of other costs did not contribute significantly to technical progress. Increased uses of some inputs have contributed to the growth of the value of output but the increase in inefficiency has offset much of the output value growth. The gain from improving efficiency can be significant since it accounts for a large part of output variation.

While the objective of government ADLI program was to sustain high growth rate and commercialization of agriculture using technological progress as the primary tool, this result shows that the objective has not been met. Among the surveyed households there are no signs of technical progress during the period covered by this study, and efficiency has declined, although the aggregate value of output has increased slightly owing to increases in some inputs. However, the results suggest a potential for increasing production using the current technology by improving efficiency of farmers.

While this study is limited in geographical coverage, the findings conform to other broad assessments of recent performance of the Ethiopian agriculture. The contribution of this paper is that it assesses the performance of crop sector based on growth accounting and efficiency measures using primary data. There are general agreements among these studies that while some aspects of the reforms have been positive, the results of the market reforms have generally not met expectations, and much remains to be done (e.g., Kherallah, 2000; Demeke, 1999).

Crawford et al (2005) provides reviews of literature arguments for and against fertilizer subsidies. Accordingly opponents of subsidy argue that fertilizer subsidies, among other things, distort resource allocation at the farm level. On the other hand, proponents argue that although subsidies result in economic inefficiency and net welfare losses in the presence of perfectly competitive markets, departure from the conditions of perfect competition provides a rationale for public intervention. They list economic, financial and non-economic benefits of subsidies. As we have noted in section two both grain and input markets in Ethiopia face many constraints and are far from perfect. Based on the arguments for and against subsidies, the results of this study suggest that the conditions of the Ethiopian markets stand in the ways of achieving the potential efficiency gains of the removal of fertilizer subsidies. To make agricultural reforms more effective it is important to overcome the remaining constraints to market participants. Kherallah et al (2000) suggest that effective reforms require more concerted efforts to go beyond the withdrawal of public sector from agricultural marketing. These efforts must include full implementation of all reforms; strengthening of investments in public goods such as infrastructure, institutions, research and extension and public market information; provision of legal infrastructure for market transactions; promotion of effective governance and state capacity to monitor market developments; provision of input credit to farmers; and instituting credible and sustainable macroeconomic policies.

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Table 1. Descriptive statistics of variables used in estimations, NT=61x2=122 observations'

Variable name	Description of variable	Expected sign	Mean 1994	Mean 2001	Mean Whole sample	Std. dev. 1994	Std. dev. 2001	Std. dev. Whole sample
Production function variables:								
Tcy:dependent Var.	Aggregate value of crop output		4406.932	4757.358	4582.145	2635.545	3257.101	2955.642
Fertilizer	Total value of fertilizer used for crop	+	167.502	842.325	504.913	112.795	453.511	472.316
Seed	Total value of seeds used	+	134.927	447.692	291.311	86.19	320.341	281.473
Cash expenditure (Expenditure)	Expenditure to purchase other inputs such as herbicides, etc.	+	32.902	53.462	43.182	42.936	73.43	60.781
Labour	Value of man days used in crop production	+	1176.74	668.118	922.429	563.893	388.68	545.705
Oxen days	Value oxen days used in crop production	+	389.287	606.42	497.853	191.923	369.962	313.080
Land	Total operated land for crop production Measured in kert*	+	8.579	6.951	7.765	4.066	3.437	3.837
Cash income	Total non-crop and non-livestock income		98.557	481.51	290.036	177.067	1245.330	906.383
Inefficiency effects variables:								
Age	Age of household head in years	?	45.246	52.574	48.909	16.737	16.908	17.153
Land	Total operated land for crop prod	?	8.579	6.951	7.765	4.066	3.434	3.837
Oxen	Number of oxen owned by the household	-	2.016	2.475	2.246	1.335	1.456	1.410
Locadum (Village dummy)	A dummy variable: Hidi=1; Hora=0	-	0.508	0.508	0.508	0.504	0.504	0.501
Rent	Ratio of rented in land to total operated land	+	0.103	0.064	0.083	0.182	0.166	0.175
Work force	Total work force of the household**	-	3.041	3.160	3.101	1.306	1.312	1.305
Edu	Education of household head in years	-	1.639	1.639	1.639	2.273	2.273	2.264
Price	Weighted average price of crops***	-	2.316	2.122	2.219	0	0	0.097

Notes: [a] All values are in 1993//94 constant prices, i.e., values are deflated using consumer and general price indices deflators. * Kert is a local measure, 1kert ≈0.35 hectare; ** This is given in standardized labour unit.

*** This was calculated as: weighted average price = $\sum_{j=1}^{k} p_j.s_j$ where p_j is market price of crop j (j=1,…., K), s_j is the share of revenue from sale of crop j at price p_j in total revenue from crop production.

Table 2. Production function parameter estimates, dependent variable is log of crop output, NT=122 observations.

Variable name[a]	description	Model I (OLS) Coefficient (standard err.)	Model II (MLE) Coefficient (standard error)	Model III (MLE) Coefficient (standard error)
Frontier production function model				
constant		4.1008 (0.4603)***	4.5604 (0.6742)***	3.7825(0.4140)***
Ln (fertilizer)	Value of organic fertilizer	0.1087 (0.0540)**	0.0922 (0.0573)	-
Ln(seed)	Value of seeds	0.0608 (0.0660)	0.0146(0.0636)	-
Ln (cash exp)	Amount of cash expenditure	0.0383 (0.0237)	0.0368 (0.0213)*	0.0544 (0.0215)**
Ln(land)	Size of total operated land	0.4986 (0.1383)***	0.5234 (0.1916)***	0.4740 (0.1074)***
Ln (labour)	Value of labour days	0.1023 (0.0640)	0.1274 (0.0606)**	0.1291 (0.0539)**
T	Time trend	-0.1756 (0.1386)	0.4850 (0.3557)	-
Ln (oxen)	Value of oxen days	0.2705 (0.1136)**	0.1873 (0.1121)*	0.4467 (0.0648)***
Variance parameters				
σ_s^2	$\sigma_s^2 = \sigma_u^2 + \sigma_v^2$ 2	-	0.1064 (0.0167)***	-
γ	$\Gamma = \sigma_u^2 / (\sigma_u^2 + \sigma_v^2)$	-	0.9463 (0.0679)***	-
L	log likelihood function	-40.2487	-27.6618	-
Function coefficient	Sum of elasticity of output with respect to inputs		0.9813	
H_0: CRS	Test for the null hypothesis of CRS		$\chi2=1.61$, $p=0.2040$	
Inefficiency model				
constant		-	0.0451 (0.9279)	-
land	Size of operated land holding in kert	-	0.0006 (0.0242)	-
Locadum	Dummy for location, 1=Hidi, 0=Hora	-	-0.1752 (0.0721)**	-
oxen	Value of oxen days	-	-0.1099 (0.0371)***	-
age	age of household head in years	-	0.0035 (0.0021)*	-
T	Time trend	-	0.5818 (0.3144)*	-
Price	Weighted average price of outputs	-	0.0002 (0.4064)	-
workforce	Total workforce of the household in labour unit	-	0.0119 (0.0323)	-
edu	Education of the household head in years	-	0.0081 (0.0163)	-
rrl	Ratio of rented to total operated land	-	-0.0979 (0.2119)	-

Notes: [a] ln indicates the natural logarithm; CRS: constant returns to scale; ***, **, * indicate significance at 1, 5 and 10 percent levels of significance, respectively. Numbers in parentheses are standard errors

Table 3. Hypotheses tests for the parameters of the inefficiency frontier Model II for crop farmers in Ethiopia

Null hypothesis	Log (likelihood)	$\chi^2_{0.95}$	Test statistic*
$H_0 : \gamma = \delta_0 = ... = \delta_9$	-40.248	19.045	25.173*
$H_0 : \gamma = 0$	-343.159	7.045	630.996*
$H_0 : \delta_1 = ... = \delta_9$	-37.765	18.31	20.208*

* Indicates significance at 5% significance level

Table 4. Summary statistics of various efficiency components by size and over time, based on estimation results from Model II.

Efficiency	Year of observation		No of oxen ownership			Size of operated land in kert			Total workforce size			Whole sample
	1993/94 (n=61)	2000/01 (n=61)	0 n=12	1 n=23	≥2 n=87	1.5-4.0 n=24	4.1-7.7 n=43	≥7.8 n=55	1.0-1.8 N=22	1.9-3.0 n=46	≥3.1 N=54	(N=122)
Technical												
Mean	59.8	36.00	40.00	49.70	48.00	41.54	43.88	53.00	44.41	45.37	51.46	47.90
Minimum	29.00	14.00	21.00	24.00	14.00	22.00	14.00	18.00	23.00	14.00	18.00	14.00
Maximum	96.00	86.00	67.00	92.0	96.00	83.00	92.00	96.00	92.00	86.00	96.00	96.00
Test of the null hypothesis that the means for 1993/94 and 2000/01 are equal	t=9. 6; p (T>t) =0.000											

Table 5. Index of crop output and input values (1993/94=100)

Year	Aggregate value of crop out put	Cash exp.	labour	Oxen (Oxen days)	land
1993/94	100	100	100	100	100
2000/01	107.95	162.5	56.8	155.8	81.1

Table 6. Accounting for crop output change using stochastic frontier production function, Model III, based on NT=122 observations.[a]

Explanatory variable	Definition of variables	Estimated coefficient (1)	Change in variable % (2)	Contribution to growth (%) (3) = (1) x (2)
Inputs*				13.800
Cash exp	Cash expenditure	0.0544	62.500	3.400
Labour	Value of labour input	0.1291	-43.200	-5.58
Oxen days	Value of oxen days	0.4467	55.800	24.93
Land	Size of operated land holding in kert	0.474	-18.900	-8.95
Residual				-5.85
Total growth	Percentage growth of value of crop output			7.95
TFP index	Measure of TFP growth			-6.0

Notes: [a] the estimated coefficients are those of Model 3 of Table 2. For the conventional inputs, the change in explanatory variable refers to the percentage change of the inputs during the two periods. Changes in output and input are calculated from Table 5. The numbers in parentheses are the percentage shares of contribution to total output change with total output change set normalized to 100 percent. * Seed, fertilizer and year are omitted from growth accounting calculation because they are not significant in the estimation of production function.

Appendix A. Crop productivity, seed production, fertilizer use, cropping pattern, GDP and price movements over time

Table A1. Crop Yields per hectare and fertilizer use, 1993-2001.

Year	Yield in quintals / hectare			Fertilizer in metric tons		
	Cereals	Pulses	Oil-seeds	DAP	UREA	Total
1993	12.91	7.38	3.80	90109	17348	107457
1994	10.71	8.79	3.43	170000	20000	190002
1995	12.43	9.00	4.99	202312	44410	246722
1996	12.90	8.87	4.46	209883	43269	253152
1997	11.60	8.12	4.48	168623	51808	220431
1998	11.40	5.10	3.60	193395	87976	281371
1999	11.40	8.40	4.00	195345	94919	290264
2000	11.50	9.20	4.10	197345	100562	297907
2001	12.17	8.70	4.30	181545	98057	279602

Source: Afrint (2003)

Table A2. Gross domestic products at 1980/81 constant factor cost, food aid and production and major and annual average prices of major crops

	1991/92	1992/93	1993/94	1994/95	1995/96	1996/97	1997/98	1998/99	1999/00	2000/01	2001/02	2002/03	2003/04
1.Gross Domestic Product (millions of ETB)			11999.3	12644.3	13987.1	14709.9	14572.6	15460.9	16284.3	17688.6			
2. Share of agriculture in GDP (%)			50.7	49.7	51.5	50.7	45.7	44.7	43.2	44.9			
3. Annual growth rate of GDP (%)			1.7	5.4	10.6	5.2	-1.2	6.3	5.3	9			
4. Annual growth rate of agriculture (%)			-3.7	3.4	14.7	3.4	-10.8	3.8	1.9	13.2			
5. Per capita grain production (Quintal/head)	1.405	1.476	1.308	1.372	1.831	1.758	1.353	1.437	1.481	1.4667	1.356	1.307	1.224
6.Food aid (in 1000' Mts)	840.00	519.00	980.00	683.00	150.19	205.47	417.31	511.03	979.56	-			
7. General inflation rate (annual %)			1.2	13.4	0.9	-6.4	2.33	4.8	4.2	-4.5			
8. Average annual price for major crops (ETB/kg)													
8.1 East Shoa (Study area-secondary market)													
Teff			1.9	1.89	1.52	1.52	1.83	1.99	2.42	2.34			
wheat			1.25	1.33	1.18	1.21	1.43	1.59	1.64	1.24			
maize			0.87	0.85	0.61	0.71	0.85	0.97	1.12	0.62			
8.2 Addis Ababa-tertiary market													
Teff			1.91	1.95	1.88	1.73	2.19	2.38	2.85	2.44			
wheat			1.31	1.40	1.26	1.29	1.53	1.74	1.95	1.406			
maize			0.94	0.88	0.72	0.75	0.99	1.10	0.94	0.61			

Source: Afrint (2003), WDI (2006) and Ethiopian Statistical Authority

Table A3. Cropping patterns of the sample farmers.

Crop type	Farmers growing the crops (%)	
	1993/1994	2000/01
Teff	86.9	86.8
Wheat	60.6	65.6
Barley	34.4	22.9
Maize	22.9	8.2
Peas	29.5	1.6
Beans	62.3	73.8
Chickpea	27.9	47.5
Lentil	14.7	3.3
Common vetch	0	1.6

Paper II

Soil fertility management strategies of smallholder farmers in Ethiopia: a simultaneous equations analysis*

Adane Tuffa Debela

Department of Economics and Resource Management

Norwegian University of Life Sciences

P.O. Box 5003, Aas, Norway

Abstract

This paper investigates factors influencing the adoption of manure and chemical fertilizer and intensity of use of chemical fertilizer in the highlands of Ethiopia using cross-section data from 1998 household survey of farm households. The model is based on a two time dynamic model that accounts for the carry-over effect of manure. It is hypothesized that organic fertilizer, which is applied prior to the former, influences application of inorganic fertilizer. We estimated the model as a system of simultaneous equations, allowing for the endogeneity of manure in other equations. Maximum likelihood and two-stage probit procedures are used to handle the simultaneity and selectivity problems. Results indicate that after controlling for other factors, adoption of inorganic fertilizer is positively associated manure adoption while there is no significant correlation between inorganic fertilizer use intensity and adoption of manure. Contrary to our expectation, the share of rented-in land in total operated holding is associated with higher probability of manure adoption. The results further indicate that most of the factors that significantly affect adoption of inorganic fertilizer are different from those affecting their use levels.

Keywords: soil degradation; fertility replenishment; manure; chemical fertilizer; adoption; Ethiopia.

JEL Classification Number: Q12; O13; R14; Q15; R34;

* We thank Prof. Ian Coxhead, anonymous reviewer and participants of the International Conference of the Ethiopian Economic Conference of (June 2004, Addis Ababa) for their valuable comments on the earlier version of this paper. We are also grateful to the staff of the Department of Economics and Resource Management, UMB, for their comments during the presentation of the earlier version of this paper at the department seminar.

1. Introduction

The ever-increasing population in the already densely populated highland areas of Ethiopia has led to scarcity of land and, at the same time, increased demand for food. Farmers are pushed onto marginal areas, which are easily exposed to soil erosion and land degradation. As a result vast areas of land are subjected to soil degradation both through erosion and nutrient depletion from continuous cultivation. Moreover, land scarcity reduced fallow period and eliminated shifting cultivation, which have been the traditional ways of restoring soil fertility (Demeke et al, 1997; Pender, 2001; Mwangi, 1996).

Soil erosion causes soil losses amounting to 3.4 to 84.5 tons per hetare per year from the densely populated highland areas (Berry, 2003) and an estimated nutrient depletion of 30 kilogram per hectare of nitrogen and 15-20 kilogram per hectare of phosphorous (UNDP2002). In addition, 62000 hectares of forest and woodland are lost every year (World Bank, 2001). The loss of production due to land degradation is estimated to be about 3% of agricultural GDP per year (Berry, 2003), without considering other losses, which cannot be quantified.

Decreasing soil productivity on the one hand and increasing population on the other have contributed to the gap between demand for and supply of food (Mwangi, 1996). For example, 5.5 million people per year on average needed food aid from 1995 to 2001 with the break down of 4, 2.7, 3.45, 5.3, 6.6, 10.2 and 6.2 for the years 1995 through 2001, respectively (FAO, 2002). Although some of this food aid need maybe due to drought, the trend seems on the rise even without considering the effect of drought.

Closing this gap requires raising production and productivity of agriculture. This can be achieved through intensification of agricultural production, which requires the use of fertilizer (both chemical and organic), other modern inputs and improved use of agricultural practices. Intensification would reduce the need to cultivate marginal lands while raising productivity of land. Over the last decade, use of fertilizer, especially chemical fertilizer, has been widely promoted through agricultural extension program currently known as Participatory Demonstration and Training Extension System (PADETES), introduced in its current form in 1994/95. The package comprises of chemical fertilizer, improved seeds, herbicides and chemical and improved management practices. About 350000 farmers were covered by PADETES during 1995/96-production season, a 10-fold increase over the previous year

(Demeke et al, 1997). At the beginning fertilizer distribution and marketing was fully under state control and fertilizer cost to farmers were subsidized. Fertilizer market was liberalized in 1992 to create multi-channel distribution system. This allowed participation of private sector in the importation and distribution of fertilizer. Alongside this liberalization the subsidies were gradually reduced and were totally eliminated in 1997. In spite of the efforts by the government to increase total consumption and per unit application rate, the use of fertilizer remains low (Afrint, 2003; Demeke et al, 1997; Kherallah et al, 2000). For example, only 32.8% of the rural households in Ethiopia used fertilizer in 1995 (CSA, 1996). The total amount of fertilizer consumption in the country was only 246722 MT and 279602 MT for 1995 and 2001, respectively, much below the amount planned by government (303605 MT and 442000 MT) (Afrint, 2003).

Moreover, the use of fertilizers varies among farmers and across crops (Afrint, 2003; Naseem and Kelly, 1999; Demeke et al, 1997; FAO, 1995). Teff, which is a major staple, receives the highest share of total chemical fertilizer used by farmers (FAO, 1995). Although farmers traditionally use manure as fertilizer, it has not been to the level that satisfactorily reduces the problem of declining soil productivity. Deforestation forced farmers to use this product as fuel rather than as fertilizer

Unless farmers adopt efficient and intensive ways of soil fertility management practices, the current gap between demand and supply of food will continue to grow. Factors that lead to the low or none use of soil fertility management inputs and practices are not fully understood. Some studies indicate that tenure security is among the factors influencing the use of soil fertility management inputs (e.g., Gavian and Fafchamps, 1996). One of the main characteristics of smallholder farmers in Ethiopia is that they are resource-poor subsistence producers, giving high priority to short-term consumption needs and low priority to investments that bring future potential benefits. These behaviors shape the way farmers manage soil fertility (Omamo et al, 2002; Pender, 2001; Binswanger and Rosenzweig, 1986).

Based on their production environment, farmers make a mix of decisions to select an optimal overall farm management practices. However, empirical studies of adoption and intensity of use of soil fertility management practices do not account for the likely links between farmers' soil fertility management practices and resource base of farm households. Most previous studies on soil fertility management have focused on individual farm practices rather than considering various practices at the same time, neglecting the possibility that some decisions depend on others (e.g., Herath and Takeya, 2003; Nelson and Cramb, 1998; Omiti et al, 1999; Brown and Shrestha, 2003; Wezel and Rath, 2003; Baidou_forson, 1999; Zeller et al, 1998). A study by Omamo et al (2002) considers manure and chemical fertilizer as mutually dependent but they omit estimation of intensity of use of manure. The distinction between chemical fertilizer and organic manure is another important area neglected in adoption literature. Unlike chemical fertilizer, which affects production of current year, the effect of animal manure lasts for more than a single crop year, making it a short-term investment in soil quality (Gavian and Fafchamps, 1996). Much of the nitrogen in manure is in organic form and must be mineralized before it can be utilized by plants (Munoz et al, 2003; Batie et al, 1993). Thus only a fraction of nitrogen available in manure is utilized by crops in the first season after its application, with the remaining part carried over to subsequent cropping seasons. Therefore, farmers weigh the sum of its current benefits plus the present value of stream of future benefits against its alternative uses. The value to the farmer of these future incomes depends on farmer's discount rate, which depends on the farmer's resource base and the certainty of the incomes, which depends on the tenure security of the operated land.

This paper will try to address these issues using a farm household survey data from the Ethiopian highlands. We develop a model that exploits data to investigate soil fertility management decisions, focusing on the idea that manure has a carry-over effect on production and the relationships between the decisions to adopt manure and chemical fertilizer and between manure adoption and the intensity of use of chemical fertilizer and other relevant farm specific variables

The paper is laid out as follows. After presenting the theoretical model of technology adoption and input use intensity in section two, section three describes the study area and data used in the study. Section four presents the empirical model and econometric issues of the estimation. Empirical results and discussions are presented in section five and the paper concludes and draws implications in section six.

2. Theoretical Framework

Soil science studies show that the combined use of organic and inorganic fertilizers enhances crop productivity and sustainability and also that the nutrient sources influence each other

(Palm et al, 1997; Giller et al., 1997). Optimum combination of these fertilizers is usually determined using simulation models, which need controlled experiments for validation and development. However, smallholder farm environments are different from controlled experiments given the constraints and objectives they face. The result is that actual farm practices deviate from recommendations based on these experiments. For example, while it is suggested organic and inorganic fertilizers enhance each other and their combined use increases yield (Palm et al., 1997; Giller et al., 1997; Demeke et al., 1997), Omamo et al (2002) found that farmers in Nakuru district area of Kenya substitute one for the other, showing that there are factors that influence the actual use of these inputs on the farm. These results motivate further studies in a different environmental setting and with different data sets.

In this section we develop a theoretical model for manure and fertilizer adoption and fertilizer use intensity. We use a farm household model since production decisions may not be separable from consumption decisions. However, we will not incorporate market imperfections in the model explicitly but we include household characteristics in the regressions. In particular, we assume the following: (i) there is labour market in the areas but farmers are often cash-constrained to hire labour due to imperfect credit markets; (ii) there is no market for animal manure[11]

The adoption of agricultural practice is a choice between the practice and the alternative practice, or a choice between the new technology and its absence. If the perceived utility of the household from adopting the practice or technology is greater than otherwise, farmers adopt it. Given that they are adopted, the intensity of use depends on the marginal utility from the technology given the constraints of the household. Consider a two-period farm household model and assume the household food consumption in the first and second periods are, respectively, given by C_0 and C_1. In addition, households consume leisure denoted by L_{L0} and L_{L1}. These consumptions are parameterized by the vector of household characteristics denoted by q^h. We assume that the carry-over effect of manure lasts until the next production year. Households also produce crops (Q_t) using fertilize (F_t), manure (M_t) and other

[11] Animal dung in Ethiopia is sold as fuel in the market with little processing by flattening and drying. Howwever, manure is not sold or bought in the market in its form as fertilizer.

inputs (Z_{ti}). Let F_o and M_o represent current (first year) applications of fertilizer and manure. Then the problem of the household is to maximize the household's present value of utility function[12]:

(1) max $U_0(C_0, L_{L0}, q_0^h) + \alpha U_1(C_1, L_{L1}, q_1^h)$

$(C_0, L_{L0}, C_1, L_{L1}, F_0, M_0, F_1, M_1)$

Subject to:

(2) budget constraint:

In the first year land tenure is secure and farmers perceive no security problem and there is zero probability of losing part of cultivated land. In this case total crop output is given by $Q_0(F_0, R_0, Z_{i0}, q_0^q)$ and the budget constraint is expressed as

(a) $P_c C_0 + P_l L_{L0} \le PQ_0 + P_l T_0 + P_m \overline{M}_0 - P_f F_0 - P_m M_o - P_z Z_0 + E_0$;

However, in the second period there is a non-zero (δ) probability of losing the rented-in land (r, 0≤r≤1), where r is part or all of the rented in land expressed as a share of total operated holding. If the household does not lose land (r=0), the expected crop production can be given by $Q_1(F_1, R_1, Z_{i1}, q_1^q)$. If the household loses any part or all of the rented land, the expected output can be given by $(1-r)\ Q_1(F_1, R_1, Z_{i1}, q_1^q)$. Given uncertainty, the expected output for the second period is given by

$(1-\delta)\ Q_1(F_1, R_1, Z_{i1}, q_1^q) + \delta(1-r)Q_1(F_1, R_1, Z_{i1}, q_1^q)$. As a result the budget constraint is expressed as

(b)
$$\begin{aligned} & P_c C_1 + P_l L_{L1} \le (1-\delta)[P\,Q_t - P_f F_t - P_m M_t - P_z Z_t] + \delta[(1-r)PQ_1 - P_f F_1 \\ & - P_m M_1 - P_z Z_1] + P_l T_1 + P_m \overline{M}_1 + E_1 \end{aligned}$$

Where P_c, P_l, P, P_f, P_m, and P_z are prices of consumption, leisure, home produced agricultural product, chemical fertilizer, manure and other inputs, respectively; R_t is the total amount of manure available in the soil at time t; q^q is a vector of farm characteristics; $\overline{M}_0$ and $\overline{M}_t$ are total amounts of manure available to the household at the two periods; T_0 and

[12] We assume a monotonic relationship between utility and benefits.

T_1 are family labor endowments; E_0 and E_1 are exogenous incomes; α is the time preference discount factor determined by $\frac{1}{(1+\beta)}$, where β is the rate of time preference.

(3) $R_1 = (1-\gamma)M_0 + M_1$

Where γ is the deterministic share of manure used up by crops during time (t=0) and therefore (1- γ) of the total amount applied at (t=0) carried over to t+1 planting season. This implies that the share of manure used up by plants from M_0 (applied at t=0) is γM_0. The assumption of deterministic manure carry-over is made for simplicity since our objective is to show only how carry-over affects investment and not to determine how much manure to apply each time, as we have no data on the intensity of manure use.[13]

(4) $M_0, M_1, F_0,\ F_1 \geq 0$

(5) manure production constraint:

(a) $\overline{M}_0 = f(TLU_0, L_{m0})$

(b) $\overline{M}_1 = f(TLU_1, L_{m1})$

The availability of manure is a function of livestock number measured by tropical livestock unit (TLU) and labor (L_{mt}).

After simplifying equation 2(b), the Lagrangean function for the above maximization problem can be written as:

$$(6)\ Max\ L = U_0(C_0, L_{L0}, q_0^h) + \lambda_0(PQ_0 + P_lT_0 + P_m\overline{M}_0 + E_0 - P_fF_0 - P_mM_0 - P_zZ_{0-} - P_cC_0 - P_lL_{L0})$$
$$+\theta_0(\overline{M}_0 - M_0)) + \alpha[U_1(C_1, L_{L1}, q_1^h) + \lambda_1((1-\delta r)PQ_1 + P_lT_1 + P_m\overline{M}_1 + E_t - P_fF_1 - P_mM_1 - P_zZ_1 - P_cC_t$$
$$-P_lL_{L1}) + \theta_1(\overline{M}_1 - M_1)]$$

The first order conditions (allowing for the corner solutions for chemical fertilizer and manure) for the first year optimal allocation of resources is given by:

$$(7)\ \frac{\partial L}{\partial C_0} = \frac{\partial U_0}{\partial C_0} - \lambda_0 P_c = 0$$

[13] Taylor (1983) used deterministic carryover function for determination of optimal fertilizer application rates. See Huang et al (1998) for the use of stochastic carry-over function for the analysis of nitrogen application.

(8) $\frac{\partial L}{\partial L_{L0}} = \frac{\partial U_0}{\partial L_{L0}} - \lambda_0 P_l = 0$

(9) $\frac{\partial L}{\partial M_0} = P\lambda_0 \frac{\partial Q_0}{\partial M_0} - \lambda_0 P_m + (1-\delta r)P\lambda_1 \alpha \frac{\partial Q_1}{\partial M_0} - \theta_0 \leq 0; M_0 \geq 0; \frac{\partial U}{\partial M_0} M_0 = 0$

(10) $\frac{\partial L}{\partial F_0} = P\lambda_0 \frac{\partial Q_0}{\partial F_0} - \lambda_0 P_f \leq 0; F_0 \geq 0; \frac{\partial L}{\partial F_0} F_0 = 0$

Assuming that the utility and production functions are strictly concave, the second order conditions are guaranteed to hold.

The optimal level of chemical fertilizer in the first year is obtained by solving equation (10) (of course, simultaneously with other equations), which equates the marginal value of fertilizer to its price. This optimal value is given by $F_0^* = f(P_f, P, M_0^*)$, where M_0^* is the optimal level of manure application (including corner solutions). If $\frac{\partial L}{\partial F_0} < 0,$ farmers will not adopt fertilizer and $F_0^* = 0.$ The same procedure is used to get the optimal level of fertilizer during the consecutive periods.

In the first period (t=0) households' decision whether or not to apply manure depends on the contribution of this input to consumption through its impact on agricultural production. Thus, households will not apply manure if $P\lambda_0 \frac{\partial Q_0}{\partial M_0} - \lambda_0 P_m + (1-\delta r)P\lambda_1 \alpha \frac{\partial Q_1}{\partial M_0} - \theta_0 < 0.$ Unlike the condition for fertilizer application, this equation equates the marginal value of manure during the current year plus the present marginal value of manure during the next year, multiplied by (1-δr) and α to its price, which is paid during the current year, plus the lagrangian multiplier for manure constraint. This means that farmers cannot reap all the potential benefits of paying for manure in the first year. The third term on the left hand side of this inequality can vary based on α, (1-δr) and λ_1. First, the discount factor depends on farmer's time preference, which in turn depends on farmers' resource base. If a household is poorer, the time preference becomes bigger and the discount factor smaller (Pagiola and Stein, 2001), making this term smaller, which leads to the probability of non-adoption or smaller amount of application. On the other hand when there is no probability of losing land (δ=0), farmers' investment decisions are affected only by the rate of discount and other factors. But when ($\delta>0$), the present marginal value of manure becomes smaller and consequently, smaller or no manure is used than otherwise. This implies that tenure insecurity leads to lesser returns to investment on manure, affecting both productivity and soil fertility. There are views that informal land contracts with less secure land rights affect allocative efficiency of inputs contributing to lower productivity (Gavian and Fafchamps, 1996; Hayes et al.,1997;). However, others (e.g., Place and Hazel, 1993) argue that lack of human capital, lack of access to credit and shortage of labour adversely affect investment decisions more than tenure insecurity. Another factor is the availability of manure. If farmers face manure availability constraint, they may use less of it or abandon using it at all since there is no market for manure. This leads to the expectation that households with more livestock are more likely to invest in manure. Labour is another important input in the use of manure as manure preparation and application is labour intensive.

3. Study area and data

The data used for this study were collected in 1997/98 from 15 different sites in the highlands of Ethiopia by the Episode project. These sites were selected to include the major agro-ecological zones, agricultural practice, institutional factors, and demographic variations in the region. Description of the study sites is provided in Table 1.Thirty to 35 households from each site were randomly selected and included in the survey (comprising 505 households) and a formal questionnaire was used to collect the data. We dropped 5 households that do not have cultivated land and 500 households are thus used for this study.

Farmers in the study areas practice different agricultural practices and use different inputs. Out of 500 households who have cultivated land, the percentages of farmers who reported using manure and fertilizer are 54% and 71%, respectively. Site level information on the level of these activities and description of the sites are provided in Table 2. Manure is applied during the dry season before the rainy season starts. Once the rainy season starts, farmers cultivate the land covered with manure so that it will be mixed with the soil. On the other hand, fertilizer is applied during planting, right after or before planting.

There are two types of land contracts in the sites. The first is the formal contract with the government. Under this arrangement, farmers have indefinite use and transfer rights but government maintains the ownership of the land. Land sales are outlawed but farmers can rent out or give out land as share contract under different arrangements. The second type of land contract is the less secure informal land contract. Under this arrangement the contract is between two farmers and can take the form of fixed rent contact, sharecropping or borrowing. In addition to being of short term, these informal contracts have only limited rights regarding investments and other activities. Also, weaknesses in legal enforcement of the contractual agreement mean that cultivators of informally contracted lands feel insecure. Nineteen percent of the sample households have cultivated one or more of informally contracted land during the survey year.

Fertilizer, seeds and chemicals are provided by government on credit basis. However, problems are reported regarding the timeliness of the supply of these inputs, limited choices of the sizes of the package and credit repayments.

The sites differ in population pressure, amount of annual rainfall, market access, the types of crops grown and livestock density. There is not much heterogeneity regarding rainfall pattern, technology, and access to extension.

4. Empirical model, estimation methods and econometric procedure

Since not all farmers in the survey use chemical fertilizer and manure and there is no data on the levels of manure used, we use a two-stage estimation procedure for fertilizer and a binary probability model to estimate the probability of manure and chemical fertilizer adoption and chemical fertilizer use intensity. Thus we model chemical fertilizer and manure as a system of simultaneous equations where fertilizer use is hypothesized to depend on the probability of the use of manure. Farmers apply manure long before the application of chemical fertilizer and the later may depend on whether manure was applied or not. However, manure does not depend on chemical fertilizer because its application precedes the application of the later. Nevertheless, manure may be endogenous in chemical fertilizer since some omitted variables that affect manure in the past and fertilizer at current time may be related to manure in the estimation of chemical fertilizers. This fact, coupled with possible cross-equation correlations makes this model a system of simultaneous equations with mixed discrete and continuous dependent variables.

Therefore, the hypothesized system of equations is given by:

(11) probability of manure adoption =f (exogenous variables)

(12) probability of fertilizer adoption=f (probability of manure adoption, exogenous variables)

(13) fertilizer use intensity=f (probability of manure adoption, exogenous variables)

There are two potential problems with the estimation of the above model. First, probit and logit maximum likelihood estimators are consistent only in the case of single equation framework (Maddala, 1983). Therefore, given that manure is endogenous in this model, maximum likelihood and OLS estimators of single equations are biased and inconsistent. On the other hand procedures analogous to two-stage least squares (known as two-stage limited dependent variable estimators by Nelson and Olson (1978), involving the estimation of reduced form parameters in the first stage and using the predicted values of the endogenous variables in the second stage as instruments for the endogenous variables are not appropriate when both the endogenous explanatory variable and the dependent variable are dichotomous (Wooldridge, 2002). Second, those households who do not adopt chemical fertilizer maybe systematically different from those who adopt it. These differences manifest themselves in the fertilizer application intensity regression introducing self-selectivity bias in the model.

We use alternative estimation procedure to generate consistent and more efficient estimates of the structural parameters in simultaneous equation systems. Accordingly equation (11) and equation (12) are estimated as bivariate probit models using maximum likelihood estimators (Greene, 2000). Next equation (13) is estimated using two-stage probit (2STP) (e.g., Hassan, 1996), where the reduced form maximum likelihood parameter estimates of manure equation are used to generate predictions that are used as instruments in the second-stage OLS estimation to generate consistent parameter estimates of equation (13). Equation (13) includes only those observations with chemical fertilizer use greater than zero. In addition, we include the Inverse Mills' Ratio (IMR) from probit estimation of equation (12), including observations for which the value of chemical fertilizer is zero, as additional regressor to correct for selectivity bias (Heckman, 1979). The standard errors of equation (13) are bootstrapped to correct for regressors generated in the first stage and used as regressors in the second stage.

The inclusion of exogenous variables is based on review of adoption literature and personal experience since there is no clear economic theory, which indicates which variables to include. However, literature on adoption studies indicate that farmers' decision to adopt agricultural practices depend on their socioeconomic and institutional environments (e.g., Heisey et al, 1996; Mwangi, 1996; Omamo et al, 2002; reardon et al, 1999). Description and expected signs of variables included in the model are provided in Table 3. We include the size of livestock; a dummy variable indicating whether manure is used as fuel; and labor force available to households only in manure regression since livestock are the sources of animal manure and the carrying and preparation of manure are labor intensive. On the other hand, mode of transportation and distance to the market are included only in fertilizer adoption and use intensity regressions. The ratio of rented-in land to total operated holding is hypothesized to affect the adoption of manure as it affects the security of landholding. In addition, it can affect the intensity of use of chemical fertilizer through its impact on efficiency, especially if the land rental contract is of the type of sharecropping. Household characteristics such as age and sex of the household head, educational level of family members and consumer worker ratio are also included. However, it is difficult to predict the impact of age of households a priori since aging means both the loss of energy and gain of experience at the same time.

Farm characteristics such as number of oxen owned and whether the farm has access to irrigation are complementary to the use of farm inputs through increasing the gains from these inputs and reducing risks to the household. It is also possible that these factors may reduce the need for farmers to intensify by using chemical fertilizers and manure since they can be in a better off position in terms of income without using the inputs. For example farmers with access to irrigation can produce multiple times a year and get better income while higher number of oxen can help raise efficiency through timely operation and also enabling farmers to cultivate larger holding through renting in land. Total operated land holding is included in all regressions. Thus larger operated holding may make farmers more risk takers to adopt the inputs (Just and Zilberman, 1983). Thus we expect positive signs on the coefficients of land holding. Land and livestock holdings are also measures of wealth and they are hypothesized to capture the impact of time preference regarding the decision to invest in manure.

Although input prices theoretically determine demands for inputs, we do not have information on prices in the data. However, this will not pose a problem in the estimation since prices are the same in the given site and we use dummy variables representing different sites in cases the site level fixed effects (site heterogeneity) are significant. Statistical test indicated that site level unobserved fixed effects were not significant for manure and chemical fertilizer adoption but was significant in chemical fertilizer use intensity[14]. Therefore, we use site dummy variables for chemical fertilizer use intensity regression. The Rivers and vuong (1988) tests for endogeneity indicated that manure is indeed endogenous in the two regressions thereby providing justification for the use of system of simultaneous equation. Moreover, the test for heteroskedasticity indicated that manure use intensity is heteroskedastic. We use the robust option in STATA (STATA, 2006) to calculate the White (1980) or Huber (1967) heteroskedasticity-robust standard errors instead of the ordinary standard errors. All continuous variables were transformed into logarithm. This helps achieve normality and reduce the problem of heteroskedasticity.

Apart from manure being endogenous, obtaining unbiased and consistent estimates of the parameters of the above variables depends on whether one or more of other explanatory variables included in the model are endogenous. While livestock acquisition might be a decision made by the household, it is a predetermined variable in this model. The animals producing manure were obtained long before the production and use of manure and fertilizer. Moreover, all factors likely to affect livestock acquisition decisions are included in the model. For example, land is the main factor determining this decision and is included in the model. Therefore, there is no reason to believe that livestock is endogenous in the model. None of the other explanatory variables included in the model is suspected to be endogenous on any theoretical grounds to affect the estimates of the parameters.

[14] This is a chow test of whether regressions from different sites produce the same estimates (Baltagi, 2001). The test for the significance of the fixed effects is produced routinely as an auxiliary product in STATA (STATA, 2006)

5. Results and discussion

Results of the estimation of manure equation are provided in Table 4. The manure adoption probit equation was estimated using maximum likelihood along with chemical fertilizer adoption probit equation as bivariate probit models. In addition we estimated separate probit models ignoring the endogeneity of manure in the fertilizer probit equation. The results indicate that estimates of the two procedures are similar. Sex of the household head is related to manure adoption positively and significantly suggesting that male-headed households are more likely to adopt manure than female-headed households. The result also show that households with more members of the household with education up to grade six are less likely to adopt manure. This could be because this category of members is school children that spend their time at school leaving little time for manure transportation.

On the other hand, total operated land holding is negatively and significantly related with the probability of manure adoption. This result was not expected. However, this may suggest the assertion that resource scarcity leads to intensification, that is, land-poor farmers invest more to produce enough food from what they have. Surprisingly, the coefficient on the ratio of rented-in land to total operated holding is positive and significant. Some authors measure tenure security with the longevity of the contractual agreement (e.g., Gavian and Ehui, 1999) and argue that tenure security is not a problem if the term of the contract is longer than the time when the farmers reap the return from their investments. However, this cannot serve to explain why farmers with larger share of rented in land are more likely to adopt manure. Rather, this result might be explained on two grounds. First, renting land may not be generally considered insecure. Experiences from Ethiopia show that tenants are better than land owners in terms of wealth such as oxen ownership and those who rent out land do so because they cannot cultivate the land themselves because of old age, lack of oxen or labour. My personal experience shows that the relationship between tenants and land owners even involve interlocked markets where land owners get loans in kind or cash from the tenant. This situation may strengthen the bond between the two parties thereby reducing tenure insecurity Second, resource scarcity as represented by larger share of rented-in land leads to intensification. This results are inline with other similar studies which found that informally rented-in plots received at least as much inputs as owner operated plots (Gavian and Ehui, 1999). Place and Hazel (1993) found that there is no significant relationship between land rights and yield in Ghana, Kenya and Rwanda. Similarly, other authors argue that the form of land tenure has little bearings upon allocative efficiency and attribute the problem of declining agricultural productivity to agricultural factor endowments and public policies rather than to the prevailing tenure arrangements. They cite evidence that indigenous tenure arrangements are dynamic and evolve in response to population pressure and factor price changes (e.g., Boserup, 1981; Pinckney and Kimuyu, 1994-abstract).

Total livestock ownership and workforce, although positive, are not significant. The dummy variable on whether the household uses manure as fuel is negative and significant, suggesting that manure is diverted to its use as fuel, one of the problems facing farmers in the use of manure as fertilizer.

The results of the regression of chemical fertilizer use probability are presented in Table 5. We estimated two regressions, one as a biprobit and the other as a univariate probit ignoring endogeneity. Comparison of the two results confirms that the system estimation is appropriate, also supported by the test on the endogeneity of manure. The coefficient on manure is positive and significant.The system regression indicates that adoption of fertilizer is more likely the higher is the probability of manure use; the higher the number of members both up to grade six and above; the lower the probability that farmers have irrigated land; the farther the household is from market; and the larger the size of operated holding. The coefficient on manure is in line with agreements by soil scientists that effective soil fertility management in Africa requires increased use of both inorganic and organic fertilizers (e.g.. Palm, 1997) as only one source may not meet the need to increase soil fertility due to different factors including resource scarcity. The contrast between the signs on the coefficient of land holding in manure and fertilizer adoption models may point to the fact that chemical fertilizer is riskier since it is obtained on credit basis while manure is home-produced and does not involve cash outlay except for its opportunity cost. The two opposing results may also indicate the difficulty farmers face in preparing and applying manure to a larger holding, which leads them to the use of chemical fertilizer. The sign on market distance was not possible to predict a priori. Economic theory suggests that the higher the input prices, the less likely it is to use the input or reduce the amount used. However, the fact that this coefficient is positive may tell us the story that fertilizer is taken from government stores, which are sometimes different from market locations, and the distance from market may not determine farm gate fertilizer prices, which would vary based on this distance if fertilizer were bought from markets. In fact, the distance may mean that those farmers far from markets do not depend on the markets and need to produce enough for their consumption needs. It may also be explained by the view that those farmers far away from market centers focus on intensification, as fewer opportunities exist for off-farm activities. The coefficient of irrigation has unexpected sign. The common view is that complementary technologies increase the probability of new technology adoption by in creasing the return from the inputs. Possible explanation for the result maybe those farmers with access to irrigation may compensate for these inputs through multiple productions.

The results for chemical fertilizer use intensity equation are also presented in Table 5. Column five presents the two-stage probit estimation allowing for endogeneity while column six presents results ignoring endogeneity. The coefficient on IMR is not significantly different from zero indicating that there would be no selectivity bias if we did not include it. These results indicate that factors that affect the levels of fertilizer use may be different from those affecting adoption. The levels of fertilizer use are higher the larger the number of family members with educational level of up to grade six; the higher the ratio of consumer units to worker units; and the larger the number of oxen owned. Manure adoption is not significant in fertilizer use intensity although the sign is negative. This indicates yet again that factors affecting adoption and the levels of use are different. Literature on the use of productive inputs show that more educated farmers are able to acquire and use information more than their counterparts (e.g., Feder et al, 1990; Hassan, 1996). On the other hand households with higher number of consumer unit per unit of worker may find it preferable to substitute these inputs for labor, leading them to use more amount of fertilizer per unit of land. Oxen provide important source of draft power. The number of oxen available is important for early operation, which increases the efficiency of inputs and also reduce risks associated with the use of this input because the return from the use of the input may be higher for farmers with larger number of oxen.

6. Conclusions and implications

Farmers in Ethiopia face many challenges including soil degradation and declining productivity. Yet there are constraints, which limit the options available to farmers to counter these challenges. The paper analyzes the determinants of organic and inorganic fertilizer adoption and intensity of use of inorganic fertilizer, which are the two main ways of replenishing soil fertility in Ethiopia. The approach in this paper differs from previous studies in that manure is hypothesized to influence chemical fertilizer and not vice versa, based on farmers' practices in time lag between the applications of the two inputs. Although the empirical model of this study is based on cross-section data, the theoretical model takes into account the fact that the actual impact of manure lasts for longer than one production season using a two-period model. The results appear to be robust to suggest that soil nutrient depletion is influenced by sex of household head; number of family members with educational level up to grade six and above; size of operated holding; proportion of rented-in land in total operated holding; use of manure as fuel; distance of market from household location; consumer to worker ratio; presence of irrigation; and number of oxen.

Effective and sustained soil fertility replenishment requires the combined use of both organic and inorganic fertilizers (Demeke et al., 1997; Palm et al., 1997). While this study indicates that once other factors are accounted for, farmers who use manure are more likely to use inorganic fertilizer, whether this complementarity exists between the levels of use of organic and inorganic fertilizers remains to be studied. The study also proves the assertion that the use of manure as fuel competes with its use as fertilizer to the extent that its use on farm as fertilizer is negatively and significantly related to whether households use manure as fuel. In the face of fast-disappearing forest covers, which are traditionally used as fuel, provision of alternative sources of fuel can contribute to successful soil fertility replenishment programmes.

Other results from chemical fertilizer adoption and use intensity indicate that only adoption may not lead to successful soil fertility replenishment programs. Once farmers adopt these inputs, it is important to design measures to help farmers to use the levels that are sufficient to compensate for soil nutrients lost through erosion and depletion. While improved education may help farmers acquire and use information, provision of supplementary inputs such as oxen can encourage farmers to use sufficient inputs.

Finally although results based on cross-section data may not be given direct dynamic interpretation, the results of this study have been useful to add ideas to the existing studies regarding soil fertility management. To fully explore the topic, we will follow up the study with a resurvey of the same households to get comprehensive data collected over time. Such data will allow us to control for the household fixed effects; contain information on soil fertility levels of the plots; and other factors that serve as proxies for levels of demand for nutrients by different crops.

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Table 1 Description of the study sites

Group	Site name	description
A	1.Damot Waja-Kero 2. Abota Olto 3. Amburse	Very densely populated, enset[a]-maize-root crop production zone with poor market access, not much cash production
B	4. Chefasine 5. Chuko 6. Dobi Gogot	Densely populated, enset-maize-beans producing areas with chat[b] and coffee produced as important cash crops
C	7. Elka 8. Woyo Gebriel	Dry, less densely populated, maize-haricot beans producing areas with many livestock production. No major cash crop production available
D	9. Beche 10. Gedeba	Relatively dry, maize producing areas (with some teff[c]) with many livestock. Chili pepper produced as major cash crop
E	11. Woyo Medhane-alem 12. kersa ilala	Grain (wheat, barley, maize) producing areas with a good amount of livestock. Some amount of onions and potatoes produced as cash crops
F	13.Deka Bora 14. Koka neghewo 15. Hidi	High potential grain (teff wheat, barley, pulses) producing areas with fairly large livestock production and relatively good market access

[a] Enset (Enset ventricosum) is a tall banana-like fibrous perennial plant cultivated in southern Ethiopia whose pseudo stem and tuber processed for food.

[b] Chat (catha edulis) is a perennial shrub whose leaves are chewed as a stimulant. It is an important cash crop for some farmers in many parts of Ethiopia now.

[c] Teff (Eragrostis teff) is an annual grass-like food crop, with tiny grains, produced in the Ethiopian highlands as a major food crop.

Source: Holden and Yohannes (2002)

Table 2 Site level information on soil fertility management practices and input use

Village (number)	Manure (%)	Fert Use (%)	Average Total land holding (Timad)	Average Operated Land holding	Average Oxen ownership (number)	average TLU	Average Fert. Use (Birr per timad)
1	88.2	79.4	0.40	0.3	0.5	2.8	15.9
2	18.7	9.4	2.1	1.9	1.7	7.3	3.5
3	0	100	1.1	1.0	1.1	4.5	42.1
4	16.66	100	1.0	1.0	1.1	4.9	38.6
5	88.23	38.2	0.3	0.3	0.1	3.9	8.6
6	88.97	48.6	0.5	0.4	0.3	5.1	6.3
7	18.2	18.2	0.6	0.5	0.4	2.4	11.8
8	3	84.8	3.4	2.8	2.1	6.7	48.4
9	97.1	97.1	1.8	1.7	2.7	4.7	110.5
10	0	70.6	2.8	2.6	3.0	5.2	11.8
11	100	60.7	0.8	0.6	1.0	4.2	10.9
12	100	79.4	0.7	0.6	0.9	4.6	20.3
13	97.1	80	0.3	0.3	0.6	2.7	20.7
14	94.3	100	1.5	1.4	1.5	5.6	24.2
15	2.8	100	7.9?	1.6	3.0	6.4	105.3
total	55	71.4	1.3	1.2	1.3	4.7	32.4

Table 3 Definition and summary of variables

Variable name	description	mean	Std dev	Expected sign		
				Manure	Fertilizer use proba-bility	Fertilizer use intensity
a. Endogenous Var.						
man	1=uses manure as fertilizer, 0=otherwise	.55	.498		?	?
fertyn	1=applies fertilizer, 0=otherwise	.71	.452			
fertamop	Amount of fertilizer applied per Operated land holding	32.46	51.007			
b. exogenous exp. Var.						
olszocu	Operated land holding per consumer unit	1.16	1.045	?	?	?
sex	1=male, 0=female	.95	.222	?	?	?
age	Age of household head in years	44.56	13.824	?	?	?
edu	Number of household members with education up to grade six	.57	1.035	?	?	?
Eduto6	Number of household members with education above grade six	2.21	1.964	+	+	+
wfolsz	Number of worker unit per operated holding	4.17	2.003	+		
irrg	1=has irrigated land, 0=otherwise	.09	.295	+	+	+
rrl	Ratio of rented in to total operated holding	.06	.135	-		-
cwr	Ratio of consumer unit to worker unit	1.65	.310	?	?	?
tluolsz	Total Livestock unit per operated land holding	.10	.910	+		
oxolsz	Number of oxen per operated land holding	.181	.21	+	+	+
Walk	1=if household only walks to market, 0 otherwise-reference transport	.714	0.452			
Publict2	1=if household uses public transport to the market, 0 otherwise	0.096	0.29		+	+
Cartt3	1=if household uses cart, 0 otherwise	0.026	0.159		+	+
mktdist	Distance of household from market	66.01	80.736		?	?
manfuel	1=if household uses manure as fuel and 0 otherwise	0.53	0.499	-		
lvarname	Variable transformed to logarithm					

Table 4 Results of probit model for the probability of use of manure

Variable name	Description of variables	Bivariate probit model[b]	Population-averaged Univariate probit model ignoring endogeneity and simultaneity
		Coefficient[a] (Standard error)	Coefficient[d] (Standard error)
Sex	Sex of household head: 1=male, 0=female	.500*(.324)	.208(.127)
Lage	Logarithm of age of household head in years	-.036(.231)	.285**(.125)
edu	Number of household members with education up to grade six	-.105*(.057)	.001(.025)
eduto6	Number of household members with education above grade six	.0002(.040)	.014(.020)
lolszocu	Logarithm of operated land holding per consumer unit	-.550***(.123)	-.038(.095)
ltluolsz	Logarithm of total livestock unit per operated holding	.009(.120)	-.046(.119)
cwr	Ratio of consumer unit to worker unit	.203(.223)	.286**(.118)
irrg	1=has irrigated land, 0=otherwise	.050(.232)	.234**(.102)
lwfolsz	Logarithm of number of worker unit per operated holding	.127(.196)	-.006(.085)
rrl	Ratio of rented in to total operated holding	.800**(.415)	.191(.158)
loxolsz	Logarithm of number of oxen per operated holding	.223(.151)	-.009(.087)
manfuel	1if household uses manure as fuel and 0 otherwise.	-.46***(.120)	-.028(.112)
_cons	constant	-.359(1.02)	-1.705**(.819)
N	Number of observations	473	473
L	Log pseudo-likelihood[C]	-474.022	
Wald chi^2 (#)	Wald chi^2 (#)	chi^2 (24)= 410.52	Chi2 (12)=68.52
Pvalue	Prob.>Chi2	0.000	Prob > chi2=. 000
rho	Correlation coefficient between the disturbances in manure and fertilizer adoption	-.944(.051)***	

[a] Numbers in parentheses are robust standard errors.

[b] Preferred model

[c] this statistic is for the full bivariate probit model.

[d] numbers in parentheses are semi-robust standard errors.

*, **, and *** denote a 10%, 5%, and 1% significance based on Z-statistics

Table 5 Results of estimation of probability and intensity of use of fertilizer

Variable name	Description of variables	Fertilizer use Probability model			Fertilizer Use intensity model	
		Bivariate probit model [b]		Population-averaged Univariate probit model ignoring endogeneity	Fixed Effect (FE) Model [b]	Fixed Effect (FE) model ignoring endogeneity
		Coefficient[a] (Standard error)	Total marginal effects (standard error)	Coefficient[d] (Standard error)	Coefficient[e] (Standard error)	Coefficient[e] (Standard error)
Man	1=uses animal manure as fertilizer, 0=otherwise	1.917*** (.122)	.834*** (.o4)	.389 (.302)	-.205 (.238)	-.225 (.314)
imr	Inverse Mill's ratio	-	-	-	-.006 (.186)	-1.28 (1.65)
sex	Sex of household head: 1=male, 0=female	-.162 (.277)	.141 (.180))	.188 (309)	.473 (.302)	.246 (.317)
lage	Logarithm of age of household head in years	.077 (.190)	.033 (.09)	.087 (.140)	-.124 (.146)	-.126 (159)
edu	Number of household members with education up to grade six	.265*** (.o70)	.120*** .033)	.159*** (.045)	.109* (.058)	.042 (.121)
eduto6	Number of household members with education above grade six	.100** (.038)	.058*** (.02)	.045 (.035)	-.007 (.026)	-.033 (.037)
lolszocu	Logarithm of operated land holding per consumer unit	.967*** (.103)	.381*** (.052)	.552*** (.130)	-.228 (.204)	-.497 (.391)
cwr	Ratio of consumer unit to worker unit	.053 (.216)	.095 (.099)	.244 (.177)	.353** (.173)	.207 (.232)
irrg	1=has irrigated land, 0=otherwise	-.838*** (.2179	-.441*** (.079)	-.281 (.589)	.209 (.193)	.338 (.249)
loxolsz	Logarithm of number of oxen per operated holding	.254* (.135)	.215*** (.066)	.169 (.137)	.326** (.137)	.224 (.142)
rrl		-	.252* (.130)	-	-.387 (.341)	-.556* (.317)
mktdist	Distance of household from market in hours	.002** (.001)	.001*** (.0003)	.001 (.001)	.0003 (.001)	-.0001 (.001)
publict2	1= household uses public transport to the market, 0 otherwise	.104 (.173)	.058 (.094)	-.060 (.114)	-.038 (.231)	.155 (.177)
cartt3	1= household uses horse cart to the market, 0 otherwise	-.548 (.366)	-.319* (.184)	-.2291 ** (.107)	.0755 (.287)	.247 (.353)
ltluolsz	Logarithm of total livestock unit per operated holding		.003 (.038)			
lwfolsz	Logarithm of number of worker unit per operated holding		.040 (.064)			
manfuel	1if household uses manure as fuel and 0 otherwise		-.143*** (.036)			
_cons	constant	-.753 (.933)		-.361 (.608)	2.993** (.818)	4.07** (1.768)
N	Number of observations	473		473	347	347
L	Log pseudo-likelihood[C]	-474.022		-474.022		
R^2	R^2				R^2=0.562	R^2=0.561
Wald chi2 (#)	Wald chi2 test statistic	chi^2 (24)= 410.52		chi^2 (24)= 410.52	Wald chi2 (14)=27.99	Waldchi2 (14) = 31.72
Pvalue	Prob.>Chi^2	0.000		0.000	.014	.004
LR	Likelihood ratio test for heteroskedasticity. H: Constant variance				Chi2(14)=81.34 Prob.>Chi2= 0.000	

[a] Numbers in parentheses are robust standard errors; [b]Preferred model; *, **, and *** denote a 10%, 5%, and 1% significance. [c] this statistic is for the full bivariate probit model.[d] numbers in parentheses are semi-robust standard errors.E numbers in parentheses are bootstrapped standard errors, which are also robust.

Paper III

Impact of perennial cash crops on food crop production and productivity

Adane Tuffa Debela
Department of Economics and Resource management
Norwegian University of Life Sciences
P.O.Box 5003, N-1432, Ås, Norway

Abstract

The argument for promoting cash crops in developing countries has generally been based on their contribution to agricultural productivity, small farmer incomes and their impact on other household activities such as household crop production through interlinked markets. These have neglected the effects that cash cropping can have on these household activities through its impact on household liquidity for purchasing productive inputs and through maintaining soil fertility and moisture and the fact that they save inputs such as labor and draft power, which can be used for food crop production. In this study we build on previous studies by developing key hypotheses by which perennial cash crops affect food crop production and the implication for household food security. In addition, we look at the link between the two types of food crops, enset and other food crops. We empirically measure these effects using survey data on 150 rural households in 1999 in Ethiopia. Our results indicate that-after controlling for conventional inputs, household wealth variables, education and other variables-higher chat production is associated with reduced value of food crop yields and total food crop production. On the other hand, higher sugarcane production is correlated with higher value of total food grain production and higher value of grain yields. Moreover, more intensive coffee production is associated with more intensive enset production. However, production of coffee and enset do not have significant effects on food crop production and productivity. These results suggest that while farmers can gain from sugarcane production through cash income and its impact on food crops, coffee and enset can be produced to bring additional income to the household at no cost to food crops. However, the real impact of chat on the welfare of households should be viewed in terms of its opportunity cost and the functioning of markets.

Keywords: Ethiopia, Cash crops, Food crops, Productivity, Enset.
JEL Classification Numbers: D13, Q12, Q15, Q16, Q18.

1. Introduction

Reducing rural poverty is one of the main challenges facing farmers and rural development workers in Ethiopia. Agricultural intensification is required to transform the subsistence, low-input, low-productivity farming systems that characterize the Ethiopian agriculture. The state-led food crop intensification program consisting of provision of mainly fertilizers and seeds on credit basis has not achieved the desired results. There have been frequent delays in input distribution and problems with loan repayment. Studies by Afrint (2003) and Demeke et al. (1997) indicate that the program did not generally fit to the specific needs of farmers. Sustainable agricultural intensification requires alternative means of financing highly productive inputs and diversification of crops to compensate for the increasing degradation and population pressure on existing cultivated land.

Perennial cash crops with high value provide one opportunity for agricultural intensification. Cash crops provide readily available cash income to households, enabling farmers to meet the expenditure, needed at the time of planting and before farmers earn income from their food crops harvests. Producer prices of cash crops are also more stable than food crop prices (Goetz, 1993; Kelly et al., 1996; Strasberg et al., 1999). This helps farmers relax the liquidity constraints to purchase inputs during planting periods.

Past studies of the contribution of cash cropping have focused on the opportunities cash crops bring through interlinked markets for accessing cash crop inputs on credit basis and the possibility of using these inputs for food crops as well to increase productivity and the associated training opportunities farmers receive through input suppliers (Govereh and Jayne, 2003; Goetz, 1993). While these opportunities may exist in some cases, these studies have neglected the benefits cash crops offer apart from the case of market interlinkages in terms of their impact on food crop production and productivity. Although cash crops can compete with food crops for resources, the claim that cash crops can exacerbate household food insecurity problem may not be a concern in mixed cash crop-food crop smallholder farming system. In this semi-subsistence agriculture households continue to store at least some of their own food instead of specializing in cash crops and depending on markets for food crops since there may not be reliable or regular markets for local food crops and there are no insurance markets (Binswanger and McIntyre, 1987, quoted in Goetz, 1993).

The net impact of cash crops and other perennial crops on household welfare depends on the magnitude of the opportunity cost of these crops in terms of land and other resources and the impact of cash cropping on cash income and food crop productivity (Coelli and Fleming, 2004). Nevertheless, the fact that households plant cash crops implies that they derive a higher utility from doing so than not, given their specific opportunities and constraints. Unlike annual cash crops, perennial cash crops put less pressure on resources in terms of input expenditures such as draft power, labour, and fertilizers. Perennial cash crops also reduce soil erosion (Future Harvest, 2000; Lewis, 1985; Clay et al., 1998; Hailseslassie et al, 2005). Moreover, perennial cash crops conserve soil moisture (Kasperon et al., 1995).The possibility of intercropping perennial cash crops with food crops is another benefit of the crops, enabling farmers to produce food crops on the same plots (Byiringiro and Reardon, 1996; Pender et al, 2004; Gladwin et al, 2001).

In this paper we study the impact of cash cropping on food crop production and productivity and enset intensification in southern Ethiopia using household level data collected in 1998/99. The study is intended to contribute to the cash crop-food crop productivity debate, and to assist in developing policy to help smallholder farmers cope with land degradation and population pressure.

In section two, we present the conceptual framework of the study; section three presents data and description of the study area; in section four methods of data analysis are presented; results and discussions are provided in section five; and section six concludes the paper.

2. Conceptual Framework

2.1 Synergies between cash crops, enset and food crops

The argument for promoting cash crops in African countries has been based on the principles of comparative advantage and the benefits related to interlinked markets. Those who base their argument on comparative advantage perceive that households, which can produce cash crops at more efficiency than other crops, can specialize in producing cash crops and increase their overall income. The perceptions of interlinked markets are that cash crops attract input supply agents, which provide agricultural inputs on credit basis to enhance the productivity of both food and cash crops in return for the purchase of the cash crops (Timmer, 1997). However, market failures, which are common in developing countries, may stand in the way of commercialization based on comparative principle by giving rise to the non-separability of production and consumption (Singh et al, 1986). This has raised a concern that specialization and commercialization lead to increased market vulnerability and food insecurity (Eicher and Baker, 1982).

The concept of interlinked market, while supported by empirical evidences (e.g., Govereh and Jayne, 2003), neglects the contribution of perennial cash crops to relaxing financial constraints during peak farm operations. Although perennial cash crops compete with food crops for resources, they make cash income available, which can be used to buy inputs to increase food crop productivity in situations where farmers are credit constrained (Strasberg, et al., 1999; Kelly et al., 1996). Unlike food crops, cash crops face a relatively stable price because some of them are exported and some are needed elsewhere domestically (Goetz, 1993). In addition to its impact on cash income, cash crops may increase the credit worthiness of farmers from moneylenders through interlocked markets since lenders think default due to risk is less probable. Reducing soil erosion and nutrient depletion is another contribution of perennial cash crops: for example, Haileslassie et al. (2005) show that in Ethiopia soil nutrient stocks did not decrease in areas under perennial cash crops. This can enhance sustainable productivity of crops intercropped with perennials. The ability of perennial cash crops to conserve soil moisture is another important contribution of perennial cash crops, especially in water stress areas of Ethiopia.

Moreover, perennial cash crops save inputs such as labour, draft power and seeds. These inputs can be used to intensify food crop production. They can also allow intercropping with other crops easing the problems of population pressure.

In this study we consider the impacts of the following three types of cash crops (coffee, chat and sugar) on food crop production and productivity. Since it is difficult to calculate the value of enset production for one year, we divide the food crops into enset and non-enset food crops. We also look at how the two types of food crops affect each other.

Coffee:
Coffee is one of the main perennial cash crops in Ethiopia, particularly in the study area. It is produced mainly for export although some of the production is consumed at home. This crop provides cash income to households; protects soil from erosion; and can support other intercrops by way of retaining moisture.

Chat:

Chat (Catha Edulis) is a large perennial shrub, which can grow to tree size (e.g., Klingele, 1998). It is mainly grown in Ethiopia and Kenya and the main markets are in Ethiopia, Kenya, Somalia, Yemen, etc. Chat is an important cash crop in the area. Chat is also used as a stimulant to dispel feelings of hunger and fatigue (e.g., Parker, 1995). This crop has been the most important cash crop in most parts of Ethiopia because of its stable prices and the fact that it is harvested year-round. In addition to being a source of cash income, it is consumed by family members to abate hunger. Chat can be intercropped with coffee. However, farmers prefer to grow chat as a monocrop.

Sugarcane:

Sugarcane typically is a 12 to 18-month crop although it can be left in the ground for a further growing period if favourable conditions exist. In this case it becomes a 'ratoon' crop (when new shoots grow from the sugarcane root after cropping) (Mushtag and Dawson, 2002). Sugarcane has been an increasingly important cash crop in the area. Traders come from as far as the capital city to buy sugarcane. The cane from these smallholders is chewed for its juice, unlike cane from the big plantations, which is converted to white sugar. Sugarcane can be intercropped with food crops such as potato. Imam et al (1990) indicated that intercropping potato with sugarcane exploits the temporal complementarity between the crops.

Enset:

In addition to cash crops, we analyse the impact of another perennial food crop well known in the area as enset. Enset (Enset venttricosum) is related to and resembles the banana plant and is produced primarily for the large quantity of carbohydrate-rich food found in a false stem (pseudo stem) and an underground bulb.

More than 20 percent of Ethiopia's population concentrated in the highlands of southern Ethiopia depend up on enset for food, fibre, animal forage, construction materials and medicine (Brandit et al, 1997). Enset resists water stress, is less prone to other risks and yields more per unit of area than other food crops in the area. Enset can also be intercropped with other food and cash crops.

While the above discussions indicate possible synergies, the actual impact can run either way. If there is little interlinkage of markets, the impact of cash crops on food crop production and productivity should go only through its impact on household liquidity, intercropping, through the impact of the crops in restoring soil fertility and soil moisture conservation. In turn, the impact through liquidity depends on the nature of food crop markets and the actual cash income farmers earn from cash crops. If food markets operate well and cash income is high, farmers may resort to specializing in cash crop production and buy food crops since this increases household utility. This paves the way for specialization. On the other hand, if food market is not reliable as it is in most regions of developing countries, there might be synergies between food and cash crops.[15]

2.2 Theoretical model

In this section we develop a theoretical model for the impact of cash crops on food crop production and productivity and intensification of enset production. Theoretically the model for food crop production and productivity, cash crops and enset production indices can be derived from the farm household model. Farmers in developing countries operate under many forms of market failures, including markets for labor, credit and land (Sadoulet and de Janvry, 1995; Singh et al, 1986; Heltberg, 1998; Taylor and Adelman, 2003; de Janvry et al, 1991). Market failures introduce binding constraints in production where households cannot make separate decisions on consumption and production rendering the household model nonseparable. We start with a household model, which draws on the model developed in Singh et al (1986).

Assume the household consumes a home produced non-enset food crop commodity, x_o, enset, x_e, a purchased commodity, x_m, a cash crop commodity, x_c, and leisure time, x_l; and let z^h represent a vector of household characteristics which parameterizes the utility function. Then the problem of the household is to maximize the household's utility function

$$(1)\ \max_{(x_0, x_e, x_c, x_m, x_l, L_0, L_e, L_c, y_i)} u\left(x_o, x_e, x_c, x_m, x_l, z^h\right)$$

[15] While there are some studies on the contribution of coffee and chat to the Ethiopian economy in terms of income (e.g., USDA, 2002; UNDP-EUE, 1998; Petit, 2007), there are no studies on the impact of these cash crops on food crop production.

Subject to:

(2) Budget constraint: $p_0 x_0 + p_e x_e + p_c x_c + p_l x_l + p_m x_m \leq p_0 Q_0 +$

$$p_c Q_c + p_e Q_e + E + p_l T - p_l L - \sum_{j=0}^{e} w\, Y_j$$

Where p_o, p_e, p_c and p_m are prices of produced food crops, enset, cash crops and purchased commodities, respectively; p_l is wage rate and w is a vector of prices of other variable inputs; L is total labor demand by the household, both family and hired; y_j is a vector of variable agricultural inputs other than labor (j=o,c,e); E is exogenous income; Q_o is home produced non-enset food production, used both for consumption and market; T is the total stock of household time; Q_e is household enset production used both for consumption and market; Q_c is home produced cash crop used both for consumption and market.

In addition, farmers face credit constraint to purchase agricultural inputs at the time of planting. There is no formal credit facility in the area except for fertilizer credit given in kind. Therefore, farmers have to cover the costs of other purchased inputs and fertilizer beyond those provided by the government agencies. Farmers have to use their own savings (S), income from sale of cash crops and income from hired-out labor. Farmers also may get informal credit from village money lenders based on their credit worthiness which again depends on their stock of cash crops. This informal borrowing, B, is a function of cash crop production given by $\mathrm{B}(Q_c)$ $(\frac{\partial B}{\partial Q_c} > 0)$. The cash from the sale of cash crops is predetermined at the time of planting food crops (produced during the previous years).

(3) Credit constraint: $\sum_{i=1}^{N} w_i y_i + p_l (L^{hi} - L^{ho}) \leq p_c Q_c + B(Q_c) + K + A + S$

Where L^{hi} and L^{ho} are labor days hired in and out, respectively; L^{hi}=L-F where F is family labor and L=$L_0 + L_c + L_e$; K is the amount of fertilizer credit; and A is exogenous cash income We assume that labor market exists at the same wage rate for hiring in and out.

(4) Food crop production function constraint: $Q_o = f_o(A_o, L_o, Y_o, Z^q)$

(5) Enset production constraint: $Q_e = f_e(A_e, L_e, Y_e, Z^q)$

(6) Cash crop production constraint: $Q_c = f_c(A_c, L_c, Y_c, Z^q)$

where $A_c + A_o + A_e = \overline{A}$; $\overline{A}$ is total operated land holding; A_c, A_e and A_o are sizes (shares) of total operated holding planted to cash crops, enset and other food crops, respectively. z^q is a vector of farm characteristics; and $f(.)$ is a strictly concave production function. We assume that land is fixed due to imperfections in land rental markets.

Furthermore, the household utility function, u (equation (1)), is assumed to be strictly concave and twice continuously differentiable.

The Lagrangian function for the above maximization problem can be written as

$$(7)\ \mathrm{L} = \mathrm{U}\,(x_o, x_e, x_c, x_m, x_l, z^h) + \lambda(p_o Q_o + p_e Q_e + p_c Q_c + p_l T + E - \sum_{j=o}^{e} w\,Y_j - p_l L$$

$$- p_o x_o - p_e x_e - p_c x_c - p_m x_m - p_l x_l) + \mu(p_c Q_c + B(Q_c) + A + K + S - \sum_{j=o}^{e} w\,Y_j - p_l(L^{ho} - L^{hi})$$

Denoting the consumer goods by c_i (i=o, e, c, l, m) the interior first order conditions of interest are:

$$(8)\ \frac{\partial L}{\partial c_i} = \frac{\partial U}{\partial c_i} - \lambda p_l = 0$$

$$(9)\ \frac{\partial L}{\partial L_0} = \lambda p_o \frac{\partial Q_o}{\partial L_o} - p_l \mu - \lambda p_l = 0$$

$$(10)\ \frac{\partial L}{\partial L_e} = \lambda p_c \frac{\partial Q_c}{\partial L_c} - p_l \mu - \lambda p_l = 0$$

$$(11)\ \frac{\partial L}{\partial L_c} = \lambda p_c \frac{\partial Q_c}{\partial L_c} + p_c \mu \frac{\partial Q_c}{\partial L_c} - p_l \mu + \mu \frac{\partial B}{\partial Q_c} . \frac{\partial Q_c}{\partial L_c} - \lambda p_l = 0$$

$$(12)\ \frac{\partial L}{\partial Y_o} = \lambda p_o \frac{\partial Q_o}{\partial Y_o} - \lambda w - \mu w = 0$$

$$(13)\ \frac{\partial L}{\partial Y_e} = \lambda p_e \frac{\partial Q_e}{\partial Y_e} - \lambda w - \mu w = 0$$

$$(14)\ \frac{\partial L}{\partial Y_c} = \lambda p_c \frac{\partial Q_c}{\partial Y_c} - \lambda w - \mu w = 0$$

The following reduced form of optimal food crops and enset production can be derived from the first order conditions:

$$(15)\, Q_{oi}^* = Q_{oi}^*\left(z^q, A_{oi}^*, A_{ei}, A_{ci}^*, L_i^*, y_i^*, z^h\right), \text{ and}$$

$$(16)\ \ Q_{ei}^* = Q_{ei}^*(z^q, A_{oi}^*, A_{ei}^*, A_{ci}^*, y_i^*, z_i^*)$$

where Q_{oi}^* is total aggregate value of food crops or value of food crops per unit of land (productivity) for household i; Q_{ei}^* is production of enset; and L_i^* and y_i^* are optimal labor and other inputs, respectively; and A_{oi}^*, A_{ei}^* and A_{ci}^* are sizes (shares) of operated land holding planted to food, enset and cash crops, respectively. A similar procedure can be used to derive the theoretical model of cash crop production indices.

Equations (9) and (12) indicate that if the credit constraint is binding, i.e., μ>0, farmers cannot use the optimal level of inputs that they would use in the absence of credit constraint. On the other hand, production of cash crops relaxes credit constraints in addition to their contribution to income enabling farmers to purchase optimal level of productive inputs, which raise productivity. Equation (11) has two additional terms, $p_c \mu \frac{\partial Q_c}{\partial L_c}$ and $\mu \frac{\partial B}{\partial Q_c} . \frac{\partial Q_c}{\partial L_c}$. These are contributions of cash crops to the household utility through relaxing credit constraint in addition to their contribution to utility through direct income, given the constraint is binding. Therefore, the optimal level of resource allocation should be determined based on the contribution of cash crops to income and relaxing credit constraints and the income from the sale of food crops and enset.

3. Data and the study area

The data used for this study was collected in the 1998/1999-production year from Wondo Genet area located in the Southern Nations and Nationalities Regional State, 270 KM south of the capital, Addis Ababa. It lies within the southern rift valley of Ethiopia. Awassa serves as the administrative capital of the region, with Shashemene town being the nearest local market.

Households were randomly selected from two peasant associations, Wesha and Chuko. The area is characterized by a mixed crop-livestock production system. It is well known for its cash crops such as coffee, sugarcane and chat (khat), making it appropriate for cash crop research. Other main crops are enset, maize, bean, kale, banana, avocado and papaya. Maize is the main staple food crop, while enset is a well-known perennial food crop in the area. Chat trading is common in Chuko, while sugarcane trading is common in Wesha. The area has been a centre of rural business because of its cash crops and proximity to Awassa and Shashemene markets (Adya, 2000).

Farmers in the area produce sugarcane, coffee, and chat, mainly for markets. Although there is no statistics on how much of the total of cash crops is sold, the number of farmers who sold the crops is presented in Table 1.

Although there are other crops grown by farmers in the area, they have little significance in terms of their area and contribution to household income. Production is mainly based on rainfall, which is bimodally distributed throughout the year. The area is among the areas receiving the highest annual rainfall in the country, making it suitable for coffee, sugarcane, and especially chat production, the yield of which is highly dependent on the amount of soil moisture throughout the year.

Interlinkages of input supply and output markets are not common in the area. Thus, most of the products are sold in the market and inputs are purchased both from the markets and from government agencies on credit basis. The inputs purchased from government agricultural development offices are mainly fertilizer and improved seeds. Farmers are expected by government offices to pay a certain portion of the input prices at the time of purchase with the remaining balance due at the end of the harvest period. Farmers cannot get these inputs on credit basis for the next season unless the previous year's credit is completely repaid. There is no control on the part of the government on the outputs (prices) and it is up to the farmers where to get the money for repayment of credits.

Seventy-five households were randomly selected from each of the two peasant associations. Households were interviewed about demographics, farm and non-farm activities, agricultural practices, asset holdings and attitudes and perceptions about different farm and non-farm activities. The data were collected using trained enumerators from the area with strict follow up by researchers for good quality data. Out of 150 households selected we use 127 households for econometric analysis because of incomplete information and outlier observations on some variables. However, data in Table 1 is for 147 households for which most of the data were recorded.

4. Methods of Analysis and hypotheses

In our conceptual framework, we argued that cash cropping could influence food crop production and productivity in different ways. This section develops an empirical model, which enables us to measure the impact of the intensity of these crops on food crop production and productivity. Since it is difficult to measure the value of enset produced in one year to aggregate it with other food crops, we divide the food crops into enset and non-enset food crops (hereafter referred to as food crops).

4.1 Impact of cash crops and enset on food crop production and productivity.

In addition to cash crops, we examine if there exists significant relationship between enset and food crops. Since it is difficult to measure the production of these cash crops and enset (Q_c and Q_e) as they are perennials harvested over time, we define a measure of the level of involvement (intensities) of households in the production of these crops. Based on the hypothesis that the intensity of cash crop production can affect food crop production and productivity, we develop indices of intensity of cash and enset crop cultivation.

We define household i's cash crop and enset cultivation indices as C_{ji} where j indexes the type of crop (j=coffee, chat, sugarcane, enset). For coffee this index (C_{cofi}) is defined as the number of coffee trees divided by total operated land holding; for chat the index (C_{chati}) is defined as the size of land planted to chat over total operated holding multiplied by 100. The sugarcane production index (C_{sugari}) is defined as the area planted to sugarcane divided by total operated holding and multiplied by 100; and the index for enset production (C_{enseti}) is defined as the number of enset trees divided by total operated holding. We use the total operated holding because food crops and cash crops are sometimes intercropped and it is difficult to know the share of each separately.

These indices simply measure the household's level of involvement in these crops' production relative to its available land for operation and do not show a production function relationship. The indices assume values of zero for some households. To study the impact of these indices on food crop production and productivity, we specify models for Q_{oi}, the aggregate gross value of food crops output, and $\frac{Q_{oi}}{fland_i}$, the aggregate gross value of food crop output over the total land planted to food crops. Thus, the empirical specification of equation (15) can be written as

$Q_{oi} = f(C_{ji}, x_i, fland_i, z_i^h, z_i^q,)$. --- (17)

$\frac{Q_{oi}}{fland_i} = f(\ C_{ji}, z_i^h, z_i^q, fland_i, \frac{x_i}{fland_i})$ -- (18)

Where x_i is a vector of variable inputs, including labour; z_i^h and z_i^q are vectors of household characteristics and farm characteristics, respectively, which include non-conventional production variables that affect production and productivity). Equation (17) specifies the empirical model of the aggregate value of total food crop production (Q_{oi}) while equation (18) specifies the aggregate value of total food crop production divided by total land planted to food crop ($\frac{Q_{oi}}{fland_i}$). In addition to conventional inputs (x_i), some elements of z_i^h and z_i^q are also normalized by the size of land planted to food crops ($fland_i$). Descriptions and overview of variables used in the analysis are presented in Table 2.

We use Cobb-Douglas (C-D) type as the basic functional form of production functions given by (17) and (18) since this is the commonly used form of production in agricultural economics research (Hayami, 1970). The C-D form is also easy to interpret and holds the promise of more statistically significant parameter estimates (Liu and Zuang, 2000). Debertin (1986), Chambers (1988) and Brown (1970) present properties of the C-D production function

The aggregate value of food crops produced by a household, Q_{oi}, include maize, teff, wheat, barley, sweet potato, potato, yam, taro, soybean, horse bean, and chickpea. To get the total value of gross output, the outputs of individual crops are weighted by average market prices, which do not vary across households. The aggregate value is used because it solves the problem associated with mixed cropping (Rao and Chotigeat, 1981; Byiringiro and Reardon, 1996). There are no high-value crops in the aggregate value of food crops, and it is assumed that differences in aggregate productivity between small and large farms are attributed to size or returns to scale (Byiringiro and Reardon, 1996). Although enset is a food crop itself, we can not include its values in the aggregate value of food crops (Q_{oi}) because it is difficult to calculate the values of enset crop for inclusion in one year production data as it is perennial and is harvested over a period. Farmers usually harvest some enset trees from a single plot and leave others standing.

The dependent variables and all continuous explanatory variables, including the crop indices are transformed into logarithmic form. For censored right-hand side variables (with zero observations), we add one to all observations before transforming them into logarithmic form. Transforming the data into logarithmic form helps reduce heteroskedasticity in error variance (Maddala, 1998; Mukherjee et al, 1998). These transformations reduce problems associated with non-linearity and outliers, improving the robustness of the regression results (Mukherjee et al, 1998; Godfrey et al, 1988).

Consistent estimation of the above model depends on two conditions. First, Q_{oi} and $\frac{Q_{oi}}{land_i}$ are not all positive observations. A significant number of farmers reported zero values for these variables. Since there could be systematic differences between the farmers with positive and zero values of these variables, taking only observations with positive values and estimating (17) and (18) can introduce selectivity bias (Heckman, 1979; Greene, 2000; Wooldridge, 2002). To correct for this selectivity bias, we use the Heckman's selection model (Heckman, 1979) which involves running a separate probit model using all observations, generating the inverse Mill's ratio (IMR) and including this in the regressions for, Q_{oi}, $\frac{Q_{oi}}{fland_i}$ >0 observations.

However, since the standard errors of the second stage estimates become incorrect because the IMR is estimated, we have to bootstrap the standard errors from the second stage to get the correct standard errors (Deaton, 1997). Second, the cash crop and enset production indices are basically the result of choices made by the households. If these indices are endogenous in equations (17) and (18), we get inconsistent parameter estimates (Shively, 1997). However, as we will show below, although they are endogenous to the household, they are predetermined variables and exogenous at the time of making food crop planting decisions as the latter are annual and the former perennials, having been planted before the annual food crops.

To make sure that they are predetermined only perennial crops older than one year are included in the indices, as they are not harvested before this age. As a precaution we use both the predicted and unpredicted values of the indices for comparison purposes and test the unpredicted indices for endogeneity. We use Tobit models to predict the indices, as many observations of the dependent variables assume zero values. We also use the log-log specification for these equations adding one before transforming the dependent variables and the right-hand side variables with zero observations. Thus, the impact of the cash crops and enset production on food crop production and productivity are determined by the coefficients of the indices in (17) and (18). We use market distance, location of the households (dummy variable for the two peasant associations) as instruments in the first stage probit equation to identify equations (17) and (18).

In addition to cash crops and enset indices and the conventional inputs, we include other explanatory variables including sex, education, and age of the household head, wealth variables such as total livestock unit, size of operated land holding, dependency ratio (consumer-worker ratio), size of male and female work forces, number of consumer units, the ratio of rented in land to total operated holding, the number of oxen owned by households, distance from markets and a dummy variable for location of the households (see Table 2)

While the conventional inputs are physical controls for production and productivity, inclusion of sex, education and age of household head assume that household head is the primary decision maker and thus provide additional controls for management input. Total land planted to food crops, on the other hand, measures the controversial relationship between the size of land and productivity on (18) and we expect positive and negative signs in (17) and (18), respectively. In areas where markets are imperfect, labour, wealth (tlu and ophold) and the number of oxen can put a given household at the advantage of early operation and credit worthiness and hence we expect positive signs both in (17) and (18). On the other hand, dependency ratio and the ratio of rented in land to total operated holding may reduce productivity and production.

4.2 Impacts of cash and food crops on enset intensification

Since enset is one of the main food crops in the area, we also look at the impacts of cash crops and food crops on enset intensification. We use the indices defined in the previous section in a model for enset intensification with a slight modification as:

(19) $c_{aenseti} = f(c_{acofi}, c_{chati}, c_{sugari}, Q_{oi}, z_i^h, z_i^q, tophold)$

where $c_{aenseti}$ now indexes total number of enset trees at all ages divided by total operated holding (tophold); c_{acofi} is the number of all-age coffee trees divided by total operated holding; c_{chati} and c_{sugari} are the same as defined in the previous section since no chat and sugar cane of less than two years were recorded, unlike coffee and enset, which include trees of less than two years of age; Qo_i is aggregate value of food crop production (equation (8)); z_i^h, z_i^q are vectors of household and farm characteristics as defined previously; and tophold is total operated holding.

The dependent variable in (19) involves zero values for households who do not plant enset. However, the number of households with zero enset production is only 5% of the total households used for econometric analysis. Therefore, we use only observations with positive values of enset production. On the other hand, if all the three cash crops and food crop production are endogenous in (19), the model will form a system of simultaneous equations and the OLS will be biased and inconsistent. Nevertheless, tests of simultaneity show that the cash and food crops production are not endogenous in (19). We have also tested for heteroskedasticity and could not reject the null hypothesis of constant variance.

5. Results and Discussion

5.1 Characteristics of cash cropping and enset farmers

Before we start discussing the results of the econometric analysis, we provide some descriptive insights on three categories of sample farmers based on their involvements in the production of cash crops and enset. Accordingly, we divide them into non-growers, average or below average growers and above average growers. We discuss only the main variables, which are used in (17) and (18), the dependent variables and some important characteristics in relation to the categories (see Table 3a and Table 3b). As the tables show, the average aggregate value of food crops is highest for non-chat producing farmers while it is lowest for farmers with more than average involvement in chat production. On the other hand, average total production is higher for farmers with more than average involvement in sugarcane production than it is for farmers with average and less than average involvement. Generally, aggregate value of food crop production per household is higher for non-producers of the cash crops (except sugarcane) and enset suggesting that these crops tend to be produced at the expenses of food crops although the decrease may not be significant.

Total operated holding and livestock holdings are generally lower for non-cash and non-enset farmers. This is in line with the argument by Timmer (1997) that farmers with larger land holdings engage in cash crop production more than their counterparts. Both total operated holding and food crop areas increase for above average enset producers indicating that larger farms have more advantage of both diversifying into enset and ensuring the family with food crops. This is in contrast with the belief that farmers with smaller holdings plant enset to intensify enset production, which is believed to give higher yields per area.

Growers of chat, sugarcane and enset also have higher number of male work force. However, the number decreases with the intensity of production. The value of fertilizer applied per unit of land of food crop is higher for non-producers of chat, sugarcane and enset but it increase with chat production intensity while it decreases with the intensities of sugarcane and enset production. On the other hand, it is higher for producers of coffee than non-producers but it decreases with the intensity of coffee production. Per unit of land uses of labour, oxen and seed are higher for sugarcane and coffee producers than non-producers while it is lower for chat producers. However, there is no indication that cash crops enable farmers to apply more fertilizer per unit of food crop land from these statistics. One reason for this might be that fertilizer is obtained on credit basis from government and farmers with lower liquidity substitute fertilizer for other inputs, which require immediate cash outlays. Nevertheless, sugarcane and coffee producers produce more food crops per unit of land than non-producers of these crops in line with our hypothesis while chat producers are less productive.

However, these descriptive statistics may not provide clear insights into the impacts of cash crops and enset on household crop production and productivity. These will be addressed in the next sections.

5.2 Econometric Results

5.2.1 Determinants of the probability of food crop production

First we look at factors influencing the probability of growing food crops. Results of probit models of determinants of the probability of growing food crops are presented in Table 4. Column (a) of Table 4 provides the two-stage limited dependent variable (2SLDV) estimation results while column (b) presents the probit estimation without predicting the four crop indices.

The results of the tests of the null hypothesis that the cash crops and enset indices are endogenous are reported at the lower part of Table 4. As we can see from the tests for the endogeneity of the crop indices, we cannot reject the hypothesis that the indices are exogenous in the model. As a result, model 1 (b) can consistently estimate the parameters of the probit model and our discussions are based on column (b)

The results show that the intensity of coffee production is associated with lower probability that the household produces food crops. This could be because of the fact that coffee is intercropped with food crops and other crops less often, which means that once land is occupied with coffee, the probability of growing food crops is low. Other cash crops and enset are not related with the probability of growing food crops significantly.

Both male and female workforces are positively correlated with the probability of growing food crops. This is an indication that food crops are demanding in terms of labour. The ratio of consumers to workers or dependency ratio (cwr) is also associated with the probability of growing food crops positively. On the other hand, total consumer unit (cu) is correlated with food crop planting probability negatively suggesting that households may use cash crops and enset as a means of intensification given scarcity of land.

5.2.2 Impacts of cash crops and enset on food production

In the second stage, we estimate equations (17) and (18), including the IMR generated from the probit model in the first stage. Model 1 of Table 5 provides estimation results of the determinants of food crops production. The coefficient of IMR is not statistically significant in (a), which also uses the predicted values of the four crop production indices, suggesting that there is no selectivity bias resulting from using the sub sample for which food crop production is greater than zero. Subsequently we estimated model (b) excluding IMR and using unpredicted crop indices. This enables us to test whether these indices are endogenous in the model. The test for endogeneity shows that we cannot reject the exogeneity of these variables with F= 1.96. The test for heteroskedasticity also shows that we cannot reject the homoskedasticity of the variance (Model (b)). This means that we can use OLS estimates with ordinary standard errors to get the consistent parameter estimates of the household total food crop production determinants. These estimates are given in column (c) of Model 1.The estimates in column (c) show that the intensity of chat production is associated with reduced total household food crop production. This may be because the results of competition for resources including land may outweigh the potential synergies between chat and food crops. This is evident in some areas where farmers replace food crops and other perennial crops such as coffee with chat. In addition, the frequent harvest of chat may not be suitable for food crop production.

On the other hand, sugarcane production is correlated with increased food crop production. Thus, an increase in the intensity of sugarcane by one percent is associated with 0.08 percent increase in value of total food crop production.[16] While sugarcane production apparently competes for land (although they can be intercropped) with food crops, the synergies between the two crops possibly resulting from reduced soil erosion, saved resources other than land and intensive use of inputs may outweigh the loss of production due to competition for land. Coffee and enset production do not have significant effect on food crops. This could be because of the counteracting effects of competition for resources and synergies between the perennials and food crop productivity and shows that these two crops can be grown at little expenses to food crops.

The availability of male workforce is positively and significantly associated with food crop production as expected. This is believed to be because of the fact that food crop production requires male labour for ploughing, threshing, and other activities. On the other hand, female workforce is negatively and significantly related with food crop production. This was not expected. The educational level of household head is also positively and significantly associated with food crops after controlling for other variables. Household food crop production is positively and significantly associated with the size of land planted to food crops as expected. A one percent increase in land is associated with about 0.5 percent increase

[16] This is a measure of elasticity because both variables are expressed in logarithm form.

in the value of food crop production, other factors held constant. This result is similar with previous studies (e.g. Govereh and Jayne, 2003). Household food crop production is also positively and significantly associated with labour and seed inputs.

5.2.3 Effects of cash crops and enset on food crop productivity

Given that the IMR is not significantly different from zero (F statistic) and that we cannot reject the exogeneity of the cash crops and enset production indices in the model, we use the OLS estimates of the food crop productivity model with robust standard errors since homoskedasticity is rejected (column (f) of Table 5).

Similar to our estimation results for total food crop production (model (c)), there is negative and significant relationship between chat production and food crop productivity (yield). This would be associated with the decreased use of inputs such as labour and seed per hectare with the intensity of chat production (Table 3) and other effects. On the other hand, food crop productivity is positively and significantly associated with the intensity of sugarcane production. Possible explanations could include the fact that more intensive sugarcane production is associated with higher use of labour and seed per hectare of food crops in addition to other possible synergies in terms of preventing soil and moisture losses. However, the intensities of coffee and enset production do not have any significant effect on food crops productivity. While coffee production is associated with the increased use of labour, seed, and fertilizer inputs per unit of food crop area, the intensity of enset production is associated with decreased use of seed, labour and fertilizer for food crops indicating the shift of attention from other food crops to enset. Nevertheless, the decreases and increases may not be significant to affect food crop productivity significantly.

Other variables positively influencing food crop productivity include educational level of household head. Total area of food crop production has a negative and significant effect on food crop productivity, other factors held constant. Farmers with smaller area of food crops have higher yields. Results in column (f) suggest that a one percent increase in food crop area reduces yield by about 1.05 percent, which is an inverse relationship between farm size and productivity. This is in line with the results found by, among others, Assuçãno and Ghatak (2003) and Heltberg (1998).

Labour and seed inputs measured by man-days and Eth. Birr, respectively, and normalized by total area of food crops are positively related with food crop productivity, with labour input having the biggest elasticity of the conventional inputs. Total male labour force available to households has a positive effect on food crop productivity suggesting the importance of male labour in food crop production. Surprisingly, the ratio of rented in land to total operated holding has a positive and significant effect on food crop productivity. The type of land contract is mostly of fixed rent and this minimizes the presence of inefficiency resulting from share tenancy.

5.2.4 Effects of cash crops and other food crops on enset Intensification

Results of the estimation of number of enset plants per total operated holding are presented in Table 6. Having rejected endogeneity and heteroskedasticity, we estimated the model using OLS. These results are reported in the third column of Table 6 (Model II). In addition, we estimated the equation using the two-stage limited dependent variable (2SLDV) procedure since the cash crop indices are estimated using tobit models for comparison purpose. These results are presented in the second column of Table 6 (Model I). The signs of the two model estimates are similar. However, the OLS estimates are more efficient owing to the fact that the 2SLDV procedure gives inefficient estimates in the absence of simultaneity (Gujarati, 1995). Therefore, the following discussions are based on results of Model II in Table 6.
We excluded female workforce (fwf) from Model II because it was found to be collinear with consumer unit and yet insignificant. Total livestock unit (tlu) was also omitted from both models due to its collinearity with oxen. Results of Model II show that the distance of the household from markets is negatively and significantly correlated with enset intensification. The intensity of coffee production is positively and significantly correlated with enset intensification. Possible explanations include the fact that enset may provide shade to coffee, making the two crops complementary. The number female labour unit is negatively correlated with the intensity of enset production, which is unexpected result since enset is believed to be female-labour intensive.

On the other hand, the larger the number of consumer unit, the higher is the intensity of enset production. This is in line with the fact that enset can insure food security from a relatively smaller landholding.

Although there are apparent competitions between enset and the other crops for some resources, these competitions do not seem to reduce the intensity of enset production. Unlike among cash crops and other food crops, most of the synergies between cash crops and enset may result from intercropping possibilities and other positive interactions, which make it possible to get more benefits from engaging in the production of many crops rather than specializing in certain crops.

6. Summary and conclusion

This study addresses the impact of emerging cash crop production activities on food crop production and productivity and enset intensification and the potential for the cash crops and enset production. In addition, we analyse the interaction of the two types of food crops. We hypothesized that in view of the decreasing landholding owing to population pressure, cash crops can have negative and positive impacts on food crop production and productivity, respectively, through competition for resources and enabling farmers to get more and stable cash income for purchasing and using productive inputs and through their impact on maintaining soil fertility. We also hypothesized that the intensity of enset production can have negative impact on other food crops and vice versa. Results show that after controlling for other relevant variables, chat production reduces both the total production and productivity of food crops supporting the claims that chat is replacing food crops while sugarcane production increases both production and productivity of food crops and coffee and enset do not have any significant impact on either of them. On the other hand, intensity of coffee production is positively and significantly related to enset production.

These point to the fact that cash crops can have both positive and negative impacts on food crops depending on the types of the cash crops and other institutional factors such as market interlinkage and also other complementarities. Whilst there are frequently heard assertions that cash crop production comes at the expenses of food crops, other authors (e.g. Govereh and Jayne, 2003) found that there are synergies between cash crops (cotton) commercialisation and food crop productivity through interlinked markets and regional spillovers). However, our results show that there is no guarantee that cash crop production per se can improve the production and productivity of food crops in areas where there are no spill-over effects and interlinked markets. Moreover, interlinked markets are not necessary for cash crops to have positive impact on food crops. Thus caution must be taken when advocating rural development policies based on the trade-offs or synergies between cash crops and food crops under all conditions.

Although there are tradeoffs between chat production and food crops, the impact of this cash crop on household welfare depends on the level of income from chat production and the foregone food crop production. Given that farmers have access to reliable food markets and other ways of using income from chat production, these crops can promote the general welfare of households.

On the other hand, coffee and enset can be grown to bring additional income to households without significant costs to food crop production, while sugarcane is beneficial both for additional cash income and its positive impact on food crop production and productivity. The results also suggest that complementarity exists between coffee and enset production.

The policy implication thus is that improving market infrastructure to reduce marketing costs can improve household welfare by encouraging farmers to produce cash crops, enset and other food crops, which can alleviate problems arising from population pressure because cash crop and enset productions are ways of farm intensification in the area ensuring food security.

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Table 1. Overview of main crops, production intensity and market orientation

Crops	Percent of sample households producing	Percent of growers who sold crops
Enset	77	9.7
Wheat	0.68	0
Coffee	71	17.1
Barley	1.4	0
Maize	69	8.8
Sugarcane	54	84.4
Chat	29	46.5
Soya bean	15	4.5
Sweet potato	8	75
Teff	6	11

Table 2. Overview and description of variables

Variable	Description	Expected sign			Mean	Std. error
		Probit for food crop production	Food crop production	Food crop productivity		
A. endogen-ous variables						
Fcropvalue (Q_{oi})	Aggregate Value of food crop production				480.82	1789.48
fcropdum	Dummy variable: 1=if fcropvalue>0, 0=other wise				0.74	0.44
Fcroppdvty ($\frac{Q_{oi}}{fland_i}$)	Aggregate value of food crop output (Fcropvalue) divided by total food crop area (fland)				1068.84	2222.06
Chathold (C_{chati})	Land planted to chat divided by total operated holding (tophold) times 100	-	-	+	0.059	0.16
Cofhold (C_{cofi})	Number of coffee trees over total operated holding (tophold)	-	-	+	17.49	27.88
Sughold (C_{sugari})	Area of sugarcane over tophold times 100	-	-	+	0.276	0.33
Ensethold(C_{enseti})	Number of enset trees over tophold	-	-	-	171.69	328.30
B. Exogenous variables						
age	Age of household head in years	?	?	?	44.22	14.27
sex	Household head sex dummy: 1=male, 0=female	?	?	?	0.9	0.30
mwf	Size of male workforce in standardized unit	+	+	+	2.22	1.44
fwf	Size of female workforce in standardized unit	+	+	+	1.52	0.99
cwr	Ratio of consumer unit to worker unit	+	-	-	1.72	0.34
edu	Educational level of household head in years	?	?	+	2.19	2.90
rrl	Ratio of rented in land to tophold	+	+	-	0.09	0.25
tlu	Size of livestock holding in tropical livestock unit	?	+	+	1.68	1.67
cu	number of consumers in standardized unit	+	+	-	6.14	2.80
oxen	Number of oxen owned by household	+	+	+	0.25	0.64
tophold	Total operated holding (in timad)	+			1.64	1.03
fland	Size of land planted to food crops (in timad)*		+	?	0.58	1.01
fertland	Cost of fertilizer used in food crop production in Birr over fland		+	+	37.63	153.50
labland	Amount of labour in man days used in food crop production over fland		+	+	36.44	51.52
oxland	Number of oxen days used in food crop production over fland		+	+	2.44	9.83
seedland	Value in Birr of seed used in food crop production over fland		?	?	101.82	241.93
mktdist	Average distance of households from markets in hours	+	+	-	1.99	3.48
padum	Dummy variable for location of household: 1=Wesha, 0=Chuko	?	?	?	0.7	0.46
lnvarname	Logarithmic transformed variable where varname is the name of one of the above variables					

*Timad is a local measure of land, equivalent to what an adult male can plough in a day using a pair of oxen: on average it is approximately equal to 0.25 hectare of land.

Table 3a. Characteristics of households based on their cash crop production indices in Southern Ethiopia, 1998/99[17]

Characteristics	Cash crops and enset production Indices					
	Chathold			sughold		
	Nongrowers	≤average	>average	Nongrowers	≤average	>average
Sample size	111	15	12	62	49	27
Dummy variable: 1=produces food crops, 0=no food crops	0.721	0.866	0.75	0.79	0.714	0.666
Total value of food crops (Et Birr)	564.63	139.83	131.88	572.89	221.23	740.51
Age of household head in years	44.25	43.14	45.25	46.33	43.5	40.7
Sex of household head: 1=male, 0=female	0.88	0.93	1	0.9	0.89	0.88
Male work force (mwf)	2.13	2.15	3.1	2.16	2.18	2.38
Female work force (fwf)	1.49	1.75	1.46	1.45	1.58	1.56
Consumer-worker ratio (cwr)	1.71	1.84	1.65	1.69	1.73	1.75
Education of household head	2.36	1.17	1.75	2.16	1.85	2.92
Ratio of rented in land to operated holding (rrl)	0.10	0.04	0.1	0.1	0.1	0.16
Livestock holding in tropical livestock unit	1.66	1.43	2.13	1.54	1.88	1.61
Total value of food crops over total food crop area (fcropdvty)	1262.1	334.13	433.84	947.53	1021.6	1484.3
number of consumers in standardized unit (cu)	5.9	7.08	7.2	5.86	6.22	6.64
Number of oxen owned by household (oxen)	0.27	0.133	0.166	0.27	0.27	0.15
size of total operated holding in timad (tophold)	1.58	1.99	1.78	1.45	1.84	1.69
Land allocated to food crops in timad (fland)	0.59	0.65	0.46	0.65	0.47	0.64
Value of fertilizer in Birr over fland (fertland)	47.28	1.23	5.56	53.15	27.73	15.49
Labour in days applied per timad of fland (labland)	40.18	21.6	25.1	25.52	46.89	45.24
Number of oxen days per fland (oxland)	2.98	0.77	0.00	0.77	2.29	7.16
Value of seed per fland (seedland)	118.84	35.8	47.76	58.21	135.47	152.68
Distance of household from market in hours (mktdist)	1.92	2.31	2.24	1.85	2.28	1.81

[17] The figures in the cells show average values of the variables based on the criteria

Table 3b. Characteristics of households based on their enset production indices in Southern Ethiopia, 1998/99[18]

Characteristics	Cash crops and enset production Indices						
	Cofhold*			Ensethold*			
	Nongr-owers	≤aver-age	>av-erage	Nongr-owers	≤aver-age	>aver-age	total
Sample size	45	66	27	42	65	31	138
Dummy variable: 1=produces food crops, 0=no food crops	0.8	0.742	0.629	0.666	0.707	0.903	0.739
Total value of food crops (Et Birr)	828.33	368.28	176.75	531.94	305.1	202.86	352.51
Age of household head in years	42.1	44.5	46.96	44.87	42.84	45.32	44.22
Sex of household head: 1=male, 0=female	0.88	0.92	0.85	0.83	0.89	1	0.89
Male work force (mwf)	1.98	2.49	1.92	1.81	2.39	2.41	2.22
Female work force (fwf)	1.48	1.55	1.52	1.3	1.761	1.33	1.52
Consumer-worker ratio (cwr)	1.74	1.71	1.7	1.68	1.73	1.76	1.72
Education of household head	2.18	1.95	2.81	2.32	2.49	2.48	2.19
Ratio of rented in land to operated holding (rrl)	0.13	0.1	0.1	0.18	0.1	0.03	0.1
Livestock holding in tropical livestock unit	1.45	1.86	1.62	1.58	1.6	2.02	1.68
Total value of food crops over total food crop area (fcropdvty)	1001.8	1231.2	722.53	1561.0	1092.43	342.77	1068.8
number of consumers in standardized unit (cu)	5.83	6.56	5.63	5.1	6.78	6.37	6.14
Number of oxen owned by household (oxen)	0.27	0.29	0.11	0.26	0.25	0.23	0.246
size of total operated holding in timad (tophold)	1.56	1.9	1.13	1.46	1.72	1.74	1.64
Land allocated to food crops in timad (fland)	0.7	0.6	0.33	0.64	0.49	0.7	0.58
Value of fertilizer in Birr over fland (fertland)	18.1	60.88	10.45	71.97	27.52	20.27	37.63
Labour in days applied per timad of fland (labland)	29.94	40.96	37.22	46.1	39.7	21.77	36.44
Number of oxen days per fland (oxland)	0.42	4.68	0.1	0.5	5.0	0.23	2.44
Value of seed per fland (seedland)	70.88	108.74	150.24	122.28	125.77	44.19	101.82
Distance of household from market in hours (mktdist)	1.93	2.19	1.62	1.52	2.34	1.93	1.99

* coffee and enset do not include trees less than two years old

[18] The figures in the cells show average values of the variables based on the criteria

Table 4. Results of econometric estimation of impacts of cash crops and enset on whether or not to produce food crops

Variables	Probit model for probability of food crop production	
	(a) 2SLDV (predicted indices)[a,+]	(b) one-stage Probit [p]
	coefficient (std. errors)	coefficient (std. errors)
imr	-	-
lnchathold	-.1344(.2894)	.0639(.1238)
lncofhold	.0270(.0427)	-.1939*(.1043)
lnensethold	.0658(.5518)	.0563(.0655)
lnsughold	-.1174(.3177)	-.0762(.0817)
lnage	-1.3735(1.3967)	-.4095(.5862)
sex	.7011(.5334)	.5517(.4925)
lnmwf	3.3722*(1.7664)	3.6351**(1.7416)
lnfwf	2.1364(1.3312)	2.2476*(1.3437)
cwr	2.6709* (1.4813)	2.9167**(1.2178)
edu	-.1281(.0900)	-.0698(.0554)
rrl	-.3158(1.5889)	-.8572(.5943)
lntlu	.3781(.6282)	.4834(.3519)
lncu	-3.4269*(1.9263)	-3.4913*(1.8539)
oxen	.1958(.5380)	.3069(.3383)
lntophold	.2836(.7084)	-.3435(.2818)
constant	.5387(5.3606)	-2.8132(3.3137)
No.of observations	124	124
Log likelihood	-58.5683	-56.4719
Pseudo R2 (R-squared)	0.1463	0.1769
LR chi2(15)	20.08	24.27
Endogeneity test for crop indices		chi2(4) = 6.66 Prob >chi2=0.1551

[a] numbers in parentheses are bootstrap standard errors; [p] preferred model; *, ** and *** denote significance at or below 10%, 5% and 1% levels.[+] indices predicted based on separate regressions.

Table 5. Results of econometric estimation of impacts of cash crops and enset on food crop production and productivity

Variables	Model 1: Value of food crop production per household in Eth Birr			Model II: Value of food crop production per timad of land (Eth Birr/timad)		
	(a) Heckman 2SLDV	(b) OLS	(c)OLS [p]	(d) Heckman /2SLDV	(e)CLAD (without prediction)	(f) OLS [p]
	coefficient (Std. errors)[a]	coefficient (Std. errors)[b]	coefficient (Std. errors)[c]	coefficient (Std. errors)[a]	coefficient (Std. errors)[a]	coefficient (Std. errors)[b]
imr	-.2238(.5224)	-	-	-.2577(.5612)	-	-
lnchathold	-.0318(.1488)	-.1217**(.0564)	-.1217* (.0646)	-.1783(.1565)	-.2002***(.076)	-.1682***(.063)
lncofhold	-.0135(.0147)	-.0137(.0505)	-.0137(.0553)	-.0184(.0177)	-.0359(.0730)	-.0031(.0570)
lnensethold	-.2950**(.1459)	.0023(.0356)	.0023(.0356)	-.2709(.3477)	.0225(.0465)	.0199(.0413)
lnsughold	-.0285(.0749)	.0801*(.0417)	.0801*(.0439)	-.0259(.1646)	.1360**(.0676)	.0995** (.0445)
lnage	.4316(.4705)	.2497(.3275)	.2497(.2966)	.7233(.5552)	.6519(.5269)	.5788(.3706)
sex	-.0607(.4329)	-.0775(.3692)	-.0775(.3683)	-.2351(.4331)	-.4654(.6255)	-.2648(.4663)
lnmwf	.9258***(.3270)	.8065**(.2685)	.8065***(0.304)	.8288(.5908)	.8806**(.4191)	.7524**(.3166)
lnfwf	-.2177(.3099)	-.5791*(.3138)	-.5791**(.2769)	-.0587(.3999)	-.1363(.5357)	-.4968(.3237)
cwr	.2727(.3985)	-.2102(.3447)	-.2102(.3181)	.4200(.9540)	-.1218(.4476)	-.2008(.4134)
edu	.1045**(.0438)	.0843***(.0292)	.0843**(.0334)	.1113**(.0435)	.0885*(.0497)	.0907***(.0322)
rrl				.2830(1.1507)	1.2719*(.7215)	.9466*(.5050)
lntlu	.2965(.2827)	.1340(.2004)	.1340(.1954)	.3809(.4005)	.1213(.2412)	.1667(.2247)
oxen	-.1881(.2046)	.0234(.1673)	.0234(.1679)	-.2844(.3101)	-.0861(.3550)	-.0173(.1994)
lnfland	.3837(.3264)	.5053(.3647)	.5053*(.2751)	-.9534***(.335)	-1.053***(.390)	-1.052***(.307)
lnfert[±]	.0597(.0620)	.0687(.0618)	.0687(.0589)	.0435(.0634)	-.0012(.0716)	.0567(.0553)
lnflab[±]	.3105**(.1436)	.2674**(.1345)	.2674**(.1309)	.3237** (.1455)	.3501*(.2008)	.2671*(.1384)
lnfoxen[±]	.0693(.1466)	.0590(.1291)	.0590(.1192)	.1033(.1565)	.1829(.1651)	.0760(.1065)
lnfseed[±]	.1517*(.0794)	.1525**(.0599)	.1525**(.0702)	.1583**(.0787)	.1958*(.1078)	.1671***(.0611)
constant	1.9731(1.4707)	2.6758**(1.187)	2.6758**(1.283)	1.8728(1.6004)	1.7624(2.0875)	2.6369*(1.3391)
No.of observations	94	94	94	94	136	94
No.of replications	100	100	100	100	100	-
Pseudo R2 (R-squared)		(0.6663)	(0.6663)			0.5315
Breusch-Pagan/ Cook-Weisberg test for heteroskedasticity		Chi2(1)=0.8 Prob>chi2=0.774				chi2(1) = 4.31 Prob>chi2=0.038
Endogeneity test for crop indices		F(4,73) = 1.96 Prob >F=0.1098	F(4,73)=1.61 Prob.>F=0.1797			F(4,71) =1.74 Prob >F=0.1514
F		F(17,76)= 12.05	F(17,76)= 8.93			F(18,75)=4.18

[a] numbers in parentheses are bootstrap standard errors;[b] numbers in parentheses are robust standard errors; [c] numbers in parentheses are ordinary standard errors; [p] preferred model; *, ** and *** denote significance at or below 10%, 5% and 1% levels. [±] these inputs are normalized by the size of land planted with food crops in Model 2.

Table 6. Results of econometric estimation of impacts of cash and food crop production on enset intensification: Dependent variable: laensethold

Explanatory Variable	Model I. 2SLDV estimates of number of enset plants per operated holding Coefficient (Standard error)[a]	Model II. OLS estimates of number of enset plants per operated holding Coefficient (standard error)
mktdist	-.0353(.0987)	-.0538(.0294)*
lfcropvalue	-.00004(.0002)	-.1412(.1455)
lacofhold	-.0068(.0292)	.2237(.09383)**
lchathold	.0139(.0075)*	.0619(.0967)
lsughold	.0032(.0064)	-.0616(.0670)
lage	.8806(.8407)	.1281(.4773)
sex	.9082(.5996)	.8945(.5376)
fwf		-.5745(.2726)**
mwf	-.1473(.1812)	-.2179(.1920)
edu	-.0150(.0819)	-.0758(.0539)
cu	.0301(.0984)	.2530(.1395)*
rrl	.3876(2.7426)	.8783(.6571)
oxen	.4370(.5272)	.2123(.2103)
ltophold	-.6340(.4016)	-.2741(.2585)
_cons	2.5334(2.8977)	4.4211(1.9348)**
Breusch-Pagan/Cook-Weisberg test for heteroskedasticity. H0: constant variance		$chi^2(1)$ =2.13 prob> $chi^2(1)$ =0.0.1442
Simultaneity test for cash and food crops. H0: No simultaneity	F(4,74)=1.15 Prob>F=0.3385	
Adjusted R^2		0.1382
Number of observations	93	93
F		F(15,78)=2.05 Prob>F=0.0238
Number of replications	100	

[a]standard errors are bootstrapped

Paper IV

The effect of market liberalization on agricultural commodity prices in Ethiopia

Adane Tuffa Debela
Department of Economics and Resource Management
Agricultural University of Norway
P.O. Box 5033, N-1432, Aas, Norway

Abstract

This paper investigates the effect of economic policy reforms on price levels and price spreads of five main agricultural commodities, namely teff, maize, coffee, sheep and oxen in five spatially separated markets. Monthly prices over the period January 1983 to Feb. 2005 were considered for the analysis. The effects of market liberalizations on grain and livestock prices are analyzed using the reduced form econometric model, which was estimated simultaneously across five markets using seemingly unrelated regression estimator (SURE). Results of the study indicate that grain market liberalization has increased average prices across markets in both deficit and surplus producing areas for some crops and livestock, and it has reduced prices of other crops and livestock. Fertilizer market liberalization has also increased prices of crops and livestock, while currency devaluation is associated with decreases in teff and maize prices. The study also indicates that volatility in price levels and price spreads has increased after grain market liberalization.

Keywords: Devaluation; Ethiopia; exchange rate; market liberalization; price; SURE.
JEL classification: E65; Q18

1. Introduction

The Ethiopian economy has seen many structural adjustment programs over the past 15 years. One of the components of these economy-wide reform programs is the liberalization of the controlled agricultural marketing systems, in order to promote agricultural production and productivity by providing price incentives to farmers (Kherallah et al, 2000; Barret 1997). To this end, the agricultural reforms were designed to reduce or eliminate the bias against agriculture and open the sector to market forces through liberalizing output prices and the marketing system as a whole. Although the package of the reforms introduced by the World Bank and the IMF include liberalizing in input and output prices; reducing overvalued exchange rates; encouraging private-sector activity by removing regulatory controls in input and output markets; and restructuring public enterprises and restricting boards to activities such as providing market information and maintaining security stocks, all these measures were not taken at the same time. Nevertheless, the country has been in the process of agricultural marketing reform since 1991.

Advocates of food market reform encourage liberalization as a means to reduce costs in the marketing system, raise and stabilize farm incomes, promote farmers' incentives to use productivity-enhancing inputs and agricultural practices, and reduce poor households' dependence on food aid for their survival (Jayne et al., 1997; Asfaw and Jayne, 1997; Zhao et al., 1991; Fulginiti et al., 1999). Similarly, devaluation of the exchange rate increases prices of exportable crops, which in turn stimulates production. Overvaluation of currency generally reduces the profitability of exportable agricultural commodities and, therefore, is thought to adversely affect the performance of agricultural sector (Pick and Vollrath, 1994; Gilbert, 1989; Binswanger and Deininger, 1997).

Existing studies on the impact of market liberalization on grain prices in Ethiopia (e.g., Dercon, 1995; Getnet et al, 2005; Asfaw, 1998; Asfaw and Jayne, 1997; Desalegn et al, 1998) provide important information on the impacts of the reforms on grain prices, market performance, structure and integration. Generally there are indications that while farmers' share of prices has increased, there remain risks of low and unstable producer prices long after the introduction of these reforms. Getnet et al (2005) and Asfaw (1998) found that reforms have improved spatial market integration. While Asfaw and Jayne (1997) and Jayne et al (1998) show that price spreads have decreased and price levels have been affected by the reforms for maize, teff and wheat, there are no studies regarding the impacts of the reforms on

the prices of other agricultural products such as cash crops and livestock.
As Ethiopian agriculture is characterized by crop-livestock integration, and livestock and cash crops constitute significant amount of agricultural income, even the grain market reforms can be expected to affect prices of livestock and cash crops such as coffee. Therefore, it is of interest to see how the reforms have affected grain-livestock terms of trade. In addition, devaluation of the Ethiopian currency and the liberalization of coffee export markets are expected to affect the domestic prices of coffee. Liberalization of fertilizer markets is another important factor to be considered. Moreover, the length of time frame and price data may influence the results of the study. Therefore, more comprehensive study using longer price data may provide more reliable information regarding the impacts of reforms than the previous studies, which use shorter price data.

This study tries to assess how the reforms are affecting the marketing system. Particular objectives are to examine: (1) how market liberalization affected the level and volatility of prices of cereal grains, coffee and livestock and (2) the impacts of market liberalization on the level and volatility of the spreads of these prices between selected markets. We use monthly time series price data to answer questions regarding the real impacts of the reforms on prices and draw implications for future market intervention measures.

The rest of this paper proceeds as follows. Section 2 provides an overview of the Ethiopian agricultural markets reforms. In section 3 the development of a model to study the effect of policy reform on prices will be described. Section 4 provides description of the areas considered for this study, data collection and sources. In section five, we present and discuss results of the analysis. The paper will end with the summaries of the main findings and some policy implications in section six.

2. Agricultural market reforms in Ethiopia

The socialist government, which took power in 1974, introduced a pan-territorial wholesale and retail price control policy.[19] The Agricultural Marketing Corporation (AMC) was created in 1976 with World Bank support as a government parastatal to buy grain from farmers and sell to urban consumers and state organizations (Kherallah et al., 2002). Its main mandate was to stabilize prices of basic agricultural commodities to protect the interests of the majority of

[19] See Aredo (1990) for the complete review of rural policy reforms in Ethiopia.

the population. To protect the AMC, government restricted private regional grain trade. The AMC forced traders to sell part of their supplies at predetermined prices. Farmers were required to deliver 10 to 50% of their grain harvest as a quota to the AMC. The pan-territorial and pan-seasonal prices were below market prices in most of the regions.

Although the pan-territorial pricing policy was intended to achieve the objective of taxing agriculture and subsidizing the urban consumers without adversely affecting agricultural production, the policy was not designed to raise food production by encouraging farmers. In general it was concluded that this ill-planned policy (i) depressed rural incomes; (ii) transferred resources from rural households to a relatively small group of urban households through artificially cheap food prices; and (iii) depressed cereal production in the country (Franzel, et al, 1989; Kherallah et al., 2000; Dadi et al., 1992;). As a consequence, the country suffered chronic economic crises manifested in severe food shortage in the 1980's.

The official exchange rate of the Ethiopian Birr was fixed at Birr 2.07 to the US dollar between February 1973 and October 1993. This overvaluation resulted in considerable losses in export markets, which led to expansion of illegal exports involving coffee, gold, chat, livestock, fruits and vegetables.

The government was forced to reconsider its policy, and in March 1990, the grain marketing policy was changed. Quotas and pant territorial grain prices were abolished. Along With this, subsidies on wheat for urban consumers were abandoned in 1992. The transitional government of Ethiopia, which came into power in 1991, reaffirmed the policy change and lifted all controls on interregional grain trade. Private traders were allowed to operate freely within the country. At the same time the AMC was renamed the Ethiopian Grain Trading Enterprise (EGTE). It was given a new mandate of maintaining buffer stock with the goal of stabilizing producer and consumer prices by purchasing when prices are very low and selling at the time of scarcity. However, it faces competition from private traders and consumers. Since its downsizing in 1992, the EGTE has accounted for less than 5% of cereals traded nationally (Jayne et al, 1998).

Devaluation of Ethiopian Birr in 1993 was another crucial reform. This devaluation resulted in an exchange rate of Birr 5 for a US dollar. The administrative exchange allocation was also replaced by an auction system involving all licensed importers, which is considered as a transition from a fixed to a free-floating exchange rate system. The devaluation was expected to encourage production for exports such as coffee by raising payment for exports in terms of national currency (Gilbert, 1989). All taxes and subsidies on exports were eliminated, and state exporting enterprises are required to participate competitively. Accordingly, the monopoly position of the Ethiopian Coffee Marketing Corporation (ECMC) has ended as private exporters were allowed to operate alongside the ECMC. This increased the numbers of coffee exporters, private traders and transporters, which provides the basis for greater competition in coffee marketing (Afrint, 2003). Another part of the reforms was establishment of trade support institutions. In this connection, the Ethiopian Export Agency (EEA) was established to help exporters. It provides information and trainings on exporting and importing. The devaluation of Birr in 1993 resulted in the increase of fertilizer prices. This situation forced the government to introduce fertilizer subsidies. The subsidies were eliminated in 1997. The removal of fertilizer subsidies resulted in a persistent low level of fertilizer usage and subsequent productivity decline. It is to be noted that fertilizer was somewhat subsidized even before the introduction of higher subsidies after currency devaluation.

The reform also included the establishment of the Livestock Marketing Authority, with a mandate to promote and expand the domestic and export markets. The establishment of the Leather and Leather Products Technology Institute is another measure targeting the livestock sub-sector.

Thus analyzing the impacts of these measures on prices helps test the hypothesis that liberalization would increase efficiency in the marketing sector; increase income to producers; and provide incentives for higher production. The interaction of the crop and livestock sub-sectors calls for the consideration of the two at the same time as measures taken to affect one sub-sector affects the other one way or another. Livestock and crop production can compete for some resources and be complementary to one another. Hence one has to expect complex interaction between the two sub-sectors. Therefore, considering livestock prices in this analysis can provide information on how grain prices moved during a particular time in relation to livestock prices and, in addition, it provides information on how the policy has affected the livestock prices themselves.

3. Conceptual Framework and Methodology

The choice of approaches to modeling the effects of liberalization on prices depends on the specific objectives of the analysis, as well as the size and quality of data available for use. The common approaches can range from simple analysis in the form of descriptive statistics to complex models consisting of behavioral equations to explain the demand and supply decisions of all participants in the market, which include producers, consumers, traders, and other agencies (e.g. state agencies) involved in food marketing. While the use of descriptive statistics does not allow us to control for changes in other factors likely to affect price levels, complex structural models require huge amounts of data collected over time on all the involved agents. However, in many countries adequate data to construct a full supply-demand model may not be available, which is also the case in Ethiopia. In addition, structural econometric models may be complicated to use as they involve many over identifying restrictions drawn from economic theory, usually taking the form of excluding variables from a particular equation to motivate a particular economic interpretation for the model.

An alternative is to specify a reduced form model for equilibrium price levels (Palm and Smit, 1991; Jayne et al, 1998; Faminow and Laubscher, 1991). This model is relatively simple in that while we can include variables dictated by economic theory, like structural models, the restrictions applied to it are minimal (Tomek and Myers, 1993). However, unlike the structural models we cannot account for the effects of liberalization on supply or demand decisions. This can be a problem to the use of the reduced form model if the objective is to analyze the effect of liberalization on the supply or demand decisions of particular market participants. But when the objective is assessing the net effect of liberalization on real price levels, as given by average price series during the pre- and post liberalization periods, the reduced form model can be used. Historical price correlations are summarized by including lagged terms and statistical criteria are used to determine how many lags to include (Judge et. al., 1985, chapter 16).

Prices in five markets will be considered for this study. The five markets are Addis Ababa (central market), and the regional markets, Debre Zeit, Debreberhan, North Omo, and Sidamo. Price equations in the five markets will be estimated as a system of equations using the iterative seemingly unrelated regression estimator (SURE), as shocks hitting one market are expected to hit other markets at the same time. To cover the period well before and after the reforms, monthly average time series price data are used for the five markets starting from

1983 to 2005. Among the cereals we consider are teff and maize, which represent the main staples. Among the cash crops we look at how the reforms have affected coffee prices. In addition, prices of the two main livestock types, oxen (average price) and sheep (estimated weight 10 kg), are considered, to see if there are differential impacts of the different policies on prices for crops and livestock.

In addition to econometric methods, descriptive statistics, such as price spreads, mean, and coefficients of variation will be calculated for prices before and after liberalization to give an idea on price movements. The differences between these statistics before and after the reform will throw light on how price variability changed after the reform.

The price of any commodity in market i at time t can be represented in a reduced form model or data generating process generally expressed as

(1) A (L) Pit = $x_{it}\beta_i$+B (L) uit, (i=1, 2,…,.n),

Where A (L) and B (L) are polynomials in the lag operator designed to manipulate the dynamic response of prices to market shocks. In this study x_{it} contains all of the observable exogenous variables that influence the level of prices, which include price of complementary goods, weather, seasonal patterns, and policy variables. u_{it} consists of two components: an identically and independently distributed disturbance term plus those parts of exogenous factors, which are not observable due to data limitations. The two polynomials A (L) and B (L) in the lag operator L can generally be represented as

(2) $A(L) = 1 + \rho L + (\rho L)^2 + (\rho L)^3 + ... = \sum_{i=0}^{\infty} (\rho L)^i$,

And

(3) $B(L) = \beta_0 + \beta_1 L + \beta_2 L + \beta_3 L_2 + ...$ where $Lp_{it} = p_{it-1,} L^2 p_{it} = p_{it-2,} ...,$ and

$Lu_{it} = u_{it-1,} L^2 u_{it} = u_{it-2}$

Moreover, statistical primary tests[20] indicated that the simplest way to represent the price dynamics was to set i in equation (2) to three for teff and maize, to four for coffee, to two for sheep and to four for oxen and to set $B(L) = 1$.

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[20] These tests, based on Akaike's information criterion (AIC) (Akaike, 1973, 1974), are used to determine the correct lag order for vector autoregression (VAR) models. This criterion selects the correct lag order, p, of a VAR (p) model, which minimizes the AIC given by: AIC= $-2(\frac{LL}{T}) + \frac{2t_p}{T}$, where LL is the log likelihood of the model; 2tp is the total number of parameters in the model; and T is the number of observations.

Thus equation (1) simplifies to

(4) $p_{it} = \partial_i + \rho_{i1} p_{it-1} + \rho_{i2} p_{it-2} + \rho_{i3} p_{it-3} + \rho_{i4} p_{it-4} + x_{it}\beta + u_{it}$

The explanatory variables included in x_{it} for this study were intercept, categorical variables differentiating the period before and after grain and input markets liberalizations, a dummy variable differentiating periods before and after currency devaluation, seasonal dummy variables and a dummy variable differentiating drought and non-drought years, and prices of fertilizers We assume that the effect of the policy reforms on prices are instantaneous. Thus the final equations to be estimated for a given commodity price in a given market i takes the form:

(5) $$p_{it} = \mu_i + \rho_{i1} p_{it-1} + \rho_{i2} p_{it-2} + \rho_{i3} p_{it-3} + \rho_{i4} p_{it-4} + \beta_i D_t + \sum_{1}^{11} \theta_{im} D_{mt} + \gamma_i \, fertlib_t + \lambda_i \, grainlib_t + \tau_i \, forex_t + \delta_i \, pfert_t + u_{it}$$

Where Dt is a dummy variable taking a value of one for months constituting years affected by drought which are 1985, 1994, 1998 and 2000; Dmt are 11 monthly dummy variables (Jan. through Nov.) to account for seasonality of prices; grainlib is a variable representing the change in grain marketing policy environment over the sample period; fertlibt is a variable representing the change in the fertilizer market policy over the sample period; forext is a dummy variable representing the change in exchange rate; and pfert is annual fertilizer prices.

The n equations (one equation for each of the five markets) in (5) were estimated simultaneously using the iterative seemingly unrelated regression (SURE). Thus, there is one system for each grain and livestock and each system consists of five equations except teff, which does not include the Awassa market.

The success of using these equations to satisfactorily estimate the effects of market liberalization on agricultural output prices depends on the level of econometric problems associated with the model. Correlation of included explanatory variables with omitted variables renders the estimates biased (Gujarati, 1995; Greene, 2000; Wooldridge, 2002)). Problems related to unobserved explanatory variables can be minimized by careful modeling of the price dynamics. Another possible problem that may arise from estimating this system of equations is regarding the value of $\rho_{i,}$ that is, whether the price series are stationary or nonstationary. If $\rho_i = 1$, the price series is nonstationary and the ordinary least squares estimate of ρ_i is biased downward in small samples, and the usual t- and f-tests are unreliable. If this is the case, the model can be improved through suitable modeling of the dynamics. In addition to the problem of estimation the question of whether $\rho_i = 1$ or $\rho_i < 1$ is important for determining how economic policy reforms affect output prices. If $\rho_i = 1$, it means that the price series is non-stationary and the effect of market liberalization is to cause a permanent shift to the rate of growth in prices. But if $\rho_i < 1$, the price series is stationary and the effect of liberalization is to cause a permanent shift in the means of the price series (Jayne et al, 1998)

The Augmented Dickey Fuller (ADF) unit root test applied to each of the price series indicated that the hypothesis of non-stationarity was rejected in 19 of 25 cases at 1% and 5% levels, that is, all price series were stationary except the price of sheep in Addis Ababa market and prices of coffee in all markets. On the other hand using the Phillips-Perron (PP) test, the hypothesis of non-stationarity was rejected in 22 of 25 cases at less than or equal to 10% levels. These results are also inline with previous studies by Asfaw and Jayne et al (1998), who found that the Ethiopian grain price series were reasonably integrated and were in most cases stationary. However, the null hypothesis of unit root for fertilizer price series could not be rejected at any reasonable level. Therefore, caution should be taken when we interpret the impact of fertilizer prices on prices of coffee in Addis Ababa and East Shoa (Debre Zeit) markets as the hypotheses of unit root were not rejected for these prices in these markets. The test for the potential problem of multicollinearity did not indicate serious problems of multicollinearity. Autocorrelation does not seem to be a serious problem based on tests of Durbin Watson H statistic.

Brief definitions and expected signs for explanatory variables included in the estimated equations (5) follow.

Drought (Dt): a dummy variable was included in the equations to account for shocks hitting market prices due to the reduction in the volume of harvest resulting from shortage of rainfall. During the sample period four years were identified as drought years. The variable will assume a value of one for the months constituting the four drought years and a value of zero for the rest of the months. A positive sign is expected on this variable for grain prices and a negative sign is expected in the case of livestock prices because the low volume of production owing to the low levels of rainfall during drought years introduces imbalance between demand and supply and this forces farmers to sell livestock either for lack of feed or to buy crops, which lowers livestock prices.

Seasonality (Dm): to capture the seasonal patterns in a given year for Ethiopian grain and livestock prices due to different volumes hitting the markets in different months, and also due to costs of storing grain over time, eleven dummy variables were included in each of the reduced form equations. These variables can have different signs depending on the volume of a given commodity supplied to the market.

Grain market liberalization (grainlib): this variable is designed to capture the impact of grain market liberalization on grain and livestock prices. Based on the assumption that market liberalization can have immediate impact on prices, this variable takes the value of zero for the pre-liberalization period and a value of one during the post liberalization period. This assumption is based on the fact that farmers take their stored grains to market and traders can move freely once the policy reform is in place. The expected sign on the coefficient of market liberalization variable depends on the mechanism through which it affects prices (Badiane, et al, 1998). If market liberalization reduces transaction costs (costs associated with the distribution of grains) the sign is expected to be negative in grain deficit areas and positive in surplus areas.

Fertilizer market liberalization (fertlib): this is a dummy variable capturing the effect of fertilizer market liberalization on grain and livestock prices. It assumes a value of one during the post liberalization period and a value of zero during the pre-liberalization period. It is expected to raise prices in subsequent years in the grain markets because fertilizer prices increased after the reform. The rise in fertilizer prices reduces the use of fertilizer (Fulginiti and Perrin, 1993) and this in turn adversely affects supply whereas reduced supply leads to increase in output prices.

Fertilizer prices (Fertprice): This represents average DAP and UREA prices in a certain market area. This is important because fertilizer prices vary between regions depending on the distance of the region from central market. This is expected to have positive sign because higher prices lead to reduced use of fertilizer depressing production. Unlike the variable representing fertilizer market liberalization, which separates the period before and after liberalization, the inclusion of fertilizer prices captures the impact of yearly fertilizer price variations.

Devaluation (forex): this variable is intended to capture the effect of the change in exchange rate (devaluation), which took place in 1993. For the period before the change in policy it is assigned the value of zero and after the policy reform it is assigned the value of one. Devaluation increases income from exportable crops as a result of which farmers increase production of the exportable crops either through intensification or shifting resources from other crops or both. This reduces the volume of other non-exported crops resulting in imbalance between demand and supply and hence positive sign is expected on this variable for both exportable and non-exportable crops. It may also affect livestock production through the shifting of resources from livestock to export crops or through raising their prices in local currency if the livestock are exported.

4. Study areas and data sources

This study covers five areas and five markets (one for each area). These are Addis Ababa (Central market), East Shoa (DebreZeit), North Shoa (Debre Berhan), North Omo (Arba Minch), and Sidamo (Awassa). Debre Zeit lies about 45 km east of the capital city and it is one of the main teff growing areas whereas Debre Berhan lies 130 km north of Addis Ababa. The last four areas are considered as regional markets. Sidamo is located about 375 km to the south of the capital city and North Omo is located some 500 km to the south of the capital city. Both Sidamo and North Omo are the main maize growing areas. In addition, these two regions are known for their coffee production. These four places were selected because of their locations in relation to the central market.

The two main food crops considered for this study were white teff and maize. These crops are the major staple crops in the study areas and in the country, and it is believed that they can reflect the general directions of price movements in these regions. Each crop is considered in all the five markets, except teff in Awassa because of incomplete data. Coffee is another crop chosen to represent the exported crops. In addition to the three crops, prices of two major livestock types, oxen and sheep are considered for the study The data cover the period January 1983 to Feb. 2005 for white teff and sheep; January 1983 to July 2000 for maize and coffee; and October 1987 to February 2005 for oxen.

Price data were collected by the Central Statistical Authority (CSA). Nominal prices were corrected for inflation (or deflation) using the consumer price indices (CPI), converting them to 2000 constant prices.

5. Results and discussions

5.1 Descriptive statistical results for price data

Before going into the econometric analysis of the impact of economic policy reforms, mean, standard deviation and coefficients of variation were calculated for real price levels and price spreads of white teff, maize, coffee, sheep and oxen for the periods before and after grain market liberalization (Table 1 and 2). For the crops the markets were divided into two categories based on whether that region is a surplus or deficit region in the production of the particular crop (Table 1). Real price trends are given in Appendix 2.

The results in Table 1 indicate that average real prices have increased for teff in both surplus and deficit areas. Maize prices have increased in surplus producing areas and decreased in deficit areas except in Debreberhan.

Real oxen prices have decreased after the policy change in all markets considered except in Addis Ababa market. Average real livestock prices indicate that sheep prices have increased in all markets after liberalization while oxen prices have decreased on average, except in Addis Ababa market. Higher prices in some of the surplus producing areas and simultaneously lower prices in deficit areas for some crops indicate that market liberalization has been associated with a reduction in average crop price spreads (the difference in average prices in surplus and deficit regions). To support this conclusion direct price spreads were computed for the markets during the pre-liberalization and post-liberalization periods. The result shows that price spreads have declined in 7 of 8 routes for maize and in all routes for coffee although they have increased for teff in all routes.

Although differences in weather conditions may partially account for changes in price levels in the pre- and post-liberalization periods, favorable weather during the post liberalization period cannot serve as an explanation for why prices in surplus-producing markets rose while prices in deficit markets declined.

The rise in sheep prices may be explained by increased prices of crops, which raises income to farmers and this, in turn, increases consumption of these small ruminants by farmers rather than selling them to get cash income. On the other hand, this could possibly reduce income to urban consumers, who consume mostly larger animals thereby reducing demand for the larger animals such as oxen. The variability of monthly real prices levels and price spreads are also included in Tables 1 and 2. For crops, the coefficient of variation in average prices has declined during the post-liberalization period in five of nine cases. However, the decline is only in four of nine cases for standard deviation. In terms of the variability of price spreads between pairs of markets, the coefficient of variation has declined in six of 13 cases while it has increased in seven cases. The decline is only one out of 13 cases in terms of standard deviation while it has increased in 12 cases.

The variability of coffee prices has increased in terms of the coefficient of variation in nine out of 10 cases while the standard deviation has decreased in eight out of 10 cases. On the other hand the variability of price spreads for coffee has increased in all cases in terms of the coefficients of variation and decreased in four out of seven cases in terms of standard deviation.

For sheep prices the variability has increased dramatically in post-liberalization period both in terms of coefficient of variation and standard deviation, indicating that liberalization has increased sheep price instability much larger than crop prices. Variability has also increased in price spreads in six out of seven cases in terms of standard deviation and in four out of seven in terms of coefficients of variation. The variability of oxen price spreads has declined in six and increased in two out of eight cases in terms of coefficients of variation while it has decreased in five and increased in three out of eight cases in terms of standard deviation. These results indicate that price instability is still a concern although real average price levels have increased in most cases.

While some variation in prices, such as intra-seasonal price increases, after the harvest to induce incentives for grain storage for consumption later in the year and variation in prices between regions to provide incentives to private traders to move grain from region to region is necessary, unpredictable price variations such as those caused by bad weather, and variations that are not matched by supply adjustment are undesirable to both producers and consumers.

5.2 Regression results

5.2.1 SUR estimates of the effects of policy reforms on prices

The preliminary analysis of data done above considered the effect of market liberalization on prices of grains and livestock under consideration. Whilst this can give the overview of price movements over time, it is flawed in that it does not control for changes in other factors if we want to isolate the impact of market liberalization on prices. Econometric analysis of the effect of market liberalization on prices attempts to separate theses factors from other developments that may have influenced prices. In this section the results of SUR of equation (5) are presented (Table 3).

In general, the results show clear seasonal patterns. The seasonal pattern is slightly different for maize since irrigated maize is harvested in summer in some areas driving maize prices down in subsequent months, unlike teff prices, which increase in summer and fall starting October. Such patterns are not distinct for coffee and livestock prices.

The effect of grain market liberalization on teff and maize prices is evident in certain markets. As expected, the impact is positive and significant in surplus market, Debre Zeit, for teff prices. It is also positive in Addis Ababa for teff and negative and positive for maize prices in Debreberhan and Addis Ababa, respectively. The positive signs on both maize and teff prices in Addis Ababa may suggest that Addis Ababa is most accessible although it does not produce these crops. All else constant, grain market liberalization has increased teff prices by 6.2% and 3.5% in Addis Ababa and DebreZeit markets, respectively, in the short-run[21]. On the other hand, it has been associated with 5.1% increase in maize prices in both Addis Ababa and Debreberhan Markets. Grain market liberalization has had significant positive impact on sheep prices in North Omo and Sidamo markets and a negative and significant impact on oxen prices in Sidamo. The short-run impact has been to raise sheep prices by 8.3% and 6.2% in North Omo and Sidamo markets, respectively, and to reduce oxen prices by 5.1% in Sidamo.

Fertilizer market liberalization has an expected positive effect on teff prices, increasing teff prices by 11.6%, 10.5% and 4.1% in Addis Ababa, Debre Zeit and Debreberhan Markets, respectively. However, the impact is not significant on maize prices, indicating the fact that fertilizer is used mostly for teff production. The impact is also positive on coffee prices in

[21] These short-run percentage price elasticities were calculated according to the methodology in Kennedy (1981) Halvorsen and Palmquist (1980).

Addis Ababa market, raising prices by 9.4% after controlling for other factors. Fertilizer market liberalization has a positive and significant impact on oxen prices in Addis Ababa, North Omo and Sidamo markets, with 3%, 5.1% and 5.1 % price increases, respectively.

Prices of teff and maize have declined after currency devaluation. Accordingly, prices of teff have declined by 7.7% in both Addis Ababa and Debre Zeit markets after devaluation. It has also been associated with 10.4%, 10.4% and 7.7% maize prices decreases in Addis Ababa, Debre Zeit and North Omo markets. However, it has no significant impact on coffee and livestock prices. This result is surprising because we expected that this would raise coffee prices to the producers. This result shows that the benefit of currency devaluation did not go to producers in terms of local prices and that the price increases has only benefited exporters. Under efficient market border prices of exportable commodities should differ with the local markets only by transfer costs (e.g. Barrett, 1999).

While the international coffee prices have generally decreased after the currency devaluation (Table A1 and Table A2), the price for the Ethiopian coffee in Birr should have still increased given that Birr was devaluated by 144.9%[22] and that the decrease in international coffee price was on average less than 10% in nominal terms (from an average of 117.49 US cents to 111.04 US cents per pound) and slightly more than 100% in real terms (from an average of 209.91 US cents to 103.43 US cents per pound. On the other hand, there is no reason to believe that transfer costs for export market have increased more than the local costs to transport coffee within the local markets, leaving the inefficiency in the market as the only possible explanation for the high disparity between domestic and border prices. The dummy variable for drought is associated with increased maize and teff prices as expected. The coefficient on drought dummy is negative on livestock and coffee prices but all are insignificant at 10% or lower significance levels. The impact of a year to year variation in fertilizer prices is insignificant on both teff and maize prices but is negative and significant on Addis Ababa and Debre Zeit coffee prices, resulting in short-run elasticities of 0.26% and 0.16%.

Given the complex relationship between livestock and crops in a mixed crop-livestock farming system like Ethiopia, one may wonder whether there exists direct dynamic

[22] The exchange rate has been rising since the devaluation and as of January 2007 it stands at 1USD=Birr 8.839

relationship between grain and livestock prices. To answer this question, we have estimated a VAR model taking white teff and oxen prices in Addis Ababa as an example to see if there exists any direct dynamic relationship between these price series other than being affected by the same policies at the same time.

We estimated the model as a system of seemingly unrelated regression (SURE), using two lags for each price series based on Akaike's Information Criterion, AIC (Akaike, 1973, 1974). Sample results are presented in Table 4[23]. The results show that there is no significant relationship between the two prices series. Other results are similar to the previous regressions for these prices.

6. Summaries and Conclusion

In addition to problems related to infrastructure and lack of information on market activities, which are inherent in developing economies, interventions in markets by governments have been major bottlenecks to agricultural activities. Removing these bottlenecks and further facilitating the free operation of markets can reduce marketing costs and represents a major opportunity to increase agricultural market efficiency, improve farm production incentives and household food security. The Ethiopian market liberalization measures have had mixed effects on prices. In general grain market liberalization has increased teff prices in one deficit market and one surplus market while it increased maize prices in one deficit market and reduced it in another. It also increased sheep prices in one market and reduced oxen prices in one market. While a rise in grain prices brings additional revenue to producers, grain prices in deficit regions have not responded in conformity with predictions of market reform advocates. Moreover, price volatility, measured by the coefficient of variation for real price levels and price spreads between pairs of markets, remains an important issue, since it has increased in some cases since the reform. This could be a result of high marketing costs owing to poor infrastructure. In addition, frequent droughts and erratic rainfall may contribute to the instability of prices. Income stability is an important factor affecting farmers' decision-making process, for example, through reducing the incentives to invest in productive inputs such as fertilizer and high yielding varieties. In addition, instability in grain market margins discourages private grain traders**,** which reduces market efficiency.

[23] We run all the regressions between Addis Ababa and regional markets for all commodities but none showed any significant relationship between the prices. Other regression results were omitted to save space.

It has also been shown that fertilizer market liberalization, which increased fertilizer prices, has raised teff, coffee, sheep, and oxen prices. While the possible impact of this policy on crop prices is through reducing the use of the inputs thereby by reducing production, the mechanism through which it affected livestock prices is not clear, as there are complex relationships between the two groups. If the impact on grain prices is through depressing production, the measure is far from achieving its objectives, which is freeing markets so as to make them competitive to raise efficiency. In order for this measure to achieve its objectives, removal of other market barriers, which reduce market efficiency, should be considered alongside the current reforms. These may include policies that enhance development of infrastructure, provision of information and credit facilities (de Janvry et al, 1991; Stiglitz, 1989). Currency devaluation is associated with decreases in teff and maize prices while, surprisingly, it has no significant impact on coffee prices. This means that producers are not beneficiaries of the increased coffee prices on the world market in terms of local currencies. To encourage production of exportable crops, ways of raising prices received by producers should be devised, for example, through increasing the bargaining power of coffee producers' associations.

In general, the results of this analysis suggest that these reforms need to be followed by other measures to improve the marketing system in general. These measures may include the improvement of market infrastructure, transportation and market information to reduce marketing costs.

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Table 1. Descriptive statistics of real grain and livestock prices for different markets in Ethiopia

Markets	Before liberalization (1983:01 to 1990:03)			After liberalization (1990:04 to 2005:02)			Change		
	Mean	St.de	CV (%)	mean	St.dev	CV (%)	Mean	St.dev	CV (%)
Teff									
Surplus areas									
Debre Zeit	1.79	0.29	16.20	2.05	0.41	20.00	0.26	0.12	3.8
Deficit areas									
Addis Ababa	1.79	0.30	16.76	2.28	0.44	19.30	0.49	0.15	2.99
North Omo	1.47	0.39	26.39	1.58	0.30	18.98	0,11	-0.09	-7.41
DebreBerhan	1.71	0.33	19.01	1.89	0.33	17.46	0.18	0	-1.55
Maize									
Surplus areas									
North Omo	0.79	0.24	30.68	0.81	0.22	27.16	0.02	-0.02	-3.52
Sidamo	0.82	0.15	18.29	0.84	0.19	22.57	0.02	0.04	4.28
Deficit areas									
Addis Ababa	1.02	0.29	28.82	0.98	0.32	32.65	-0.04	0.03	3.83
Debre Zeit	0.95	0.30	31.79	0.88	0.25	28.41	-0.07	-0.05	-3.38
DebreBerhan	1.14	0.36	31.57	0.93	0.16	17.20	-0.21	-0.2	-14.37
Coffee									
Surplus areas									
North Omo	1.9	1.73	91.05	6.66	2.57	38.59	4.76	0.84	-52.46
Sidamo	2.66	2.61	98.12	7.24	2.17	29.97	4.58	-0.44	-68.15
Deficit areas									
Addis Ababa	6.27	6.71	107.02	8.31	3.39	40.79	8.31	-3.32	-66.23
Debre Zeit	4.62	4.55	98.48	8.85	2.77	31.3	8.85	-1.78	-67.18
DebreBerhan	5.27	5.43	103.03	9.29	3.19	34.34	9.29	-2.24	-68.69
Oxen									
Addis Ababa	814.4	158.32	19.44	902.25	164.7	18.25	87.84	6.38	-1.19
Debre Zeit	896.74	131.8	14.69	808.18	122.36	10.87	-88.56	-9.41	-3.82
DebreBerhan	860.8	210.5	24.46	843.8	162.4	19.27	-17.03	-48.13	-5.19
North Omo	556.8	198.9	35.72	522.72	95.72	18.31	-34.14	-103.21	-17.41
Sidamo	714.8	145.9	20.41	577.07	131.79	22.84	-137.76	-14.08	2.43
Sheep									
Addis Ababa	53.02	11.92	22.48	74.32	24.62	33.13	21.3	12.7	10.65
Debre Zeit	54.52	14.97	27.46	67.16	19.12	28.47	12.64	4.15	1.01
DebreBerhan	51.06	10.34	20.25	59.85	14.16	23.66	8.79	3.82	3.41
North Omo	36.21	7.63	21.07	49.18	9.18	18.67	12.97	1.55	-2.4
Sidamo	44.74	10.34	23.11	62.00	17.09	27.56	17.26	6.75	4.45

Table 2. Summary statistics of monthly real grain and livestock price spreads between different markets.

Markets	Before liberalization (1983:01 to 1990:03)			After liberalization (1990:04 to 2005:02)			Change		
	Mean	St.dev	CV(%)	mean	St.dev	CV (%)	Mean	St.dev	CV (%)
Teff									
Addis Ababa-DebreZeit	0.004	0.06	1500.0	0.22	0.27	122.73	0.22	0.21	-1377.00
Addis Ababa-North Omo	0.32	0.35	109.38	0.70	0.52	74.3	0.38	0.17	-35.08
Addis Ababa-Debre Berhan	0.08	0.2	250.00	0.38	0.35	92.11	0.3	0.15	-157.9
North Omo-DebreZeit	-0.32	0.35	-109.38	-0.47	0.45	-95.74	-0.15	0.1	13.64
Debre Berhan-DebreZeit	0.08	0.2	250.0	-0.16	-0.31	100.94	-0.24	-0.51	-149.1
Maize									
Addis Ababa-DebreZeit	0.06	0.14	233.33	0.10	0.23	200.30	0.04	0.09	-33.03
Addis Ababa-North Omo	0.23	0.22	95.65	0.17	0.27	221.43	-0.06	0.05	125.78
Addis Ababa-Sidamo	0.20	0.20	100.0	0.14	0.31	221.43	-0.06	0.11	121.43
Addis Ababa-Debre Berhan	-0.12	0.38	316.67	0.04	0.40	1000.00	0.16	0.02	683.33
Debre Zeit-North omo	0.16	0.24	150.00	0.08	0.65	812.50	-0.08	0.41	662.5
Debre Berhan-North omo	0.35	0.41	177.14	0.12	0.73	608.33	-0.23	0.32	431.19
Debre Zeit-Sidamo	0.14	0.23	164.3	0.08	0.25	312.50	-0.06	0.02	148.2
Debre Berhan-Sidamo	0.32	0.38	118.75	0.13	0.29	223.10	-0.19	-0.09	104.35
coffee									
Addis Ababa-DebreZeit	1.65	3.58	216.97	-0.53	2.65	500.00	-2.18	-0.93	283.03
Addis Ababa-North Omo	4.36	5.33	122.25	1.54	2.73	177.27	-2.82	-2.6	55.02
Addis Ababa-Sidamo	3.61	4.67	129.36	0.93	2.57	276.34	-2.68	-2.1	146.98
Addis Ababa-Debre Berhan	99.00	2.62	2.65	-1.04	3.83	368.27	-100.04	1.21	365.62
Debre Berhan-North omo	3.37	4.07	120.77	1.60	4.51	281.88	-1.77	0.44	161.11
Debre Zeit-Sidamo	1.96	2.50	127.55	1.31	2.34	178.63	-0.65	-0.16	51.08
Debre Berhan-Sidamo	2.61	3.45	132.18	1.09	4.34	398.17	-1.52	0.89	265.99
Oxen									
Addis Ababa-DebreZeit	-82.33	118.69	-144.16	44.07	164.68	175.06	126.4	45.99	319.22
Addis Ababa-North Omo	258.55	222.24	85.96	379.53	137.19	36.15	120.98	-85.05	-49.81
Addis Ababa-Sidamo	99.58	163.04	163.78	325.19	141.14	43.40	225.61	-21.9	-120.38
Addis Ababa-Debre Berhan	46.23	77.94	168.59	59.45	175.84	295.78	13.22	97.9	127.19
Debre Zeit-North omo	339.88	201.45	59.27	285.46	126.51	44.32	-54.42	-74.94	-14.95
Debre Berhan-North omo	303.97	241.66	79.50	320.08	152.36	47.60	16.11	-89.3	-31.9
Debre Zeit-Sidamo	181.91	153.75	84.52	231.12	158.72	68.67	49.21	4.97	-15.85
Debre Berhan-Sidamo	146.01	194.72	133.36	265.74	162.41	61.12	119.73	-32.31	-72.24

Table 2 (continued)

Sheep	Mean	St.dev.	CV (%)	mean	St.dev	CV(%)	Mean	St. dev	CV (%)
Addis Ababa-DebreZeit	-1.5	6.4	-426.67	7.16	20.13	281.01	8.66	13.73	707.68
Addis Ababa-North Omo	16.81	7.41	44.08	25.14	24.03	95.58	8.33	16.62	51.5
Addis Ababa-Sidamo	8.29	5.86	706.88	12.32	21.92	177.92	4.03	16.06	-528.96
Addis Ababa-Debre Berhan	1.97	5.63	285.79	14.47	20.8	14.75	12.5	15.17	-271.04
North Omo-DebreBerhan	-14.85	6.50	-43.77	-10.67	14.29	-133.93	4.18	7.79	-90.16
Sidamo-DebreBerhan	6.32	6.4	101.27	-2.15	12.3	572.09	-8.47	5.9	470.82
North Omo-Debrezeit	-83.31	10.18	55.60	-17.97	18.73	-104.23	65.34	8.55	-159.83

Table 3. SUR estimates of real Price equations for teff. Maize, coffee, oxen and sheep (1983:01 to 20005:02)

	Markets				
	Addis Ababa	DebreZeit	North Omo	Sidamo	DebreBerhan
Teff					
Pt-1	.48[a]	.53[a]	.54[a]		.50[a]
Pt-2	.14[b]	.15[b]	.13[c]		.06
Pt-3	.08	.09[c]	.04		.23[a]
fertprice	.003	-.01	-.08		.02
Jan	.02	-.02	.03		-.07[b]
Feb.	-.003	.02	.02		-.03
March	-.01	.01	.05		-.02
Apr.	.002	.01	-.001		-.06[c]
May	.01	.03	.01		-.02
June	.04	.05[b]	.06		-.01
July	.05[c]	.05[c]	.11[a]		.03
August	-.0003	.01	.04		-.01
Sept.	.04	.06[b]	.04		-.03
Oct.	.03	-.02	-.04		-.06[c]
Nov.	-.02	-.03	-.09[b]		-.06[b]
Fertlibt	.11[a]	.10[a]	.03		.04[c]
Grainlibt	.06 [a]	.03[c]	.01		.03
forex	-.08 [a]	-.08[a]	.02		-.04[c]
drought	.04 [b]	.04[b]	.06[b]		.02
Constant	.15 [a]	.12[a]	.10[b]		.13[a]
R2	0.79	0.82	0.58		0.67
Maize					
Pt-1	.81[a]	.59[a]	.69[a]	.50[a]	.94[a]
Pt-2	-.05	.02	.09	.18[b]	.05
Pt-3	.04	.21[a]	-.05	-.06	-.09
fertprice	.05	.02	.04	.04	-.07
Jan	-.003	.02	.03	.04	-.04
Feb.	.04	.05	.05	-.03	-.06[c]
March	.03	.04	.05	.05	-.04
Apr.	-.01	.03	.05	.03	-.07[b]
May	.03	.11[b]	.02	.06	-.03
June	.06	.05	.04	.09[c]	-.04
July	.05	.05	.05	.06	-.03
August	-.05	-.04	-.13[b]	-.04	-.07[b]
Sept.	-.03	-.10[b]	-.13[b]	-.04	-.02
Oct.	-.002	-.01	-.07	.05	-.04
Nov.	-.05	.02	.01	-.06	-.06[c]
Fertlibt	.01	.03	-.002	-.01	.02
Grainlibt	.05[c]	.04	.05	.03	-.05[b]
forex	-.11[a]	-.11[a]	-.08[b]	-.05	.03
drought	.04[c]	.06[c]	.03	.07[b]	.03
Constant	-.03	-.05	-.09[c]	-.13[b]	.08[b]
R^2	0.80	0.73	0.71	0.49	0.87
Coffee					
Pt-1	.91[a]	.84[a]	.78[a]	.77[a]	.92[a]
Pt-2	.06	.08	.08	.16 [b]	.06
Pt-3	-.14[b]	-.09	-.003	-.19 [b]	-.11
Pt-4	.13 [b]	.10[b]	.06	.18[a]	.08
fertprice	-.26[a]	-.16[c]	-.10	-.09	-.10
Jan	.09	.13 [b]	.06	.01	-.01
Feb.	.09	.10	.12	.05	.12
March	.07	.11[c]	.05	-.03	-.16[c]
Apr.	.04	.04	.01	-.04	-.01
May	.0002	.02	-.01	-.06	-.14
June	.01	.03	-.03	.01	.07
July	-.05	.02	-.12	-.15[b]	.05
August	.06	.10[c]	.03	.003	.05
Sept.	.10[c]	.09	-.04	-.02	.06
Oct.	.04	.08	.02	-.16[b]	.00
Nov.	.06	.08	-.06	-.09	.04
Fertlibt	.09[c]	.07	.03	.04	-.02
Grainlibt	-.05	.06	.08	.06	-.001
forex	.06	.004	.04	.03	.05
drought	-.02	-.03	-.04	-.04	-.08
Constant	.15[b]	.09	.09	.15[b]	.13
R2	0.96[a]	0.96[a]	0.95[a]	0.95[a]	0.92[a]

Table 3. (Continued)

	Addis Ababa	DebreZeit	North Omo	Sidamo	DebreBerhan
Sheep					
Pt-1	.81[a]	.56[a]	.44[a]	.56[a]	.61[a]
Pt-2	.06	.25[a]	.22[a]	.26[a]	.14[b]
Jan	.04	-.03	.06	-.03	-.05
Feb.	-.01	-.02	.07[c]	-.09[b]	-.11[a]
March	.02	-.04	.02	-.05	-.05
Apr.	-.001	.002	.03	-.04	-.03
May	-.04	-.10[b]	.02	-.12[a]	-.20[a]
June	-.004	-.06	.01	-.07[c]	-.10[b]
July	.01	-.04	-.03	-.12[a]	-.09[b]
August	-.03	-.04	.01	-.11[a]	-.10[b]
Sept.	-.01	-.04	.04	-.07[c]	-.08[b]
Oct.	-.03	-.04	.04	-.06[c]	-.09[b]
Nov.	.02	-.05	.03	-.05	-.06
Fertlibt	.04[c]	.04	-.03	.03	.03
Grainlibt	.01	.03	.08[a]	.06[b]	.04
forex	.01	-.02	.05	-.02	-.01
drought	-.02	-.01	.02	-.02	-.01
Constant	.52[a]	.74[a]	1.16[a]	.76[a]	1.07[a]
R2	0.89[a]	0.81[a]	0.67[a]	0.81[a]	0.67[a]
Oxen					
Pt-1	.96[a]	.66[a]	.38[a]	.44[a]	.75[a]
Pt-2	-.27[a]	-.04	.15[b]	.06	-.26[a]
Pt-3	.18[c]	-.05	.02	.06	.20[b]
Pt-4	-.01	.14[b]	.13[b]	.31[a]	.05
Jan	-.02	-.03	-.01	.003	-.02
Feb.	-.04	-.03	.0003	-.04	-.05
March	-.02	-.04	-.03	-.02	-.01
Apr.	-.03	-.03	-.002	-.003	-.04
May	-.07[a]	-.003	.02	-.03	-.01
June	-.01	-.02	-.06	-.05	-.05
July	-.04	-.11[a]	-.03	-.03	-.07[c]
August	-.06[b]	-.05	-.05	-.02	-.05
Sept.	-.05[c]	-.06[b]	.002	.03	-.05
Oct.	-.04	-.07[b]	-.05	.07[c]	-.06
Nov.	-.03	-.04	-.04	.01	-.06
Fertlibt	.03[c]	-.001	.05[c]	.05[b]	.01
Grainlibt	.01	-.02	-.03	-.05[c]	.01
Forex	-.02	-.04	-.03	-.02	-.04
drought	-.003	-.002	-.02	-.01	-.01
constant	1.06[a]	2.00[a]	2.08[a]	.85[b]	1.77[a]
R2	0.79[a]	0.65[a]	0.40[a]	0.75[a]	0.64[a]

Table 4. VAR regression results for the relationship between oxen and teff prices

variable	Commodity (Market)	
	Teff (Addis Ababa)	Oxen (Addis Ababa)
$P_{tefft-1}$	.52[a]	.05
$P_{tefft-2}$	.15[b]	.002
$P_{oxent-1}$	-.004	.99[a]
$P_{oxent-2}$	.04	-.15[b]
fertprice	.01	-
Jan	.03	-.02
Feb.	-.02	-.04
March	-.02	-.01
Apr.	.01	-.01
May	-.001	-.07[b]
June	.04	.005
July	.05	-.03
August	.01	-.06[b]
Sept.	.04	-.04
Oct.	.04	-.03
Nov.	.001	-.03
Fertlibt	.12[a]	.01
Grainlibt	.05[b]	.01
forex	-.08[a]	-.01
drought	.01	-.01
Constant	-.04	1.07[a]
R2	0.78[a]	0.79[a]

Appendix 1. International coffee prices

Table A1. Nominal monthly averages of ICO Indicator prices in US cents per lb for mild Arabica coffee*

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1983	129.96	126.93	125.04	124.76	128.47	127.33	128.34	129.54	132.31	140.73	144.56	146.66
1984	143.71	145.91	148.32	150.21	150.25	147.3	144.11	145.7	142.23	136.87	140.21	140.8
1985	145.39	144.08	141.88	141.47	142.69	141.89	135.07	133.48	133.48	140.51	155.65	196.96
1986	237.87	228.19	239.6	226.04	211.34	177.08	172.31	173.86	199.5	177.59	156.69	136.23
1987	123.53	120.96	103.77	107.55	117.3	105.12	99.9	102.19	110.52	119.38	126.34	126.88
1988	128.02	138.54	136.55	136.42	138.65	143.93	141.97	132.57	137.85	133.73	135.39	147.63
1989	152.13	139.95	140.31	143.88	140.37	125.32	88.09	78.51	78.42	68.65	70.87	72.47
1990	76.02	83.95	94.73	94.71	92.97	89.15	86.65	94.43	95.39	91.58	84.72	89.18
1991	85.93	89.21	93.56	91.96	87.88	85.78	83.24	81.77	87.06	79.77	78.2	75.35
1992	73.41	68.45	70.37	65.92	60.86	59.09	58.2	52.93	53.23	61.57	67.31	77.19
1993	69.39	67.65	63.62	57.87	62.18	62.5	71.81	76.92	80.77	76.64	78.6	81.19
1994	78.95	83.93	87.06	90.57	121.88	143.43	218.89	200.44	222	201.85	182.91	168.54
1995	172.62	169.79	179.43	174.4	171.01	154.49	145.66	153.21	134.46	127.27	125.25	106.24
1996	110.65	124.09	120.84	123.5	129.27	125.46	122.47	126.22	118.7	124.2	124.07	117.02
1997	132.86	168.37	194.7	206.99	267.27	222.02	190.41	190.8	189.87	167.66	160.27	177.44
1998	177.8	178.18	157.65	150.35	137.72	124.93	117.6	123.21	111.85	109.72	116.37	117.39
1999	112.96	105.48	105.39	102.11	111.07	107.21	94.85	91.37	84.31	94.2	113.38	124.46
2000	111.11	103.44	100.73	94.61	94.15	86.44	87.35	76.92	75.78	76.66	71.54	66.16
2001	65.98	67.19	66.5	66.13	69.22	63.9	58.72	59.72	58.07	56.4	58.85	56.72
2002	58.25	59.12	64.47	65.29	61.4	58.57	56.48	54.27	60.67	65.73	69.87	64.16
2003	65.57	66.41	61.75	64.69	66.26	61.04	62.95	63.89	66.41	64.3	62.28	64.86
2004	72.73	76.21	78.06	75.44	76.99	82.21	74.94	73.61	80.47	80.55	90.27	104.12
2005	107.16	120.86										

* Average nominal price for pre-liberalization period (Jan 1983-Oct. 1993) is 117.49 US cents while average nominal price for postliberalization is 111.04 US cents
Source: International Coffee Organization (ICO)

Table A2. Real monthly averages of ICO Indicator mild Arabica coffee prices in US cents per lb*

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1983	297.80	290.92	288.97	277.85	283.37	290.00	298.18	305.95	364.10	334.42	338.19	347.52
1984	338.68	349.64	345.57	314.75	307.18	300.98	310.30	306.25	270.21	255.11	262.92	270.43
1985	233.03	219.24	189.38	188.30	178.62	166.65	143.42	138.72	152.60	164.29	209.72	326.65
1986	451.28	419.13	438.01	423.57	399.06	341.38	353.75	343.04	388.68	369.27	324.32	292.23
1987	255.54	247.16	213.20	214.74	247.61	225.54	213.88	206.51	231.05	245.60	272.31	266.64
1988	265.18	290.02	282.85	267.56	263.09	283.57	266.40	243.91	249.52	244.72	254.23	280.57
1989	289.93	262.30	259.92	258.24	257.87	224.33	158.24	138.39	143.07	123.38	127.58	129.83
1990	134.31	150.45	175.30	169.68	159.88	151.65	149.84	160.36	159.57	152.16	142.24	144.78
1991	130.52	125.60	116.91	110.76	103.15	94.59	96.30	94.68	102.88	96.41	90.44	91.09
1992	90.33	79.00	80.57	70.57	67.39	63.78	62.73	55.23	55.17	63.68	70.43	82.96
1993	74.88	73.28	68.75	58.00	65.64	66.32	76.48	83.43	86.94	81.44	88.10	91.15
1994	86.46	89.57	91.57	88.49	116.61	142.94	213.27	187.12	204.09	186.26	167.56	155.42
1995	162.38	150.52	153.59	142.72	138.87	127.74	123.04	128.82	114.71	116.37	115.39	97.17
1996	101.12	116.37	112.19	115.58	123.83	121.94	123.39	124.09	116.58	114.06	113.50	100.83
1997	128.86	163.47	192.84	202.44	253.69	206.95	170.02	167.80	176.81	163.80	160.79	177.25
1998	173.71	169.30	144.08	139.17	118.12	116.45	105.01	108.36	104.16	107.20	116.74	117.26
1999	112.96	101.16	100.12	94.25	102.42	98.41	86.59	83.65	74.21	82.63	109.15	124.83
2000	120.57	111.29	113.72	110.52	110.63	103.38	79.19	69.93	70.62	72.80	70.76	68.56
2001	71.10	72.87	72.52	74.64	77.60	70.30	62.40	62.80	62.37	60.52	62.81	60.66
2002	57.39	57.51	62.17	60.73	56.85	53.34	59.77	56.95	62.16	66.87	71.30	65.54
2003	62.69	63.07	57.18	58.49	59.64	53.54	56.11	57.51	58.67	56.95	56.41	61.07
2004	63.85	67.32	68.06	63.99	64.92	67.06	65.68	62.22	68.95	69.14	77.35	91.74
2005	83.13	91.42										

* Average real price for pre-liberalization period (Jan 1983-Oct. 1993) is 209.91 US cents while average real price for post-liberalization is 103.43 US cents
Source: International Coffee Organization (ICO)

Appendix 2. Commodity price trends in real terms (2000=100)

Fig. A1. White teff price trends in real terms (price per kilogram)

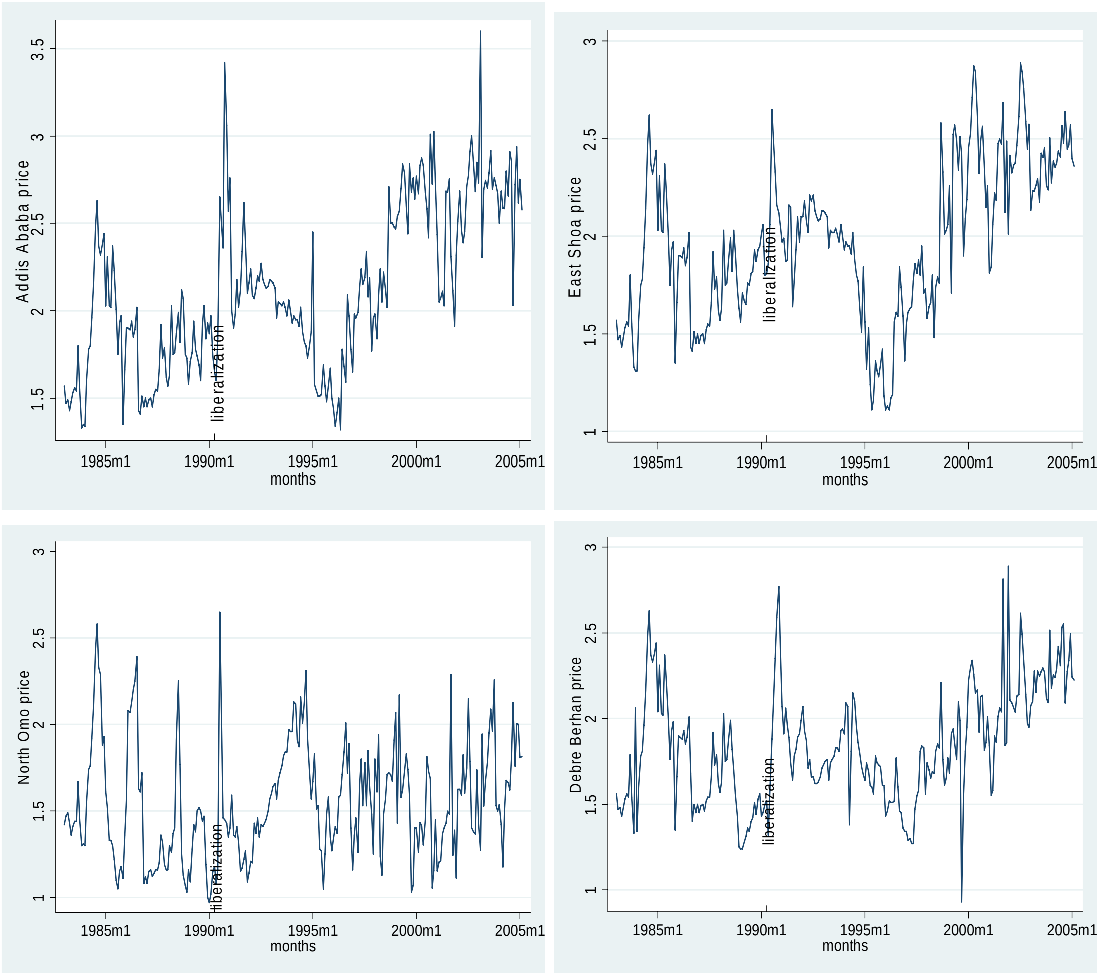


Figure A2. Maize price trends in real terms (price per kilogram)

Figure A3. Coffee price trends in real terms (price per kilogram)

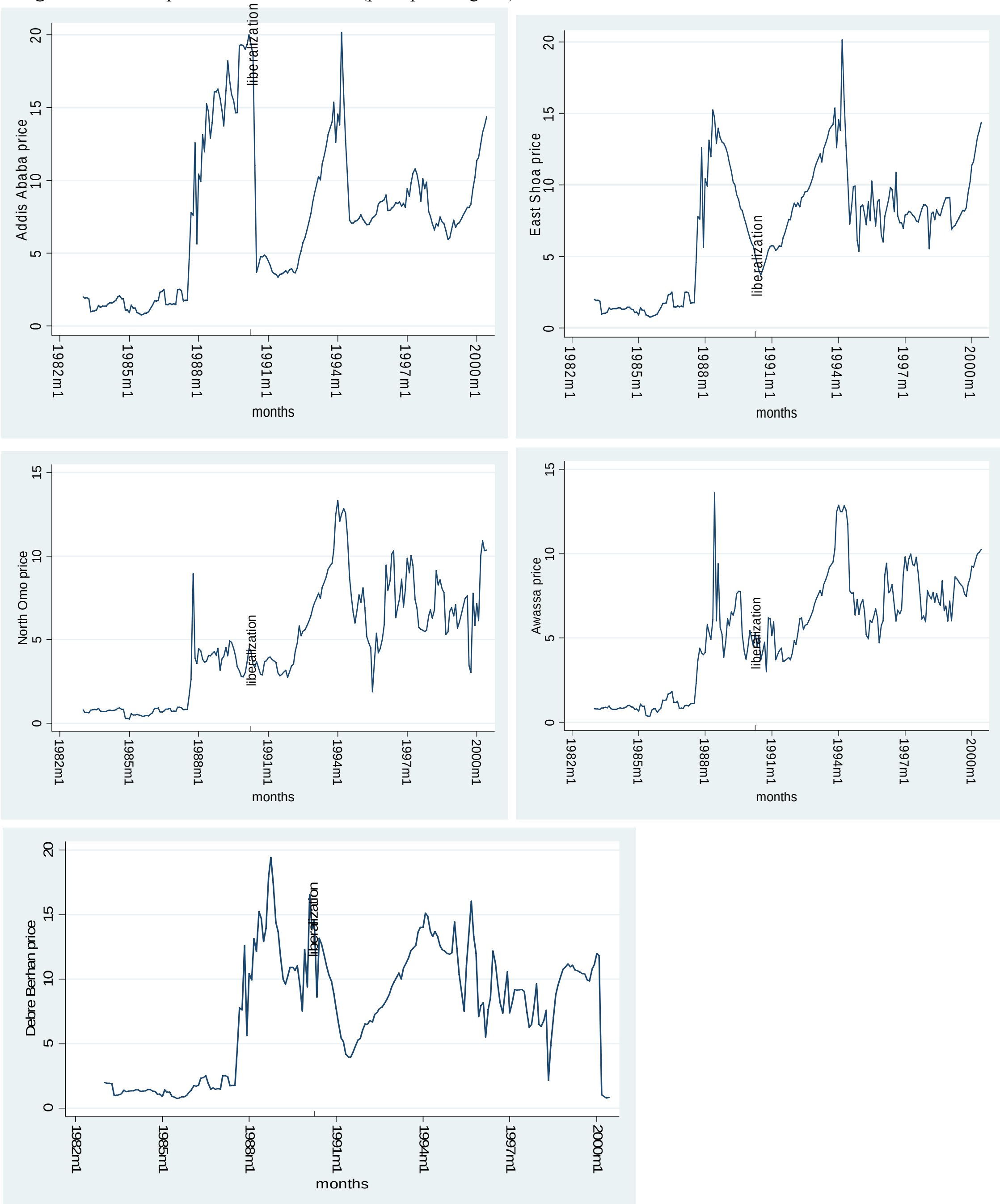


Figure A4. Sheep price trends in real terms (price per head)

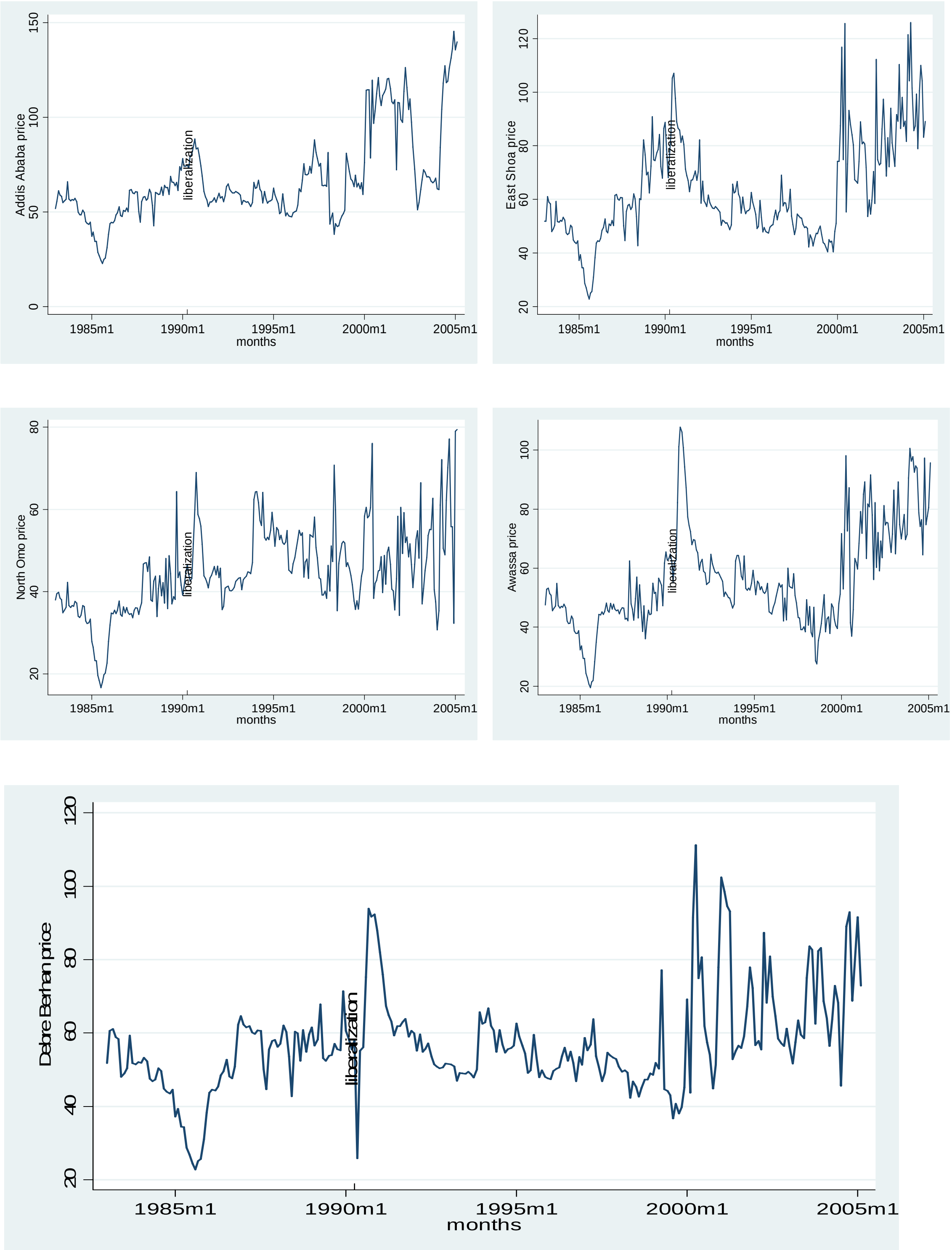
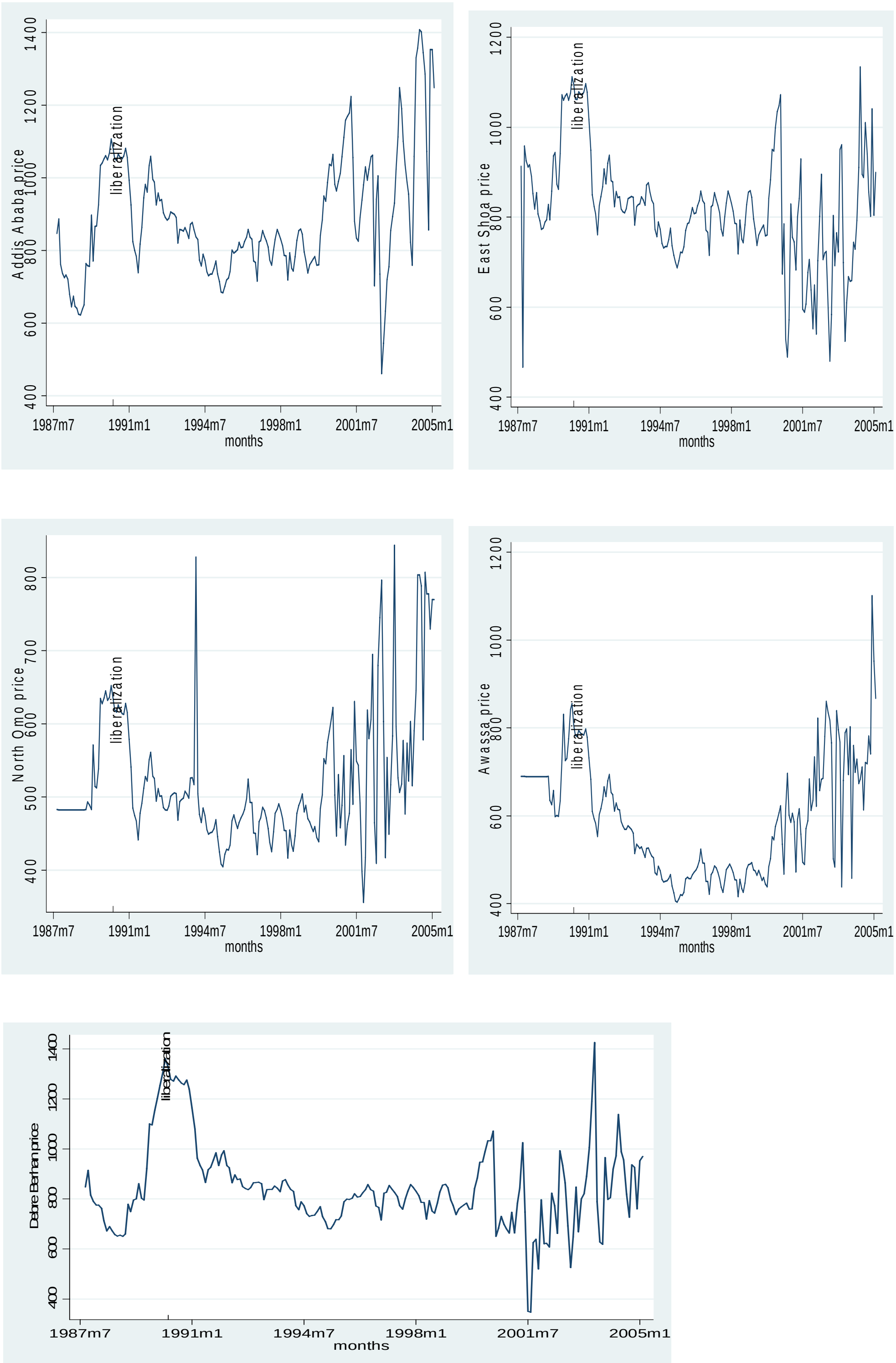


Figure A5. Oxen price trends in real terms (price per head)



Adane Tuffa Debela

Adane Tuffa Debela was born in Selale, Ethiopia, in 1967. He holds a BSc. Degree in Agricultural Economics from Haromaya University (1990), a MSc. Degree in Development Economics from the Norwegian University of Life Sciences, Norway (2001) and a post-graduate certificate in Agricultural and Resource Economics from the University of California at Davis, USA (2002). The thesis consists of an introduction and four independent papers. The papers aim at investigating agricultural productivity and factors that affect the performance of agriculture and food security directly or indirectly. Paper I analyses the impacts of economic policies on the productivity and efficency of crop production Results suggest that inefficiency increased after the introduction of policies while technical progress stagnated. As a result, total factor productivity declined during the same period. Paper II deals with fators influencing soil fertility management practices, the use of animal manure and chemical fertilizer, in the highlands of Ethiopia. Results indicate that adoption of chemical fertilizer is positively influenced by animal manure and farm and household characteristics. The results further indicate that adoption of manure and the intensity of use of chemical fertilizer are influenced by farm and household characteristics. Paper III concerns the impacts of perennial cash crops on food crop production and productivity in southern Ethiopia. The food crops are divided into enset and other food crops. Results show that more intensive chat production is associated with lower production and productivity of other food crops while more coffee production is associated with more intensive production of enset. On the other hand, more intensive sugarcane production is associated with reduced production and productivity of other food crops. However, production of coffee has no significant impact on food crops. Paper IV concerns the impact of market liberalizations on prices of crops and livestock. Results suggest that market liberalizations have mixed impacts on prices of grain, cash crop and livestock. Prices have increased in some markets and decreased in others both for crops and livestock. Moreover, grain market liberalization has increased price volatility in price levels and price spreads overall.

Associate Professor Ragnar Øygard was Adane's supervisor

E-mail:adtufdeb@hotmail.com

Department of Economics and Resource Management
Norwegian University of Life Sciences
PO Box 5003
N-1432 Ås,
Norway

Telephone: +47 6496 5700
Telefax: +47 6496 5701
e-mail: *ior@umb.no*
http:/www.umb.no/ior

ISSN: 1503-1667
ISBN: 978-82-575-0760-2