Importance of Irrigated Agriculture to the Ethiopian Economy: Capturing the direct net benefits of irrigation

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Abstract

This study is an attempt to quantify the actual and expected contribution of irrigation to the Ethiopian economy for 2005/06 and 2009/10 cropping seasons using adjusted net gross margin analysis. After obtaining adjusted gross margin values for rain-fed and irrigation systems under different typologies, irrigation's contribution was calculated to be about 5.7 and 2.5 percent to agricultural and overall GDP during the 2005/06 cropping season. By the year 2009/2010, irrigation's contribution to agricultural and overall GDP is estimated to grow to about 9 and 3.7 percent, respectively. After relaxing some of the underlying assumptions, the future contribution of irrigation to agricultural GDP will rise to about 12 percent while the contribution to overall GDP will be about 4 percent. Recommendations for enhancing irrigation's contribution and policy implications for cost recovery and sustainability of irrigation investment are drawn.

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Introduction

Heavy reliance on rain-fed agriculture, in conditions of very variable rainfall and recurrent droughts, adversely affects agriculture and hence the economy of Ethiopia. In fact, the World Bank (2006) estimated that hydrological variability currently costs the economy over one-third of its growth potential and has led to a 25% increase in poverty rate. Enhancing public and private investment in irrigation development has been identified as one of the core strategies to de-link economic performance from rainfall and to enable sustainable growth and development (World Bank, 2006; MoWR, 2002; MoFED, 2006). In government policy documents, irrigation development has already been identified as an important tool to stimulate sustainable economic growth and rural development and is considered as a cornerstone of food security and poverty reduction (MoWR, 2002; MoFED, 2006). This policy has led to concerted efforts to expand irrigation development in the country during the last decade or so, especially since 2005/06.

Ethiopia has an estimated irrigation potential of 3.5 million hectares (Seleshi *et al.*, 2007). By 2005/2006 the total estimated area of irrigated agriculture in the country was 625,819 ha, which in total constitutes about 18 percent of the potential (MoWR, 2006). It is planned to expand irrigation development in the country by an additional 528,686 ha by the year 2010 (Atnafu, 2007; MoWR, 2006; MoFED, 2006), which will constitute about 33 percent of the potential.

Not withstanding these developments, there has been little systematic analysis to estimate the aggregate benefits[i] of irrigation development. This study aims to partly fill this gap by quantifying the current and future direct benefits of irrigation to the national economy. It also addresses the issue of the economic viability of irrigation investments. Studies of this kind, in comparing the actual and expected direct benefits of irrigation with the actual and expected costs of irrigation expansion, can guide policy makers in irrigation development.

Irrigation contributes to the national economy in several ways. At the micro level, irrigation leads to an increase in yield per hectare and subsequent increases in income, consumption and food security (Bhattarai and Pandy, 1997; Vaidyanathan *et al.*, 1994; Ahmed and Sampath, 1992; Lipton *et al.*, 2003; Hussain and Hanjra, 2004). Irrigation enables smallholders to diversify cropping patterns, and to switch from low-value subsistence production to high-value market-oriented production (Fitsum *et al.*, 2007). Irrigation can benefit the poor specifically through higher production, higher yields, lower risks of crop failure, and higher and all year round farm and non-farm employment (Hussain and Hanjra, 2004).

Macro level impacts manifest themselves through agricultural impacts on economic growth. At the aggregate level, irrigation investments act as production and supply shifters, as they push the production frontier to higher level and render production possible which otherwise is risky, if not impossible, because of shortage of moisture and thereby have a positive effect on economic growth. Studies in Asia show that agricultural growth served as an "engine" of overall economic growth (Van Koppen *et al.*, 2005; Francks *et al.*,1999), and irrigation-led technological changes were identified as the key drivers behind productivity growth in the agricultural sector (Hussain and Hanjra, 2004; Alagh, 2001; Dhawan, 1988).

Irrigation development, however, does not only has direct and indirect positive impacts on the economy but also generates negative direct and indirect effects (Hanjra, 2007; Bhattarai *et al.,* 2007). Numerous studies have discussed the importance and difficulties of evaluating a number of these impacts (Hanjra, 2007; Bhattarai *et al.,* 2007; WCD, 2000; Bell and Hazel, 1980). For instance, the World Commission on Dams report (WCD, 2000) underlines the need to extend consideration to indirect benefits and costs when assessing impacts of dam projects. Hanjra (2007) and Bhattarai *et al.*, (2007), on the other hand, report that indirect irrigation benefits could be larger than direct benefits through the multiplier effects.

Various methods were proposed to capture the diverse impacts of irrigation on the economy, be they are direct or indirect. The methodological approaches applied included linear programming; regression models; partial equilibrium models; and economy–wide models such as input-output models, Social Accounting Matrices (SAM) and Computable General Equilibrium (CGE) Models. For instance, Bhattarai and Pandy (1997) used a linear programming technique to isolate the impact of irrigation from other factors (such as road and market) on crop production and productivity in Nepal. Vaidynathan *et al*., (1994) used regression analysis at the aggregate level to assess the difference in land productivity between irrigated and unirrigated lands in India. Ahmed and Sampath (1992) used a partial equilibrium model that incorporated demand and supply shifts to assess the impact of irrigation on efficiency and equity in Bangladesh. Makombe (2000) used a similar partial equilibrium model to estimate the impact of irrigation induced technological change in Zimbabwe. Bell and Hazel (1980) used SAM and a semi input-output model to measure the magnitude and incidence of regional downstream effects of the Muda irrigation project in Malaysia. Bhatia *et al*. (2003) used SAM for detailed analysis of multiplier effects of dams in India, Brazil and Egypt. Many of these studies focused on Asia with few studies of Africa. This study is the first of its kind in the region trying to capture the direct contribution of irrigation to the national economy.

In this paper, we focus only on quantifying the direct benefits on the national economy. Quantifying the indirect effects with methods as described above requires more data than are readily available currently. In doing so, we adopt a simple methodological framework that draws on the method of adjusted gross margin analysis which accords with the System of Environmental and Economic Accounts (SEEA) recommendations (UN, 2003) and provides a "best estimate" of the change in GDP generated by irrigation at the farm gate (Doak, 2005). We believe our approach provides the "best" approach in data-limited environments. However, it should be noted that a large number of estimates and assumptions are required to estimate the impact on GDP, and the results should be interpreted with caution. The sensitivity of our results to some of the assumptions is tested in our scenario analyses.

A final note: as the increased output from irrigated farms will have different multiplier effects in the wider economy, the total impact of irrigation on GDP is likely to be higher than the farm gate impact.

We relied on data collected during the 2005/6 season from eight representatives small and medium scale irrigation schemes in four regional states in Ethiopia and secondary data gathered from selected large scale commercial farms in the Awash and Blue Nile basins.

Background

Agriculture is the mainstay of the Ethiopian economy in terms of income, employment and generation of export revenue. Its contribution to GDP, although showing a slight decline over the years, has remained very high, at about 44 percent (see Table 1). From among the sub-sectors of agriculture, crop production is major contributor to GDP accounting for about 28 percent in 2005/06. The most important crops grown and their area are described below.

Table 1: Contribution of agriculture to GDP (1995/96- 2005/06) (in 000 ETB)

Year	GDP at Current Market Prices (in Million ETB)	Agricultural GDP (in Million ETB)	Crop GDP (in Million ETB)	Agriculture contribution to GDP	Crop contribution to GDP
1995/96	53.6	28.6	17.3	0.53	0.32
1996/97	55.5	28.7	16.7	0.52	0.30
1997/98	53.4	25.2	14.5	0.47	0.27
1998/99	57.4	25.4	15.5	0.44	0.27
1999/00	64.4	28.4	17.7	0.44	0.28
2000/01	65.7	27.7	16.3	0.42	0.25
2001/02	63.5	24.4	13.1	0.39	0.21
2002/03	68.9	26.2	14.9	0.38	0.22
2003/04	81.7	32.2	19.9	0.39	0.24
2004/05	98.4	42.2	27.3	0.43	0.28
2005/06	115.6	50.9	32.2	0.44	0.28

Source: FDRE (2006).
Note: 1 US$ was equivalent to 8.67 ETB in 2005/06 prices.

Ethiopia has an estimated irrigation potential of 3.5 million hectares (Seleshi *et al.*, 2007). Irrigation schemes in Ethiopia are classified in three ways: size, technology use and management. First by the size of command area of the scheme, schemes are classified as small (less than 200 ha), medium (200 to 3000 ha) and large-scale (over 3000 ha) schemes (MoWR 2002; Seleshi *et al.,* 2005). The small scale irrigation schemes, in turn, are classified into two major categories, namely, modern schemes and traditional schemes. Modern schemes usually have fixed or improved water control/diversion structures. These schemes are generally constructed by government or NGOs, mostly constructed since the mid eighties. Traditional schemes, on the other hand, are different from the modern schemes because their diversion weirs are usually made from local materials, and are usually reconstructed every year. Many are constructed by local communities and have been functional for relatively longer periods of time, some extending close to a century. Werfring (2004) and Seleshi *et al.*, (2005) describe the typology of small scale irrigation in

Ethiopia, the former in more detail. The differences in the technology used to control and divert water have implications to water availability, water loss and establishment and for operation and maintenance costs.

The third classification is by management system, namely traditional, modern, public and private (Werfring, 2004). The management systems of the two small scale irrigation systems is similar, usually involving local leadership and a water users' association or irrigation cooperatives with the government providing extension support while the medium and large schemes are usually managed by the government (Werfring, 2004). There are studies that, however, show that local water management institutions are stronger in traditional schemes (Alamirew *et al.,* 2007) compared to modern irrigation as a result of which the performance of traditional schemes could be higher. In this paper, we have used a combination of the first three classification systems, without significant consideration of pubic versus private management because we did not have any schemes falling under private ownership and management. Thus, modern medium scale schemes are those in which the size is between 200 and 3000 ha with fixed or improved water control/diversion structures (Table 2).

Table 2: Summary of typologies of irrigation schemes in Ethiopia

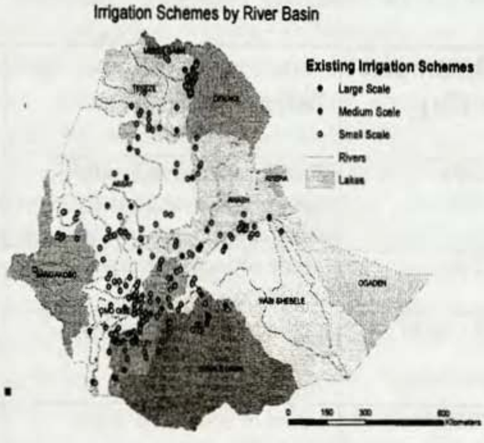
Typology	**Scheme size (in Ha)**	**Infrastructure**	**Water management**
Small scale modern	< 200	Fixed or improved water control & diversion structures	Water users' association or irrigation cooperatives
Small scale traditional	< 200	Made of local materials and not permanent	Local water users association
Medium scale	200 - 3000	Fixed or improved water control & diversion structures	Water users' association/irrigation cooperatives or state
Large scale	> 3000	Fixed or improved water control & diversion structures	Mostly state enterprises

Source: Werfring et al, 2004; Seleshi et al 2007

The total reported area of irrigated agriculture in the country in 2005/2006 was about 625,819 ha, out of which 483,472 is from the traditional irrigation, 56,032 ha is from modern small scale, 86,612 ha is from modern medium and large scale schemes. Out of the total irrigated area, 197,250 ha are covered by the so-called modern schemes while the remaining are traditional schemes (MoWR, 2002). The total and modern irrigated area respectively account for about 18 and 5 percent of the reported potential. The total cultivated land area, rainfed included, in 2005/06 was about 12.28 million hectares (MoFED, 2006). The total current irrigated land area, hence, accounts for about 5 percent of the total cultivated land. When the traditional schemes are not considered, the irrigated land area covers a minimum of about 1.6 percent of the total cultivated area.

There is high spatial variability in water resources endowment and development in the country. Hence, 90% of the country's water resources development hitherto occurred in four river basins (World Bank, 2006). Much of the formal irrigation developments are located in the Awash Basin, where about 50 medium and large scale irrigated farms are located (Fig. 1).

Fig.1: Existing irrigation schemes in various river basins in Ethiopia



Source: Seleshi and colleagues 2007

In terms of regional distribution, Afar and Oromia have the bulk of the share in irrigated agriculture accounting for 45 and 31 percent of the total irrigated area. Amhara, SNNPR and Tigray account for 8, 7 and 5 percent of the total irrigated area, respectively (Seleshi *et al.*, 2007).

From our survey data, we present below the composition of crops under irrigated and rainfed conditions. The dominant crop categories under traditional irrigation system, in terms of the percentage area covered are: cereals (55%), vegetables (11%), fruits (11%), pulses (10%), spices (8%), oil seeds (5%), and others (0%) (Figure 2a).

In the modern irrigation systems, in the order of importance, the dominant crops are: cereals (67%), vegetables (21%), fruits (4%), pulses (3%), spices (0%), oil seeds (0%), and others (5 %) (Figure 2b). Under the rainfed agricultural system the dominant crops are: cereals (78%), pulses (16 %), vegetables (1 %), fruits (1%), oil seeds (1%), spices (0 %), and others (3 %) (Figure 2c).

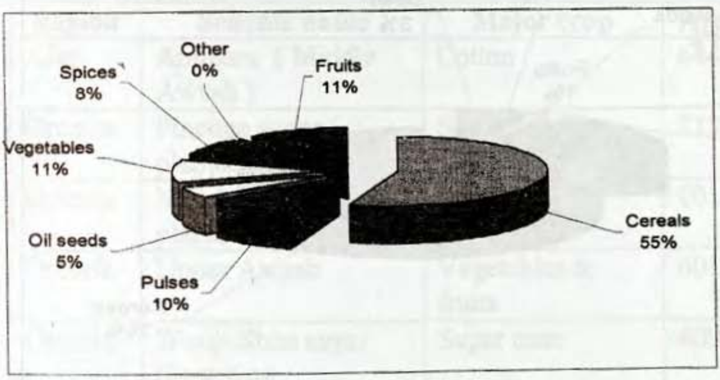


Fig. 2a: Dominant crops under traditional irrigation system (n= 1240)

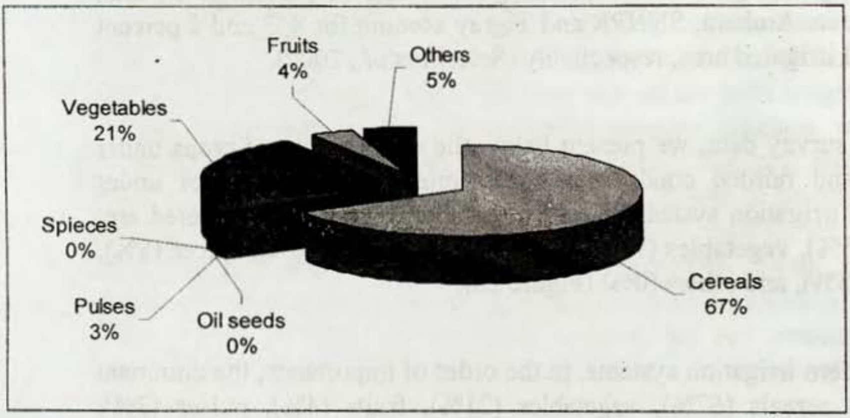


Fig. 2b: Dominant crops under modern rainfed system (n= 1533)

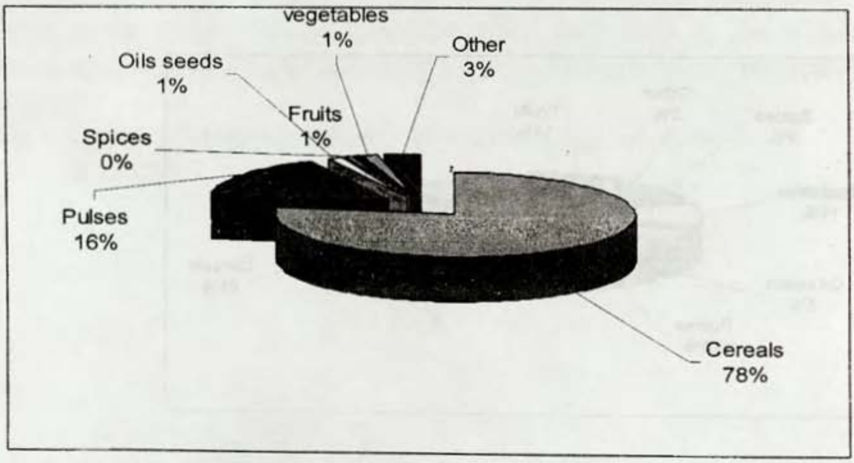


Fig. 2c: Dominant crops under modern irrigation system(n= 2092)

Source : Hagos *et al* (2007)

The figures above show that there is emerging difference in the relative importance of the crop categories under different systems. Cereals and pulses are dominant under rainfed system while vegetables and fruits cover about 2 percent of the land area. While cereals are still remain dominant under the irrigation systems, covering about 61 percent of the land area, vegetables and fruits are becoming important under both traditional and modern systems. There is also noticeable difference in the share of land taken by vegetables and fruits between the modern and traditional irrigation systems. Vegetables take more land area under the modern systems compared to that of traditional systems while more land area is covered with fruit trees under the traditional system likely reflecting the longer time since establishment of traditional schemes.

Medium and large-scale irrigation schemes, on the other hand, grow mainly sugar cane, cotton and fruits and vegetables. Wonji/Shoa, Metehara and Finchaa schemes grow sugar cane, while the Amibara and Upper Awash schemes grow cotton and Fruits and vegetables respectively (Table 3).

Table 3: Large scale schemes under irrigation and type of cropping

Region	Scheme name	Major crop	Area 2005/06 (in ha)
Afar	Amibara (Middle Awash)	Cotton	6448
Oromia	Finchaa sugar plantation	Sugar cane	7185
Oromia	Metehara sugar plantation	Sugar cane	10145.9
Oromia	Upper Awash	Vegetables & fruits	6017.34
Oromia	Wonji/Shoa sugar plantation	Sugar cane	4094

Source: ESDA (2007); MoFED (2006)

The Irrigation Development Program (IDP) as set out in the government's Plan for Accelerated and Sustained Development to End Poverty (PASDEP) document (2005/06-2009/10) envisages the expansion of irrigation in the country by an additional 528,686 ha by the year 2010 (MoWR, 2006; MoFED, 2006). Of this 430,061 ha will consist of mainly medium and large scale schemes while 98,625 ha will involve small scale irrigation schemes to be developed by the regional governments in Ethiopia (Atnafu, 2007). Accordingly, 39 significant irrigation projects are planned to be implemented during the PASDEP period. The major ones are World Bank projects around Tana (100,000 ha); Anger Negesso Project in Oromia (49,563 ha); Humera project in Tigray (42,965 ha); Kessem Tendaho in Afar (90,000 ha); Upper Beles in Benishangul Gumz (53,000 ha) and Ilo-Uen Buldoho (32,000 ha) in Somali (MoFED, 2006; MoWR, 2006). Most of these irrigation schemes will be large scale community managed schemes to be used by smallholder farmers. Exceptions are the schemes to be developed in the Awash and Abay basins, which will mainly involve expansion of the already existing large scale schemes or development of new ones (Table 4). About 90,000 ha of irrigation land will be developed in Kesem and Tendaho to grow sugar cane while there are planned expansions in the already existing sugar plantations. By the year 2010 there will be an additional 122,000 ha of irrigated land developed to grow sugar cane (ESDA, 2007). Overall, the total extension to irrigated area by the year 2009/10 compared to 2005/2006 will be in the range of 528,686 ha. This implies that further development will extend the irrigated area to cover about 33 percent of the irrigated potential and about 9 percent of the total cultivated land area. These plans are used as indicative targets for future irrigation development for valuing the future contribution of irrigation to the national economy.

Table 4: Future development plans of large scale schemes

Region	Scheme name	Basin	Main crop	Future expansion/ development until 2010 (in ha)
Oromia	Finchaa	Abay	Sugar cane	12000
Afar	Kesem	Awash	Sugar cane	40000
Oromia	Metehara	Awash	Sugar cane	10000
Afar	Tendaho	Awash	Sugar cane	50000
Oromia	Wonji/Shoa	Awash	Sugar cane	10000

Source: ESDA (2007)

Methodology in Valuing the Contribution of Irrigation for the National Income

The methodology calculates the contribution of existing irrigation to gross domestic product (GDP) by taking into account contribution from the alternative rainfed production from the same area of land.

The method adopted follows, a "with minus without" irrigation approach, adjusted for changes in farm type and scale.

Following Doak (2005) the formula is:

Farm gate GDP due to irrigation = GDP with irrigation – GDP without irrigation (1)

*Where GDP with irrigation is calculated as irrigated land use mix in ha * (irrigated Gross Margin – fixed costs/ ha) and GDP without irrigation is calculated as rainfed land use mix in ha * (rainfed Gross Margin – fixed costs/ ha).*

A gross margin (GM) is the total revenue associated with a particular production (income) less the costs that clearly vary in direct proportion to the level of production - the direct or variable costs associated with the enterprise. Gross margin analysis is an accepted tool commonly used in the evaluation of farming enterprises (Barnard and Nix, 1979), also used in the evaluation of the costs and benefits of irrigation (Gittinger, 1984). Assessing the change to the gross margin per unit area as a result of irrigation and then scaling this appropriately by the total affected area provides an initial estimate of the GDP change (at the farm gate) likely to occur as a result of irrigation, i.e. the average net gross margin (NGM) from a given area (in ha) from a specific scheme j, is given as:

$$NGM_j = NGM_j / ha * SchemeArea_j \text{ in ha} \quad (2)$$

where $j = 1,2......K$ represents the different schemes in the country and NGM_j is the average value of the net gross margin expressed in per ha terms from a specific scheme and is obtained as the difference given in Eq. (1).

In the Ethiopian context, farmers use full irrigation to grow crops during the dry season when crop production from rain is not possible. This implies that households get additional income from irrigation in addition to that what farmers get during the main cropping season. Under small scale irrigation system, irrigation does not replace rainfed income but complements it.

Large scale schemes, however, are under full irrigation throughout the year. In this case, to obtain the value of irrigation under large scale scheme, we deducted the rainfed income that could have been achieved without irrigation during the wet season. Hence, for a given farmer, the total income for a specific year includes income from rainfed and income from irrigation. Once these adjustments were made, we aggregated the income to calculate farm gate GDP. In other words, the gross margins (GMs) were determined for farm types in each of the schemes and aggregated to a scheme scale throughout Ethiopia using the data obtained from the household surveys and secondary sources. The formula we used is as follows:

$$Farmgate\ \ GDP = \sum_{j=1}^{K} \sum_{i=1}^{N} NGM_j * schemearea_j \text{ in ha} \quad (3)$$

Where $i = 1,2,...,N$ represent crop types grown in the different schemes and $j = 1,2,...,K$ represent the different schemes under the smallholder and large scale irrigation systems respectively.

The gross margins are those for the 2005/06 season and are defined as the revenue generated from the activity less the direct costs of producing the revenue. The gross margins were also adjusted to account for the differences in overheads (fixed costs)[ii] of land uses with and without irrigation, and also for differences in shadow prices of labor and oxen in irrigated and rainfed systems (for the small scale schemes). Shadow prices of labor and oxen were estimated from the production data by first estimating elasticities, which were used to estimated the marginal values of labor and oxen,[iii] in a production function framework (for details see Jacoby, 1993).

The "without irrigation" land use is that which would now exist if irrigation had not been developed, rather than if irrigation was no longer available for that particular land. This was estimated based on GM of rainfed agriculture from similar plots around the scheme or average GM value for all rainfed, if data for adjacent rainfed plots were not available. The value of irrigated production and the value of production from rainfed use that would be most likely if there was no irrigation were derived from the survey data for each scheme. For the large scale schemes, we explored the dominant rainfed production type and estimated average gross margins per ha from the household survey.

The assumption here is that all of the now irrigated lands would have been under some sort of rainfed farming had it not been converted to irrigation plots. However, there are also some other possible scenarios. It is possible that some of the current irrigated lands are hitherto uncultivated lands or new openings,[iv] If this is true, the methodology we adopted may underestimate the true contribution of irrigation development without considering the environmental costs of such changes. It may also be that the current irrigated land may have been used for grazing livestock.[v] The direction of bias on our estimation depends on whether the gross margin per unit area from livestock husbandry is greater or less than the gross margin per unit area for cropping under rainfed. While a meaningful analysis should take account of these diverse scenarios, the lack of data on livestock productivity under pastoral production in Ethiopia and environmental costs of land use change made it impossible. Hence, the approach described above (in equations 1 and 3) was used to assess the current and future contribution of irrigation to the national economy.

In estimating the future contribution of irrigation to the national economy, we used information about the expected growth of the irrigation sector during 2005/2006 to 2009/2010 based on the country's Irrigation Development Program (IDP) (Atnafu, 2007; MoWR, 2006; World Bank, 2006; MoFED, 2006). These policy documents outline how irrigation is expected to develop over the planning period. The details were provided in section two of this report.

A complex issue related to the calculation of the future contribution of irrigation to the national economy is how to address the impact of increased output on prices. Gross margin calculations generally assume that a change in output has no effect on prices. While for small-scale changes at the individual farm level this might well approximate reality[vi], the large-scale land use changes generated by irrigation on the national scale are believed to be sufficient to have some measurable effect on output prices. Lipton *et al.* (2003) state that if irrigation leads to increases in staples or non-staple food output then this may result in lower prices for staples and food in imperfectly open economies or if there are significant transport costs from food-surplus area to towns or food deficit areas. For crops that are largely dependent on the local markets and for which there is little opportunity to develop large-scale export markets, increases in production tend to have a dramatic effect on price (Doek, *et al.*, 2004). A complicating factor in assessing the impact of future irrigation-driven increases in output on prices is also that growers of annual crops are very flexible in the combinations of crops that they choose to grow (Doak *et al.*, 2004). If, for example, tomatoes are in over supply, growers would switch to another crop which proves more profitable. The farmer is, therefore, able to choose the most profitable product to produce, and to increase the value of the product e.g., by producing at a time of the year when price is highest, or by increasing the quality of the product. There is also the possibility that as irrigation expands, it tends to get more government support (e.g., better extension services) and hence intensification can increase. This upside potential has by and large been included in the analysis. We suggested possible scenarios in changes in cropping patterns. However, it is difficult to exactly forecast the possible future changes in cropping patterns. The crop combinations and gross margins used in the analysis are, therefore, only indicative of a range of possible crops and their outcomes.

To quantify the price effect of irrigation development we assumed different price scenarios based on certain assumptions about demand growth and output growth. In the light of all these considerations, we assumed different price changes in price of the major produce when assessing the impact of future irrigation driven increases in output.

This is described in detail in section seven of this report. Important to note is that, we assumed that there is limited impact of world prices on local prices or irrigation's expansion in Ethiopia on global prices or vice versa.

Finally, there are hosts of multiplier effects expected to manifest themselves with irrigation development, including expansion of the off-farm sector, provision of inputs to industry and better nutrition for rural households. These effects are not captured in this study. Our calculated GDP represents, at best, the return to producers' labor

and capital (including capital tied up in land). It is also worth noting that the high income sector of irrigation (emerging flower farming and capital intensive commercial farms) are not included in our assessment. Our method, therefore, probably underestimates the true contribution of irrigation to GDP; at best, it provides the lower margin of irrigation's contribution to GDP.

Data Sources

This study made use of both primary data on smallholder production, both rainfed and irrigated, collected from household surveys and data from various secondary sources. The household survey was part of a comprehensive nationwide study on the Impacts of Irrigation on Poverty and Environment (IIPE) run in Ethiopia between 2004 and 2007 by the International Water Management Institute (IWMI) with support from the Austrian government. The major components of the project included: assessment of performance of irrigated agriculture; assessment of the importance of irrigated agriculture to national economy; assessment of the institutional frameworks and support services of irrigated agriculture; and assessment of generic environmental and health issues (Seleshi *et al.*, 2007). This study focuses only on the importance of irrigated agriculture to national economy.

The component, which investigated irrigation's contribution to national economy, addressed a total sample size of 1024 households from eight irrigation sites in four regional states involving traditional and modern irrigation and rainfed systems. The total sample comprised 397 households practicing purely rainfed agriculture and 627 households (382 modern and 245 traditional) practicing irrigated agriculture. These households operate a total of 4,953 plots (a household operates five plots on average). The data collected include demographics, asset holdings, access to services, plot level production and sale and input use data (distinguished between irrigated and rainfed), constraints to agricultural production and household perceptions about the impact of irrigation on poverty, environment and health and other household and site specific data. The data were collected for the 2005/2006 cropping season. All data were collected in local areal units (in *timad*) and local currency (in Ethiopian Birr (ETB)) and they were converted into ha (4 *timad* ≈ 1ha) and US$ (1 US$ ≈ 8.67). We used part of this comprehensive dataset for the analysis here. Summaries of data used and their source are given in table 5 below.

We also used secondary data from various sources. From the large scale schemes we gathered data on investment cost/initial capital outlays, cost of production, output and revenue among others. From official documents such as the policy documents of the government (MoWR, 2006; World Bank, 2006; MoFED, 2006) we gathered developed and projected irrigation development plans. Furthermore, for specific data on future expansion and new development plans on sugar estates we used the revised master plan of the Ethiopian Sugar Development Agency (ESDA, 2007). The plans for the development of small scale irrigation are prepared by the regional governments and are compiled by the Ministry of Agriculture and Rural Development that oversees the development of the sub-sector.

Table 5: List of variables used in the study and their source

Variable name	Description	Source
Crop cover	Type of crops grown with average land area under all kinds of irrigation typologies and rainfed (in ha)	Household survey
Irrigated area	Land under irrigation (in ha)	IWMI Database and MoWR data sources
Investment cost	Capital costs (in ETB)/ initial capital outlays of projects	Project documents and feasibility studies
Input use and expenditure	Quantity of labor, seed/seedling, fertilizer, chemicals, etc., and their prices	Household survey
Output prices	Price of farm outputs for small scale systems	Household survey
Operation & Maintenance cost	Annual operation and maintenance costs (in ETB) for small and large scale systems	Calculated by authors
Cost of production	Inputs and other costs production from large scale schemes	Annual reports of schemes
Output	Yield ha-1 or aggregate output per scheme	From household survey and annual reports
Revenue	Quantity sold and price per unit of output or reported sales	From household survey and annual reports
Future expansion plans	Envisaged expansion plans for small, medium and large scale schemes	MoWR and other documents

Valuing Irrigation's Contribution to National Economy

The contribution of agriculture to national economy is estimated on the basis of the estimated production during the ***meher*** (main rainy season) and the ***belg*** seasons (small rainy season) (BoFED, 2006). We assume that the contribution from irrigation is included in the production during the ***belg*** season, although not explicitly stated in

the official document. As already mentioned, farmers use full irrigation to grow crops during the dry season when crop production using rainfall alone is not possible. Thus households get additional income from irrigation in comparison to farmers who can only grow during the main rainy season. Under small scale irrigation systems, irrigation does not replace rainfed agriculture but complements it. Large scale schemes in Ethiopia, however, are under full irrigation throughout the year.

Based on the net gross margin calculations (see table 6), irrigation in the study sites generates an average income of US$ 323/ ha compared to the calculated gross margin for rainfed which is US$ 147/ha. This indicates that after accounting for annual investment replacement cost, net gross margin from irrigation is more than double the gross margin from rainfed agriculture.

When we disaggregate net income by irrigation typology, we also see a strong difference between the typologies. Average income from small scale but modern schemes is about US$ 355/ha while from small scale traditional is about US$ 477/ha. This may sound counter-intuitive in the sense that schemes with permanent structures and well lined canals should have better returns.

There are three possible reasons for these differences in gross margins. First, higher margins for traditional schemes have to do with high average investment cost of modern schemes compared to the traditional ones as modern schemes have fixed or improved water control/diversion structures yielding higher annual investment replacement costs than traditional schemes, which is roughly about US$ 165/ha and 25/ha respectively. Second, the relatively longer irrigation experience and, hence, acquired improved irrigated crop management practices of farmers working under traditional systems may have also contributed to this difference. Third, better institutional setting (as a result of stronger local water institutions) under traditional irrigation schemes is also expected to contribute to differences in performance. There are already evidences in support of superior performance of traditional schemes compared to modern ones in Ethiopia. Using frontier technical efficiency analysis, Makombe *et al.*, (2007a) showed that farmers in traditional irrigation schemes displayed lower inefficiency compared to modern irrigation schemes although the later were found to be on a higher frontier. Moreover, Alamirew *et al.*, (2007) showed that traditional water institutions were efficient in ensuring efficient distribution of water and in enforcing their byelaws and their penalty sanctioning mechanisms were stronger. Gashaye and Alamirew (2007) also reported the case of poor performing schemes because of weak institutional arrangements. Hence, although not conclusive, there is a growing body of evidence that point to the superior performance of traditional schemes resulting from better water management institutions. There are also huge intra-scheme differences in income within the same typology which could be attributed to relative difference in cropping patterns and access to market (Table 6). On the role of irrigation to market oriented production, Fitsum *et al.*, (2007) reported that irrigation has contributed significantly to increases in market participation, volume of marketed produce and, hence, household income by inducing shifts in farmers' cropping mix.

Table 6: Gross margin calculation from small and medium scale irrigation schemes (in US$)

Scheme name	Scheme scale	Typology	Area (in ha)	O & M cost	GM/ha rainfed	GM/ha irrigated	GI- minus FC	Total income
Indris	Medium	Modern/ traditional	382	8.5	49.5	213.4	204.8	78266.6
Gologota	Medium	Modern	850	34.9	123.2	876.1	841.2	715016.5
WBS	Medium	Modern/ traditional	685	23.1	171.3		277.1	189810.4
Tikurit	Small	Traditional	102	10.5	156.1	300.2	467.1	47644.9
Zengeny	Small	Modern	270	25.6	227.3	389.3	363.5	98173.0
Haiba	Small	Modern	250	50.4	182.8	322.4	272	67997.4
Golgol Raya	Micro irrigation	Modern	104	158.2	197.2	258.4	100.1	10412.9
Hare	Medium	Modern/ traditional	1345	18.3	74.5	109.6	91.2	122745.8

Source: Own calculation

When it comes to medium scale irrigation schemes, the average income from modern irrigation schemes was US$ 400/ha, which is higher than the gross margin from modern small scale schemes but lower than the margin from the traditional small scale schemes.Taking these average margins from smallholder managed small and medium scale irrigation schemes in the country and multiplying it by the total irrigated area under both typologies, we calculated the total income driven from irrigation to about 262.3 million US$. This accounts for about 4.5 percent of the agricultural GDP in 2005/2006 and 2 percent of the total GDP.

Table 7: Gross margin calculation from large scale irrigation schemes (in US$)

Scheme name	Main crop	Area (in ha)	Average investment cost/ ha	Annual recovery Cost/ ha	Total GM (in million)	GM per ha	Net income	Total income
Amibara*	Cotton	5358	1316.3	26.3	1.59	139.79	113.49	607882.69
Finchaa	Sugar cane	7185	7728.6	144.5	21.27	339.45	194.81	1411309.4
Metehara	Sugar cane	10146	1073.0	21.45	35.03	3765.74	3744.3	3798922.7
Upper Awash	Fruits & vegetables	6017	437.5	8.8	7.25	1913.95	1905.19	11464462.4
Wonji/Shoa **	Sugar cane	4094	4150.8	83.1	5.68	1408.30	1325.26	5425664.3

* Based on 2004/2005 estimate

** Average investment cost for Wonji is taken as the average for Metehara and Fincha (source: Ethiopian Sugar Support Industry)

When it comes to valuation of the contribution from large scale schemes, we followed the approach outlined in section three. Hence, in calculating net income from large scale schemes we deducted the contribution of rainfed from the net income obtained under irrigation to account for the income foregone for not using the land under rainfed production. The rationale behind this is that irrigation in the large scale schemes is a full year enterprise without possibilities to practice rainfed agriculture. Before netting out the contribution coming from rainfed, the average income from large scale schemes was US$1456/ha. There are strong differences in GM between the schemes, however. This difference in performance is strongly related to the type of crop grown in the schemes, and perhaps differences in management and efficiency (Table 7). Overall, schemes growing sugar cane have on average higher gross margin compared with schemes growing other crops. In line with this, using scheme level physical and economic performance indicators, Ayana and Seleshi (2007) showed that schemes that grow sugar cane attained outputs per units of land and water used compared to other crops, namely, cotton and vegetables and fruits.

As we did not have data from rainfed in and around the large scale schemes, we used rainfed data from other sites where we sampled the medium and small scale sites. The calculated average gross margin per ha from rainfed agriculture, as indicated earlier, was US$ 147. Taking this value into account, the net income from a hectare of irrigation under large scale schemes is US$ 1308. When we differentiate the large scale schemes into sugar plantation and other crop growing plantations (i.e. predominantly vegetables and fruits and cotton growing schemes) the average net income is US$ 1782.5 and US$ 998.9 respectively. Taking all large scale schemes in the country, differentiated by their cropping pattern, and the average income from the selected learning sites, the total income earned from large scale schemes amounts to about 74.0 million US$. This accounts for about 1.26 percent of the agricultural GDP and 0.5 percent of the total GDP respectively. Overall, the contribution of irrigation to agricultural GDP and total national GDP was about 5.7 and 2.5 percent during the 2005/06 cropping season. When only the modern system is considered, it contributed to about 1.3 and 0.5 percent of the agricultural GDP and GDP, respectively.

Projecting Future Contributions of Irrigation

In this section we present the projected expansion of irrigated agriculture vis-à-vis rainfed agriculture and the contribution of the former to agricultural GDP. To set the future scenario we used cropping patterns as observed in our empirical results and projected cropping patterns based on the PASDEP (2005/06-2009/10) document projections (Table 8). The projected irrigation development, both small-and medium scale and large scale schemes is taken into account in setting the future scenario.

Table 8: Cropping pattern under different systems (% area covered by) by small and medium scale irrigation

Crop category	Area under Rainfed system (%)	Area under Traditional irrigation (%)	Area under Modern irrigation (%)	Average area Cover under irrigation (%)
Cereals	77	55	67	61
Vegetables	1	11	21	16
Perennials/fruits	1	11	4	7
Pulses	16	10	3	6
Oil seeds	1	5	0.4	3
Spices	0.5	8	0.3	4
Others	3	0.2	5	2.5

Source: Own calculation

In projecting future scenarios we assumed that the cropping pattern of the large scale sugar plantations to be the same. We ruled out reductions of irrigated land due to salinity or other environmental damages in those sugar plantations for lack of data that clearly shows the magnitude of the problem, although there are indications of soil crusting and rise in groundwater table in two of the large scale schemes (Ruffeis *et al.*, 2007). On the other hand, we assumed that the cropping pattern in the smallholder managed large, medium and small scale irrigation schemes to be the same as depicted in Table 8. The land cover statistics of the irrigation, all typologies considered, and rainfed systems are also given in Table 9. We relaxed this assumption later in the sensitivity analysis as it is realistic that farmers will shift to high paying crops as they gain experience and the market situation is likely to improve.

Table 9: Land use assumptions for future irrigated areas (2005/06-2009/2010)

Land use	Area with irrigation (in 000 ha)	Area without irrigation (in 000 ha)
Cereals	809.2	9200
Pulses		1600
Oil seed crops	119.4	1200
Vegetables	212.2	0
Fruits	99.5	419
Cotton		43
Sugar cane	122.0	60
Coffee		734*
Floriculture	n.a.	2*
Tea		3.8*
Other	86.2	39*
Total	**1326.5**	**12650**

Source: MoFED (2006) and own calculation; n.a.= no data available,* not considered in the calculation.

The PASDEP document also outlines the projected development of the economy for the whole planning period. Accordingly, the Ethiopian economy is expected to grow at an average of 7.3 percent throughout the PASDEP period.[vii] Agriculture, the major sector of the economy is also expected to grow at an average rate of 6.2 percent (MoFED, 2006). Agriculture's share to the economy will show slight reduction from 46.2 percent in 2004/2005 to 43.9 percent at the end of the planning period. Taking the baseline situation (2005/06), Ethiopia's GDP will grow to 17.67 billion US$ while agricultural GDP will grow to US$ 7.46 billion both at 1999/2000 constant basic prices.

Table 10: Estimated average gross margin for different crop categories

Average Gross margins by crop category	US$/ ha - rainfed	US$/ ha - irrigated
Cereals	147.9	198.5
Vegetables		394.6
Fruits		317.75
Pulses & oil seeds	170.87	179.7
Sugar cane		522.34
Cotton		81.85
Others (hops, chat, etc)	144.73	333.54

Source: Own calculation

For the assumptions about the IDP differentiated into small-medium scale and large scale we used MoFED (2006) and MoWR (2006), as indicated in section three. As the national IDP indicates the country's irrigation coverage will increase from the current 625,819 ha to 1.15 million hectares by 2009/2010. Accordingly, there will be 638,129 ha of small scale irrigation, both traditional and improved, 328,485.9 ha of smallholder managed medium and large scale irrigation schemes and 122,000 ha of large scale schemes dedicated for sugar plantations and 35,511 ha of large scale commercial farms dedicated to growing of vegetables, fruits and cotton.

Table 11: Current and future % contribution of irrigation to GDP and Agricultural GDP (by typology)

Typology	2005/2006		2009/10	
	Agr. GDP	GDP	Agr. GDP	GDP
Smallholder managed	4.5	2	5.5	2.3
Large scale sugar plantations	1.26	0.5	2.9	1.2
Other large scale plantations			0.4	0.2
Overall	**5.7**	**2.5**	**9**	**4**

Source: Own calculation based on MoFED (2006) projections

Taking all the envisaged areal expansions, crop cover assumptions as indicated in tables 8 and 9 and the average gross margin by crop category (Table 10), we calculated that the contribution of smallholder managed irrigation to national economy to increase from US$ 262.3 million in 2005/2006 to about US$ 414.2 million in 2009/2010, which accounts to about 5.5 percent of the agricultural GDP and 2.3 of the overall GDP for the same year. On the other hand, the contribution coming from the large scale sugar growing estates in 2009/2010 is estimated to be US$ 217.5 million which amounts to 2,9 and 1.2 percent of the agricultural and overall GDP respectively. Similarly the contribution coming from large scale commercial farms growing crops other than sugar cane is expected to increase to US$ 35.8 million in 2009/2010 which accounts to 0.4 and 0.2 percent of the agricultural GDP and overall GDP respectively. This implies that large scale commercial farms will contribute about 3.3 and 1.4 of the agricultural GDP and overall GDP respectively. This shows that the bulk of the contribution is expected to come from smallholder managed irrigation systems. In summary, this indicates that under conservative estimates the future contribution of irrigation to agricultural GDP and overall GDP will be in the range of 4 and 9 percent respectively (Table 11).This estimation is based on the projected areal expansion, current cropping patterns and prices. These results are likely to change when some of the assumptions were allowed to change as shown below.

Sensitivity Analysis

In projecting the future contribution of irrigation to national economy or agricultural GDP our assumptions were rigid: only a change in area expansion was assumed. However, it is realistic to assume that there will be various changes associated with irrigation expansion. For instance, given the significant difference in the gross margin between different crop categories, farmers will benefit economically from growing more vegetables and fruits than growing cereals. Hence it is realistic to assume that farmers will gradually shift to high value crops. Prices of inputs and outputs cannot be taken to remain constant. It is realistic to assume that there could be either upward or downward movements in prices of agricultural inputs and outputs. Furthermore, the efficiency of farmers is also expected to improve with time as they gain irrigation experience, experiment with various technologies and combinations, and local water management institutions are strengthened. There are already attempts to strengthen water users' associations with the expectation that it will improve water management on a scheme level and that will have a bearing on gains in efficiency. Hence it is important to relax these assumptions and see the effect of these changes on irrigation's contribution to national income. This section presents the results of the sensitivity analyses.

Simulating changes in cropping patterns under smallholder managed irrigation schemes

To simulate the effect of changes in cropping pattern on the agricultural GDP we set the following scenarios: Scenario 1 involves 10 percent increase in area coverage of vegetables and fruits (10 percent decrease in area for cereals) while areas for pulses and oil seeds and other crops remain the same; Scenario 2 assumes 10 percent increase in area of vegetables and 5 percent in fruits (15 percent reduction in area for cereals *ceteris paribus*) and Scenario 3 assumes 10 percent increase in area for both vegetables and fruits (20 percent reduction in area for cereals) and finally scenario 4 assumes a 25 percent increase in area of vegetables and fruits (i.e. 25 percent reduction in area for cereals ceteris paribus). The finally scenario 4 assumes a 25 percent increase in area of vegetables and fruits (i.e. 25 percent reduction in area for cereals ceteris paribus). The outcomes of these scenarios were compared against the baseline scenario where we assumed that there will be only aerial expansion (Table 12).

As can be seen from Table 10 there is significant difference in the gross margin between different crop categories. On average farmers get US$ 394.6 from growing cereals, US$ 317.8 from vegetables, US$ 2755 from fruits, US$ 179.7 from pulses and oil seeds, and US$ 198.3 from growing other crops such as spices and stimulants on per ha basis.

Table 12: The effect of change in cropping pattern on the projected contribution of smallholder managed irrigated agriculture to Agricultural GDP (Net gross margin in ETB)

Crop type	Total NGM (in Million US$)	Contribution to Ag. GDP in 2009/2010 (%)	Contribution to GDP in 2009/2010 (%)	Relative change (%)
Baseline	315.2	4.22	1.78	
Scenario 1	327.9	4.39	1.85	+17
Scenario 2	335.8	4.5	1.9	+28
Scenario 3	340.6	4.56	1.92	+34
Scenario 4	3.84.5	4.67	1.97	+45

Source: Own calculation

As can be seen from the simulation results, the contribution from smallholder managed irrigation schemes to Agricultural GDP increases to about 4.5 percent or even more when these various changes in cropping patterns are assumed. 15 and 10 percent increases in the area of vegetables and fruits (25 percent reduction in the area of cereals) lead to about 45 percent increase in the contribution of smallholder irrigation to agricultural GDP as compared to the baseline scenario. This intuitively obvious result reflects that the direct monetary contribution of irrigation could be maximized if smallholder farmers shift their cropping pattern to high value crops.

Simulating changes in crop prices

The factors that influence price changes could be related to overall demographic change and improved economic performance (through increased demand) and increase in supply of output. It is reasonable to assume that the population of Ethiopia will continue to grow in the foreseeable future while there could be differences in opinion about the prospects of and rate of economic growth in the country. As indicated earlier, the prospects point towards improved economic performances which are expected to stimulate demand. For this exercise, hence, we assumed that demand factors will play a more significant role in influencing the price of outputs. To simulate the effect of these changes in prices of output on the contribution of irrigation to national economy, we set various scenarios: baseline scenario GM net of annual investment recovery cost; 10 percent increase in price of vegetables and fruits *ceteris paribus* (scenario 1); 15 percent increase in price of vegetables and fruits *ceteris paribus* (scenario 2); 10 and 15 percent increase in price of cereals *ceteris paribus* (scenarios 3 and 4); 10 and 15 percent increase in the price of pulses and oil seeds *ceteris paribus* (scenarios 5-6); and 10 and 15 percent increase in price of other crops *ceteris paribus* (scenario 7 and 8). The simulation results are reported in table 13 below.

These simulation results show that a 10-15 percent increase in the price of fruits and vegetables leads to 15-23 percent increase in the relative contribution of smallholder irrigation to agricultural GDP. An equivalent increase in the price of cereals leads to 22-32 percent increase in the relative contribution of the sub sector. One the other hand, the same level of increase in prices of pulses, oil seeds and other crops did not yield significant change in their contribution. The relatively higher contribution from cereals comes from the bigger share cereals have on land cover claiming about 61 percent of the cultivated area under irrigation. Hence, vegetables and fruits are economically more attractive. This implies that an increase or decrease of prices of vegetables and fruits will have a stronger relative impact on the contribution of irrigation to national economy compared to the price change of cereals and pulses.

Table 13: The effect of change in output prices on the projected contribution of small holder managed irrigated agriculture to Agricultural GDP

Scenarios	Description	Contribution to Ag. GDP in 2009/2010 (%)	Contribution to GDP in 2009/2010 (%)	Relative change (%)
Baseline	GM net of investment recovery cost	4.22	1.8	
Scenario 1	10 % increase in price of vegetables & fruits	4.37	1.85	15
Scenario 2	15 % increase in price of vegetables & fruits	4.45	1.88	23
Scenario 3	10 % increase in price of cereals	4.44	1.87	22
Scenario 4	15 % increase in price of cereals	4.55	1.92	32
Scenario 5	10 % increase in price of pulses and oil seeds	4.25	1.79	3
Scenario 6	15 % increase in price of pulses and oil seeds	4.26	1.80	4
Scenario 7	10 % increase in price of other crops	4.25	1.79	3
Scenario 8	15 % increase in price of other crops	4.26	1.80	4

Source: Own calculation

Simulating changes in input prices

Fertilizer is the most important input for smallholder farmers working under irrigation. The average cost of fertilizer varies by type of crop category. Cereals and vegetables are major consumers of fertilizer with average expenditure per hectare of US$ 33.10 and US$ 46.5 respectively. Pulses and oil seeds, other crops and fruits reported expenditure per hectare of US$ 27.5, 18.6 and 5.4 respectively. In projecting the impact of irrigation on national economy, one needs to consider the effect of changes in input prices on the gross margin. To simulate such an effect, we determined the impact of the following scenarios: 10, 15, 25 and 35 percent increase in the price of fertilizer. Given the current trends in fertilizer prices, it seems realistic to assume that fertilizer prices will increase.[viii]

Table 14: Effect of changes in fertilizer prices on contribution of smallholder irrigation to agricultural GDP

Crop category	Contribution to Ag. GDP	Contribution to GDP	Relative change
Baseline	4.22	1.78	
Scenario 1	4.17	1.76	-5
Scenario 2	4.14	1.75	-8
Scenario 3	4.08	1.72	-14
Scenario 4	4.03	1.70	-19

Source: Own calculation

As can be seen from the simulation results (table 14), the contribution from smallholder managed irrigation schemes to agricultural GDP does fall significantly compared to the baseline scenario if there is a 10 percent or more increase in price of fertilizer.

A 35 percent increase in price of fertilizer, while assuming other things remain constant, for instance, leads to a 19 percent reduction in its relative contribution to agricultural GDP compared to the baseline scenario. This calls for policy measures to stabilize the price of important production inputs, particularly fertilizer, not to retract the benefits expected from irrigation development.

Improvement in efficiency of smallholder managed schemes

Besides exogenous changes in prices and endogenous changes in cropping patterns, farmers are also expected to gain irrigation experience and improve their efficiency in using land and water.

This is also expected to lead to increases in gross margin. We, hence, explored what happens to irrigation's contribution if gross margin of farmers in smallholder modern schemes increases to that of irrigators in the traditional schemes. The simulation results show that the contribution from smallholder managed irrigation will increase to about US$ 475.5 million that accounts to 6.4 and 2.7 percent of the agricultural GDP and overall GDP in 2009/2010. This has also an important policy implication; government and extension support through education and training may contribute to improved efficiency and increased contribution of irrigation to national economy. Strengthening local water management institutions in modern schemes, such as water users associations, could also have efficiency enhancing effects.

In summary, taking these scenarios into account the contribution of smallholder managed irrigation to agricultural and overall GDP will vary between 4 to 6 and 1.8 to 1.9 percent respectively.

Projecting the future contribution of large scale plantations

In projecting the future contribution from large scale commercial plantations, we tested various scenarios. First we need to differentiate between large scale smallholder managed and large scale commercial plantations. The former category was covered in

the proceeding sections, as smallholder farmers are characteristically the same, while in this section we focus on the large scale commercial productions. The major expansion in the state owned commercial plantations involves predominantly growing of sugar cane for sugar production. There is no information on future expansion plans of fruits and vegetables and other crop growing large scale commercial farms. Our focus in this section, hence, will be on sugar plantations. Worth noting is that in the existing sugar plantations there is huge difference in annual investment recovery costs and net gross margin (Table 7). These differences could be attributed to differences in structure of investment and management performance and, hence, efficiency of the schemes. The lack of relevant information on initial investment cost for some of the schemes has also made the analysis difficult. In schemes where we couldn't get data on initial investment costs we used data related to initial capital outlays. The huge differences in annual investment recovery costs and net gross margin could partly be attributed to lack of reliable data, although there is more reason to believe that there are underlying causes that yield huge inter-scheme differences in physical productivity (Ayana and Seleshi, 2007).

In simulating the future contribution of large scale schemes, we set certain assumptions based on the differences in net gross margins between the three major sugar growing schemes. Since there will be emerging schemes, e.g. Kesem and Tendaho on 90,000 ha of land, in sugar cane production, we need to set certain assumptions about these schemes' performances. We first assumed that the net gross margin for Finachaa, Metehara and Wonjo/Shoa respectively applies to the new schemes (scenario 1-3); Kesem & Tendaho perform on the average of the three exiting schemes (scenario 4); all schemes, existing and emerging, perform like Finachaa (scenario 5); all schemes perform like Metehara (scenario 6), all perform like Wonji/Shoa or all perform on the average of the three (scenarios 7 & 8). Finally we assumed a 10 and 15 percent increase in the price of sugar while the average gross margin works in all schemes (scenarios 9 and 10; Table 15). Following these scenarios, the contribution from large scale plantations to agricultural GDP, ranges from less than 1 percent for scenario 5 (worst scenario) to about 6 percent in scenario 2 (best scenario). The intermediate outcomes lie somewhere in between contributing about 3 percent to the agricultural GDP. These results show that the structure of investment and the way these schemes are managed may have a significant bearing on their contribution to national economy.

Table 15: Projected contribution of large scale sugar estates to Agricultural GDP

Scenarios	Description	Contribution to Ag. GDP	Contribution to GDP	% Change
Baseline	average NGM for LSS assumed	2.9	1.2	
Scenario 1	Kesem & Tendaho performs like Finchaa	1.5	0.65	- 140
Scenario 2	Kesem & Tendaho performs like Metehara	5.8	2.46	290
Scenario 3	Kesem & Tendaho performs like Wonji/Shoa	2.9	1.22	0
Scenario 4	Kesem & Tendaho achieves average performance	3.4	1.4	50
Scenario 5	All perform like Finchaa	0.32	0.13	-258
Scenario 6	All perform like Metehara	6.1	2.5	320
Scenario 7	All perform like Wonji/Shoa	2.16	0.9	-74
Scenario 8	All perform like average	2.87	1.2	-3
Scenario 9	10 percent increase in baseline NGM	2.87	1.2	-3
Scenario10	15 percent increase in baseline NGM	2.87	1.2	-3

Source: Own calculation

In summary, the contribution from large scale irrigation to agricultural and overall GDP will be in the range of 3 to 6 and 1.2 to 2.5 percent respectively. Overall, the future contribution of irrigation to agricultural GDP will be in the range of 7 to 12 percent while the contribution to overall GDP will be in the range of about 4 percent.

Conclusions and Recommendations

Irrigation development is quite a recent phenomenon in Ethiopia. While the country has huge potential for irrigation only about 18 percent of this potential is currently utilized. Irrigation development is identified as an important tool to stimulate economic growth and rural development and is considered as a cornerstone for food security and poverty reduction in the country. To this effect a comprehensive National Irrigation Development Strategy (2005/06-2009/2010) has been developed and is being implemented with the aim of establishing small, medium and large scale irrigation schemes, either for use under smallholder managed systems or large scale commercial plantations. In spite of this, there is little attempt to measure the actual and expected contribution of irrigation to the national economy. Hence, the objective of this study was to estimate the net contribution of irrigation to GDP at the farm gate using an adjusted gross margin analysis approach. Studies of this kind could be instrumental in comparing the actual and expected direct benefits of irrigation with the actual and expected costs of irrigation expansion to guide policy makers in irrigation development. One limitation of this study is that it does not attempt to capture the multiplier effects of irrigation. Doing that requires more data than is presently available. However, this first attempt can be extended to more precise analysis of economy wide effects of irrigated agriculture development once more data is made available through future research.

To summarize some of the most important findings: our results show that irrigation in the study sites generates an average income of about US$ 323/ha. This compares to the calculated average gross margin for rainfed which is US$ 147/ha. This indicates that after accounting for replacement cost, net gross margin from irrigation is 219.7% higher than the gross margin from rainfed agriculture. This underlines that irrigation investment is a viable investment as more value is added to the economy after netting out for investment costs. Whether irrigation investment is a worthwhile investment compared to other investments in the sector or outside is something we did not address in this study. This could be another future research area in its own right. Nonetheless, our result besides underlining the financial viability of smallholder irrigation has important implication on cost recovery for sustainable irrigation development as will be discussed later.

When disaggregated by irrigation typology, average income from small scale modern systems is about US$ 355/ha while from small scale traditional systems it is about US$ 477/ha. These differences in net income between the traditional and modern systems are attributed to differences in the structure of investment, cropping pattern and institutional settings, among others. We also found huge inter-scheme differences in average income within the same typology, where differences in cropping pattern, access to market and relative irrigation experience are the major factors behind these differences. In medium scale irrigation schemes, the average income from such schemes was US$ 400/ha. Taking the average adjusted gross margins from all typologies under the smallholder managed systems and the total land area under these systems in the country, we calculated the total income driven from irrigation to be about US$ 262.3 million. This accounts respectively for about 4.5 percent of the agricultural GDP and 2 percent of the overall GDP in 2005/2006.

The average income net of annual recovery cost from a hectare of irrigation under large scale schemes is US$ 1,308, because they primarily produce higher value sugar cane. Taking all the large scale schemes in the country, differentiated by their cropping pattern, and the average adjusted gross margins from the selected learning sites, the total income earned from large scale schemes is estimated to be 74.0 million US$. This accounts for about 1.3 percent of the agricultural and 0.5 percent of the total GDP respectively. Overall, the contribution of irrigation to agricultural and overall GDP in the 2005/06 cropping season was about 5.7 and 2.5 percent respectively. When only the modern system is considered, it contributed to about 1.3 and 0.5 percent of the agricultural GDP and GDP respectively. Our results, therefore, show that the bulk of the contribution to national economy comes from the smallholder managed irrigation schemes, most importantly from the traditional schemes. The same results also show that the contribution of irrigation to national income is still very small compared to the 28 percent contribution of crop production to the national income. This is in stark contrast to the role of irrigation to national economy in some countries in the region such as the Sudan and Egypt. In the Sudan irrigation contributes about 50 percent of the crop production while almost all agriculture in Egypt is irrigated (FAO, 1997; FAO, 2007).

Taking all the envisaged expansions, exiting cropping patterns, and the average adjusted gross margin values for different crop categories, the expected contribution of smallholder managed irrigation to national economy is expected to increase from US$ 262.3 million in 2005/2006 to about US$ 414.2 million in 2009/2010, which will account to about 5.5 percent of the agricultural GDP and 2.3 of the overall GDP for the same year. On the other hand, the contribution coming from the large scale sugar growing estates in 2009/2010 is estimated to be US$ 217.5 million which amounts to 2.9 and 1.2 percent of the agricultural and overall GDP respectively. Similarly the contribution coming from large scale non-sugar cane growing farms is expected to increase to US$ 35.8 million in 2009/2010 which accounts to 0.4 and 0.2 percent of the agricultural and overall GDP respectively. This implies that large scale commercial farms will contribute about 3.3 and 1.4 of the agricultural and overall GDP respectively. To conclude, our results indicate that under conservative estimates the future contribution of irrigation to agricultural and overall GDP will be in the range of 4 and 9 percent respectively.

After relaxing some of the underlining assumptions, to check the sensitivity of our results to model assumptions, such as changes in cropping patterns, in input and output prices and improvement in levels of efficiency, the contribution of irrigation to national income increases somewhat substantially. If a 15 and 10 percent increase in the area of vegetables and fruits respectively (i.e. 25 percent reduction in the area of cereals) is assumed, this leads to about 45 percent increase in the relative contribution of smallholder irrigation to agricultural GDP as compared to the baseline scenario. This result also underscores the role improved extension support to irrigation could play in providing and promoting high value crops.

Likewise, a 10-15 percent increase in the price of fruits and vegetables leads to 15-23 percent increase in the relative contribution of smallholder irrigation to agricultural GDP. An equivalent increase in the price of cereals leads to 22-32 percent increase in the relative contribution of the sub sector. One the other hand, the same level of increase in prices of pulses, oil seeds and other crops did not yield significant change in their contribution. The relatively higher contribution coming from cereals is attributed to the bigger share cereals have on land claiming about 61 percent of the cultivated area under irrigation. This implies that an increase or decrease of prices of vegetables and fruits will have a stronger relative impact on the contribution of irrigation to national economy compared to that of cereals and pulses. Hence, vegetables and fruits are economically more attractive and could yield more value to the economy if more and more land is shifted from cereal production to production of vegetables and fruits. This may have implications on staple crop production, which should be considered.

On the other hand, a 35 percent increase in price of fertilizer, a very realistic assumption given current trends in fertilizer prices, while assuming other things remain constant, leads to a 19 percent reduction in small holder irrigation's contribution to agricultural GDP compared to the baseline scenario.

Improved efficiency is found to increase the contribution of irrigation to national economy. Our simulation results show that the contribution from smallholder managed irrigation will increase to about US$ 475.5 million, which is 6.4 and 2.7 percent of the agricultural and overall GDP in 2009/2010, when all smallholder irrigation farmers perform to the level of traditional irrigators. This has also an important policy implication: there is a need for increased government and extension support through education and training, and strengthening of local water institutions to improve scheme level efficiency and, thereby, their contribution to the national economy.

Furthermore, changes in efficiency levels of existing and emerging large scale sugar plantations and changes in the price of sugar, assuming a move from worse to best scenarios, will increase the contribution from large scale plantations to agricultural GDP to about 6 percent. The intermediate outcome lies somewhere in between contributing about 3 percent to the agricultural GDP. These results show that the structure of investment and the way these schemes are managed (e.g. viable crop choice) may have a significant bearing on their contribution to national economy.

In summary, taking these scenarios into account the contribution of smallholder managed irrigation to agricultural and overall GDP will vary between 4 to 6 and 1.8 to 1.9 percent respectively. Similarly, the contribution from large scale irrigation to agricultural and overall GDP will be in the range of 3 to 6 and 1.2 to 2.5 percent respectively. Overall, the future contribution of irrigation to agricultural GDP will be in the range of 7 to 12 percent while the contribution to overall GDP will be in the range of about 3 to 4 percent. To realize these outcomes, there is a need to implement the planned irrigation developments as envisaged in the National Irrigation Development Plan.To enhance the contribution of irrigation to national economy, however, there is also a need to: i) improve provision of agricultural inputs including high value crops, ii) improve the performance of the agricultural extension system to support irrigation; iii) improve market access conditions and marketing infrastructure, and iv) improve the management of the schemes to increase the efficiency of small and large schemes. Our results have important implications on cost recovery and sustainability of irrigation investment, with far reaching policy implications for irrigation development. A relatively higher financial return to irrigation investment implies that such investments could be made in a sustainable a manner if the government were to introduce irrigation cost recovery schemes. If policy makers were to introduce irrigation cost recovery schemes in Ethiopia, farmers are able to pay, including investment recovery.

This study reinforces the findings of Makombe *et al.,* (2007b) which also concluded that small scale irrigation systems are financially viable considering operation and maintenance requirements, investment cost recovery, and the ability to replicate investments. This could ensure the sustainability of irrigation development in Ethiopia.

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[i] There are various studies that examine the poverty and food security impacts of irrigation at a scheme or local level using household level data (see, Awulachew, B. S and Loulseged, M. (Forthcoming) for proceeding compilation of important studies).

[ii] For the fixed cost, we calculated an annual replacement cost on per ha basis. Annual replacement cost was computed as initial investment divided by project lifetime (25 years) and O & M was assumed to be 10 percent of annual replacement for small scale schemes and 50 yrs and 5 percent for medium and large scale schemes (Inocencio et al., 2007).

[iii] The shadow price of labor/oxen can be computed, by first estimating the elasticity of labor or oxen from a production function, as a product of elasticity and the ratio of the predicted quantity of output to the quantity of labor/oxen input used.

[iv] The development of Finchaa Sugar estate is a case in point where forest land is being transformed to sugar cane plantation.

[v] The development irrigation in the middle and lower Awash basin is a case in point.

[vi] Even at the small scale, we observe increases in crop output of tomato and onion leading to crashes in prices.

[vii] Actual annual GDP growth rate between 2003/2004 and 2006/7 was more than 11% (IMF, 2008).

[viii] Between the cropping years 2004/05 and 2006/07 the average price of a 100kg of DAP increased by 5.% that of UREA by 12% annually. It is reported that the price of fertilizer has continued to increase in 2007/2008 (EEA, 2008).