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Agricultural policies, agricultural production and rural households' welfare in Ethiopia

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Abstract

The paper employs the computable general equilibrium (CGE) model of the Oromia region of Ethiopia to assess the macroeconomic impacts of agricultural policy on agricultural growth and rural households' social welfare. The analysis is based on social accounting matrix (SAM) of Oromia region. This Oromia SAM is employed as a framework to estimate the effects of policy shocks on rural households' social welfare. This SAM provides base year data needed for policy simulation in CGE model of Oromia region. This study develops two simulations based on economic assumptions and tests their effects on agricultural production, and social welfare. The first set of experiment focuses on the irrigation policies that change the factor intensities in the production of agricultural commodities, and the second one focuses on the precision agriculture that raises agricultural productivity in the use of technologies. The analysis identifies that irrigation scaling up has a positive effect on agricultural production, and social welfare. The application of precision agriculture generates a significant and positive effect on agricultural productivity and production, and rural households' income and consumption. This finding suggests that price support policy should be implemented simultaneously with suggested policies.

Keywords: Agricultural policies, Agricultural production, Employment, Income and consumption

1 Introduction

A large body of literature suggests the various agricultural policies to raise agricultural productivity and improve rural social welfare. Agricultural policies play a key role in the process of agricultural economic growth. Among them, technological change has been acknowledged as the principal driver of productivity growth (OECD 2012; Morris et al. 2007). The differences in aggregate agricultural productivity across countries are mainly attributed by modern technical inputs, human capital, agricultural research and infrastructure (Hayami and Ruttan 1985; Mundlak and Hellinghausen 1982; Lau and Yotopolous 1989). Change in agricultural productivity is the fundamental policy to initiate agricultural transformation and raise the income of the rural people (Ngai and Pissarides 2007; Urgessa 2015). The empirical literature documents the significant effects of agricultural productivity on rural people welfare (Thirtle et al. 2003; Irz et al. 2001; de Janvry and Sadoulet 2010; Birner and Resnick 2010). The agricultural productivity improvement increases farmers' real wages and secures food supply at reasonable prices (Otchia 2014). The magnitude of the effects of agricultural productivity growth on rural people welfare improvement varies largely across countries, depending on the way they developed and used new technologies (de Janvry and Sadoulet 2010).

The government in Ethiopia has implemented various agricultural policies such as market liberalization, structural adjustment, Agricultural-Led Industrialization, Sustainable Development and Poverty Reduction Program, Participatory and Accelerated Sustainable Development to Eradicate Poverty and successive Growth and Transformation Plans I and II to raise productivity in agriculture between 1991 and 2016. Since 1991, the government abolished all subsidies and price support measures to agriculture. A structural adjustment program reduces the role of the government and increases the role of demand and supply forces in the allocation of resources in the Ethiopian economy. All these policy interventions have been implemented to increase agricultural productivity and production which, in turn, reduce poverty and food insecurity. However, the agricultural sector in many developing countries has suffered from price distortions and low productivity, attempts to find solutions have often overlooked the interaction between these two problems (Rakotoarisoa 2011). Market incentives play a key role in the realization of the economic potential created by modern technology because they affect the producer's choice of technique (Mundlak 1988). Agricultural research and development, irrigation, access to credit and price support policies have great impacts on agricultural transformation if they are implemented jointly and successfully (Eicher 1995; Smale 1995). The need for the roles of information market on the status of macro and micro-nutrients in soil and rates of technology usages, and price support policies has neglected in Ethiopia. As result, domestic supply shortages of agricultural and manufacturing commodities are the important causes of the current inflation in Ethiopia, particularly high food prices that are mostly affecting the welfare of households with fixed income. This paper makes a critical review of agricultural subsidization, price support, and stabilization policies, describes their significance with reference to the experience of the developed, and developing countries in the literature. The study does describe the modeling methodology. The study provides base year data needed for policy simulation in a regional CGE model. A model for the economy of Oromia region is stated and calibrated employing 2010 as a benchmark equilibrium. Assumptions are stated about some elasticity parameters, and closure rules. A policy shock applied to an exogenous variable is deemed in the experiments and the impacts of separate and combined policies are tested.

Various studies have explored the Ethiopian agricultural policies and their implications for agricultural production and food security (Alemu et al. 2002; Byerlee et al. 2006; Khairo et al. 2005; Rahmeto 2008; Alemu 2010; Bekele 2010; Admassie 2015). Moreover, most studies on agricultural policies are largely based on literature reviews. There are no studies that have actually explored the effects of agricultural policies on production, employment and social welfare using CGE models. CGE models provide a unique opportunity to measure the effects of proposed agricultural policies on agricultural production, employment and social welfare in Ethiopia. To my knowledge, these model simulations have not been explicitly used in earlier studies to suggest better agricultural policies for policy-makers in Ethiopia. An important innovation in this paper is the inclusion of combined policies simultaneously in the model. Thus, the study fills the knowledge gap in the agricultural policy modeling literature. It also adds new knowledge to the existing empirical knowledge by analyzing the impacts of agricultural policies on agricultural production. The paper contributes to the scant literature on agricultural policies in Ethiopia.

The rest of the paper is organized as follows. Section 2 provides background justifications for model simulations. Section 3 discusses theoretical framework of models and presents database for the computable general equilibrium model of the economy. Section 4 presents the model simulations and assumptions. Section 5 discusses the results of the policy experiments. Finally, Sect. 6 gives conclusions and policy implications for policy-makers.

2 Background

Agricultural policies in both developed and developing countries have been employed to increase agricultural productivity and production, social welfare and redistribute incomes (Krueger et al. 1988; Schiff and Montenegro 1997; McKay et al. 1998). Countries use agricultural policies to achieve self-sufficiency, transfer income among economic agents, and secure food supplies and low prices to consumers. Industrial countries adopt agricultural policies to raise agricultural product prices above market prices that transfer income from consumers to farmers while; developing countries employ agricultural policies to reduce agricultural product prices below market prices that provide cheap food for consumers (Krueger et al. 1988). Developing countries use indirect and direct means to tax agriculture that adversely influences rural households' welfare.

Moderate agricultural taxation or subsidization has a significant impact on aggregate agricultural productivity; but high or low rates of agricultural taxation or subsidization do not have a significant effect on agricultural productivity (Hu and Antle 1993). Agricultural support policies in advanced countries influence rural households' welfare (World Bank 2003; Tangermann 2005). Many Asian and Latin American countries have employed different price support and stabilization policies to increase crop production as well as social welfare. In general, Asian countries used price support policies to address price fluctuation that affect production adversely since the 1960s. These policies have accelerated the extensive utilization of Green Revolution innovations that increased crop production (Hazell 2010). Many Asian countries stabilized grain prices at or above world price levels that made rural households to have better social welfare (Cummings et al. 2006; Dawe 2007). By contrast, many poor African countries used inadequate or no price support programs to manage agricultural price uncertainty that led to slow change in productivity and growing reliance on food imports. The absence of price support policies in Africa leads producers to have a low social welfare (Demeke et al. 2012).

Developing countries strongly oppose domestic and export subsidies by developed countries. Since developing countries cannot afford to support their producers at the levels of developed countries, subsidies tend to limit fair competition. In general, both domestic and export subsidies distort production patterns. Some argue that subsidies given to producers in developed countries have resulted in overproduction and lower world prices of agricultural commodities, which have been harmful to agriculture in developing countries (Koo and Kennedy 2006). Although subsidies distort trade flow, they influence the welfare of consumers in both exporting and importing countries (Bhagwati 2004) because subsidies reduce world prices for agricultural commodities.

In general, scholars and policy-makers view that trade liberalization in developing countries negatively affect rural households' welfare by depressing world agricultural product prices, for which advanced countries have a comparative advantage in agricultural technologies. For instance, removing import tariffs on farming commodities benefit consumers from lower consumption costs, but leave agricultural producers vulnerable to competition from foreign agricultural producers that result in both lower profits and wages in developing countries. The microeconomic agricultural household theory argues that agricultural market liberalization adversely affect agricultural producers' welfare and positively influence rural household consumers' welfare in developing countries.

Government of Ethiopia has imposed restrictions on exports of cereal crops to stabilize domestic supply and encourage oilseed, pluses, and coffee exports that have either a positive or negative impact on social welfare. The government has used agricultural export policies in the form of export taxes and export bans on different agricultural commodities. The tax on coffee export was abolished in 2002 following declining coffee prices in the international markets. The government banned the export of major food grains to reduce the food price for urban consumers. The domestic grain prices were tried to reduce through banning the exportation of teff, wheat, maize and sorghum in December 2006. In June 2008, banning is applied to the exportation of all cereals (Admassie 2015). The chat has been taxed at a 29% since 1993. The oilseed and pulses have been freed from export taxes (Rashid et al. 2009). The Ethiopian government has used overvalued exchange rates to tax farmers and promote oilseed, pluses and coffee exports that increase costs of agricultural production.

Since 1991, the government of Ethiopia has employed a number of agricultural policies to increase productivity and production in agriculture, efficiency in the processing and marketing chain that have a substantial positive effect on rural households' welfare. Policy instrument in structural adjustment program is market liberalization to raise crop productivity and production, rural households' participation in emerging markets and increase their income through commercialization and, therefore, enhance rural households' welfare (Von Braun and Webb 1994; Kennedy and Haddad 1994; Wang et al. 2009). Agricultural markets have been liberalized in favor of market mechanisms for allocating resources. The fertilizer markets were liberalized to move the fertilizers from sources to the farmers or ultimate users. The government deregulated the prices of fertilizers at the wholesale and retail levels. Input subsidies were abolished to reduce the government budget deficit. Liberal input and product prices did not lead to competitive markets due to the government's continued intervention in the commodity markets and financial markets from 2000 to 2007. Private companies exited from the fertilizer markets in 2000. The government of Ethiopia has authorized monopsonies and monopolies' powers to Agricultural Input Supply Enterprise to import and distribute fertilizers in 2005. Like private companies, this enterprise has imported pesticides and herbicides and distributed these inputs to farmers through cooperatives. Some of the agricultural inputs, such as pesticides, herbicides, tractors and combine harvesters have been imported and distributed to farmers by private companies. Cooperatives are given monopoly's power to distribute fertilizers to farmers (Habte et al. 2020).

These policies tend to underestimate the role of technology and information markets that can determine agricultural productivity. For instance, government interventions in output markets, and input markets did not address the shortage of agricultural commodities, and stop upward trending of agricultural prices. Because these policies have ignored the roles of information market on the status of macro and micro-nutrients in soil and rates of technology usages in accelerating agricultural productivity, as observed by Schneider et al. (2011) and Habte et al. (2020). Rapid growth in agricultural productivity is strongly associated with well function of agricultural technology and information markets. Neoclassical theory suggests that well-functioning knowledge and information markets are necessary to increase productivity. But, this theory does not work in developing countries assuming knowledge and technologies are freely available within countries, to all producers. As a result, the government of Ethiopia could not achieve intended targets using these policies. Thus, precision agriculture policy is necessary to create information markets on the status of macro and micro-nutrients in soil and rates of technology usages in Ethiopia. These new markets provide both adequate flows of information to farmers regarding macro and micro-nutrients testing facilities and technology usage rating facilities. Incentives should be adequate to confirm that private sectors invest their capital in technological infrastructure.

In order to examine the impact of agricultural policies on rural households' social welfare, Oromia region in Ethiopia is selected for this study as it plays a central role in the national crop production, accounting for 43.72% of total pulses, 49.82% of oilseeds, 40.81% of root crops and 21.79% of total fruit crop production. It also supplies 36.99% of the total vegetable product of the country (CSA 2018), and 49.35% of grain products for national consumption. The agricultural sector is a means of livelihood for the majority of rural households. The sector employs about 85% of the labor force and is still of strategic significance to rural income generation. However, agriculture is the unproductive sector in Ethiopia because of outdated technologies (Rahmeto 2008) and inappropriate agrarian policy (Kibret 1998).

Moreover, the Oromia region has 63 rivers and 688 tributary streams. These rivers and tributary streams provide about 58 billion cubic meters of surface water, and half the country's surface water resources. The region has used only 5% of the irrigated land to produce agricultural products that is about 1.7 million hectares (ha). The total estimated irrigated land is about 85,402 hectares (ha). The common irrigation types are traditional irrigation schemes (i.e., 48,816 ha), small-scale irrigation (i.e., 9160 ha) and large-scale irrigation (i.e., 27,426 ha). Irrigation policy has been established to increase irrigated area by 11.25%. This policy facilitates credit services for farmers and encourages them to use water pumps (Wodon and Zaman 2010). However, there is a significant gap between the actual irrigated area and a land area equipped for irrigation (Fig. 1).

Poor regulatory framework is the reason for the big gap between actual irrigated and planned areas for irrigation (Awulachew et al. 2010). On the contrary, the researcher argues that price fluctuation is the main reason for irrigation policy failures. Good irrigation policy is necessary for securing high productivity and production, but good policy

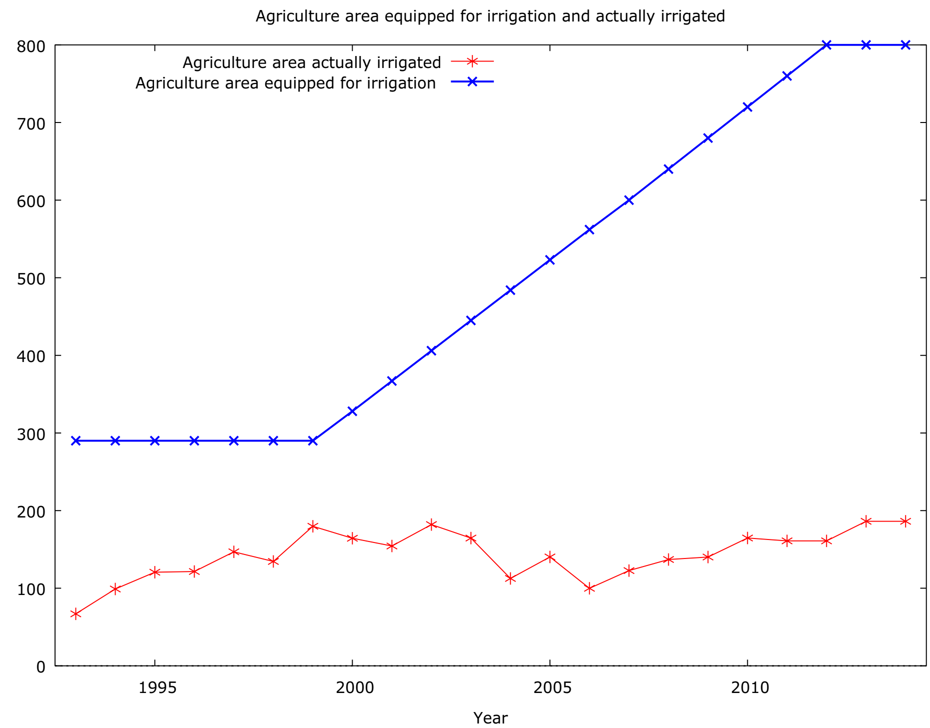

Fig. 1 The gap between actual irrigated and planned areas for irrigation (source: author's drawing based on FAOSTAT database FAO (2018))

may not function well if there is no price incentive or price support policy. The price support policy is necessary to secure stable productivity and supply of agricultural output. The historical fact is that both developed countries and developing countries used price stabilization and support policies to reduce variability in agricultural productivity and supply. This study suggests government to use irrigation policy along with price support policy to address shortages of agricultural commodities, which are the main causes of the current inflation in Ethiopia, particularly high food prices that are mostly affecting the welfare of households with fixed income. This combined agricultural policy may effectively address fluctuations in price and productivity, which may have significant effects on rural households' welfare as well as on urban households' welfare.

3 Modeling methodology

3.1 Theoretical framework of models

CGE models are developed to measure the effects of policies on welfare at country and region levels (Burfisher 2011). The CGE models are a useful tool in quantifying the impact of policy shocks on aggregate social welfare (Gunning and Keyzer 1995; Dixon and Parmenter 1996; Devarajan and Robinson 2002). The agent behaviors determine demand and supply functions in the economy: producers want to maximize profits and consumers want to maximize utility subject to their budget constraint, agricultural technologies, migrant remittances, and a time constraint (Dyer et al. 2006). The choice of the CGE model is justified in the sense that it has certain features that make it suitable for such analysis. First, the CGE models simulate the functioning of factors, and product markets. Also, the CGE models provide a simulation laboratory that enables researchers to quantify the effects of various policy shocks on factors of production supply and demand, productivity, and social welfare in the economy. Finally, the CGE models provide a theoretically consistent framework for welfare analysis (Arndt et al. 2009). CGE models are widely employed in estimating the effects of agricultural policies on household aggregate welfare (Adenikinju et al. 2012). The theoretical underpinning of the effect of policy on welfare, such as the increase in agricultural productivity, is found in consumption theory. The theory is useful in the estimation of the welfare impact of the policy change (Arrow and Debreu 1954).

The model equations are specified at the region level based on the basic structure of the single-country model as explained in the standard IFPRI CGE model (Lofgren et al. 2002). A standard CGE model used in this study is static CGE models adjusted to the structure of Oromia regional economy. Like many CGE models, the CGE model applied in this study has some limitations; particularly results of the model rely on economic assumptions. This study also assumes that increases in agricultural productivity and irrigated area are exogenous, and the model does not consider the resources needed to implement policies in area.

Selections of elasticity or parameter values depend on agent behaviors and the choice of exogenous variables (the closure" of the model). This method usually is employed to determine parameter value, called calibration. The calibration process allows us to determine the values of parameters that are consistent both with the values in SAM and the mathematical structure. The procedure employed in calibration reproduces the initial data as an equilibrium solution. The solution provides a new equilibrium which can be compared with the benchmark equilibrium or reference equilibrium. The limitation of calibration procedure is that it requires very restrictive assumptions about technology and utility (Roberts 1994). In this study, 2010 is chosen as a reference year for calibration. This year is the reference year of the SAM of Oromia region. The elasticities or parameter values for Oromia regional CGE model are taken from Ethiopian SAM. The determination of elasticity values influences CGE model results. Furthermore, the values of elasticities or parameters which are most crucial may depend on the experiment conducted (Pagan and Shannon 1987).

This study considers solutions of only some of equations in whole model solutions that are required for objective of this study. The study argues Cobb–Douglas production function represents value added in each sector (Eq. 1). Output produced in each sector comprises value added, which is a function of aggregate labor and capital is given in Eq. (1):

$$Q = AK^{\alpha}L^{\beta}, \tag{1}$$

where Q is value added, L is aggregate labor supply, K is aggregate capital supply, A is the value added shift parameter and α is the share of capital in value-added and β is the share of labor in value added for agriculture sector.

The labor denotes a nested constant elasticity of substitution (CES) aggregation of rural labor. Output in agriculture sector is denoted by a Leontief function of intermediate inputs and value-added. The agriculture sector produces output with fixed yield coefficients. A fixed share would give technology ultimate command to determine the necessary combination or ratio of value-added and intermediate inputs per unit of output rather than the producers' decision-making power (Thurlow 2004). The minimization of the value-added equation (Eq. 1) gives the demand for the primary input. Hence, labor and capital in agricultural sector is given by Eqs. (2) and (3):

$$L_i = \theta \mathrm{VP}_i \frac{Y_i}{w}, \tag{2}$$

$$K_i = \theta \mathrm{VP}_i \frac{Y_i}{V}. \tag{3}$$

VP_i, Y_i and w and v are the value-added price, domestic output, wage rate, and price of capital in sector, respectively.

The institutional factor income is given

$$\mathrm{YIF_{if}} = \mathrm{S_{if}}[(1 - \mathrm{dxf}).\mathrm{YFf} - \mathrm{trnsfi.EXR}], \tag{4}$$

where $\mathrm{YIF_{if}}$ = institutional factor income, $\mathrm{S_{if}}$ = the share of domestic institution i in income of factor, d*x*f = direct tax rate of factor, trnsfi = transfer from factor to institution i.

The total income of rural households equals the sum of factor incomes, transfers from other non-government institutions, the government, and the rest of the world. The rural household income is a function of labor supplied, and capital stock of the households, the share of factor income from labor received by household i, the share of factor income from capital received by rural household. The formula is used in the equation for the computation of the income of household:

$$\mathrm{Yh_i} = \sum_{\mathrm{f \in F}} \mathrm{YhF_{if}} + \sum_{\mathrm{i \in INSDNG}} \mathrm{TRII_{ii}} + \mathrm{trnsfrgov}.\overline{\mathrm{CPI}} + \mathrm{trnsfi} \cdot \mathrm{EXR}, \tag{5}$$

where INSDNG = domestic non-government institutions, YI = income of household i and $\mathrm{TRII_{ii}}$ = transfers from institution i to i household's spending on marketed commodities and home commodities. Household income from factors is provided by Eqs. (2) and (3).

$$\mathrm{YhL_i} = \sum \mathrm{S_{Lf}}(\mathrm{LabW}), \tag{6}$$

$$\mathrm{Yhk_i} = \sum \mathrm{S_{Kf}}(\mathrm{Kapv}), \tag{7}$$

where Lab represents labor, and Kap represents capital.

Household consumption is a function of income, share of net income, marginal propensity to save, and direct tax rate. Households choose the levels of consumption that maximize their utility on the basis of disposable income and prices. Household consumption covers marketed commodities, purchased at market prices, and home consumed commodities valued at their opportunity cost; the activity specific producer prices. Hence, the quantities of composite commodities consumed by household is given by

$$H_{\mathrm{c}} = \left(1 - \sum \mathrm{Sh_i}\right) \cdot (1 - \mathrm{MPS_h}) \cdot (1 - \mathrm{d}x) \cdot \mathrm{YIh}, \tag{8}$$

where H_c = household consumption, $\mathrm{Sh_i}$ = share of net income of rural household h to institution i, $\mathrm{MPS_h}$ = marginal propensity to save for rural household h, dx = direct tax rate, and Yhi = income of rural household. Thus, this equation implies that household consumption is the remaining income after subtracting direct taxes, savings and transfers.

3.2 Database for the CGE model of the economy

The SAM is constructed to employ as database in Oromia region CGE modeling as suggested by Pyatt and Round (1985). The sources of benchmark equilibrium data are obtained from the surveys of Central Statistical Agency of Ethiopia (CSA), Oromia Finance and Economic Development Bureau (OFEDB), Ministry of Finance and Economic Development (MoFED) and other institutions. The benchmark SAM has the 14 rows and 14 columns that represent sellers of goods and services, and buyers of goods and services, respectively, in the regional economy. This matrix framework is called a square matrix that describes the transactions and transfers between all economic actors in the economy (Pyatt and Round, 1985). As a comprehensive, consistent and complete accounting method, the total spending (its column sum) must equal to total revenue (its row sum). This SAM is a useful framework to estimate the effects of policy shocks on rural households' social welfare; and investigate interactions among production, and rural households' income and consumption. The demands for all products equal supplies for all products in several markets simultaneously.

The SAM is an extended set of regional accounts that disaggregate the value added in each production activity into payments to various factors of production. The production account is split into three agriculture, industry, and service sectors using CSA databases. The three sectors produce different goods and services which are sold in domestic markets and/or international markets. Then I split the intermediate input use of each activity among commodities using recent information such as surveys of industries, Ethiopian system of national accounts and Ethiopian SAM accounts. Commodities are disaggregated into agricultural commodities, industrial commodities, and service commodities. Factors of production are disaggregated into labor and capital using the CSA databases and the Ethiopian system of national accounts. Households are disaggregated into rural and urban using the Household Income and Expenditure Survey (HIES). Other institutions are split into government (direct and indirect taxes), savings-investment and rest of world. The rest of the world is disaggregated into export and import using data from the surveys of FOASTAT databases.

The available data do not allow me to dis-aggregate household into different groups and combine the CGE model with a microsimulation model that provide better insight.

SAM provides base year data needed for policy simulation in a regional CGE model. In practice, there are no standardized steps, and guidelines to construct SAM (Keuning and

Ruuter 1988). The SAM construction and CGE modeling are classified into nine steps in this study. The study followed the following steps in SAM construction and CGE modeling:

1. The study identifies data sources.
2. 2010 is chosen as the base year based on the availability of sufficient data for regional SAM construction.
3. This study carries out the disaggregation of various accounts.
4. The study operates data cleaning, error correction, and reconciliation to maintain consistency.
5. The study specifies a consistent mathematical model.
6. The study codes the model and determined the values of the parameters.
7. The study replicates the benchmark to ensure consistency.
8. The study carries out policy experiments. To conduct the experiments with a general equilibrium model, this study assumes that labors are unemployed (i.e., fixed wage rate). Closure for capital market is that capital is fully employed and activity-specific because the simulation results can be affected by the choice of closure.
9. The study run CGE model to produce the counterfactual solutions and compare them with the benchmarks.

3.3 Description of the SAM for Oromia region

The study provides some descriptive information on six accounts, namely the activities, the commodities, factors of production, the institutions, saving-investment and the rest of the world (ROW) accounts. It also provides some information on the economic structure, structure of import and export. More detailed information about the economic structure, structure of import and export of Oromia region can be found in the work of Shikur (2020). The descriptive information of the Oromia SAM, and economic structure is presented in Tables 5, 6, 7, 8, 9, 10.

A. Value-added

   The result indicates that about 85.00% of agriculture value added of out of the total agriculture contribution goes to labor and 15.00% goes to capital. The finding implies that agriculture sector is labor intensive. The regional GDP at factor costs is Birr 131.1 billion. About 62.45% of regional GDP goes to agriculture sector which is the largest, followed by service sector (21.5%) (Table 6).

B. Trade shares

   Share of primary products in the region's export is 74.30% which indicates that agriculture has the largest share in supplying export products. Manufactured goods, such as machinery, transport, electronics and other equipment have the largest share in region's total imports which are about 93.95%. The regional economy produced and exported both limited agricultural and manufactured goods to other regional and international markets (Table 7).

The export intensity shows that 24.09% of export is the primary agricultural products which are relatively the most export intensive sector in the economy. Only 25.70% of the total output is supplied to the rest of the world. Finally, the share of total trade in gross domestic product at market prices is about 43% that indicates that regional economy is a fair open.

C. Intermediate demand and factor inputs

The finding shows that there is a greater demand of intermediate and factor inputs indicating the sectors use inputs to produce more outputs that could lead to backward and forward linkages among sectors (Table 8). Total demand for all intermediate inputs is about Birr 56.93 billion in the production process. Household spent about Birr 121.80 billion on commodities for private consumption. Agricultural commodities have the largest share (53.20%) in private consumption, followed by industry (35.33%).

D. Supply

GDP is measured using the expenditure and income approach. The expenditure approach refers to the total amount of spent on goods and services produced in the region by households, firms, government and foreigners during a year, whereas the value-added (income) approach refers to the total income earned by the households in region during a year. Table 10 describes values of private consumption and government consumption, investment, factor incomes (wage compensations) and gross operating surplus, indirect taxes, and imports and exports of goods. GDP at market price is equivalent to private consumption plus government consumption plus investment plus net export. GDP at market prices and net import (trade deficit) were 136.39 and 16.21 billion ETB, respectively. Domestically supplied goods accounted for about 79.5% of total supply to regional economy. The remaining 20.5% accounted for imports which were equivalent to the IPR. Total supply must equal total demand; the total demand is the sum of intermediate and final demand, also valued at Birr 242.94 billion (Table 10).

4 Model simulation and assumptions

I design experiments to examine policy options for the Oromia region to increase agricultural productivity and production, labor productivity and increase the social welfare of households. Ethiopia is endowed with abundant water resources with 12 river basins and with an annual runoff volume of 122 billion m^3 of water and an estimated 2.6–2.65 billion m^3 of ground water potential (Awulachew et al. 2010; Makombe et al. 2011). However, only about 11% of this potential has so far been used to produce crops (MoA 2011). An increase in the irrigated area is a vital to increase agricultural production and meet the growing food demands of rapid population growth in Ethiopia. It has the power to stimulate economic growth and rural developments (Hagos et al. 2009; Makombe et al. 2011). The government of Ethiopia is also committed to invest more in irrigation schemes (Wodon and Zaman 2010). This study assumes that government should use price support policy to secure continuous agricultural product supply and provide investment subsidies and soft credit to farmers in order to invest in irrigation equipment. The agricultural policy instruments should be complements for accelerating agricultural growth (de Janvry 1985). Price support measure has a more impact on production decision than market prices resulting in a net increase in welfare (Koo and Kennedy 2006). Improved price incentives alone will not bring about the desired improvements because agricultural aggregate supply is deemed to be highly inelastic (de Janvry 1985). Responsive prices will lead private agents to make investments in irrigation equipment, storage and delivery of both inputs and outputs (to supplement and/or complement those made by the public sector) (Koo and Kennedy 2006). The government should include the followings in policy: a set of objectives, instruments for achieving those objectives, and rules for functioning instruments. The irrigated area is affected by industrial policies which facilitate an organized marketing system, provide incentives, and encourage industries to invest in these sectors. The regulatory frameworks (the rules of policy) play a central role in implementing instruments and controlling the impact of the policy instruments. This is because institutional change plays a key role in the success of agricultural productivity in the region as transaction costs within the input supply system are very high (Otchia 2014).

The study estimates the amount of labor and capital required to produce the values of total output under the area of irrigated land to carry out scenario 1. Even though there is no closure rule on irrigated area in the methodology section, irrigated land is proxied by values of total output that are obtained from irrigated land. The total returns/values of output from irrigated land are split into rural labor and capital. The first and second scenarios assume an increase in the area of irrigated land by 15% and 31%, respectively. The third and fourth scenarios assume a significantly larger increase in irrigated area by 46% and 61%. The government should give emphasis to rules of policy which are very necessary to implement and operate instruments including water fees, water rights, water conflict resolution, incentives for collaboration among the levels; incentives for accurate reporting of current projects, etc.

Precision agriculture combines advanced technologies to achieve quantitative and qualitative crop production (Gebbers and Adamchuk 2010). This study uses investment subsidies and credit facilities as a proxy for economic incentives. The government should provide investment incentives and credit facilities for cooperatives and private companies to invest in the various technologies (Van Genderen 2013). The precision agriculture can be implemented due to the development of sensor technologies combined with procedures to link mapped variables to appropriate farming management actions such as cultivation, seeding, fertilization, herbicide application and harvesting (Gebbers and Adamchuk 2010). Precision agriculture is the use of technology to assist in optimizing agricultural production by improving the accuracy of existing management activities (Shockley 2010). I complement this analysis with two scenarios of institutional arrangements that lead to an increase in the supply of inputs. This simulation also means that farmers invest in new methods of production and information market on the status of macro and micro-nutrients in soil and rates of technology usages to increase the effectiveness in the use of chemicals. In scenario 1, I assume that the Oromia region adopts new methods of production with precision agriculture in agriculture, increasing productivity by 25%. This scenario implies that farmers in Oromia region apply inorganic chemicals and best practices to increase efficiency of technologies or the value added

Table 1 Design of policy experiments. Source: author's own design

Scenarios	Description	Design
Scenario 1	Scale up irrigation practices	Increase coverage of irrigated area (15%, 31%, 46% and 61%) in agriculture
Scenario 2	Precision agriculture and technological change	Increase of precision agriculture practices and technical progress (25%, 30%, 50% and 60%) in agriculture
Scenario 3	Joint implementations	Changes in both practices at a time (30%, 40%, 65% and 80%)

Table 2 The impacts of irrigated area expansion on output, factor income and consumption. Source: own computation result based on Oromia region SAM.

Experiment	Output		Labor income		Capital income		Consumption	
	Wosp	Wsp	Wosp	Wsp	Wosp	Wsp	Wosp	Wsp
Base	102.07	102.07	82.67	82.67	13.99	13.99	96.64	96.64
SIM 1	103.46	104.44	83.68	85.40	14.182	14.52	98.01	99.925
SIM 1%	1.43	2.32	1.22	3.30	1.36	3.75	1.42	3.40
SIM 2	103.71	104.99	84.46	86.13	14.33	14.66	98.87	100.75
SIM 2%	1.61	2.87	2.16	4.18	2.43	4.79	2.31	4.25
SIM 3	104.15	105.53	85.03	86.83	14.44	14.81	99.51	101.55
SIM 3%	2.04	3.39	2.85	5.03	3.22	5.81	2.97	5.08
SIM 4	105.26	106.16	86.48	87.68	14.73	14.98	101.151	102.53
SIM 4%	3.13	4.01	4.60	6.06	5.30	7.07	4.67	6.09

Base scenario refers to agriculture operating without any intervention. Simulation (SIM 1) refers to the increment of the irrigated area by 15%. SIM 1–4 refer simulations. Source: own computation result based on Oromia region SAM. Wosp refers to only irrigation policy; Wsp refers to combination of irrigation policy with price support policy

shift parameter. Economic incentives are necessary to address the needs of investment significantly in the sector (Bartels et al. 2009; Tuomi 2011). Technically, I also implement the scenarios as a joint simulation of a 30%, 40%, 65%, 80% increment in the irrigated areas and precision agriculture (Table 1).

Theory suggests that it is price fluctuations that maximize or deteriorate the welfare of a household. Joint implementations with price support policies are necessary to manage fluctuation in prices and agricultural productivity to maximize overall welfare of a society (Evenson and Golin 2003). Many developed countries suffered from low productivity and uncertain grain prices before implementation of price support policies or World War II. Supported and stabilized domestic prices has resulted in high levels of production and secured a faster food supply than demand in many advanced countries (Boussard 2006; Alston et al. 2009).

5 Results

The simulations 1, 2 and 3 will increase output, demand for factors of production and rural households' income and consumption (Table 2). This implies that irrigation policies raise aggregate agricultural output supply which leads to higher labor and capital demand, and increases rural households' welfare. The interventions address the shortages of raw materials in downstream sectors (Table 2). For instance, simulation 1 increases incomes of rural households from labor and capital, which has a great positive impact on the demand for downstream sectors' commodities. The irrigation policy, simulation 3 raises rural households' consumption of all commodities by 2.97% while combination of irrigation policy with price support policy (simulation 3) raises rural households' consumption of all commodities by 5.08% (Table 2).

Table 2 indicates the impacts of agricultural policies on output, factor income and consumption. I allow for unemployment and sectoral labor mobility, changes in factor income are a response to the change in employment. This result indicates that irrigation policy will increase the demand for rural low-skilled and semi-skilled workers. In rural areas, capital and high skill appear to be complementary as capital-intensive technology increases the demand for high-skilled workers. High-skilled workers are needed to operate tractors or to spray chemical as manual work is less needed. Change in area of the irrigated land (Scenario 2) influences labor income by increasing the intensity of workers on the farm and, therefore, raising working hours and the frequency of work throughout the year.

Table 3 indicates that precision agriculture and technological change raise the returns for all factors of production involved in the production process. The adoption of both auto-steer systems will increase the expected net returns under all four scenarios when compared to the base scenario because it will reduce the costs of production and increase productivity at a time (Table 3). Table 3 shows that all the four simulations of precision agriculture and modernization (Scenarios 1, 2, 3 and 4) lead to an increase in income and consumption. This finding suggests that precision agriculture and technological change can be independently sufficient in reducing poverty via productivity and income growth effects. Improved precision agriculture practice has a great potential to enhance growth outside agriculture.

Table 3 The impacts of precision agriculture practices on output, factor income and consumption Source: own computation result based on Oromia region SAM

Experiment	Variables							
	Output		Labor income		Capital income		Consumption	
	Wosp	Wsp	Wosp	Wsp	Wosp	Wsp	Wosp	Wsp
Base	102.07	102.07	82.67	82.67	13.99	13.99	96.64	96.64
SIM 1	103.86	105.97	84.65	87.346	14.37	14.91	99.085	102.142
SIM 1%	1.74	3.82	2.39	6.569	2.70	5.650	2.67	5.69
SIM 2	104.80	96.47	85.95	88.18	14.625	15.09	100.54	103.11
SIM 2%	2.73	5.49	3.96	6.66	4.53	7.82	4.04	6.70
SIM 3	106.16	108.71	87.68	91.27	14.98	15.76	102.53	106.74
SIM 3%	4.01	6.50	6.06	10.39	7.07	12.65	6.10	10.45
SIM 4	106.46	109.66	88.35	92.68	15.12	16.09	103.30	102.53
SIM 4%	4.48	7.44	6.86	12.10	8.07	14.98	6.89	12.22

Base refers to operating without any intervention. SIM 1–4 refer simulations. Simulations (SIM 1–4) refer to the increment of the precision agriculture practices by different rates of adoption. Wosp refers to only precision agriculture; Wsp refers to combination of precision agriculture with price support policy

Table 4 The impact of joint implementation of policies on the regional output Source: own computation result based on Oromia region SAM

Experiment	Variable							
	Output		Labor income		Capital income		Consumption	
	Wosp	Wsp	Wosp	Wsp	WOSP	Wsp	Wosp	Wsp
Base	102.07	102.07	82.67	82.67	13.99	13.99	96.64	96.64
SIM 1	106.16	108.71	87.68	91.27	14.98	15.76	102.53	106.74
SIM 1%	4.01	6.50	6.06	10.39	7.07	12.65	6.10	10.45
SIM 2	106.46	109.66	88.35	92.68	15.12	16.09	103.30	102.53
SIM 2%	4.48	7.44	6.86	12.10	8.07	14.98	6.89	12.22
SIM 3	107.67	110.95	89.77	94.66	15.429	16.56	104.96	110.88
SIM 3%	5.48	8.75	8.58	14.49	10.23	18.37	8.61	14.74
SIM 4	108.00	112.45	91.70	97.08	15.86	17.17	107.26	113.94
SIM 4%	58.14	10.17	10.91	17.42	13.36	22.73	10.99	17.90

The joint implementations of these scenarios lead to an increase in supply and demand of agriculture inputs. Firstly, the increase in supply and demand of agriculture inputs implies creates back and forward linkage between the upstream and downstream sectors. It has a positive implication for the expansion of agro-processing industries.

The joint implementation of policies in agriculture increase factor income of rural workers as they are intensively employed in agriculture. Increasing agricultural productivity and production lead to a reduction of poverty and food insecurity. Under these scenarios, the changes in the income of rural farmers lead to higher demand for industrial commodities. Simulations 2, 3 and 4 increase consumption of commodities of rural households by 12.22%, 14.74%, and 17.90%, respectively (Table 4). They have the significant implications for a reduction of poverty and food insecurity.

Similarly, the joint implementation of scenarios indicates that welfare gains are associated with policy measures in rural area. From a policy standpoint, this indicates that technological changes play an important role in boosting agricultural productivity. Wosp refers to only scenarios 1 and 2; WSp refers to combination of scenarios 1 and 2 with price support policy.

6 Conclusions and policy implications

The CGE models are analytically important to simulate the functioning of factors, products, and foreign exchange markets. The solutions from CGE models are useful to narrow the gap between factor demand and supply. The solutions can be used to increase factor and output productivity, which in turn have a positive effect on social welfare. Price support policies in both developed countries and developing countries have been used to reduce fluctuations in agricultural productivity and prices which are the main driver of agricultural growth. This paper introduces a new dimension in the debate on price support policy by pointing out that, historically; the developed countries themselves did apply price support policy to manage variations in productivity and prices.

This study draws three major implications. First, irrigation policies increase agricultural production and investment in irrigation equipment and encourage investment simultaneously in other sectors, and raise rural households' income and consumption. The analysis identifies the significance of technological change with scaling up irrigation practices in improving agricultural productivity and production, and social welfare (Rada et al. 2010). Irrigation policies have a positive implication for returns to rural and urban low-skilled labor and semi-skilled workers because it increases the volume and frequency of transactions of agricultural commodities that create job opportunities in various nodes of agricultural value chains. Second, technological changes and precision agriculture will increase productivity by providing information market on the status of macro and micro-nutrients in soil and rates of technology usages. The adoption of precision agriculture reduces the costs of production, increases aggregate agricultural output by increasing technical efficiency, and increases labor and capital productivity. Third, the joint implementations of two policies will increase productivity which helps way out of poverty. The implications may extend to other sectors. These policies will reduce a shortage of raw materials in agro-processing industries.

From a policy perspective, this finding suggests that price support policies should be implemented simultaneously with these policies to increase farmers' market incentives and improve marketing efficiency. Market incentives motivate farmers to invest in irrigation equipment and technologies increase the adoption of precision agriculture practices. These policies secure adequate agricultural food supply, resulting in lower prices and higher consumption for rural and urban poor people, enabling them to earn enough money to invest in new technologies. It leads to an increase in income for all labor types and consumption for urban and rural households. By implementing price support measures, the government can stimulate production and ensure adequate supplies of agricultural commodities without the need for compulsory quotas (Franzel et al. 1989).

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Author's contributions
The author collected data for SAM construction. He has constructed Oromia regional SAM. He has developed CGE models, calibrated, and run the models. He has generated quantitative results. The author read and approved the final manuscript.

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Availability of data and materials
The data and material are available. But I do not want to share data because I will use data for other purposes.

Competing interests
The author declares no competing interests.

Appendix

See Tables 5, 6, 7, 8, 9, 10.

Table 5 2010 SAM for economy of Oromia region with 3 sectors (in billions of Ethiopia Birr)

Accounts	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	
AGR-A	1				103.45												103.45
I-A	2					35.99											35.99
S-A	3						53.77										53.77
AGR-C	4	5.22	5.11	3.86						54.89	9.94	1.01			1.57	24.85	106.45
I-C	5	3.47	9.66	6.82						31.31	11.84	1			9.97	8.63	82.7
S-C	6	2.70	7.84	12.23						9.32	4.5	11.18			6.00		53.77
LAB	7	77.77	2.99	15.58													96.34
CAP	8	14.19	9.56	13.01													36.76
RHH	9							81.64	13.48			2.87				1.04	99.03
UHH	1							14.7	23.28			2.24				5.49	45.71
Gove	0												6.27	3.22		8.81	18.3
Dtax	11									0.92	5.35						6.27
Idtax	12	0.10	0.83	2.27												0.02	3.22
S-I	13									2.59	14.08					0.87	17.54
Row	14				3	46.71											49.71
Total		103.45	35.99	53.77	106.45	82.7	53.77	96.34	36.76	99.03	45.71	18.3	6.27	3.22	17.54	49.71	809.01

AGR-A agriculture activity, *I-A* industrial activity, *S-A* service activity, *AGR-C* agricultural commodity, *I-C* industrial commodity, *S-C* service commodity, *Gove* government, *Dtax* direct tax, *Idtax* indirect tax, *S-I* savings-investment, *Row* rest of the world, *Total* column and row total

Table 6 Value added at factor costs in billion ETB. Source: author's computation using GAMS

Variable	AGR-A	I-A	S-A
GDP factor cost	90.92	13.27	28.91
% of GDP factor cost	69.10%	9.41%	21.50%
Labor to GDP	85.01%	24.12%	55.12%
Capital to GDP	15.00%	75.91%	44.90%

Where Ethiopian Birr (ETB) is Ethiopian currency; 14.409 ETB was approximately equal to 1.00 US dollar in 2010

Table 7 Structure of trade values in billion ETB. Source: author's computation using GAMS

Variable	AGR-A	I-A	S-A
Exports of goods	24.90	8.61	–
Share in total exports	74.31%	25.70%	–
Gross domestic output	103.40	35.97	53.77
Export intensity (EI)	24.09%	23.94%	–
Imports of goods	3.00	46.71	–
Share in total imports	6.05%	93.95%	–
Total demand	103.6	85.68	53.77
Import penetration ratios	2.90	54.52	–

Table 8 Input–output accounting for the Oromia economy in billion ETB. Source: author's computation using GAMS

Total intermediate inputs	56.93		
Agriculture intermediate inputs	10.89	Agriculture sector output	103.47
Industrial intermediate inputs	22.91	Industrial sector output	35.99
Service intermediate inputs	23.13	Service sector output	53.77
Value added at factor costs	133.10	–	–
Indirect tax	3.20	–	–
Total inputs at basic prices	193.23	Gross domestic output	193.23

Table 9 Input–output accounting for the Oromia economy in Birr billion. Source: author's computation using GAMS

Sector	Intermediate demand		Private consumption		Government consumption		Investment		Exports	
	Value	%	Value	%	Value	%	Value	%	Value	%
AGR-C	10.90	19.70	64.90	53.20	1.11	8.34	1.57	8.97	24.91	74.3
I-C	22.99	40.41	43.10	35.33	1.00	7.51	9.97	56.80	8.61	25.73
S-C	23.13	39.90	13.80	11.48	11.21	84.22	6.00	34.20	–	–
Total	56.93	100	121.80	100	13.32	100	17.50	100	33.50	100

Table 10 GDP, demand and supply accounting for the Oromia economy. Source: author's computation using GAMS

GDP accounting in billion ETB			
Income approach		**Expenditure approach**	
Compensation to labor	96.34	Total private consumption	121.80
Gross operating surplus	36.81	Total government consumption	17.54
Indirect tax	3.20	Total investment	13.30
	–	Export of goods	33.48
	–	Less import of goods	49.71
Value added at market prices	136.39	GDP at market prices	136.39

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