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July 2017

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General Equilibrium Effects of Public Adaptation in Agriculture in LDCs: Evidence from Ethiopia

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Abstract

Ethiopia is one of the most vulnerable countries to climate change. This is because its important economic sector, agriculture, is virtually rain-fed. The role of the sector in the current economic structure and the potency of the anticipated biophysical impacts of climate change necessitates proactive adaptation in agriculture. This, however, breeds questions of adaptation costs and adaptation finance. This study attempts to derive plausible range of planned adaptation costs in agriculture along with their economy-wide and regional effects in Ethiopia. It also assess the economy-wide and regional effects of the likely options available to a government of a least-developed country to finance adaptation in agriculture. The results show that planned public adaptation in agriculture puts pressure on government surplus, impedes on manufacturing and private services, and GDP of urbanized regions. As such, it may strain the current macroeconomic endeavors of the country which puts government driven structural transformation and reducing fiscal deficit relative to GDP at the center. Government of Ethiopia may reconcile this by laying out incentives to urban agriculture and private investment in agriculture. Besides, foreign support in the form of biotechnology transfer and debt-relief may help to control the side effects of grants on foreign exchange market and trade balance.

JEL classification: C68, D58, H50, H60, O55, Q16, Q28, Q54, Q56, Q58, R11, R13

Keywords: Climate change, agriculture, public adaptation, CGE model, Ethiopia

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1. Introduction

Ethiopia is one of the most vulnerable countries to climate change. This attributes to the fact that the virtually rain-fed and smallholder subsistence agriculture of the country (AgSS, 2014) is the main source of income and merchandise export earnings (NBE, 2016) and employment (NLFS, 2005; 2013; HICES, 2011). As a result, adaptation in agriculture is an urgent need in Ethiopia (Conway and Schipper, 2011; FDRE, 2011; 2015).

However, planning and mainstreaming adaptation in a single sector (i.e. agriculture) to a single stressor (i.e. climate change) into the overall macroeconomic framework entails additional task for policy-and decision-makers of a given country. First, planned public adaptation in agriculture entails incremental budgetary burden to the public sector. Despite the high anticipation, international climate finance for adaptation in least developed countries (LDCs) is inadequate and unpredictable (Adaptation Watch, 2015; UNEP, 2016). This may compel LDCs to look for new finance from domestic resources and earmark them for adaptation in agriculture and rural settlements. Among others, governments of LDCs may simply scale up the public spending on agriculture efficiency improving measures (and prepare to shoulder the resulting fiscal deficit), to compromise public spending on other public services, or to raise new finance by raising tax rates. Such decisions usually have non-negligible allocation and distributional effects in low-income countries. Second, public adaptation costs and finance for agriculture may have distributional effects among different regions of the country. By implication, regional effects may matter in adaptation policy- and decision- making process besides the economy-wide (aggregate) effects. The third challenge to policy-and-decision makers comes if the economy-wide and regional effects of public adaptation are in conflict with the current and future macroeconomic goals of a country. For instance, it requires to figure out to what extent to compromise the general (medium-and long-term) goals for the sake of adaptation in agriculture which itself is justifiable on many grounds.

Therefore, climate change and adaptation to climate change will require to go beyond the business-as-usual development planning approach. As such, it may be necessary to conduct an *ex ante* analysis of the public adaptation policy to climate change. Nonetheless, the topic is barely touched in the scientific discourse on adaptation with respect to Ethiopia in particular and to LDCs in general. That is where the present study aims to contribute to. It applies a method to derive the direct costs of adaptation in agriculture that can be taken as an alternative to the commonly used "experts' opinion" approach. The study also attempts to identify the sectors, households, and regions that would gain or lose from planned public adaptation in agriculture and alternative adaptation finance schemes. It also combines economy-wide and regional analysis for each policy experiments which paints better picture for adaptation policy-and-decision makers.

The general objective of this study is to assess the economy-wide and regional effects of government responses to anticipated impacts of climate change in Ethiopia.[1] It specifically intends to address two interdependent objectives. First, it examines the economy-wide and regional effects of planned public 'full' adaptation in agriculture. It specifically focus on the planned public adaptation that aims to fully neutralize agricultural productivity shocks induced by climate change that are discussed in Yalew et al. (2017).[2] Second, following from the first objective, it examines the economy-wide and regional effects of alternative finance schemes for adaptation in agriculture. The study applies the static IFPRI-CGE model (Lofgren et al., 2002) calibrated to the 2005/06 Social Accounting Matrix (SAM) of Ethiopia (EDRI, 2009). We use the CGE model to simulate the economy-wide effects of different policy experiments. We further map the economy-wide effects on sectoral output into a regional module to glean information on the regional effects of each policy experiments. The latter is important to the Ethiopian context since the economic structure of some of the regions is significantly different from the national average while the regional governments primarily depend on federal government block-grants.

The results show that planned adaptation to anticipated agricultural productivity shocks due to climate change (5%, 10%, and 15%) may require to uplift public budget for agricultural efficiency enhancing measures by 25 % to 100%. This results in declining government budget surplus by 32% to 173%. This will shift the savings adjustment burden (in order to maintain the macroeconomic savings-investment balance) to households, and eventually, reduces aggregate households' welfare (from 0.6% to 2.7%). Like any other public services, public adaptation increases demand for skilled labor types which has two further implications. First, it implies gains to urban households which owns such factors. Second, it pulls factors of production, following which output from other sectors decline. This is reflected in declining output in manufacturing (-2% to -10%), in 'other' services (-3% to -13%), and in hotels and restaurants (-1% to -6%). The regional projections show that urbanized regions will bear the bulk of the trade-offs of public adaptation in agriculture. For instance, the regional effects may reach to -3% in Addis Ababa, and to -2% in Dire Dawa. The key insight here is that full public adaptation in agriculture bears residual and indirect effects despite it helps to avert the aggregate (such as on GDP, on total absorption) effects of climate change.

This general conclusion holds true even if planned public adaptation spending is supplemented with new finance obtained from either domestic or international sources. The marginal effects of alternative adaptation finance schemes on GDP, compared to default scheme through government deficits, are insignificant. Also, the aggregate effects vary little across the schemes. However, the distributional effects reflected on macroeconomic components, industrial activities, household groups, and regions are considerable. Availability of foreign

[1] The anticipated productivity effects of climate change in this paper refers to changes in average agricultural yields under future climate (2035-2065) relative to the average agricultural yields under current climate (1980-2010)) which is consistent with the literature (cf. Müller and Robertson, 2014; Admassu et al., 2013; World Bank, 2010a; 2010b; Nelson et al., 2010).

[2] The productivity effects on Ethiopian agriculture discussed in Yalew et al. (2017) are also in the range of projections in previous studies on the country (cf. World Bank, 2010a; Robinson et al., 2012; World Bank, 2008), on the African continent (cf. Müller et al., 2014; Waha et al., 2013; Knox et al., 2012; Schlenker and Lobell, 2010), and on the world (cf. Müller and Robertson, 2014).

finance seems better for real households' consumption. Nevertheless, adaptation finance as foreign grants may appreciate the real exchange rate. Consequently, exports will relatively be worse off. Relative to the default scheme, urban households are slightly worse off under taxing schemes. Raising direct (income) tax rates implies the worst welfare effects for urban households. Diverting schemes (from general public administration or public social services) would imply lesser distributional effects between households. However, the range of regional effects are yet considerable. For instance, diverting from general public administration implies -0.5% for Ethiopia-wide value-added GDP, but -0.1% for Tigray region, and -1.7% for the city of Addis Ababa.

The remainder of the paper discuss the related literature with respect to adaptation in LDCs (2) and Ethiopia (3), the materials and methods of the study (4), the CGE model calibration and the regional projections (5), the results and discussions (6), and conclusions and policy implications (7).

2. Adaptation as a public policy issue in LDCs

Climate change poses palpable risks to agricultural growth (Padgham, 2009), and economic growth and development of many LDCs (Tanner and Horn-Phathanotahi, 2014). Because the global warming over the next three decades is unavertable (Hertel and Lobell, 2014), adaptation in agriculture in LDCs is important (UNFCCC, 2009; Watkiss et al., 2010).

Adaptation to climate change refers to "adjustments in ecological, social, or economic systems in response to actual or expected climatic stimuli and their effects" (Smit and Pilifosova, 2001, p.879). Therefore, adaptation involves changes in the process, practices, and structures with the aim to moderate potential damages (or take opportunities, if any) associated with climate change (IPCC, 2007). There are different ways to classify adaptation (cf. Smit and Pilifosova, 2001). Adaptation can be proactive (undertaken before the impacts are observed) or reactive (undertaken when the impacts are experienced) (IPCC, 2007). Adaptation is also classified as autonomous (automatic or spontaneous) or deliberate (planned or policy) adaptation (Smit and Pilifosova, 2001; IPCC, 2007). Autonomous adaptation refers to a non-conscious response to climate change triggered by ecological, market, and welfare changes (IPCC, 2007). In contrast, planned adaptation is a result of a deliberate policy decision "based on an awareness that conditions have changed or are about to change and that action is required to return to, maintain, or achieve a desired state" (IPCC, 2007, p.869).

Deliberate and planned adaptation measures are required, especially, when autonomous adaptation is doomed to be inadequate. This is usually true in LDCs where individual agents lack the information, finance, and technology necessary to deal with climate change and variability. Public adaptation primarily aims to fill these missing adaptive capacities (Antle and Capalbo, 2010). It also aims to aware, trigger, and facilitate autonomous adaptation by individual agents. Besides, when there are multiple beneficiaries of the adaptation measures, then, government action is the only efficient way to undertake collective adaptation (Mendelsohn, 2000). As such, the role of government in anticipating, planning, and preparing to climate change adaptation in LDCs is indispensable (Mendelsohn, 2000; Antle and Capalbo, 2010).

The direct costs (incremental budget demands) as well as the general equilibrium effects are expected to be high in poor countries.[3] These, however, will be well beyond the economic capacity of LDCs (UNEP, 2016; Tanner and Horn-Phathanothai, 2014; World Bank, 2010b). Therefore, climate finance and technology transfers from developed countries are expected to support measures related to climate change in LDCs (Tanner and Horn-Phathanothai, 2014; UNFCCC, 2009). Nevertheless, the international climate finance in general and adaptation finance in particular are doomed as uncertain and inadequate (Fenton et al., 2014; Buchner et al., 2015; UNEP, 2016; Afful-Koomson, 2014; Westphal et al., 2015; Tanner and Horn-Phanathanothai, 2014; Nakhooda et al., 2013).[4] Generally speaking, the international climate finance lacks clear definition and measure (Tanner and Horn-Phanathanothai, 2014; Adaptation Watch, 2015; Westphal et al., 2015) and is dominated by mitigation finance (Buchner et al., 2015; Nakhood et al., 2013; Afful-Koomson, 2014). As such, adaptation finance reported by developed countries overstate the real magnitude of adaptation finance, perhaps, four times of the actual amount (Adaptation Watch, 2015). There also lacks clear criteria of raising and allocating funds that entail operational problems related to the access and management (Tanner and Horn-Phanathanothai, 2014; Afful-Koomson, 2014; Fenton et al., 2014; Nakhood et al., 2013). The definition and operational problems have bred concerns over the amount, time, and ways of disbursing international climate (adaptation) finance (Tanner and Horn-Phanathanothai, 2014; CFU, 2016; Afful-Koomson, 2014; Adaptation Watch, 2015; Nakhood et al., 2013). Besides being insufficient, the adaptation finance is fragmented and not transparent (Nakhood et al., 2013; Adaptation Watch, 2015). Unless significant progress is made to secure new and additional finance for adaptation, the gap between adaptation costs and adaptation finance in LDCs is likely to grow substantially over the coming decades (UNEP, 2016). As such, developing countries in general (Adaptation Watch, 2015), and African countries in particular (Afful-Koomson, 2014) are encouraged to implement policies to mobilize adaptation finance from their domestic resources. The burden apparently rests on the public sector as the private sector's willingness to invest in adaptation activities is limited (Mendelsohn, 2012).

As such, planned adaptation may requires either new climate change adaptation oriented public services or additional tasks on existing climate change adaptation relevant public services. However, planned public adaptation efforts

[3] Adaptation costs include costs of planning, preparing for, facilitating, and implementing adaptation measures, including transaction costs (IPCC, 2014; UNEP, 2016).

[4] Each year, adaptation in developing countries may cost euros 10-20 billion between 2010 and 2020 (Project Catalyst, 2009) and USD 70-100 billion between 2010 and 2050 (World Bank, 2010b). Further, as the sum of adaptation costs is equal to the annual foreign aid from developed to developing countries, adaptation finance demand in developing countries would need doubling annual aid to developing countries (World Bank, 2010b). Some studies argue that the costs may go well beyond the current global estimates (cf. Fankhauser, 2010; UNEP, 2016). Currently, adaptation costs in developing countries are at least 2 to 3 times higher than international public finance for adaptation (UNEP, 2016). Yet, the costs of adaptation are likely to be two to-three times higher than current global estimates by 2030 (and potentially four-to-five times higher by 2050) implying a substantial adaptation finance gap in developing countries (UNEP, 2016).

entail measures that are more or less in economic development toolbox (McGray et al., 2007). In other words, planned adaptation is inextricable from other endeavors for economic development (Padgham, 2009; Fankhauser and Schmidt-Traub, 2011). Therefore, integrating and mainstreaming adaptation to climate change with the wider development plans and practices will yield better outcomes than treating as stand-alone environmental problem in LDCs (Fankhauser and Schmidt-Traub, 2011; Tanner and Horn-Phathanothai, 2014). The implication is that public adaptation measures shall be built upon the existing sectoral and macroeconomic institutions, policies, and practices (Padgham, 2009; Kissinger et al., 2013; Tanner and Horn-Phathanothai, 2014). Accordingly, for example, adaptation in agriculture requires an extra public budget on top of public spending on agricultural and rural development. This apparently will have non-negligible economy-wide and regional effects since public resources in LDCs are scarce.

3. Planned public adaptation in Ethiopia

The economic consequences of climate change on agriculture are paramount in Ethiopia (cf. Yalew et al., 2017 and references within; World Bank, 2008; 2010a). Consequently, government of Ethiopia puts planned public adaptation in agriculture as its primary response to climate change (NMA, 2007; FDRE, 2011; 2015). The government underlines that "a major shift is needed to ensure that climate resilient actions in agriculture are implemented" (FDRE, 2015, p.7). The government commitment to adaptation in agriculture is justifiable, at least, on three main grounds. First, the sector is already vulnerable to the observed climate change trends in the second half of the twentieth century (cf. World Bank, 2006; Ali, 2012). Second, agriculture is the main source of employment (NLFS, 2005; 2013), and income and merchandise export earnings (NBE, 2016). As consequence, climate change effects on agriculture impede the macro economy (cf. Yalew et al., 2017; World Bank, 2010a; Arndt et al., 2011). Third, despite the favorable institutional and budgetary support, the growth in the sector has been unsatisfactory in the past decades (BMGF, 2010; Mitik and Engida, 2013). Besides, government action is necessary for effective adaptation in agriculture since farmers in different parts of Ethiopia indicate that lack of climate information, extension services, irrigation, and financial capacity inhibit them to undertake adaptation by their own (cf. Hadgu et al., 2014; Tessema et al., 2013; Tafesse et al., 2013). Therefore, government's role to expand irrigation, agricultural research and extension, and rural feeder road is indispensable. Government at different levels can also inform, induce, and facilitate autonomous adaptation by the farmers themselves.

The costs of planning and implementing public adaptation in agriculture are considerable. For instance, the design and implementation of ten adaptation projects in agriculture may cost about USD 767 million (NMA, 2007). Agricultural adaptation that include irrigation, R&D, draining and watershed management requires an extra budget of USD 68–71 million per year (Robinson et al., 2013). Delivering forty one agricultural adaptation measures identified and prioritized by FDRE (2015) may require an additional investment of USD 600 million by 2030 from federal and regional governments, donors, and private sector. Since the country has put building agriculture resilience to climate change as a domestic priority, about 80% of this incremental budget requirement falls on the public sector (FDRE, 2015). Yet, public adaptation in agriculture is only part of the country's climate change related actions that include mitigation, adaptation, or both in many sectors. As such, Ethiopia desperately needs enormous amount of international climate finance especially in the form of grants (Eshetu et al., 2014).

Nonetheless, in the past years, international climate finance to Ethiopia was far below what is envisaged in the climate-resilient green economy strategy of the country (Eshetu et al., 2014; CFU, 2016). Between 2008 and 2012, the international support accounted for only 20% of public spending on mitigation and adaptation relevant measures (Eshetu et al., 2014) while only 16% of the total USD 123 million approved international climate finance to the country is disbursed in the past decade (CFU, 2016). When available, the international climate finance is inclined to mitigation measures (circa 60%), and what is allocated to adaptation measures focuses on building institutional capacity (cf. Eshetu et al., 2014; CFU, 2016).

Therefore, one may contend that Government of Ethiopia shall prepare itself to mobilize adaptation finance for agriculture from domestic resources. The default option is to commit extra public spending on agriculture, and to shoulder the ensuing fiscal deficit. However, the government is unlikely to bear additional budget commitments for agriculture (BMGF, 2010) as the existing public expenditure structure emphasizes agriculture and rural development (MoARD, 2010; Lanos et al., 2014) while the country desperately needs public resources to foster structural transformation (NPC, 2016). In addition, climate change and hence adaptation to climate change are overarching problems that shall not be left to a specific government agency and public budget account (McGray et al., 2007; Fankhauser and Schmidt-Traub, 2011). Seen from both sides, the government may seek for new international and domestic resources for adaptation in agriculture. These, among others, may include diverting from other public budget accounts, seeking for foreign grants, and increasing tax revenue which all require fiscal decisions bearing general equilibrium effects.

To sum up, the opportunity costs of the incremental budget demand for adaptation in agriculture in Ethiopia may be immense, especially, compared to the country' level of development (NBE, 2016), public budget scarcity (MoFED, 2015), and strong drive to expand transport, energy, and urban infrastructure (NPC, 2016). The adaptation policy making process is further complicated with the time lag between adaptation costs (present and certain) and adaptation benefits (future and uncertain). Under such conditions, an *ex-ante* evaluation of public adaptation measures for agriculture is crucial. In particular, it requires to examine its general equilibrium and regional effects. So doing helps to get the glimpse of the type, size, and strength of the indirect effects of public adaptation costs and finance in agriculture. It helps policy makers to identify and be prepared for compensation mechanisms in advance. It also hints the possible conflicts and synergies of planned adaptation in agriculture with the current and planned economic plans of the country. The questions are topical as the country is at early stage of planning adaptation like other developing countries.

However, as in elsewhere, neither the micro case studies (cf. Tessema et al., 2013; Hadgu et al., 2014; Berhanu and Beyene, 2015) nor policy documents (cf. NMSA, 2001; NMA, 2007; FDRE, 2011; FDRE, 2015) in Ethiopia attempt to address these appealing questions. Costs of adaptation in agriculture are scantily researched with the exception of NMA (2007), World Bank (2010a), Robinson et al. (2013), and FDRE (2015). Cost estimates in NMA (2007) are based on limited project type measures which is difficult to integrate with the general macroeconomic framework. FDRE (2015) provide estimates of the direct costs of adaptation in agriculture leaving out the general equilibrium effects. The World Bank (2010a) and Robinson et al. (2013) attempt to address the general equilibrium effects. However, the studies do not make it explicit as to how to mobilize the required resources which is critical, especially, as the likelihood of using domestic sources of finance is high. In addition, regional effects may matter since not every region will benefit equally from the increased public spending to adaptation in agriculture.

This study centrally aims to fill the aforementioned gaps in the literature. Even though the study particularly aims to examine the economy-wide and regional effects of alternative public adaptation costs and adaptation finance schemes for agriculture in Ethiopia; the conceptual framework, the methods, and the general conclusions can easily be adopted to other developing countries with similar economic and public expenditure structure.

4. Materials and methods

A list of specific adaptation measures in agriculture in a given country follows from the sign and the size of anticipated biophysical impacts and the aim of adaptation. In general, adaptation in this study is in response to anticipation of rising temperature and unpredictable rainfall in Ethiopia (Conway and Schipper, 2011; IPCC, 2014; FDRE, 2011; 2015; Admassu et al., 2013), rising evapotranspiration and decreasing soil moisture (Admassu et al., 2013), and consequently, declining crop and livestock productivity (World Bank, 2010a; Yalew et al., 2017).

More specifically, in this study, we focus on the case of a bundle of proactive planned adaptation measures, and assume to fully offset the anticipated agricultural productivity shocks discussed in Yalew et al. (2017) which are also in range of empirical studies (see Footnote 2). Government of Ethiopia is in charge of planning and undertaking this set of deliberate adaptation measures. Public adaptation is assumed to be part of the country's development endeavors. Accordingly we align adaptation with the existing agricultural development policies, and public budget account. As such, planned public adaptation measures can be regarded as extra services on an existing public services as discussed in the subsequent section.

4.1. Public adaptation measures for agriculture

We start with initial list of agricultural adaptation measures based on the general literature (e.g. Smit and Skinner, 2002; Kurukulasuriya and Rosenthal, 2003; Padgham, 2009). Then, with reference to the farm level case studies in Ethiopia (e.g. Tessema et al., 2013; Kassie, 2014; Berhanu and Beyene, 2015) we focus on measures that seem beyond farmers' autonomous adaptive capacity. Next, to facilitate integrating adaptation measures with the rest of the sectoral and macroeconomic plans, we review a set of government sectoral and macroeconomic policies in general (e.g. MoFED, 2010; MoARD, 2010), and climate change and climate change adaptation reports/plans in particular (e.g. NMSA, 2001; NMA, 2007; FDRE, 2011; 2015). We further make review of various reports (e.g. various years Annual Agricultural Sample Survey, AgSS, reports) and research papers (e.g. BMGF, 2010 and background reports for it) to learn gaps in implementing agricultural policies in the country. We consider two further aspects, the ease to quantify the costs and the benefits of a specific adaptation measure and the economic model (i.e., a static CGE model). Accordingly, we review a set of agricultural economics studies that link agricultural development and public expenditure on agriculture (e.g. Benin et al., 2009; Fan et al., 2000; Evenson et al., 1999).

The procedures bring us to the final list of four broad measures which include irrigation and water management, agricultural research and development, extension services and farmers' training, and rural feeder roads. Irrigation and water management as adaptation measures help to produce the same quantity of output (by letting farmers to produce more than once a year), value of output (by allowing farmers to cultivate a mix of crops), and augmenting labor and land productivity (by compensating soil moisture lost due to warming climate). Agricultural R&D helps adaptation to climate change though producing heat resistant and high yield crop and livestock varieties, and introducing new techniques of production. Agricultural extension services and trainings are complementary to agricultural R&D, and include government efforts to build the capacity of its institutions to plan and facilitate adaptation, to improve the effectiveness of climate relevant extension services, and to augment farmers' skill to adopt climate compatible biotechnologies, to seek and understand climate information, to use water efficiently, and to undertake autonomous soil and water management practices. We assume extension services to include 'climate services' which refers to measures that are expected to influence farmers to adjust and make climate-sensitive decisions in crop and livestock farming such as scheduling (e.g. planting, harvesting operations), tactical crop management (e.g. fertilizer and pesticide use), crop selection (e.g. wheat or sorghum) or herd management, crop sequence (e.g. long or short fallows) or stocking rates, crop rotations (e.g. winter or summer crops), crop industry (e.g. grain or coffee; native or improved pastures), agricultural industry (e.g. crops or pastures), land use (e.g. agriculture or natural systems), and land use and adaptation of current systems (Meinke and Stone, 2005 cited in Tall, et al., 2014). Last, but not least, since rural feeder roads contribute to agricultural productivity through input and output prices, diffusion and application of biotechnologies, they can be regarded as indirect climate change adaptation measures (Nelson et al., 2010).

4.2. Direct benefits of adaptation in agriculture

The direct benefits of each of the four adaptation measures are expressed in terms of their contribution to agricultural productivity with respect to public spending on each of them (see also Nelson et al., 2010). We collect the minimum, mean, and maximum elasticities from agricultural economics studies (see Table 1 in the Appendix). Accordingly, the collective productivity effect of the adaptation catalog will depend on the amount of total budget available, the allocation across the four adaptation measures, and how effectively is the budget used.

However, budget allocation to each adaptation relevant measures is not explicit in the public budget and in the national income accounts of Ethiopia. Yet, public expenditure principles for effective climate finance delivery requires 'on-budget' public spending (Bird et al., 2013). It requires climate change expenditure to be planned and budgeted in the national budget formulation process, and to be executed through government systems during the budget year (Bird et al., 2013). We have to find a way to reconcile the two issues. We blend the four measures to form as a 'composite' public services that aim to improve efficiency in agriculture sector. Accordingly, we create a new public service activity/commodity and call it as 'public administration (agriculture)' in modifying the SAM and calibrating the model.[5] The procedure gives us a benchmark annual government expenditure on 'adaptation relevant agricultural services', or government recurrent spending on 'public administration (agriculture)' or government recurrent spending on a set of agricultural efficiency improving measures, to be around 2.04 billion Ethiopian birr (or 234 million USD) in 2005/06 prices. This amount is 13% of total government recurrent budget, 9% of total government spending, and 2% of GDP in 2005/06.[6]

4.3. Direct cost of adaptation in agriculture

Direct costs of adaptation in this study refer to the incremental public budget for adaptation in agriculture. Direct costs of adaptation depend on the adaptation policy targets and adaptation policy effectiveness. The elasticity of agricultural productivity with respect to change in public spending captures the adaptation policy effectiveness. The aim of adaptation is to fully offset the agricultural productivity that would have been lost due to climate change. Therefore, the policy (productivity) targets are reciprocals of the anticipated productivity shocks

[5] Such public activities fall in public administration (MoFED, 2005; UNDESA, 2008). Thus, we split the public administration in the original SAM (EDRI, 2009) in to two: 80% (public administration, general) and 20% (public administration, agriculture). In segregating, we have referred to relevant policy documents on feeder roads (e.g. NBE, 2016), on irrigation (e.g. MoWE, 2001), agricultural extension services and R&D (e.g. Lanos et al., 2014; ReSAKSS, 2014), and total budget to agriculture and natural resources (MoARD, 2010; MoFED, 2014; 2015).

[6] The new public budget account roots to agriculture, natural resources, and roads in national budget accounts (cf. MoFED, 2014; 2015). The figure seems acceptable compared to the total annual budget for agriculture and rural development which is estimated to be about 15% of total government spending and 5% of GDP (MoARD, 2010).

induced by climate change. Therefore, the shift (efficiency) parameter of agricultural activities, i.e., the CGE parameter on which climate change induced productivity shocks are commonly imposed on (cf. Yalew et al., 2017; Robinson et al., 2012) represents the aim of adaptation.

In Yalew et al. (2017) we deal with climate change impacts pertaining to grain and livestock activities. Per contra, the elasticities from the literature links the adaptation measures with agriculture as a sector. Therefore, we weigh the grain and the livestock productivity shocks by the shares of the two activities in the total value-added GDP of agriculture with and without 'fish and forest'. The procedure gives us agricultural productivity shocks induced by climate change to be in a range of -4% and -12%. However, neither the impacts nor the benefits of adaptation measures are confined to grain and livestock. Direct climate change effects to other agricultural activities (cash crops, enset crop, and even fish and forest) are not usually incorporated only because of lack of an applicable biophysical model. On the adaptation side, for instance, farmers can still use the same irrigation infrastructure for growing not only grains but also vegetables, fruits, cash crops, and enset. To account these possibilities, we enlarge the anticipated productivity shocks to the whole agriculture to be -5% (minimum), -10% (mean), and -15% (maximum). By implication, the adaptation policy targets are to increase total agricultural productivity by 5% (minimum), 10% (medium), and 15% (maximum) which is in range of country, regional, and global studies. See, for example, Müller et al. (2011) and Knox et al. (2012) for review of climate change induced productivity shocks in African agriculture.

The next is to gauge policy effectiveness uncertainty. We capture this by a minimum (0.05), mean (0.2), and maximum (0.35) average elasticity of agricultural productivity with respect to public spending on the "composite" agricultural efficiency improving measure (see Table 1 in the Appendix). However, the elasticities from the literature are commonly per a specific measure not per "composite" measure. Therefore, we generate thousands of random variables (elasticities) between the minimum and maximum of elasticities per each measures. Then, we compute the average of the four that yields us an average random elasticity with a minimum (0.05), mean (0.2), and maximum (0.35) values. The average elasticity of productivity, 0.2, with respect to the public spending on the "composite" agricultural efficiency improving measure is close to the elasticity (0.24) with respect to public expenditure in agriculture in Nigeria (Diao et al. 2010) and the elasticity (0.2) with respect to public expenditure irrigation and extension services in Ethiopia (Mitik and Engida, 2013).

We can now derive the incremental public spending required for adaptation in agriculture or simply direct costs of adaptation in agriculture as a function of the elasticities (measure of effectiveness of adaptation) and the productivity targets (measure of anticipated impacts). Uncertainty is inherent in climate change impacts as well as the effectiveness of public policies (Heal and Millner, 2014). To deal with the former, for a certain policy effectiveness (elasticity = 0.2), we derive three direct costs for each policy targets (5%, 10%, and15%), and to deal with the latter, for a given target of productivity (anticipated productivity effect= 10%), we derive three direct costs scenarios for each average elasticities

(0.05, 0.2, and 0.35). The procedures give us a range of 25-100% incremental budget relative to the benchmark budget for agricultural efficiency resulting a range USD 60 to 234 million (at 2005/06 prices) of derived costs of adaptation in agriculture per year (see Table 2 in the Appendix). The larger the anticipated impacts or the lower the elasticities, the higher are the direct costs of adaptation.

Our medium adaptation costs estimate, USD 117 million in 2005/06 prices, is higher than the costs (USD 68-71 million per year in 2005 prices) in Robinson et al. (2013) but close to the additional public expenditure (USD 132 million in 2008 prices) required for the urgent fifteen adaptation measures in agriculture (FDRE, 2015). Of course, the measures in Robinson et al. (2013, p.15) do not include rural feeder roads while the measures in FDRE (2015, p.63) include measures related to biodiversity and forests. Despite the approach we pursue here is completely different, however, the derived direct costs are in an acceptable range of the two studies which derive the costs based on experts' opinion (see Robinson et al., 2013, p.14; FDRE, 2015, p.48).

4.4. Adaptation finance for agriculture

In the previous section, we assume that the government will commit itself to allocate extra budget to agriculture and rural development and shoulder the ensuing deficits. However, the government of Ethiopia may not easily take additional budgetary commitments for agriculture (BMGF, 2010). On the one hand, the current budget commitments to the sector are one of the highest in Africa (MoARD, 2010; Lanos et al., 2014) while the country is thirst for structural change driven by government (NPC, 2016). The unsatisfactory growth of the sector (BMGF, 2010; MoARD, 2010; Mitik and Engida, 2013) itself has sparked policy debate on continuing the priority given to agriculture in public policies and budgets. In addition, as climate change is an overarching development problem it shall not be regarded as a stand-alone environmental problem left to a single government agency or budget account (McGray et al., 2007; Fankhauser and Schmidt-Traub, 2011). Therefore, the government may go a step further to look for new sources of adaptation finance. The second part of this study investigates this.

We build on the previous section. The adaptation measures and aim remain the same. We draw and focus on the medium adaptation cost case. The additional spending on public administration (agriculture) services will remain intact and is considered as the default (benchmark) adaptation finance scheme. It can be regarded as adaptation finance through public deficits. To complement this incremental budget demand, we design six adaptation finance schemes. The fiscal schemes include: 1) diverting from public administration (general) services, 2) diverting from public social services, 3) increasing transfers from the rest of world to government, and for a given tax base, 4) increasing direct tax rate, 5) increasing sales tax rate, and 6) increasing import tariffs. Therefore, the financing approach here is kind of 'earmark' financing (Bailey, 2002). Accordingly, the incremental revenue collected is allocated to only to adaptation in agriculture. Our approach is also a 'balanced-budget' analysis according to which "any increase in expenditure has to be matched by a decrease in somewhere else or by a new source of tax revenue" (Stigltiz, 2000, p.509).

The main hypothesis here is that adaptation finance schemes may dampen the effect of planned adaptation costs on government surplus but further distress the households' welfare or pull out resources from other economic sectors compared to the benchmark finance scheme. Also, alternative adaptation finance schemes will have different implications for different sectors, household groups, and regions. The diverting approaches only switch budgets (or government consumption demand), in effect, they may bear the least general equilibrium effects. The international adaptation finance scheme brings an additional resource to the Ethiopian economy and shall dampen the effects on households' welfare. Nevertheless, transfers from abroad may appreciate real exchange rate, and as a result affect the trade balance. Increasing direct tax rates reduce income left for consumption and hence impedes on households' welfare. Increasing sales tax and import tariffs alter relative prices and may have distortionary effects. However, the strength of the distortionary effects will depend on own- and cross-price elasticities (Stigltiz, 2000; Bailey, 2002), square of the tax rates (Stigltiz, 2000), and second-best efficiencies (Burfisher, 2011).[7]

5. The CGE model calibration and Regional projections[8]

5.1. The CGE model calibration

We use the standard IFPRI-CGE model (see Lofgren et al., 2002 for details). The CGE model database is a modified 2005/06 SAM of Ethiopia (EDRI, 2009) that consists of 54 total accounts that consists of 17 activity, 18 commodity, 8 factor, 2 household, 3 tax, and 6 other accounts (i.e., enterprise, government, ROW, savings-investment, changes in stock inventory, and transport and trade margin). The calibration of the model involves a specification of production technology nest, a range of elasticities, a factor market closure, and a combination of macro closures that are common to the empirical CGE modeling for developing countries (see for example, Robinson et al., 1999; Lofgren, 2001; Lofgren et al., 2002; Hosoe et al., 2010; Diao et al., 2012).

Each producers face a two-stage production technology nest, and are allowed to produce one or more commodities that can be consumed at home or sold at domestic or foreign markets. Households' consumption (of both home and market commodities) decision is specified by Linear Expenditure System (LES) demand system. The value of the elasticities (of factor substitution, import substitutions, export transformations, and households' demand) are borrowed from the related literature and can be said low in general. All factors are assumed to be fully employed. All categories of labor and cropland are assumed to be mobile across activities whereas livestock (TLU) and capital are activity-specific. The observed employment of each labor categories by activity are retrieved mainly from NLFS (2005). We use the AgSS (2006) to allocate the total agricultural labor employment (from NLFS, 2005) among the five agricultural activities of the modified SAM, and to compute TLU. As we set the average wage rate for capital

[7] CGE models are able to consider second-best efficiencies, i.e., increasing a specific tax rate may increase or decrease excess burden, if any, due to other tax types in the economy/model (Burfisher, 2011).
[8] This subsection has many similarities with Appendix 2 in Yalew et al. (2017).

equal to unity, the observed employment of capital in each activities is the same as payments from activities to factor capital in the SAM. The combination of the macroeconomic closures is the 'Johansen' type (see Lofgren et al., 2002 and Hosoe et al., 2010 for more). Consumer price index (CPI) is the *numeraire* of the model relative to which the CGE model determines prices.

5.2. Regional projections

It can generally be argued that the economy-wide representative agents (markets) fairly represent the regional representative agents (markets) in Ethiopia. The households' consumption pattern (HICES, 2011) and the retail prices for the majority of commodities, especially of food items (NBE, 2016; CSA, 2011; HICES, 2011) in different regions exhibit similar pattern and hovers around the national average. The tax rates across regions are more or less the same (MoFED, 2009). With the exception of Addis Ababa, the federal block-grant comprises about 80-95% of regional governments' recurrent budget (MoFED, 2009). Similarly one can assume that each of the production activities of the CGE model exhibit similar production technology irrespective of their regional location.

Yet, the Ethiopian regions vary in terms of their level of socio-economic development, economic structure, and relative contribution to different national indicators. Under such conditions, the policy relevance of regional projections of policy/exogenous changes modeled at economy-wide level would be paramount. We pursue a top-down approach comparable to the ORANI Regional Equations System (ORES) for Australia (see Dixon et al., 1982 for the details).[9] However, we do lack data and a priori knowledge of technological and institutional reasons which underpin the ORES-Australia (see Higgs et al., 1988 and Dixon et al., 1982 for more) to apply to Ethiopia. Instead, we consider all regional activities to be 'national' activities, and the labor intensity (and production technology) of an activity to be same across regions. By the virtue of 'national' industries assumption, a regional industry maintains its share in the aggregate (or Ethiopia-wide) output of the same industry irrespective of the sales pattern of its output. The regional shares are exogenous and fixed (Naqvi and Peter, 1996). As such, the effects of a specific CGE experiment on output of an activity in a region (q_a^r) is equal to the economy-wide effect of the same simulation on the activity's output (q_a^e) (Higgs et al., 1988; Dixon et al., 1982). Mathematically,

$$q_a^r = q_a^e$$

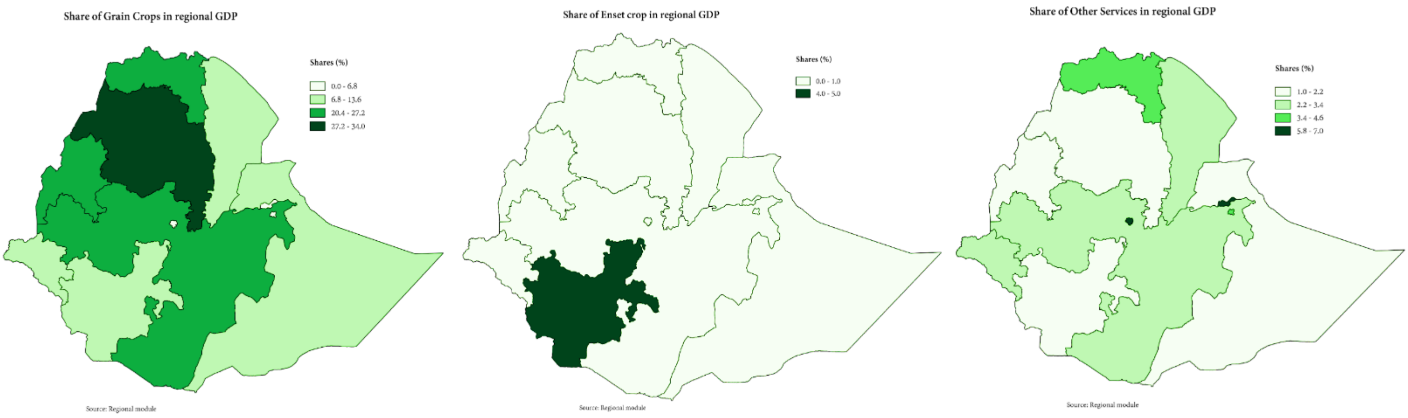
Then, for each of the eleven administrative regions, the regional projections involve taking the Ethiopia-wide effects on all of the economic sectors as 'inputs' to a regional module showing the economic structure of each regions. Then, we compute the regional effects on the region-wide value-added GDP (q_A^r) of a specific CGE experiment as follows:

$$q_A^r = \sum w_a^r . q_a^e$$

[9] See Naqvi and Peter (1996) and Higgs et al. (1988) for more on the relative merits and demerits of the three approaches.

Where w_a^r represents the share of industry *a* in region *r*'s region-wide GDP at factor cost. However, with the exception of some years for Addis Ababa, there are no estimates of regional industries' output and region-wide GDP in Ethiopia. We take a remedial measure here. We compute sectoral and region-wide GDP at factor cost directly from the SAM complemented with data from NLFS (2005), AgSS (2006), PHC (2007), and MoFED (2015).[10] The share of each industries (w_a^r) in the region-wide GDP are given in Yalew et al. (2017, Table 1A). It captures the importance of a specific industry in region *r*. The sum of w_a^r is equal to unity. The economy-wide effect (q_a^e) (see Table 3 in the Appendix) captures the sign and strength of a specific CGE experiment on industry *a*'s output.

Figure 1: Shares of selected economic activities in region-wide GDP



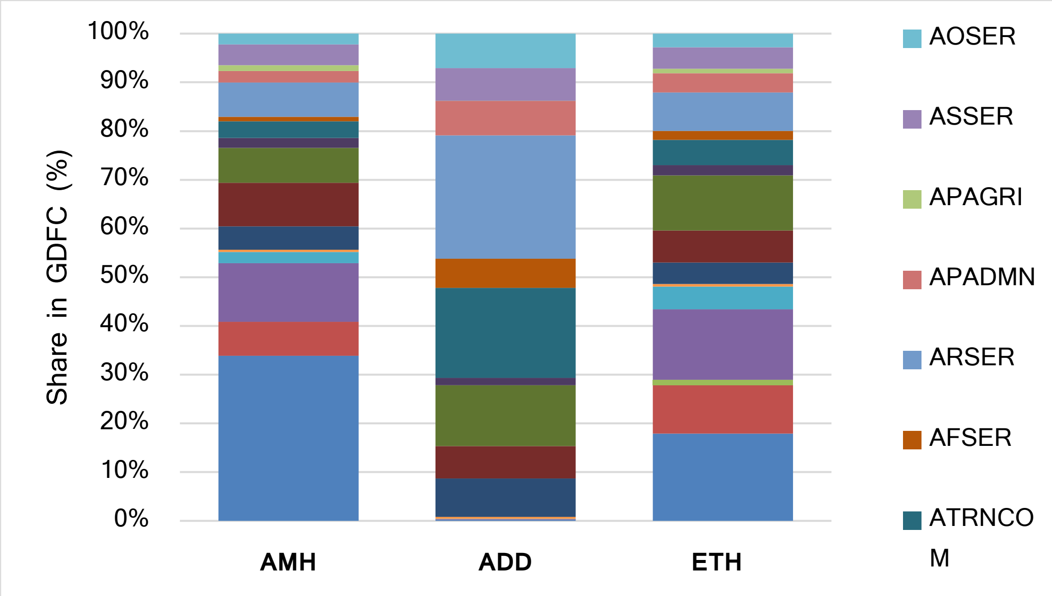
(A) Grain crops (AGRAIN) | (B) *Enset* crop (AENSET) |(C) Other Services (AOSER)

Source: Authors' regional module

To sum up, our remedial approach implies the regional effects depend on the nature of the CGE experiment as well as the economic structure of the regions. In addition to being remedial to both data availability and consistency problems, our approach does not require to modify the CGE model as long as the SAM is modified to accommodate this.

[10] Our main source of employment data in each regions per industry is NLFS (2005). We make adjustments. We use the population and housing census (PHC, 2007) to control for sampling bias in regional labor force reported in NLFS (2005). We use AgSS (2006) to adjust employment among agricultural activities. We use the government expenditure on agriculture and rural development in each regions (MoFED, 2015) to compute regional shares of public administration (agriculture) activity. To check the robustness the regional module, we apply the same procedures using employment data from HICES (2005) instead of NLFS (2005). The regional economic structure remains more or less similar except for Tigray region. Since the employment in manufacturing as per HICES (2005) is lower than reported in NLFS (2005), the regional module based on the former increases the role of agriculture in Tigray region. Despite this, there are no notable differences in the rest of regions. Therefore, we stick on the former as it is used for creating the original SAM (EDRI, 2009). Further explanation may be offered by authors upon request.

Figure 2: Value-added GDP of Amhara (AMH), Addis Ababa (ADD), and Ethiopia (ETH)



Source: Regional module by authors

6. Results and Discussions

We regard adaptation in agriculture as new public policy problem. Accordingly, we correspond each policy experiments with parameters or exogenous variables related to the government account in the calibrated CGE model. The real government consumption of public services (general, agriculture, and social services), the rest of world transfer to government as well as the three tax rates (direct, sales, and tariff) are fixed at observed level. Since we assume 'full' adaptation to each anticipated productivity shocks in agriculture, we only need to model the costs of adaptation (or incremental budget demand) into the CGE model. The economy-wide and regional effects of the incremental budget demand and finance for adaptation in agriculture are given in Table 3 in the Appendix.

6.1. Public adaptation costs

Adaptation costs would require to increase public administration (agriculture) recurrent spending by 25-100% (see Table 2 in the Appendix). Public adaptation costs are represented by five simulations. We believe that the range of the simulations gauges the uncertainty in the anticipated impacts as well as the adaptation policy effectiveness

The macroeconomic effects show that the total government consumption increases by 3 to 13% that leads to government saving to decrease by 33 to 173%. Falling government saving shifts the saving-adjustment burden, to maintain the macroeconomic saving-investment balance, to households. In effect, private households' consumption declines by 0.6 to 2.7%. Therefore, increasing government consumption crowds out private consumption in the macro economy. In addition, due to the increasing government consumption of 'adaptation relevant' public services, output from public services (agriculture) expands. This in turn drives up the demand (and average wage rates) especially for nonagricultural factors. This has two further implications. First, it increases non-agricultural factor income and ultimately, urban households' real consumption. This, partly, offset fall in private consumption due to shifting saving-adjustment burden. Second, it increases cost of production in manufacturing and private services, and thus, lowers output and exports from these sectors. Consequently, aggregate exports fall by 0.5 to 2.3% following which imports slightly decline to satisfy the external sector closure. In balance, at the macroeconomic level, the decrease in private consumption and exports surpass the increase in total government consumption only slightly. This entails negligible effects of planned adaptation costs on the GDP and the total absorption of the economy.

The sectoral output effects reveal the general equilibrium effects clearer. Public administration (agriculture) output increases by 25 to 100% which is directly proportional the budget uplifts. This has two further implications. On the one hand, it increases construction output as government activities uses (contracts) construction services. It also expands region-wide GDP of some regions (e.g. 0.7% to 2.3% in Tigray) where the benchmark share of public administration (agriculture) in region-wide GDP is higher than in the national average share in the country-wide GDP. On the other hand, it increases the economy-wide wage rate, especially, of the administrative labor and professional labor. This pulls up the cost of production in manufacturing and in private services. As a result, in all adaptation cost scenarios, such resource-pull effects are vivid on manufacturing (-2% to -10%) and 'other' services (-3% to -13%). Hotels and restaurants, transport and communications, and mining and quarrying are other activities that bear the indirect effects. Consequently, public adaptation in agriculture squeezes value-added GDP of urbanized regions like Addis Ababa (-0.6% to -3%) and Dire Dawa (-0.4% to -2%). The decline in the region-wide GDP of these two federal cities is larger than that of the national average (-0.1% to -0.7%) as well as in each of the other regions. Needless to say, the resource-pull effects get worse as the direct costs of adaptation increase. The resource-pull effects, especially, on manufacturing and private services imply that planned public adaptation in agriculture may deter structural transformation in the economy.

Due to increasing households' saving burden (i.e., due to falling government saving), households' consumption budget and hence their real consumption decline. Per contra, the increasing demand (and hence income) for especially skilled labor types contributes to urban households' wellbeing. Because, in Ethiopian context, such labor types are owned by urban households. Therefore, while the rural households' welfare (and total households as majority of population lives in rural areas) decreases, and that of urban households' increase. The equivalent variation (EV) for rural and urban households, respectively, may reach up to -5% and 4%. The welfare effects between the two household groups widen as adaptation costs increase. However, it shall be noted here that the rural households' welfare loss due to planned adaptation costs are not comparable the loss that they would have encountered due to climate change (see Yalew et al., 2017).

6.2. Public adaptation finance

This section is built upon the previous section. It particularly focus on the economy-wide and regional effects of the alternative finance schemes to supplement the medium adaptation costs. The medium case scenario is equivalent to about 50% of government spending on composite agricultural efficiency improving measure, to about 12% of government spending on public administration (general), to 18% of government spending on social services, and to about 27% of transfer from abroad to government of the respective benchmark values. For a given tax base, the government can also generate the amount equivalent to the medium adaptation cost by raising the exogenous rates of direct tax by 25% , of sales tax by 32%, and of import tariffs and duties by 14%. We believe that the set adaptation finance experiments fairly gauge the range of main financing options in low-income countries. In all of the adaptation finance simulations, the shock to government consumption of public administration (agriculture or simply composite agricultural efficiency improving measure) remains intact. Accordingly, for example, diverting resources from public social services involves increasing government spending on the agricultural efficiency improving measure by about 50% and decreasing public demand for social services by about 18%: And, tariffs scheme involves increasing government spending on the agricultural efficiency improving measures by about 50% and increasing import tariff rates by about 14%.

Therefore, results of this section shall be seen only relative to the default option which is increasing government spending on the agricultural efficiency improving measure by about 50%. The CGE results show that the marginal effects of the proposed finance schemes are negligible. The macroeconomic effects of all finance schemes on the aggregate variables (total absorption and GDP) hovers around -0.3%. However, different schemes influence the macroeconomic components differently.

The diverting approaches involve no increase in total government spending. Therefore, their indirect effects on private consumption and exports are relatively small compared to the default finance approach. From the two diverting schemes, diverting from social services seems better, at least, it relatively dampen the burden to government saving. This may attribute to the fact that public social services interact with private social services compared to the public administration (general) which is entirely produced and virtually consumed by the public sector.

The international transfers help to dampen the pressure on public saving, and consequently the saving adjustment burden on households. Therefore, compared to others, adaptation finance from abroad scheme implies the least general equilibrium effects on private consumption (-0.4%). Foreign grants, however, may appreciate real exchange rate (expressed as local currency to foreign currency) that reduce exports (-3.7%) but increases imports (0.6%).

However, the effects on government saving will not cease (remains to be high around -55%). The implication is that the resource pull-effects of public adaptation on manufacturing and private services still inhibits the growth of total government revenue.

The resource allocation effects of direct and sales tax are more or less similar. Except on government saving, the economy-wide effects of the two taxing schemes are similar to the default (or deficit) finance scheme. This mainly accrues to the progressive nature of the tax system in the economy, and the nature of the CGE experiments. Increasing direct tax rate is a lump-sum tax on households' income. Similarly, the sales tax scheme can be regarded as a lump-sum tax on households' consumption income since we uniformly increase the sales tax rates in all market commodities. Besides, neither of the two tax schemes would cease the negative effects of public adaptation on government surplus. This attributes to the interaction among different tax systems in the economy. For instance, increasing the direct tax rates reduce income left to spend on consumption. Consequently, the revenue from sales tax may decline. Of course, the resource pull effects on the rest of the economy (as we still retain government spending on adaptation relevant measures) still reduce the total taxable income and value of market commodities. Compared to the default as well as other tax approaches, the macro economy is slightly worse off under tariffs scheme. Tariffs reduces total imports (-0.9%) which also pulls down exports (-2.4%) to satisfy the trade balance. Tariffs are applied only in three commodities of the CGE model implying the higher initial tax rates compared to sales and direct tax rates. Thus, the distortionary effects of tariffs are slightly worse. The total households' welfare decline due to tariff scheme (-1.3%) is the worst among adaptation finance schemes. The distortionary effects are yet small as one of the imports (making up to 15% of the total imports) is entirely imported while the substitution elasticities for the other two commodities are low.

Diverting budget from other public budget accounts imply least general equilibrium effects. This is reflected on manufacturing and 'other' services. The sectoral output effects in other adaptation finance schemes resemble the effects of the default scheme. This attributes to the factor reallocation effects of public adaptation. Particularly, the indirect effects on manufacturing (around -4%) and 'other' services (around -6%) persist. Foreign grants scheme slightly worsens the decline in output of activities (e.g. cash crops and manufacturing) which contribute to exports. In contrast, it may offset some of the effects in activities that produce no or little tradable commodities (e.g. enset, and hotels and restaurants). Increasing tariffs makes imports (which are mainly manufactured) relatively expensive. As a result, households switch into domestic manufactured goods, and thus, output from manufacturing sector shall increase. This, to some extent, offsets the output decline (-3.4%) compared to the default financing option (-4.2%). Taken together, the factor-pull effects of public adaptation (and adaptation finance) are negative and strong on non-agricultural activities. This impinges on the country's thirst for structural change.

In terms of effects on households' welfare, diverting approaches imply the least absolute value of households' welfare effects as they do not generate new employment. There is no new public spending implies two more things. First, factor income changes are relatively low and thus urban households' welfare gain become smaller compared to the default scheme. Second, households' saving burden get lesser and thus the rural households' welfare loss become smaller. The international adaptation finance scheme reduces the savings burden on households (hence dampen rural households' welfare loss from -2.1% to -1.3%). As it improves urban households' welfare gain from 1.5% to 2.2%. The direct tax scheme implies the worst welfare effect (-0.1%) to urban households. This accrue to the considerable share of income tax in the total urban households' expenditure. As we pointed out earlier, sales tax approach can be considered as tax on households' consumption expenditure. Neither its distortionary effects are expected to be high since the values of elasticities used in calibration are low. As a result, generally, we see little difference between the default and the sales tax schemes. However, urban households' are slightly worse off under sales tax approach. Tariffs scheme bears the slightly the worst aggregate households' welfare effects. Increasing import tariffs increases import prices relative to domestic prices which will increase the demand (and price) for domestic varieties. The combined effects result in relatively the highest aggregate households' welfare loss among the adaptation finance schemes. Nevertheless, the distortionary effects are still little as one of the imports is entirely imported with no domestic substitute while the other two imports of the CGE model have low substitution elasticities.

In conclusion, compared to with no finance case, simulations with adaptation finance imply urban households bearing the burden of adaptation finance. Of course, both household groups are better off under all adaptation costs and finance schemes if we consider the avoided welfare damages due to climate change (see also Yalew et al., 2017; Robinson et al., 2012; Arndt et al., 2011; World Bank, 2010a).

Our results on households' welfare under taxing schemes corroborate with the theoretical and empirical discussion elsewhere. For instance, the marginal welfare costs of sales tax is lower than that of income tax and import tariffs in many African countries including Ethiopia (Auriol and Warlters, 2012), and that of import tariffs in other developing countries (Devarajan et al., 2002 cited in Auriol and Warlters, 2012 and Burfisher, 2011).

The regional effects of alternative adaptation finance schemes, in general, resembles the regional effects of the default scheme. Diverting from public administration (general) budget shows negative effects to all regions. The sales tax scheme implies relatively narrow range of variation of the regional effects. Diverting public resources from public administration and social services imply the highest indirect effects to the urban regions. The effects of all tax schemes on Addis Ababa's regional GDP are four times than the average effects on Ethiopia-wide GDP. As the capital city of the country, Addis Ababa is the center of manufacturing and commercial activities of Ethiopia, and hence represent broader tax base compared to other regions (MoFED, 2015).

7. Conclusions and policy implications

We analyze the economy-wide and regional effects of public adaptation costs and finance in agriculture. The CGE simulations show that the effects on GDP and total absorption of the incremental budget demand for adaptation in agriculture are negligible. However, increasing adaptation relevant government expenditure reduces government surplus. This in turn shifts the saving adjustment burden to households, in effect, it reduces total households' welfare. Besides, it impinges on structural transformation of the country because it will reduce public resources available for other investments such as in railways, hydropower, transport and communications, and industrial parks. This is particularly true in Ethiopia where the government regards its role in structural change as indispensable (NPC, 2016).

On the other hand, increasing government spending expands public services that pulls factors of production, and squeezes manufacturing and private service, and urban GDP. This will deter the structural and spatial transformation in the country which already have been unsatisfactory in the last two decades (Dorosh and Thurlow, 2010; 2011; NPC, 2016). The effects on urban GDP may even have far reaching consequences. Because, barely 20% of the total population of the country lives in urban areas (ICPS, 2012) whilst the urban unemployment rate is about 17% (ICPS, 2012). In fact the policy discourse on urban development itself is a recent phenomenon in Ethiopia (Dorosh and Thurlow, 2011).

In general, with the exception of the effects on government surplus, the economy-wide and regional effects of alternative adaptation finance schemes are similar to the case of adaptation financed by increasing spending on public agricultural efficiency improving services. It is also shown that the aggregate effects vary little across alternative finance schemes. However, different finance schemes do have different implications to different macroeconomic components, sectors, factors, households, and regions. For instance, transfers from abroad may appreciate real exchange rate and hence may affect exports at macroeconomic level. However, compared to other schemes, transfers from abroad imply better outcome to factor markets and households' welfare. While foreign grants imply the highest, the income taxes scheme implies that lowest welfare gain to urban households. Rural households' welfare loss reaches its minimum when resources are diverted from social services and maximum with tariffs scheme. Urban regions benefit least from public spending on adaptation in agriculture.

The regional effects show that those least affected by climate change (see Yalew et al., 2017) will confront the largest burden of public adaptation in agriculture. We argue that regional dimension is very important in adaptation policy-and-decision making process. First, the main source of regional governments' budget is federal block-grant (MoFED, 2009; Eshetu et al., 2014; Lanos et al., 2014). The existing formula, among others, takes into account the regions' population and revenue generating capacity (for recurrent budget), and infrastructural deficiency (for capital budget) (MoFED, 2009). However, climate change and planned adaptation in agriculture, may need adjustments or compensation mechanisms. The first may be related to how to regard adaptation finance for agriculture. Shall it be part of capital or recurrent budget? The second may be related to the set of criteria that shall be appropriate to allocate adaptation finance among the regions? Would it be appropriate to index to the exposure (which mainly depend on existing environmental conditions of the regions) or the economic vulnerability (which mainly depend on the relative contribution of climate sensitive sectors such as agriculture, and the regional socio-economic adaptive capacity) of the regions to climate change? In the case of economic vulnerability, shall it be based on sectoral effects (i.e., agricultural GDP) or region-wide GDP effects of climate change? Third, in using either of the criteria, would it be necessary to index to the impacts or potential of the regions? For instance, regardless of the potential effects, regions with better irrigation potential may receive the largest share of federal adaptation finance as block-grant. Such allocation aims to maximize the national-wide returns of adaptation sponsored by the government. When we consider all of these, regional effects may matter even more than economy-wide effects of adaptation costs and finance. If considering these influence (and need adjustments) in the existing federal block-grant formula, planned public adaptation in a single sector may further have political implications.

To sum up, the results of this study show that planned public adaptation in agriculture (and its costs and finance) impede on the main actor (i.e. government), economic sectors (i.e. manufacturing and private services), and regions (i.e. urban regions) of structural change in Ethiopia. The regional effects may have further implication for the allocation of federal block-grants among regional states of the country. The concern over these tradeoffs due to public adaptation in agriculture mounts as one considers adaptation in agriculture is only one among the multiple sectors such as water, energy, transport, and health sectors (NMSA, 2001; NMA, 2007; Robinson et al., 2013; FDRE, 2016) that need public support to adapt to climate change. Most importantly, as low-income country, the forgone opportunities of adaptation finance are high. The government still strives to invest in human capital, transport and communication, and renewable energy as they are critical for moving the Ethiopian economy forward (NPC, 2016; MoFED, 2010).

Government of Ethiopia shall laying out incentives to urban agriculture and private investment in agriculture. This may reduce the share of smallholder agriculture which was the prime reason for public adaptation in agriculture. Besides, foreign support in the form of biotechnology transfer and debt-relief may help to control the side effects of grants on foreign exchange market and trade balance.

Future research that fine-tune sources of adaptation finance, and that explicitly identify and estimate the costs of specific measures which are compatible with structural transformation and contribute to dampen (strengthen) the potential negative (positive) direct and general equilibrium effects of climate change in one or more sectors may pay off.

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Appendix

Table 1: Summary of elasticities of agricultural productivity w.r.t public spending on agriculture sector

Measure	Elasticity			Main References
	Min.	Mean	Max	
Irrigation	0.03	0.09	0.20	Fan et al. (1999), Fan et al. (2000), Mitik and Egida (2013)
Research & development	0.03	0.15	0.44	Criag et al. (1997), Evenson et al. (1999), Fan et al. (1999), Thirtle et al. (2003), Alene and Coulibaly (2009)
Extension, education, & training	0.00	0.10	0.71	Evenson et al. (1999), Fan et al. (1999), Fan et al. (2000), Chen et al.(2008), Felloni et al. (2001), Mitik and Engida (2013)
Rural roads	0.06	0.07	0.08	Fan et al. (1999), Fan et al. (2000)
Agriculture	0.15	0.20	0.24	Benin et al. (2009), Diao et al.(2010), Mitik and Egida (2013)

Table 2: Summary of Simulations

Simulation	%Δα	ε	%ΔG	Direct costs (ΔG)		Finance
				Billion ETB	Million USD	
Adaptation Cost Experiments						
PAG1	10	0.05	100	2.0	234	↑ in spending on public administration (agriculture) by 100%
PAG2	10	0.20	50	1.0	117	↑ in spending on public administration (agriculture) by 50 %
PAG3	10	0.35	29	0.6	68	↑ in spending on public administration (agriculture) by 29 %
PAG4	5	0.20	25	0.5	59	↑ in spending on public administration (agriculture) by 25 %
PAG5	10	0.20	50	1.0	117	↑ in spending on public administration (agriculture) by 50 %
PAG6	15	0.20	75	1.5	176	↑ in spending on public administration (agriculture) by 75 %
Adaptation Finance Experiments						
PAGGA	10	0.20	50	1.0	117	PAG2 + ↓ in spending on public administration (general) by 12%
PAGSS	10	0.20	50	1.0	117	PAG2 + ↓ in spending on public social services by 18%
PAGF	10	0.20	50	1.0	117	PAG2 + ↑ in foreign grants to government by 27%
PAGD	10	0.20	50	1.0	117	PAG2 + ↑ in direct tax rate by 25%
PAGS	10	0.20	50	1.0	117	PAG2 + ↑ in sales tax rate by 32%
PAGT	10	0.20	50	1.0	117	PAG2 + ↑ in import tariff rate by 14%

The required budget uplift on the composite adaptation measure or public administration (agriculture) (%ΔG) to meet the productivity target (i.e., to avert productivity shock induced by climate change, %Δα) is computed from the standard elasticity equation.

$$\varepsilon = \frac{\%\Delta\alpha}{\%\Delta G}$$

Table 3: Economy-wide and Regional effects of planned adaptation in agriculture

Notation	Description	Without Finance					With Finance					
		PAG1	PAG2	PAG3	PAG4	PAG6	PAGGA	PAGSS	PAGF	PAGD	PAGS	PAGT
Macroeconomic effects												
ABSORP	Absorption	-0.6	-0.2	-0.1	-0.1	-0.4	-0.4	-0.3	0.3	-0.2	-0.2	-0.3
PRVCON	Private cons.	-2.7	-1.2	-0.7	-0.6	-1.9	-0.6	-0.4	-0.4	-1.2	-1.2	-1.3
EXPORTS	Exports	-2.3	-1	-0.6	-0.5	-1.6	-0.9	-0.6	-3.7	-1.3	-1.3	-2.4
IMPORTS	Imports	-0.8	-0.4	-0.2	-0.2	-0.6	-0.3	-0.2	0.6	-0.5	-0.5	-0.9
GDPMP	GDP at market prices	-0.8	-0.3	-0.1	-0.1	-0.5	-0.5	-0.4	-0.3	-0.3	-0.3	-0.3
GOVCON	Government cons.	12.8	6.4	3.7	3.2	9.6	0.1	-0.2	6.3	6.3	6.3	6.3
GSAV	Government saving	-173.6	-72.5	-38.7	-32.9	-119.2	-24.4	-13	-54.5	-50.4	-50.8	-55.8
EXR	Real Exchange Rate	-1.6	-0.6	-0.3	-0.3	-1.0	-0.4	-0.1	-1.5	-0.6	-1.2	-1.9
Sectoral output effects												
AGRAIN	Grain crops	-0.2	-0.1	-0.1	0	-0.2	0	0	0	-0.1	-0.1	-0.1
ACCROP	Cash crops	0.4	0.3	0.2	0.1	0.4	0	0	-1.1	0	0	-0.2
AENSET	Enset crop	-1.6	-0.6	-0.3	-0.3	-1.1	-0.2	-0.2	-0.1	-0.4	-0.5	-0.5
ALIVST	Livestock	0.9	0.3	0.2	0.2	0.6	0.2	0.1	0.3	0.3	0.3	0.5
AFISFOR	Fish and forest	-1.6	-0.6	-0.3	-0.3	-1.1	-0.3	-0.2	-0.2	-0.5	-0.5	-0.5
AMINQ	Mining and quarrying	-3.8	-1.6	-0.9	-0.7	-2.6	-1	-0.7	-1.5	-1.7	-1.5	-1.4
ACONS	Construction	0.4	0.2	0.1	0.1	0.3	0	0.2	0.2	0.2	0.2	0.2
AMAN	Manufacturing	-9.8	-4.2	-2.3	-1.9	-6.9	-2.4	-1.9	-4.4	-4	-4.1	-3.4
ATSER	Wholesale and retail	-1.6	-0.6	-0.3	-0.3	-1.1	-0.6	-0.3	-0.8	-0.7	-0.7	-0.9
AHSER	Hotels & restaurants	-6.3	-2.7	-1.4	-1.2	-4.4	-1.3	-1.1	-1.8	-2.4	-2.6	-2.8
ATRNCOM	Transport and comm.	-3.6	-1.6	-0.9	-0.8	-2.6	-1	-0.6	-1.7	-1.5	-1.4	-1.8
AFSER	Financial intermediaries	-2.8	-1.3	-0.7	-0.6	-2	-1.4	-0.1	-1.1	-1.4	-1.1	-1.3
ARSER	Real estate & renting	-0.3	-0.1	-0.1	-0.1	-0.2	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1
APADMN	Public admin. (general)	-0.1	0	0	0	-0.1	-11.9	0	0	0	0	0
APAGRI	Public admin. (agriculture)	98.9	49.4	28.7	24.7	74.2	48.5	48.5	48.5	48.5	48.5	48.5
ASSER	Social services	-2.6	-1.3	-0.7	-0.6	-1.9	-1	-13.8	-1.1	-1.2	-1.2	-1.2
AOSER	Other services	-13.2	-6.2	-3.4	-2.9	-9.6	-3.8	-2	-5.6	-5.9	-5.8	-5.9
GDPFC	Total GDP at factor cost	-0.7	-0.3	-0.1	-0.1	-0.5	-0.5	-0.4	-0.3	-0.3	-0.3	-0.3
Households' welfare effects												
RURH	Rural	-5.0	-2.1	-1.1	-1	-3.5	-0.9	-0.6	-1.3	-1.6	-1.9	-2.1
URBH	Urban	4.1	1.6	0.8	0.7	2.7	0.5	0.2	2.2	-0.1	1.0	1.1
TOTAL	Total	-2.8	-1.2	-0.7	-0.6	-2.0	-0.6	-0.4	-0.4	-1.2	-1.2	-1.3
Regional effects												
ETH	Ethiopia	-0.7	-0.3	-0.1	-0.1	-0.5	-0.5	-0.4	-0.3	-0.3	-0.3	-0.3
TIG	Tigray	2.3	1.3	0.8	0.7	1.8	-0.1	1	1.2	1.2	1.2	1.3
AFR	Afar	-0.8	-0.3	-0.1	-0.1	-0.5	-0.9	-0.3	-0.3	-0.3	-0.2	-0.2
AMH	Amhara	-0.5	-0.2	-0.1	0	-0.3	-0.2	-0.3	-0.2	-0.1	-0.1	-0.1
ORO	Oromia	-0.7	-0.2	-0.1	-0.1	-0.4	-0.3	-0.4	-0.4	-0.3	-0.3	-0.3
SOM	Somali	-0.7	-0.3	-0.1	-0.1	-0.5	-0.5	-0.2	-0.2	-0.2	-0.2	-0.3
BNG	Benshangul-Gumuz	-0.3	0	0	0	-0.1	-0.6	-0.3	-0.1	0	0	0
SNNP	Southern NNP	-0.5	-0.2	-0.1	-0.1	-0.3	-0.3	-0.3	-0.3	-0.2	-0.2	-0.2
GAM	Gambela	-0.5	-0.1	0	0	-0.3	-0.9	-0.6	-0.3	-0.2	-0.1	-0.2
HAR	Harari	-0.8	-0.3	-0.1	-0.1	-0.5	-1.7	-1.4	-0.4	-0.3	-0.3	-0.4
ADD	Addis Ababa	-2.9	-1.3	-0.7	-0.6	-2.1	-1.7	-1.4	-1.3	-1.3	-1.2	-1.3
DD	Dire Dawa	-2	-0.8	-0.4	-0.4	-1.4	-0.9	-0.7	-0.9	-0.8	-0.8	-0.9

Source: CGE Simulations and Regional Projections

Notes: The CGE results are robust to ±25% of the elasticities of production (i.e., factor substitution), international trade (i.e., import substitution and export transformation), and household's demand (i.e., income and Frisch parameter) used in the calibration.