PUBLIC POLICY MAKING
THEORIES, ANALYSIS, AND MODELS (VOL 1)

NAGMA AHMED

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Evaluation and Modeling for Policy Support: Challenges and Solutions

Ousmane Badiane, Christian Henning, and Eva Krampe

In 2003, African leaders endorsed the Comprehensive Africa Agriculture Development Programme (CAADP) as the action plan for putting agriculture back on Africa's development agenda. A critical challenge for all policymakers wrestling with economic development and poverty reduction in Africa—as well as everywhere else in the world—is how to assess which programs and policies actually work. A corollary to this challenge is to identify, among the programs that do work, those that provide the best value for money (OECD 2004). A key approach of CAADP is the promotion of evidence-based policies, where it has been fully recognized that policy impact evaluation is an important prerequisite for evidence-based policy processes. In the literature, quantitative policy impact evaluation is considered a key method for generating scientific knowledge on which policies actually work best in a country. However, the incorporation of this knowledge into the political decisionmaking process is a non-trivial process. Hence, beyond generating knowledge, incorporating it into the political process is another prerequisite of an effective evidence-based policy process. In this regard, it is widely expected that active stakeholder participation will not only increase politicians' incentives to select the most efficient policies, but also increase the capacity of policy learning inherent in a political system (see e.g. Ball 1995). The principles of review, accountability, and inclusivity, which are core principles of CAADP, reflect the belief that participatory policy processes at the continental, regional, and

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national levels lead to improved coordination, mutual learning, and the adoption of best practices, which together should result in improved policy planning and execution, better growth, and poverty reduction outcomes.

Linking economic analysis to policy formulation and outcome is a very complex and tedious process. The problem is not just one of applying rigorous economic theory to high-quality data in order to tackle relevant questions. This is difficult enough but may still be the easiest part. A greater challenge is for the knowledge and insights generated from policy research and analysis to find their way into the decisionmaking process. And even when it does, science-based evidence forms only one part, and often not the most important part, of the understanding that influences the decisionmaking process, where imperfect political competition often induces biased incentives for politicians, impeding the implementation of available best-practice politics.

Contained in the present volume are a selection of tools and methodologies that can help to tackle the complexities in the analysis of policy processes and outcomes under the implementation of the CAADP agenda. The contributions go beyond the innovative methods and tools applied for quantitative policy impact analyses by international organizations like the Organisation for Economic Co-operation and Development (OECD), the World Bank or the European Union, as they also to examine the process behind the choice of policies and the factors that determine the likelihood of their adoption and implementation. It is the product of a workshop organized by the University of Kiel (CAU), the *International Food Policy Research* Institute (IFPRI) and the *Poverty Reduction, Equity, and Growth* Network (PEGNet) of the Kiel Institute of World Economy in 2011. The workshop brought together scholars working in the field of policy modeling and evaluation at the microeconomic and macroeconomic level or in the field of quantitative modeling of policy processes.

The various contributions in these proceedings are not targeted only to experts and interdisciplinary scholars working on empirical or theoretical research using quantitative policy modeling and evaluation techniques. They are also intended for technical experts, including policymakers and analysts from stakeholder organizations, who are involved in formulating and implementing policies to reduce poverty and to increase economic and social well-being in African countries.

In order to facilitate discussion on the recently developed evaluation methodologies and their applicability in the context of CAADP and its evaluation mechanisms, we first develop a general assessment framework. This framework incorporates guidelines and principles not only for economic policy impact evaluation, but also for methodological approaches and tools assessing policy processes quantitatively.

1 A General Framework for Policy and Policy Process Evaluation

1.1 The Basic Setup

At an abstract level, impact evaluation of a given policy instrument, say 'γ', includes two different aspects. First, it is necessary to assess the technical transformation of policy γ into relevant policy outcomes z. This transformation is captured by the technical transformation function $T(z, \gamma)$, which links specific outcomes to the policy in question. Second, different policy outcomes have to be evaluated from the viewpoint of society. Formally, welfare analysis is a tool that provides for an adequate evaluation criterion, i.e., an index function $EC(z)$. $EC(z)$ transforms each state of the world z into an index number, and by doing so allows for a consistent ordering of states. For example, $EC(z1) > EC(z2)$ implies that state $z1$ is preferred to state $z2$. Accordingly, if we were to know both functions, EC and T, evaluation would be a purely technical task. For a set of available policies $\gamma \in A$, where A is the set of all feasible policies a society can choose from, the policy with the maximal evaluation value EC would be implemented:

$$E(\gamma) = \mathrm{Max}\{EC(z)|T(z, \gamma) = 0\} \tag{1}$$

In reality, however, an empirical specification of both the welfare function EC and the technical transformation function T is extremely complex and difficult. Conventional policy impact analyses that focus on identifying the technical transformation function usually assume a welfare function as exogenously given. The main argument for this assumption is that a comprehensive modeling of the decisionmakers' evaluation of his or her preferred outcome and of the political decisionmaking processes cannot be attained with the research approaches at hand. A corollary to this argument is that research can at best focus on the technical relationship (T) between alternative policies and outcomes, thereby offering evidence-based guidance for decisionmaking.

Even when assuming an exogenously given welfare function ($EC(\gamma)$), policy impact evaluation still remains a quite complex undertaking, because it is by no means straightforward to specify the technical transformation function. This results from many different reasons. First, policy outcomes are often formulated in terms of abstract, higher level policy objectives, e.g., equal quality of life conditions in rural and urban regions. These objectives need to be transformed into a set of measurable policy outcome indicators, which then can be systematically related to policy programs. Second, the relationship between policy programs and lower level policy objectives, as well as the relationship between the latter and higher level objectives, all reflect the behavior of people and thus require a theory of human behavior. Therefore, a quantitative specification and assessment of the technical relationship between inputs of a policy program and their effects on higher level policy objectives remains a tricky business. More importantly, disentangling the effects of a specific policy program becomes more challenging when many policy programs are implemented simultaneously.

1.2 Policy Impact Evaluation

The framework includes three major components, which are discussed in the subsequent sections. They include policy evaluation criteria, intervention logic, and evaluation methods.

1.2.1 Policy Evaluation Criteria

Clear and relevant evaluation criteria should be the starting point of developing adequate evaluation tools. Five such evaluation criteria can be distinguished (European Commission 2004):

– Relevance: What are the general needs, problems, and issues, both short and long term, that are being targeted under the policy programs? Given the identified needs, a hierarchy of general, intermediate, and specific program objectives can be derived, where objectives at a lower-level function as inputs to achieve objectives at the next higher level.
– Effectiveness: To what extent does a policy program deliver results or outputs that correspond to program objectives? Effectiveness is a technical relationship between program objectives and program results.
– Efficiency: To what extent are program objectives achieved at the lowest costs? Efficiency is a technical relationship between program inputs and program results.
– Utility: To what extent does a policy program contribute to the identified needs?
– Sustainability: To what extent does the utility of a program last after the program has been terminated?

1.2.2 Intervention Logic

Any evaluation of policy programs is based on intervention logic, or the systematic derivation of the hierarchy of measurable objectives relating a policy program, all the way from specific, operational objectives to more abstract, general policy objectives. The intervention logic, as a central evaluation tool, thus corresponds to a set of hypothetical cause-and-effect linkages that describe how an intervention is expected to attain its global objectives.

To this end, an intervention can be systematically subdivided into specific elements that are related to each other at specific stages of the project, as demonstrated in Fig. 1.

In general, we can distinguish program implementation and program effects. Any policy program starts with its implementation; for example, financial inputs or administrative capacities are used to realize specific outputs. In an investment program, for example, the inputs might correspond to a specific amount of financial resources that are spent to subsidize investment projects on farms. The output of

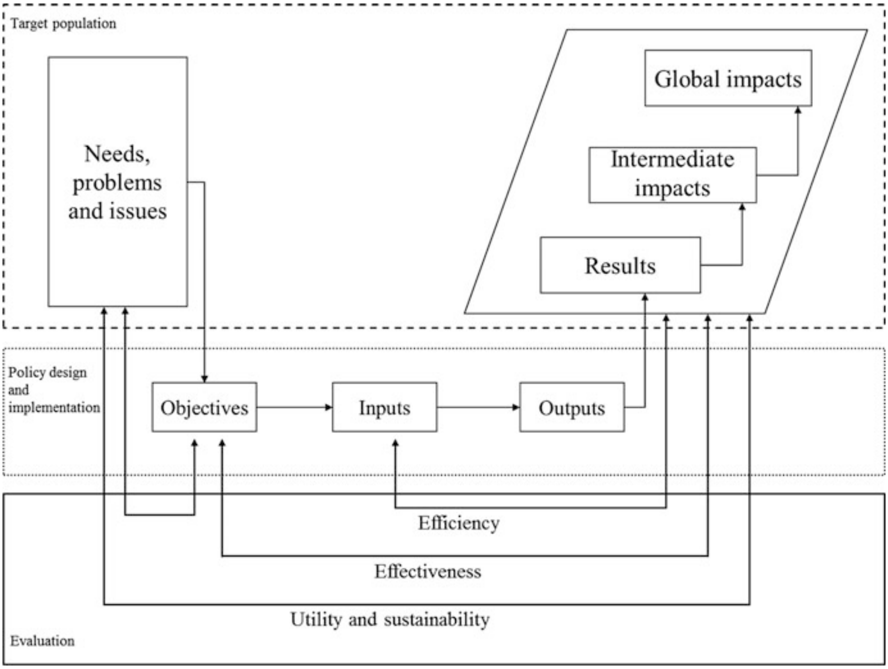


Fig. 1 Schematic presentation of a policy impact evaluation framework. Source: Authors, based on European Commission (2004)

this investment project corresponds to the number and type of investment programs that are actually subsidized. Depending on the applied implementation procedure, the number and type of investment projects might differ. In particular, if farms are heterogeneous, the type of farms that will be subsidized under a program might differ according to applied implementation procedures.

The outputs of a project generate effects, which can be further subdivided into results (short-term effects that occur at the level of direct target groups) and impacts (medium- and long-term effects). Medium-term impacts involve effects on both direct and indirect beneficiaries/recipients of assistance, while long-term effects correspond to the global impacts of a policy program. Moreover, the global impact of a policy program is related to the general needs, problems, and issues identified at a higher policy level, where the program's utility is defined as its contribution to identified needs (see Fig. 1).

1.2.3 Evaluation Methods

Any intervention logic for policy programs is based on theory. Two different evaluation approaches can be distinguished: (1) qualitative and (2) quantitative models. Qualitative models, for example the logical framework matrix, simply provide a qualitative description of the intervention logic. Quantitative impact evaluation is based on a quantitative specification of relevant cause-and-effect linkages. Quantitative evaluation models can be further subdivided into model based, and econometric policy evaluation approaches.

Model-Based Policy Evaluation

The common approach in economics for specifying an intervention logic of policy programs is to apply a theoretical model. Different approaches are available for model-based policy evaluation, ranging from simple incidence analysis, to more advanced micro and macro behavioral models, to complex micro-macro linkages models. These approaches differ regarding the set of agents and actions they consider, as well as the assumed coordination mechanism of individual actions. The complexity increases with the number of agents and the level of behavioral response that models explicitly take into account.

Simple Incidence Analysis

Simple incidence analysis ignores any behavioral response of involved actors. For example, an ex ante evaluation of a planned tax reform or a planned investment subsidization project may be based on a simple arithmetic representation of the incidence of a tax or subsidy, without simulating any policy response of involved agents (Bourguignon et al. 2002). However, policies often have important price or income effects, which in turn induce changes of agents' behavior, such as changes in supply, consumption, or labor demand behavior. A behavioral model is needed in this case.

Micro-simulation Partial Equilibrium Models

In contrast to incidence models, behavioral models take the policy responses of involved actors explicitly into account. However, there exist different types of behavioral models that differ regarding the level of response they take into account. Micro-simulation models take only the direct policy response of involved actors into account. Basically, these models are partial equilibrium models that neglect the indirect effects of policy programs resulting from agents' interaction at the macro level. The structure of these models can be described as follows:

$$x_i = F(\xi, \varphi_i, \gamma) \tag{2}$$

$$z = G(x_i, \xi, \varphi_i, \gamma) \tag{3}$$

where x_i denotes the vector of relevant behavioral variables of an individual agent i, φ and ξ denote the general and agent-specific exogenous variables, respectively, that determine individual behavior, γ is the evaluated policy, and z is the policy outcome.

For a policy evaluation, the behavioral Eq. (2) has to be estimated based on survey data. Given the specified Eqs. (2 and 3), the impact of different policies can be simulated. The relevant agents are, for example, all households or firms in a specific region. Often census data is used to provide information on their individual characteristics. The response of all relevant agents can be estimated using Eq. (3), given this information. The behavioral function $F()$ is either specified as a reduced form or an explicit functional form is derived from the underlying microeconomic optimization problem.[1] All micro-simulation models neglect the interaction of individual agents. Micro-simulation models are not adequate tools for policy evaluation if behavioral response at the micro level crucially depends on interactions among actors at the macro level.

Macro or General Equilibrium Models

General equilibrium models are designed to include policy effects at the macro level (Bourguignon et al. 2002). The most simple general equilibrium models are linear models, e.g., regional input-output models or social accounting matrices (SAMs). More advanced (nonlinear) general equilibrium models are standard computable general equilibrium (CGE) approaches. With the CGE approach, policy-induced behavioral responses at the micro level are explicitly transmitted onto the overall economy via induced price changes at the macro level. However, the explicit inclusion of macro-level effects comes at a cost. Standard CGE models are highly aggregated, assuming only a small number of representative economic agents (firms and households). Theoretically, CGE models could be more disaggregated into a large number of heterogeneous firms and households, but they become difficult to solve with the computer capacities usually available. Moreover, the empirical estimation of functional parameters of the CGE model is also a major problem due to very limited adequate data. Thus, although CGE models can be linked with a micro-accounting model, if relevant policy evaluation criteria include distributional effects, aggregated CGE models are less appropriate tools for an adequate policy evaluation (see Chapter "Sequential Macro-Micro Modelling with Behavioral Microsimulations" in this volume).

[1]A very interesting nonparametric approach applies propensity score matching techniques, originally developed as an advanced ex post evaluation technique, to simulate policy effects at the micro level (Todd and Wolpin 2006). An advantage of a nonparametric estimation strategy, when compared to parametric approaches, follows from the fact that the former are less demanding regarding data requirements and do not require any specific functional form assumptions (Todd and Wolpin 2006). However, in many cases nonparametric approaches are not applicable to ex ante policy evaluation, but stronger modeling assumptions, e.g., functional form assumption, have to be made.

Micro-Macro Linked Models

In order to deal with computational capabilities and empirical complexity issues, some authors suggest micro-macro linked models, which combine micro-simulation models and macro general equilibrium models (Robilliard et al. 2001). A full integration of micro and macro models is hard to achieve, although technically possible (Bourguignon et al. 2008). Therefore, often a sequential approach is applied where first macro models are solved and central variables of the macro model are then incorporated into corresponding micro models (Robilliard et al. 2001). Standard CGE models assume that interactions among individual agents are coordinated through perfect markets. In reality, transaction costs as well as market power imply imperfect competition and thereby perfect markets rarely exist. Of course, the standard CGE approach can be extended to include market imperfection due to transaction costs or market power. But these extended approaches are technically more demanding and therefore have been rarely applied for policy evaluation. More feasible alternatives include a linked or sequential micro-macro model, in which different micro-behavioral models can be combined with macro equilibrium models. Linked micro models include farm-household models incorporating non-market activities or nonlinear transaction costs (Singh et al. 1986).

1.3 Econometric Policy Evaluation

A general problem of model-based policy evaluation is that models are often quite complex, and an empirical specification of the model is often impossible due to limited data. Central causal relationships assumed by a model cannot easily be verified or tested empirically. Hence, it is necessary to develop methods that are able to provide empirical evidence suitable for guiding policy. This is not an easy task, because it refers to causal inferences that require special research methods that are not always easy to communicate due to their technical complexity.

This section surveys econometric methods that the economics profession has used increasingly over the past decade to estimate causal effects of policies. A causal linkage can be specified as a simple binary relationship between program participation and a relevant performance variable, e.g., the impact of participation in a training program on farm profit or employment. The most straightforward way to measure the policy impact in this context would be to compare the performance of a program participant with the counterfactual performance of the participant without participation. A major challenge of this approach is to simultaneously observe both performances, assuming participation and the counterfactual performance. The different methods applied in this area are designed to distinguish accidental association from causation. They provide empirical strategies to identify the causal impact of different reforms on any kind of policy outcomes.

The best approach to identifying program impact on a given performance variable is to conduct field experiments, i.e., to undertake a random selection of the units of interest into participating (treatment) and non-participating (control) groups in a policy program. Based on a comparison of the average performance of the randomly selected treatment and control groups, the impact of the policy program can be statistically evaluated. While experimental approaches can be applied for ex post and ex ante policy evaluation, a huge drawback of this approach is that it is extremely expensive and, for many policies, it is impossible to design sophisticated field experiments allowing a quantitative evaluation. In this case, other econometric procedures based on observational data are available that allow one to identify the true impact of a policy program assuming a non-random selection of treatment and non-treatment groups. These econometric approaches can be subdivided into non-parametric and parametric approaches. An increasingly popular non-parametric approach to policy evaluation is matching on observable factors, especially propensity score matching (PSM) (Caliendo and Hujer 2006). Matching and other econometric methods that build on the idea of controlling for observable factors have clear limitations. The policy impact is very often determined by factors that are unobserved by the researcher. This implies that PSM delivers biased results or that policy impact is heterogeneous across participants. In order to get around these problems, alternative methods have been developed. They are used to emulate experimental settings using observational data, i.e., 'natural' experiments, such as the instrumental-variable approach and the regression-discontinuity approach, or panel-data-based methods that aim to account for endogeneity.

A general cutback of all statistical models, however, is the fact that they are limited to causal inferences, i.e., empirical testing on the question of whether a given policy program achieved its intended outcome or not. In general, they are not alone suitable to elucidate the question of why or how a policy program works. Therefore, the best approach to policy evaluation is to combine model-based and econometric methods as complementary approaches, where econometric techniques are applied to identify causal relations between specific policy programs (γ) and central economic factors (θ), and model-based techniques to analyze the impact of a change in these economic factors on central outcome indicators (z). The transformation function $T(z, \gamma)$ is separated into two parts: (i) a policy impact function $\theta = PI(\gamma)$ describing the relationship between policy interventions and the economic factors θ, and (ii) a policy outcome function $PO(z, \theta)$ describing the linkages between the economic factor θ and policy outcomes z. Econometric methods are more suitable for tackling the policy impact function, whereas economic models do a better job of tracking the policy outcome function.

1.4 Modeling and Evaluation of Policy Processes

Many countries around the globe continue to apply suboptimal policies despite available scientific knowledge demonstrating the existence of policy instruments that would lead to more desirable overall economic and social outcomes. For example, there is evidence that many developing countries that still largely depend on agriculture, especially in Africa, underinvest in this sector. They especially spend too little budget on, e.g., agricultural research and extension which are areas of public investment with high returns in terms of growth and poverty reduction (Fan and Rao 2003).

Thus, evidence-based policy formulation includes, beyond the generation of scientific knowledge, the effective incorporation of this knowledge into the political decisionmaking process. The latter is by nature complex and dynamic, involves multiple actors (individuals and organizations), and is defined by local political, social (cultural and belief systems) and institutional realities (bureaucratic structures and capacities). Essentially, the policy process corresponds to an aggregation of the heterogeneous preferences of different stakeholder groups into a common policy decision. In representative democracies, preference aggregation is subdivided into two steps. First, heterogeneous voter preferences are transformed into the corresponding preferences of a subset of political representatives via democratic elections. A central property of democratic elections is their representativeness, i.e., the correspondence between the distribution of preferences among elected representatives with the distribution of preferences among the voting population. Second, the heterogeneous preferences of political representatives are aggregated into a final political decision via legislative voting procedures.

The above process can be modeled as follows: Let a society comprise of n_I different groups, where $I = 1, \ldots, n_I$ denotes the index of stakeholder groups. Further, let $U_I(z)$ denote the utility function of an individual group member $i \in I$, and w_I denotes the population share of group I. Then, an ideal policy process can be defined as a process that results in a policy choice γ^*:

$$\gamma^{ideal} = \arg\max_{\gamma} \sum_I w_I U_I(z) \quad s.t. \quad T(z,\gamma) = 0 \tag{4}$$

where $T(z,\gamma)$ is the political technology, that is, the subset of all policy outcomes z that can be optimally achieved by available policies γ, given existing political knowledge.

Differences between observed and ideal policy choices result from two different sources. First, a biased aggregation of society preferences, i.e., real policy processes, results in different political weights of groups when compared to the ideal democratic process. At a theoretical level, existing political economy models highlight this bias as a main cause of persisting inefficient policies. Biased political weights correspond to biased incentives of elected politicians, and result from asymmetric lobbying activities (Grossman 1994) or biased voter behavior (Bardhan and Mookherjee 2002). More recently, Persson and Tabellini (2000) highlight the role of formal constitutional rules as determinants of politicians' incentives to misrepresent society interests and choose inefficient policies.

Beyond biases resulting from the aggregation of society preferences, a second source of biased policy is that the true political technology is not fully known by the relevant political actors. Understanding the complex relationship between policy instruments and induced policy outcomes is difficult. As a result, political actors use simple mental models to understand how policies translate into outcomes. We call these simple mental models policy beliefs. Based on their policy beliefs, political actors derive their individual preferences with respect to policies. Similarly, some authors have recently highlighted the role of biased voter beliefs as a main determinant of inefficient policy choices (Beilhartz and Gersbach 2004; Bischoff and Siemers 2011; Caplan 2007). In particular, the work by Caplan (2007) has been highly recognized in public choice literature, as he has collected an impressive amount of evidence showing persistently biased voter beliefs. Based on his empirical findings, Caplan (2007) draws the rather pessimistic conclusion that democratic mechanisms of preference aggregation naturally lead to the choice of inefficient policies.

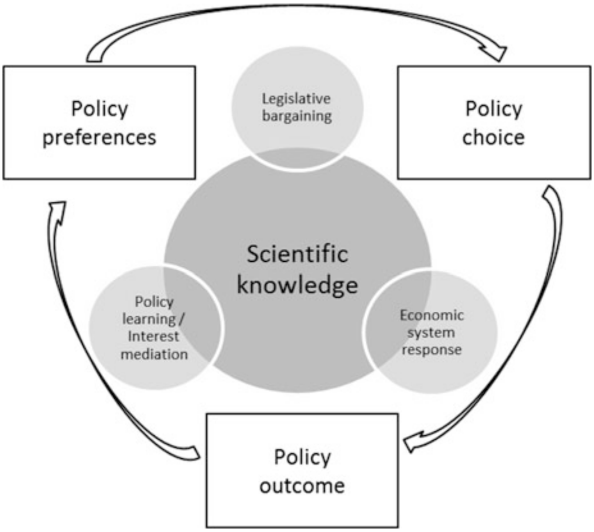
In this context, two key underlying premises that define the framework of evaluating policy processes are adopted here. The first premise is that biased voter beliefs imply biased voter behavior and hence a biased aggregation of preferences. The second premise is that politicians and lobbyists do not fully understand the complex relationship between political instruments and desired policy outcomes. Hence, beyond biased incentives, lack of political knowledge becomes another important cause of policy failure.

The evaluation of policy processes can be based on the comparison between actual, implemented policy choice γ^{actual} and the ideal policy choice γ^{ideal} : $\|\gamma^{actual} - \gamma^{ideal}\|$. $\|\|$ is the Euclidian distance. That is, the evaluation of policy processes should be able to identify political performance gaps as defined above. Policy diagnosis should also allow for the separation of identified performance gaps into incentive-induced and knowledge-based gaps. Finally, a comprehensive evaluation of policy processes should provide the possibility of developing a political therapy, i.e., the derivation of a strategy to reduce identified performance gaps. The latter in particular calls for model-based evaluation methodologies.

Our methodology is derived from the model described in Fig. 2.

Schematically, a dynamic policy process includes a sequence of political decisionmaking based on actors' policy beliefs, the transformation of the selected policy into outcomes via induced policy responses in the economic system, the translation of economic and political outcomes into political support via elections and lobbying and policy learning, i.e., the updating of policy beliefs (see Fig. 2). Policy learning occurs via two mechanisms. First, based on observed outcomes, political actors engage in observational policy learning, i.e., they update their policy beliefs by comparing observed outcomes with the policy outcomes they expected based on their initial policy beliefs. Individual observations, however, are noisy and hence individual observational learning is limited. Accordingly, political actors engage in communication learning, i.e., they update their policy beliefs based on political beliefs communicated by other actors. Within policy processes, communication learning occurs via political mass communications, i.e., the formation of a public opinion, as well as via exclusive political communication within a political elite comprising of relevant politicians and stakeholder organizations. Interestingly, the social organization of political communication processes has a significant

Fig. 2 Schematic representation of a policy process. Source: Authors



impact on the speed of policy learning. In particular, the structure of a communication network has a significant impact on its capacity to aggregate decentralized information within a political elite. Moreover, network structure also determines the influence of individual organizations on the policy beliefs of relevant politicians and hence the direction of the bias of political decisionmaking.

Few studies have explicitly mapped out the above processes in explaining the poor past performance of policy reforms and investment strategies, particularly in the agricultural sector. Most have offered narratives based on historical accounts, pointing to the strong role of powerful personalities, vested interests, corruption, and external pressures, in influencing policy outcomes (Clay and Schaffer 1984; Juma and Clark 1995; Keeley and Scoones 2003; Young 2005).

The challenge of analyzing participatory and evidence-based policy processes empirically is to develop an applicable model framework that allows for quantitative modeling of political decisionmaking and policy-learning processes, including the endogenous formation of a legislator's political preferences and policy beliefs. In this context, four components of a political process framework can be distinguished (see Fig. 2): (i) the derivation of politicians' incentives from electoral competition and lobbying, i.e., modeling voter behavior and interest group activities; (ii) modeling legislative bargaining, i.e., the derivation of a collective policy decision by a set of heterogeneous legislators based on constitutional rules; (iii) economic modeling of policy impacts, i.e., the transformation of policies into outcomes; and (iv) modeling of policy learning, i.e., the formation and updating of policy beliefs via observational and communication learning. The existing evaluation literature focuses only on the third component, although the other three components represent aspects of the policy process that play a key role in explaining why some nations succeed while others fail in adopting efficient and effective policies.

The current volume assembles different contributions, which together provide a comprehensive set of innovative quantitative approaches that can be used to model these various aspects of the policy process. In particular, Chapter "Modeling and Evaluation of Political Processes: A New Quantitative Approach" presents an evolutionary computable general political economy equilibrium (eCGPE) model, combining all four components listed above as an integrated quantitative approach to model and evaluate real policy processes.

2 Contributions to This Volume

Following this overview of methodological approaches to quantitative policy evaluations, the twelve contributions to these proceedings can be subdivided into two parts: I. Theory and application of quantitative policy impact evaluation models, and II. Theory and application of quantitative approaches to model and evaluate policy processes.

Part I is subdivided into three sections: 1. Macroeconomic Models, 2. Micro-Econometric Models and 3. Micro-Macro Linked Models. As an opener to Sect. 1, O. Badiane, S. Odjo and F. Wouterse present their results for CAADP-reform strategies and the long-term outlook for growth and poverty reduction of Economic Community of West African States (ECOWAS) member countries (Chapter "Comparative Analysis of Strategies and Long Term Outlook for Growth and Poverty Reduction among ECOWAS Member Countries"). They use a recursive dynamic CGE model linked with a micro accounting model, transforming economic macro shocks into individual household income changes for their analysis. The second contribution of the section is by M. Wiebelt, K. Pauw, J.M. Matovu, E. Twinmukye and T. Benson. They provide a comprehensive analysis of the different policy options to use oil revenues in Uganda (Chapter "How to Spend Uganda's Expected Oil Revenues? A CGE Analysis of the Agricultural and Poverty Impacts of Spending Options"). As their analysis focuses on the implication on poverty, a recursive dynamic CGE model is linked with a micro accounting model transferring average income changes of representative households generated in the CGE model into a corresponding change of individual household income at the micro level.

Econometric evaluation techniques are applied and discussed by S. Benin et al. in Chapter "Impact of the National Agricultural Advisory Services (NAADS) Program of Uganda: Considering Different Levels of Likely Contamination with the Treatment". In particular, they develop and apply innovative matching approaches to assess the impact of an agricultural advisory services program in Uganda based on observational data.

Furthermore, Sect. 2 contains two innovative micro-macro-linked approaches. In Chapter "Modeling Agricultural Growth and Nutrition Linkages: Lessons from Tanzania and Malawi", K. Pauw applies a CGE model that is sequentially linked with a microeconomic nutrition demand model to analyze the impact of different growth strategies on income growth and nutrition in Tanzania and Malawi. J. Lay derives and applies a macroeconomic CGE model that is sequentially linked with a reduced form model of households' occupational choices on formal and informal labor markets (Chapter "Sequential Macro-Micro Modelling with Behavioral Microsimulations"). The micro model explicitly includes household's fixed effects to include unobserved heterogeneity among households into the structural labor market model. The approach is used to empirically analyze poverty and the distributional implications of Doha round scenarios in Brazil and poverty and the distributional implications of the Bolivian gas shock.

Part II focuses on innovative quantitative models to evaluate evidence-based and participatory policy processes under CAADP. In particular, an eCGPE approach is theoretically derived and empirically applied to the CAADP reform process in Malawi. It is demonstrated how political performance and incentive gaps can be identified and quantitatively calculated using an eCGPE. This part opens with the presentation of the complete eCGPE framework by C. Henning (Chapter "Modeling and Evaluation of Political Processes: A New Quantitative Approach"). In particular, the theories used to develop an eCGPE, which includes an economic, a legislative decisionmaking, an interest mediation, and a political belief formation module, are explained. The other contributions of the section present findings from the empirical application of the framework to Malawi's policy process.

Chapters "A Network Based Approach to Evaluate Participatory Policy Processes: An Application to CAADP in Malawi" and "The Formation of Elite Communication Networks in Malawi: A Bayesian Econometric Approach" focus on the findings from the political belief formation module. Applying social network theory and methods, they analyze collective political belief formation of governmental and non-governmental actors through communication learning in networks. C. Henning and E. Krampe (Chapter "A Network Based Approach to Evaluate Participatory Policy Processes: An Application to CAADP in Malawi") also develop an evaluation framework for participatory policy processes based on the political belief formation module. C. Aßmann, E. Krampe and C. Henning (Chapter "The Formation of Elite Communication Networks in Malawi: A Bayesian Econometric Approach") test some theoretical hypotheses on the determinants of communication ties among key national stakeholder organizations, donors and central political actors. They apply an adaptation of the Bayesian estimation scheme for binary probit models, which can deal with missing values inevitably occurring within survey data.

L. Seide, C. Henning, and S. Petri (Chapter "Voter Behavior and Government Performance in Malawi: An Application of a Probabilistic Voting Model") present an analysis of voter behavior and its impact on governmental accountability and capture. They derive the implications of voter behavior on governmental accountability and capture using probabilistic voting theory.

The final chapter of Part II is by C. Henning, J. Hedtrich, L. Sene, and E. Krampe. They use the eCGPE model to provide a comprehensive analysis of the economic impacts of policy options and knowledge and political incentive gaps in Malawi (Chapter “Whither participation? Evaluating Participatory Policy Processes Using the CGPE Approach: The Case of CAADP in Malawi”).

The book closes with two chapters summarizing the central practical policy implications of the presented scientific work. In particular, M. Johnson discusses how quantitative policy monitoring and evaluation systems can be translated into political action based on the empirical example of the strategic analysis and knowledge support system (SAKSS) implemented within CAADP (Chapter “Strategic Analysis and Knowledge Support Systems (SAKSS): Translating Evidence into Action”). In Chapter “Lessons Learned and Future Challenges”, C. Henning and O. Badiane present lessons learned for practical policy implementations by highlighting the book’s main findings in the areas of economic modeling of growth-poverty and policy-growth linkages, as well as political economy modeling of participatory policy processes. Beyond presenting innovative methodological approaches, the empirical studies in this book also shed light on the role of voters, stakeholders, and donors in participatory policy processes, and provide convincing evidence that beyond constitutional rules, policy beliefs and policy network structures are important determinants of government performance. The chapter also highlights the future outlook and challenges to the modeling and evaluation of policies and political processes.

References

Ball, R. 1995. Interest groups, influence and welfare. *Economics and Politics* 7 (2): 119–146.

Bardhan, P., and D. Mookherjee. 2002. *Relative capture of local and central governments: An essay in the political economy of decentralization*. Working Paper C99-109. Hong Kong: Center of International and Development Economics Research.

Beilhartz, H.-J., and H. Gersbach. 2004. *General equilibirium effects and voting into a crisis*. Center for Economic and Policy Research (CEPR) Discussion Paper 4454.

Bischoff, I., and L.-H. Siemers. 2011. Biased beliefs and retrospective voting: Why democracies choose mediocre policies. *Public Choice* 156 (1–2): 163–180.

Bourguignon, F., L. P. da Silva, and N. Stern. 2002. *Evaluating the poverty impact of economic policies: Some analytical challenges*. Mimeo. Washington, DC: The World Bank.

Bourguignon, F., C. Diaz-Bonilla, and H. Lofgren. 2008. *Aid, service delivery, and the millennium development goals in an economy-wide framework*. Policy Research Working Paper 4683. Washington, DC: The World Bank.

Caliendo, M., and R. Hujer. 2006. The microeconometric estimation of treatment effects – An overview. *Journal of the German Statistical Society/Allgemeines Statistisches Archiv* 90 (1): 197–212.

Caplan, B. 2007. *The myth of the rational voter – Why democracies choose bad politics*. Princeton: Princeton University Press.

Clay, E., and B. Schaffer. 1984. *Room for Manoeuvre; An exploration of public policy in agricultural and rural development*. London: Heineman Educational Books.

European Commission. 2004. *Evaluating EU activities? A practical guide for the commission services*. Luxembourg: Office for Official Publications of the European Communities.

Fan, S., and N. Rao. 2003. *Public spending in developing countries: Trends, determination and impact*. EPTD Discussion Paper 99. Washington, DC: International Food Policy Research Institute.

Grossman, J.B. 1994. Evaluating social policies: Principles and U.S. experience. *The World Bank Research Observer* 9 (2): 159–180.

Juma, C., and N. Clark. 1995. Policy research in sub-Saharan Africa: An exploration. *Public Administration and Development* 15 (2): 121–137.

Keeley, J., and I. Scoones. 2003. *Understanding environmental policy processes: Cases from Africa*. London: Earthscan.

OECD (Organisation for Economic Co-operation and Development). 2004. *Analysis of the 2003 CAP Reform*. Number 16. 2003. Paris: OECD.

Persson, T., and G. Tabellini. 2000. *Political economics – Explaining economic policy*. Cambridge: MIT Press.

Robilliard, A.-S., F. Bourguignon, and S. Robinson. 2001. *Crisis and income distribution: A micro-macro model for indonesia*. Mimeo. Washington, DC: The World Bank.

Singh, I., L. Squire, and J. Strauss. 1986. *Agricultural household models. Extensions, applications, and policy*. Baltimore: The Johns Hopkins University Press.

Todd, P. E., and K. I. Wolpin. 2006. *Ex-ante evaluation of social programs*. Penn Institute for Economic Research Working Paper 06-022. Philadelphia: University of Pennsylvania. http://ssrn.com/abstract=931393.

Young, J. 2005. Research, policy and practice: Why developing countries are different. *Journal of International Development* 17: 727–734.

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Part I
Modeling Economic Policies: An Introduction

2

ECOWAS Members: Techniques for Poverty Reduction and Growth

Ousmane Badiane, Sunday P. Odjo, and Fleur Wouterse

1 Introduction

The Common Agricultural Policy of ECOWAS (ECOWAP) was adopted in January 2005, following a close consultation among member states and regional professional organizations. The adoption came <2 years after the launch of the Comprehensive Africa Agriculture Development Program (CAADP) under the New Partnership for Africa's Development (NEPAD), an initiative of the African Union. In March 2005, ECOWAS organized, in Bamako, Mali, the Regional Implementation Planning Meeting for CAADP in West Africa. The meeting reviewed the objectives, targets, and principles of CAADP and their alignment with ECOWAP, and confirmed the latter as the political as well as institutional framework for the implementation of the former in the West Africa region. In May 2005, ECOWAS and the NEPAD Secretariat developed a joint ECOWAP/CAADP action plan for the period 2005–2010 for the development of the agricultural sector.

In adopting CAADP, African governments had, amongst others, set for their countries a collective goal of achieving a 6% agricultural growth rate as a key strategy toward achieving the Millennium Development Goal of reducing poverty to 50% of its 1990 level by 2015. They had also opted for a partnership framework to mobilize the required funding to achieve the above growth rate, including the allocation by national governments of a budget share of at least 10% to the agricultural sector. Finally, CAADP also reflects an option for evidence and outcome based planning and implementation in support of an inclusive sectoral review and dialogue process, in line with the broader NEPAD peer review and accountability principle. A key element of ECOWAP/CAADP is, therefore, to

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support and add value to the efforts of individual member states, where necessary, to ensure that they meet the above growth, budgetary, and poverty reduction targets and align with the above principles.

An important part of the planning work carried out by the technical teams in individual member states consisted of reviewing past, current, and emerging country efforts against the above objectives. This includes:

1. Examining the recent growth performance of the agricultural sector, as well as future growth and poverty outcomes based on observed trends;
2. Determining how such outcomes compare with the targets established for the sector under the ECOWAP/CAADP agenda and how they compare with the Millennium Development Goal to halve the proportion of people living on less than a dollar a day (MDG1);
3. Measuring the prospects of meeting these targets and analyzing the implications for future sector growth and poverty-reduction strategies;
4. Estimating the long term funding needs to accelerate agricultural growth and achieve the poverty MDG.

The embracing of ECOWAP/CAADP as the centerpiece of poverty-reduction strategies by member states also implies that agriculture and its individual subsectors must play a primary role as leading sources of pro-poor growth at the national and rural levels. Successful implementation of the agenda at the country level should therefore be guided by a good understanding of the impact of sector wide growth and growth within individual agricultural subsectors on income and poverty levels among different categories of rural households and across geographic zones.

To facilitate implementation of ECOWAP/CAADP, the ECOWAS Commission established a task force and mobilized the necessary technical expertise and funding for the preparation of regional and national agricultural investment programs, including US$9 million of its own funds. The technical preparation of the National Agricultural Investment Plans (NAIPs) was coordinated by the ministries in charge of integration, led by the ministries in charge of agriculture, and carried out by a team of national and regional experts, with assistance from the International Food Policy Research Institute (IFPRI) and the Regional Strategic Analysis and Knowledge Support System (ReSAKSS), established at the International Institute of Tropical Agriculture (IITA).

The current report summarizes the content of the NAIPs as well as the findings of the technical analysis that has guided their formulation. It is organized around the four main questions that constitute the focus of the analytical work to guide country level planning processes. These questions deal with the key sources of agricultural growth and related impact on poverty levels; the extent to which individual countries are on track to meet the CAADP growth and budgetary targets; the required growth rates and expenditure levels to achieve alternative growth and poverty reduction outcomes; and finally the degree of realism of proposed country investment plans to achieve the CAADP growth and budget targets.

1.1 What Are the Key Sources of Agricultural Growth and Poverty Reduction in ECOWAS Countries?

Figures 1 and 2 show the recent growth and poverty reduction performance among ECOWAS countries compared to other African countries. Figure 1 categorizes countries in four groups based on the rates of agricultural growth and poverty reduction at the start of the new millennium. Countries that perform better overall with higher rates of growth (>6%) and relatively lower rates of poverty (<40%) would occupy the North-West quadrant. The opposite holds for countries in the South-East quadrant. On the whole, the ECOWAS region seems to perform better in terms of recent growth but shows relatively higher average rates of poverty. Between 1999 and 2005, the agricultural sector in the region grew by 5.0% a year, well above the African average of 3.3%. However, the average poverty rate in the region (50.2%) for the same period is higher than the African average (45.6%). As a result, only two ECOWAS countries, Cape Verde and The Gambia, are found in the North-West corner of Fig. 1. In contrast, a majority of its member countries, eight in all, are assembled in the South-East corner. Figure 2 presents a separate distribution of ECOWAS countries with respect to both past agricultural growth and poverty outcomes: 54% of countries are in group IV, with growth rates that are below 6% and poverty rates that exceed 40%.

A recursive dynamic version of the standard IFPRI Lofgren-Harris-Robinson CGE model coupled with a micro-simulation module is used to simulate future agricultural growth and its impact on poverty levels in individual ECOWAS

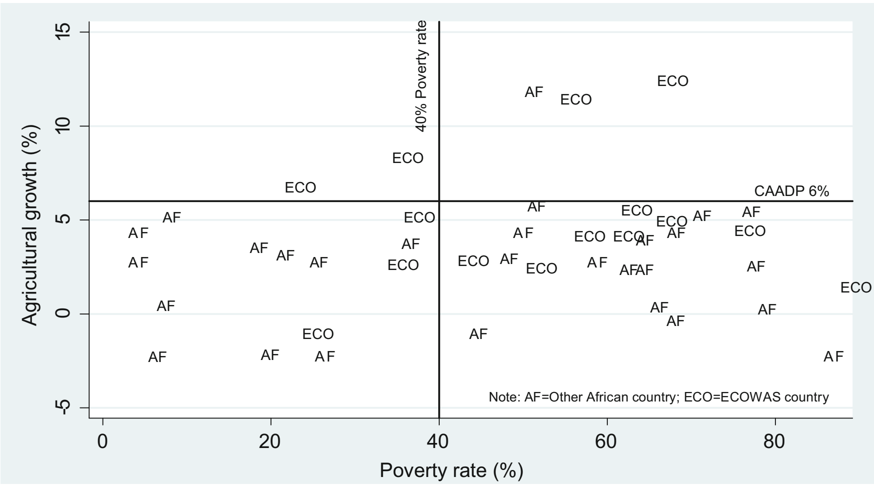

Fig. 1 Position of ECOWAS with respect to CAADP growth and poverty targets (1999–2005). Source: World Development Indicators (2008). Notes: AF indicates a non-ECOWAS African country and ECO an ECOWAS member country

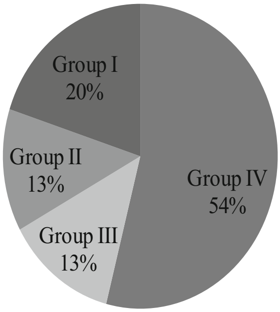

Fig. 2 Distribution of ECOWAS countries with respect to CAADP growth and poverty targets (1999–2005). Source: World Development Indicators (2008). Note: Group I countries have growth rates <6% and poverty rates <40%; group II countries have growth rates >6% but poverty rates <40%; group III countries have growth rates >6% and poverty rates >40%; and group IV countries have <6% growth rates and poverty rates >40%

member countries.[1] Due to lack of sufficient data, instead of the CGE model a simplified model was used for The Gambia and Liberia. Table 1 summarizes the results of the simulation for 13 ECOWAS member countries. The first two columns compare the simulated reductions in poverty rates resulting from an additional 1% point increase in the agricultural and non-agricultural rates of growth through to 2015. Although the simulations are run separately for each sector, the prices, activity levels, and factor incomes in the other sectors also change. Hence, the observed decline in poverty rates resulting from growth in one of the sectors in reality also reflects the effect of changes in the remaining sectors. Given that the latter changes emanate from the intersectoral multiplier effects induced by growth in the sector under consideration, we attribute the entire reduction in poverty to that sector. The figures in the Table represent the sectoral shares in the combined decline in poverty rates. The contribution of agricultural growth is consistently higher but diverges considerably across countries: from 10–20% higher in Benin, Ghana, and Senegal to nearly three times higher in Cape Verde, Côte d'Ivoire, Nigeria, and Togo. For most other countries, the contribution of agriculture is at least 50% higher compared to other sectors.

The importance of accelerated agricultural growth for poverty reduction in individual countries is demonstrated by the figures in the last two columns. They indicate the contribution by 2015 of an additional 1% point increase in the rate of agricultural growth to farm incomes and poverty reduction in various ECOWAS countries. Accelerating the rate of agricultural growth as indicated above would raise agricultural GDP (value added) by amounts ranging from US$21 million in the Gambia to as much as nearly $400 million in Mali. The corresponding reduction in the national poverty rates is shown in the last column and hovers around 10% for

[1] See Löfgren et al. (2002) for description and Löfgren (2001) and Thurlow (2004) for other applications of the model.

Table 1 Agricultural growth and poverty reduction in ECOWAS countries

	Sectoral contribution to poverty reduction resulting from an additional 1% point of sectoral growth by 2015		Growth and poverty impact of an additional 1% point agricultural growth by 2015	
	Due to Agricultural growth	Due to Non-agricultural growth	Increase in Agricultural Value Added (US$ million)	Reduction in national poverty rate (%)
Benin	52.5	47.5	270.9	−10.7
Burkina Faso	60.0	40.0	215.6	−10.3
Cape Verde	72.0	28.0	27.5	−25.9
Gambia	66.7	33.3	20.8	−11.1
Ghana	54.0	46.0	296.2	−2.9
Guinea	59.2	40.8	57.0	−10.0
Côte d'Ivoire	73.0	27.0	498.5	−6.5
Liberia	69.6	30.4	53.0	−11.9
Mali	65.2	34.8	389.5	−6.7
Niger	60.0	40.0	253.0	−6.5
Nigeria	75.0	25.0	NA	NA
Senegal	56.6	43.4	132.0	−12.6
Togo	75.0	25.0	231.0	−9.8

Source: Model simulation results for ECOWAS countries. Figures for Nigeria and Ghana are from Diao et al. (2010) and Breisinger et al. (2008), respectively

most countries. It is highest for Cape Verde, Senegal, and Liberia and lowest for Ghana, where it amounts to $<3\%$.

Although accelerated growth of the agricultural sector as a whole may be the most promising strategy currently available to ECOWAS countries for poverty reduction, such a strategy must also recognize that agricultural sub-sectors do not contribute to the same extent to growth and poverty reduction. The importance of the contribution to growth of each subsector is determined by its initial share in income and employment and its potential for future growth. For each country, the impact on growth and poverty reduction resulting from an incremental 1% point increase in the rate of growth by 2015 in individual subsectors was simulated. The leading sectors in terms of poverty reduction impact are listed in Table 2. For most countries, the food staples subsector has the greatest potential to contribute to increases in farm incomes and poverty reduction. Livestock also emerges as a strategic subsector, in particular among Sahelian countries. The main message from Table 2 should not be to identify winners but rather to highlight the relative contribution of various subsectors. Given limited growth potential and the geographic as well as demographic implications of growth in individual subsectors, the best strategy would be to marry such concerns with the priority ranking to harness the contribution of a broad range of subsectors. In fact, results from the same simulations show that isolated strategies exclusively targeting a commodity or a subsector would be less effective for poverty reduction than a comprehensive strategy aiming for largely diversified agricultural and non-agricultural growth.

Table 2 Strategic agricultural subsectors for agricultural growth and poverty reduction

Benin	Food crops (maize, roots and tubers)[a]
Burkina Faso	Cattle and sorghum/millet
Cape Verde	Food crops
Côte d'Ivoire	Yam, cassava and plantains
The Gambia	Cereals (millet/sorghum)[a] and livestock
Ghana	Root crops and fisheries
Guinea	Rice
Guinea Bissau	Food crops and fisheries
Liberia	Food crops
Mali	Food crops (rice; millet/sorghum)[a]
Niger	Livestock
Nigeria	Cassava, Rice
Senegal	Livestock and food crops (millet/sorghum; rice)[a]
Sierra Leone	Cassava, rice
Togo	Food crops

Source: Model simulation results for ECOWAS countries. Figures for Nigeria and Ghana are from Diao et al. (2010) and Breisinger et al. (2008), respectively
[a]Country SAMs do not usually disaggregate the food sector. The subsectors in parentheses are added here only for the purpose of illustrating the leading food commodities in the respective countries

1.2 Are ECOWAS Countries on Track to Meeting CAADP's Growth and Poverty Reduction Targets by 2015?

Under current trends or business-as-usual (BAU), agricultural growth among ECOWAS countries is projected to stabilize at around 4–5% by 2015, as indicated in the first column of Table 3.[2] Although these rates are high by historical standards for most countries, they are less than the 6% targeted under CAADP. Mali and Nigeria are the only countries with expected rates of growth that are close to that target. It can also be seen from the figures in the third column that the projected rates of growth under current trends would not allow any county, except Cape Verde and Ghana, to achieve the MDG1 target of halving poverty by 2015. Senegal and Sierra Leone and, to a lesser extent, Burkina would come close. In three countries, Benin, Côte d'Ivoire and Liberia, the rate of poverty in 2015 is expected to be, respectively, 18%, 37% and 24% higher in 2015 compared to 1990. The problem in these countries is that poverty has continued to rise after 1990 in the face of severe economic contraction in the first and prolonged civil wars in the other two countries. The decline in poverty resulting from projected agricultural growth under current trends would not be sufficient to offset the increase in the poverty rate by 2015.

[2]Current trends describes the period leading up to the signing of the CAADP compact, which for most countries refers to the first decade of the 2000s.

Table 3 Long term growth and poverty outcomes under alternative scenarios (%)

Country	Agricultural growth rate by 2015 under BAU/current trends	Agricultural growth rate by 2015 under pre-CAADP strategies	Poverty reduction by 2015 under current trends	Poverty reduction by 2015 under pre-CAADP strategies	Poverty reduction by 2015 under CAADP 6% growth target
Benin	5.1	14.3	17.7	−55.9	9.4
Burkina Faso	5.1	5.3	−40.0	−44.1	−50.5
Cape Verde	2.6	5.0	−61.0	−75	−78.0
Gambia	3.7	3.8	−9.8	−10.4	−11.3
Ghana	4.2	7.5	−50.1	−54	−66.0
Guinea	3.0	3.2	−25.9	−28.2	−42.2
Côte d'Ivoire	2.5	2.6	37.0	35.3	10.0
Liberia	5.0	4.0[a]	24.3	24.2	22.6
Mali	5.5	8.5	−11.0	−29	−14.1
Niger	4.4	6.2	−6.5	−17.4	−16.6
Nigeria	5.7	9.5	−10.0	−30.0[b]	[c]
Senegal	4.1	NA	−43.8	NA	−49.7
Sierra Leone	4.2	NA	−42.5	NA	−47.6
Togo	4.7	5.0	−17.2	−19.4	−26.4

Source: Model simulation results for ECOWAS countries. Figures for Nigeria and Ghana are from Diao et al. (2010) and Breisinger et al. (2008), respectively

NA Not applicable

Notes: [a] The rate of growth is projected to decline as the country transitions out of the immediate post-war recovery period (current trends scenario). [b] The target year chosen by Nigeria is 2017. [c]There were no separate simulations of this scenario, given that the country was already growing at 5.7% under the current trends scenario

Prior to embracing CAADP, many countries had on-the-shelf strategies that pre-date the signing of the Compact and were at difference stages of readiness for implementation. The implied growth rates under these strategies, assuming that they could be successfully implemented and their declared targets achieved, are listed in the second column of the Table. The rates are universally higher than projected rates under current trends. The only exception is Liberia, for which the scenario under current trends refers to the post-conflict period. For the region as a whole, the average rate of growth for the agricultural sector would increase from under 5% under status quo to slightly more than 6%, thus meeting the CAADP growth target. However, for several of the countries, such as Benin, Nigeria, and Mali, the implied growth rates are significantly higher than would be expected based on recent performance, hence suggesting a problem of realism of declared investment and growth targets under these strategies. The implied rate of growth is high for Ghana as well, relative to historical records, but is less challenging in absolute terms than the rates for the other three countries. Nevertheless, the projected rates of growth for the majority of countries would still fall well short of the CAADP target of 6%.

With respect to the goal of poverty reduction, Benin would be the only country to join Ghana and Cape Verde in halving poverty rates below the 1990 levels under the present scenario, as shown in column 4. It is, however, clearly unrealistic to expect Benin's agricultural sector to nearly triple its pre-CAADP rate of growth to 14.3% a year by 2015. Strategies for all other countries would imply changes in poverty levels that are significantly below the MDG1 target. And for the two post-conflict countries, Liberia and Côte d'Ivoire, poverty rates would still be considerably higher than their 1990 levels: by nearly 25% and 35%, respectively. In contrast, the adoption and successful implementation of strategies and programs that would enable all ECOWAS member countries to achieve the 6% CAADP growth target would lead to substantial reduction in poverty rates across the region, although less than half of the countries would be expected to reach MDG1 by 2015 (fifth column). The challenge in realizing the poverty MDG by 2015 is made difficult for Benin, Côte d'Ivoire, and Liberia because poverty rates in these countries have continued to rise after 1990 and have not stabilized or started to decline before the end of that decade. In the case of Liberia, the poverty rate jumped from 61% in 1990 to 84% in 2007. Under continuation of growth trends during the period leading up to the signing of the CAADP compact, with a rate of 5%, as shown in the first column, the rate of poverty by 2015 would have fallen by <10% points to 76%, still close to 25% above the 1990 level. Because the rate of growth under current trends is already close to the CAADP target and projected to even decline slightly under implementation of pre-CAADP strategies, the rate of poverty in Liberia is significantly higher than the 1990 level in all of these scenarios.

In Côte d'Ivoire, the rate of poverty rose by 50% from 32% in 1993 to 49% in 2008. The achievable reduction in poverty under the BAU scenario or the implementation of pre-CAADP strategies is <5% points for that country. Realization of the CAADP growth targets would have merely brought poverty levels close to their levels of the early 1990s. The increase in poverty during the 1990s was less considerable for Benin. Poverty level estimates in that country rose from slightly more than 25% in 1990 to 36% in 2006. Under the BAU scenario, poverty levels would fall to 30% by 2015, corresponding to a decline of about 18% compared to the 1990 level.

1.3 How Fast Should ECOWAS Countries Grow to Achieve the Poverty MDG? How Much Would They Have to Spend?

In order to achieve the goal of halving poverty by 2015, many countries would have to reach double digit rates of growth in the agricultural sector: between around 12% and 15% for Benin, Mali, The Gambia, Niger and Côte d'Ivoire, and as much as 26% for Liberia, as shown in the first column of Table 4. A history of civil war explains the very serious situation in the latter country. These extremely high growth rates indicate that it will be impossible for these countries to achieve the

Table 4 Long term agricultural growth and funding requirements

Country	Required agricultural growth rate to achieve the poverty MDG target by 2015 (%)	Required agricultural growth rate to achieve the poverty MDG target by 2020 (%)	Required agricultural funding growth rate to achieve the poverty MDG target by 2015 (%)	Required agricultural funding growth rate to achieve the poverty MDG target by 2020 (%)	Required agricultural funding growth rate to achieve CAADP 6% target rate by 2015 (%)
Benin	13.1	9.1	22.8	13.9	7.9
Burkina Faso	7.1	5.9	11.6	9.0	9.1
Cape Verde	–	–	–	–	11.2
Gambia	14.4	8.6[a]	99.3	59.3[a]	19.6
Ghana	–	–	–	–	21.7
Guinea	10.3	7.5	33.5	26.5	12.3
Côte d'Ivoire	14.8	9.0	62.2	25.1	27.0
Liberia	26.1	14.6[a]	117.7	65.7[a]	27.0
Mali	12.5	8.1	45.8	13.7	8.2
Niger	11.9	9.0	25.1	18.2	26.5
Nigeria	–	9.5[a]	–	23.8[a]	4.7[b]
Senegal	–	6.8[c]	–	10.0[c]	7.6
Sierra Leone	–	–	–	–	10.0
Togo	9.6	6.9	74.2	43.1	35.4

Source: Model simulation results for ECOWAS countries
Notes: Not applicable as these countries are already on track under current trends to achieving the poverty MDG by 2015 (Cape Verde and Ghana) or scenarios were otherwise not relevant or feasible
[a]Projection years are 2017 for Nigeria and 2025 for The Gambia and Liberia
[b]For Nigeria, this is the required agricultural spending growth rate to sustain current growth trends, which at 5.7% is nearly identical to the CAADP target of 6%
[c]For Senegal, the numbers shown correspond to the required agricultural growth rate and funding growth rate to achieve the government's objective of the reducing poverty rate to 17% by 2020

poverty reduction goal by 2015. Some could, however, do so by 2020, namely Benin, Côte d'Ivoire, Mali and Niger, although all would require growth rates of around 9%, which by historical standards are still high (Table 3, second column). For The Gambia and Liberia, the poverty MDG could not be achieved by 2020 but could be reached by 2025, if they were to realize agricultural growth rates of nearly 9% and 15%, respectively. While it is true that post-conflict countries can sometimes grow rapidly during the recovery phase, whether Liberia would be able to sustain such a high growth rate over a long time is questionable.

The extent of the challenge for many countries in achieving the poverty MDG or the CAADP growth target is also illustrated by the required rise in public funding for the agricultural sector. As shown in the third column of Table 4, the required funding growth rate to achieve the poverty MDG by 2015 is prohibitively high for most countries. The required annual rate of increase in public expenditure remains still extremely high, even if the target date for achieving MDG1 is moved to 2020. For six of the eleven countries for which estimates are available, funding for the agricultural sector would have to rise by around 20% or more annually. The remaining countries would still have to expand funding for the sector by double digit rates or close to that in the case of Burkina Faso. Realization of the MDG poverty target by ECOWAS member countries is therefore not only a question of physically achievable agricultural growth but also a question of financial resource mobilization capacity.

The significance of the financial resources constraint is illustrated by the increase in funding required for achieving the CAADP target of 6% growth through to 2015. Although the increase in funding may be feasible for several of the countries, it is still quite challenging and would nonetheless not be sufficient to allow any of the countries to realize the poverty MDG, as can be seen from the last columns of Tables 3 and 4. The only exception would be Burkina Faso. A look at current levels of sectoral funding sheds light on the feasibility of the pace of funding increase that is called for under the various scenarios. Figure 3 below presents the share of agricultural sector funding for the various countries in the latest year for which the information is available. Several countries such as Benin, Côte d'Ivoire, Nigeria, Sierra Leone and Togo are currently allocating the lowest share of country budgets to agriculture. The scope of raising the level of agricultural funding should, a priori, be greater in these countries. For instance, achieving the CAADP growth target by 2015 or MDG1 by 2020 in Benin or Mali would call for annual rates of growth in agricultural funding of around 8% and 14%, respectively. Starting from agricultural sector budget shares in the range of 9–10%, there may be some room to achieve such increases in sectoral spending. The scope for expanding agricultural sector spending is greater in the case of Nigeria, which spends currently only about 3% of

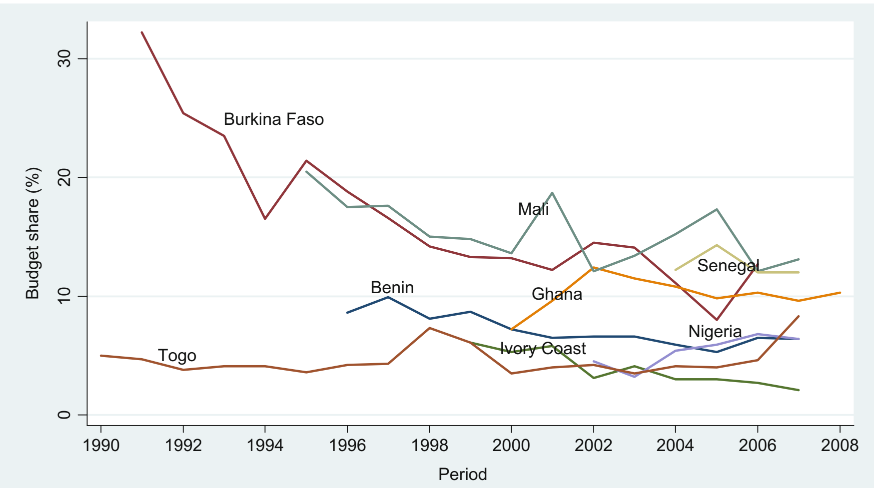

Fig. 3 Trends in pre-compact agricultural sector budget shares (%). Source: Based on agricultural budget data survey across West Africa countries

Table 5 Public expenditure allocation to agriculture and efficiency

	Agricultural sector budget share at time of compact signing (%)[a]	Estimated expenditure elasticity of agricultural growth
Benin	8.6	0.26
Burkina Faso	21.2	0.24
Cape Verde	1.3	0.11
Gambia	6.6	0.15
Ghana	4.9	0.15
Guinea	13.7	0.25
Côte d'Ivoire	3	0.25
Liberia	6	0.22
Mali	9.7	0.25
Niger	22.3	0.53
Nigeria	3.4	0.39
Senegal	19.2	0.48
Sierra Leone	2.8	0.24
Togo	3.2	0.11

Source: Budget shares are from respective country CAADP Roundtable Brochures No. 4 (http://www.resakss.org); elasticities are based on model simulation results for ECOWAS countries. The average elasticity estimate for Africa by Fan et al. (2008) as a whole is 0.31
[a]Current refers to the latest year for which data is available at time of compact signing

its budget on agriculture. The required rate of increase of 24% of sectoral funding to achieve MDG1 by 2017 should be considered realistic and feasible.

The other challenge related to meeting the funding requirement of achieving the CAADP growth and MDG poverty targets is reflected in the numbers in the last column of Table 5. Out of 13 ECOWAS countries for which estimates are available, only three show an elasticity of agricultural growth with respect to public expenditure that is above the African average of 0.31 estimated by Fan et al. (2008). For many of these countries, therefore, achieving the CAADP growth target by 2015 or MDG1 within the next 10 years would require both an increase in the level and in the efficiency of agricultural sector funding. This is because these countries are already spending relatively high shares of their budgets on agriculture and also have historically recorded relatively lower levels of responsiveness of agricultural growth to public sector spending. Other countries have very little room to raise already very high shares of agricultural spending and thus would need to focus primarily on raising the efficiency of funding to the sector. Burkina Faso, for instance, would need to expand sectoral spending by <10% annually to meet the CAADP growth target and realize MDG1 by 2020 (Table 3). However, the country is already allocating more than 20% of its budget to agriculture (Table 5). On the other hand, the elasticity of agricultural growth with respect to public funding in that country is estimated at 0.24 or 20% below the average African estimate. Gambia, Liberia, and Togo, on the other hand, are currently spending much less on agriculture but require a significantly larger increase in agricultural spending (above 20%) to meet either the CAADP growth target or MDG1 by 2020. The three countries also have historically lower expenditure elasticities of growth compared to the African average, with estimates of 0.15, 0.22, and 0.11, respectively. Niger and Senegal are in a peculiar situation characterized by high sector spending shares and above-average public expenditure elasticities of growth but still needing to further increase sectoral funding, albeit moderately in the case of Senegal, to achieve the CAADP growth and MDG1 poverty targets.

The CAADP target of allocating at least 10% of national budgets to agriculture translates the conviction that achieving the growth target would require most countries to significantly raise the level of funding allocated to the sector. The figures in Table 5 show where individual ECOWAS member countries stand with respect to the budget target. Although the average agricultural sector budget share of 11% for ECOWAS as a whole is above the CAADP target, there is a wide variation across countries with shares ranging from about 3% in Sierra Leone to 22% in Niger.

Five of the 13 countries for which data is available, namely Burkina, Mali, Ghana, Niger and Senegal, have managed to allocate at least 10% of their budget to agriculture. The first two have had historically high levels of agricultural funding, which is primarily explained by heavy subsidies to the cotton sector. Senegal has recently considerably expanded funding for agriculture under a variety of presidential programs.

The funding levels do not only vary across counties, they have also been unstable over time. More noticeably, they have trended downwards for most countries during the decade and a half preceding the adoption of the CAADP expenditure target. The declining trend has continued in Ghana, Nigeria and Mali up until the time of compact signing, as shown by a comparison of shares in Table 5 and by considering the shares for the three countries at the end of the period shown in Fig. 3. In contrast, Senegal, Burkina, and to a lesser extent Benin have raised sector expenditures going into the CAADP roundtable and the signing of the compact. On the other hand, Togo went from a stable and rising trend in expenditure levels to a sharp drop by the time of the signing of the CAADP compact. The change in trends in the latter country can be explained by the political crisis and interruption of external funding for the sector for most of the 2000s. The continued decline in sectoral funding in Côte d'Ivoire in the period leading up to the signing of the compact can also be explained by the political crisis in that country and its impact on local fiscal resources and domestic services delivery institutions.

The likelihood of countries expanding and sustaining levels of agricultural sector funding is not only a function of political will but also of domestic fiscal capacities. Figure 4 presents domestic resources as a share of total agricultural spending. In most countries, the domestic share represents 60% or less of total agricultural sectoral spending over the nearly 20 year period covered by the data.

In order to achieve the CAADP budget target by relying only on domestic sources, most countries would have to nearly double their current share of domestic resources in total agricultural spending. The mobilization of external funding will therefore be a critical component of CAADP implementation among ECOWAS countries. This is particularly so for Niger and Burkina, which already allocate a

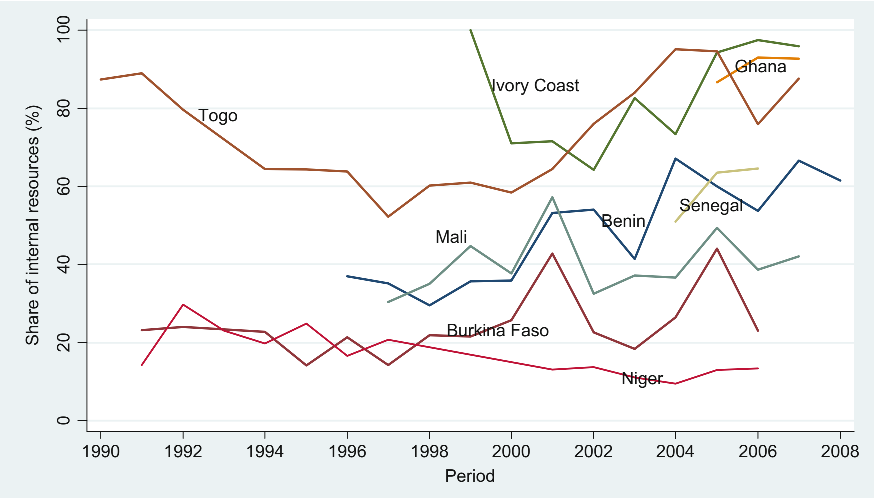

Fig. 4 Share of internal resources in agricultural spending (%). Source: Based on agricultural budget data survey across West Africa countries

significant share of overall funding to agriculture but rely on external sources for 80% or more of the funding for agriculture.

In addition to the level and efficiency of funding, the degree of actual budget execution has historically been the third dimension of the problem of effective financing of agricultural growth among African countries. As shown in Fig. 5, the average rate of disbursement of agricultural budgets is distinctly lower than the rate of overall budget execution, which for most countries is in the 80% range or lower. The exceptions are Burkina and Senegal, which show higher execution rates for agriculture, although it is to be noted that Burkina exhibits an extremely low rate of overall budget execution of <50%. High performers in terms of agricultural budget disbursement include Senegal, Nigeria and Ghana with execution rates exceeding 90%; lagging behind are Burkina, Côte d'Ivoire, and Togo. The key message from Fig. 5 is that efforts to increase agricultural funding under CAADP will have to address the constraints to effective budget execution, which appears to be a general problem and not specific to the agricultural sector.

1.4 How Consistent Are Agricultural Investment Priorities and Related Growth and Poverty Outcomes Among ECOWAS Countries?

The National Agricultural Investment Plans (NAIPs) are the next step in the CAADP implementation process after the agreement around key policy, budgetary, and partnership priorities during the roundtable. They define specific sub-sector objectives and identify specific activities to be funded. The main priority sectors

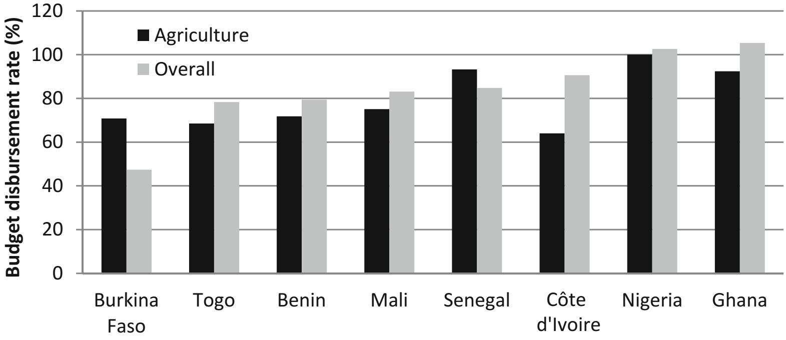

Fig. 5 Agricultural and overall budget disbursement rates (%; latest year). Source: Based on ReSAKSS survey of agricultural budget data across West Africa countries

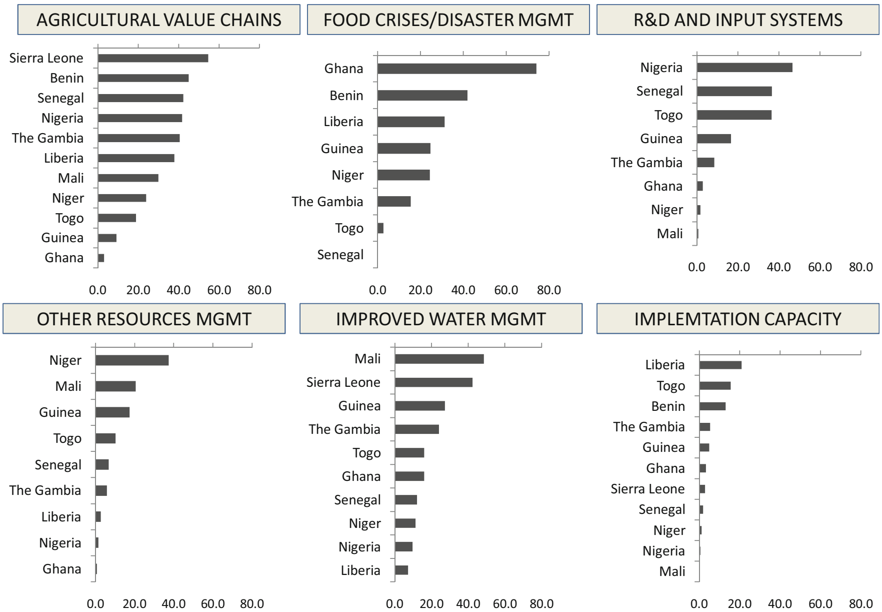

Fig. 6 Common priority areas in country investment plans. Source: Authors using information from various agriculture investment plans

that cut across individual countries are presented in Fig. 6. They cover the following: value chain development; food and other emergency crises and disaster management; research and development, including seeds systems; improved water and other resources management; as well as capacity building for successful implementation. The horizontal bars denote the percentage share of each of these sectors in the overall investment budgets of individual countries. The difference across countries reflects the diverging priorities accorded to individual investment areas by different countries. Although the differences most likely reflect different advances in specific areas by different countries, it is interesting to note the wide variations between countries. The overall level of planned investments is shown in the second column of Table 6. It is in the one billion US$ range for most countries, and double that amount or more for four countries. It is highest for Ghana and Nigeria, where planned investment levels exceed the US$5 billion mark. The smallest countries, Cape Verde and Gambia, have, as expected, the smallest levels of planned investments. In addition to defining priority investment areas and investment levels, country investment plans in many cases also specify a given rate of agricultural growth to be achieved. In others, they specify specific investment outcomes such as total areas of land under irrigation or specific crop yields that can be converted to corresponding changes in overall output and translated into sector growth rates.

Ideally, the design of the investment plans should be guided by the results from the analysis of alternative growth and poverty reduction options. The speed of planning and implementation was so high that the growth analysis and planning activities have overlapped, leading to an iterative rather than sequential process in integrating the two sets of activities. In all countries, however, a key step is a consistency analysis that takes place after the first version of the investment plan is completed. The consistency analysis assesses the extent to which investment levels as well as growth and poverty reduction outcomes that are being pursued in individual country investment plans are in line with the alternative long term growth, poverty reduction, and funding requirement scenarios, as well as historical expenditure levels discussed in the previous sections. In carrying out the analysis, proposed investment activities and related crop yields and/or target subsectoral growth rates are fed into the country CGE models to simulate the overall rate of agricultural growth and reduction in poverty levels that would result from individual country NAIPs. The results are then contrasted with the outcomes from the alternative long term scenarios. The comparisons can be as detailed as looking at differences in subsector growth rates and poverty outcomes among targeted geographic areas or demographic groups.[3]

For the current paper, we are considering consistency between target outcomes under investment plans and long term scenarios at the sectoral or national level. The results are summarized in Table 6 and Fig. 6. The Table compares the sectoral growth targets and associated expenditure levels under individual investment plans (first and second columns) with those of the closest long term growth scenario (third and fourth columns). The comparison suggests that in some cases there are significant discrepancies between proposed investment levels and simulated funding requirements for similar rates of growth. As shown by the ratios in the last column, the discrepancies are observed in both directions. For countries such as The Gambia, Mali, Nigeria, and Benin, the investment plans appear to be significantly underfunded in order to deliver the expected growth outcome. In contrast, suggested funding levels for the investment plans appear considerably higher than

[3]See IFPRI Discussion Paper No. 1019 by Badiane et al. (2010)

Table 6 NAIP costs versus long term funding benchmarks

	National Agricultural Investment Plans (NAIPs)		Comparable pre-compact growth scenario		
	Expected agricultural growth rate (%)	Cost (million USD)	Expected agricultural growth rate (%)	Cost (million USD)	Cost ratio
	[1]	[2]	[3]	[4]	[2]/[4]
Benin	14.3	884.1	14.3	1276.2	0.69
Cape Verde	6.9	96.4	6.0	51.6	1.87
Gambia	8.0	296.6	8.6	1065.8	0.28
Ghana	5.2	5479.5	6.9	3082.2	1.78
Guinea	10.3	1601.2	10.3	222.0	7.21
Liberia	9.9	947.7	9.4	149.5	6.34
Mali	8.8	727.2	8.5	5376.4	0.14
Niger	7.4	2457.0	6.4	2233.4	1.1
Nigeria	21.0	7535.4	9.5	28563.1	0.26
Senegal	9.7	2727.5	6.8	1771.1	1.54
Sierra Leone	7.0	388.0	7.1	100.6	3.86
Togo	6.8	947.2	6.7	989.3	0.96

Source: Respective country investment plans and CAADP Roundtable Brochures No 4 (http://www.resakss.org)

Note: The comparable growth scenarios for the different countries are summarized below: Benin (PSRSA), Cape Verde (ECOWAP/PDDAA), Gambia (MDG1 by 2025), Ghana [MIC (reaching Middle Income Country status by 2015)], Guinea (MDG1 by 2015), Liberia (MDG1 by 2025), Mali [SDDR (Schéma Directeur de Développement Rural)], Niger [SDR (Stratégie de Développement Rural)], Nigeria (Agricultural TFP growth driven by agricultural expenditure only), Senegal (Government's objective to reduce poverty rate to 17% by 2020), Sierra Leone [MDG1-2015 (while keeping non-agricultural sectors growing at current rates)], Togo (MDG1 by 2020)

required to meet the growth targets in the case of Sierra Leone, Liberia, and Guinea, and to a lesser extent for Cape Verde, Ghana, and Senegal. Only for Togo and Niger do the suggested funding levels appear to be consistent with projected long term growth outcomes.

The consistency analysis also assesses the degree of realism of pursued poverty reduction outcomes. It does so by comparing targeted poverty reduction levels under the investment plans with projected outcomes under continuation of pre-CAADP trends or business as usual (BAU). The results are plotted in Fig. 7. Benin, Nigeria, and Guinea exhibit the largest potential improvement from successful implementation of country investment plans. The first two however appear to have underfunded their investment plans and are thus less likely to achieve the expected poverty reduction outcome. Gambia and Mali are other countries with underfunded NAIPs, which may not achieve the expected improvement in poverty outcomes. Sierra Leone, Liberia, Guinea, Ghana, and Senegal all have seemingly overfunded NAIPs and should be in a position to realize the expected decline in poverty levels at a lower cost than budgeted under the current investment plans.

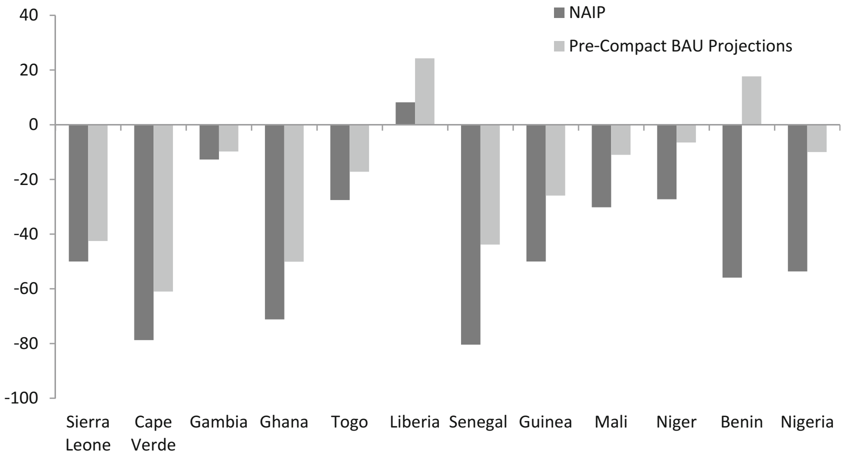

Fig. 7 Decline in poverty rates by 2015 under investment plans compared to pre-compact projections under BAU (%). Source: Authors' model simulation results for ECOWAS countries

2 Conclusion

Overall, there were no data to evaluate post-compact food security trends. It is vital that necessary arrangements are made to regularly update the baseline household survey information so as to facilitate tracking of poverty, food security and distributional impacts of the investment plans.

To ensure high return, investment commitments under the NAIPs must be supported by strong governance and monitored in a timely and transparent fashion. Therefore, it should be of high priority that countries improve policymaking by adopting an evidence-based approach. Such an approach should include review and dialogue mechanisms and knowledge support systems to facilitate benchmarking, mutual learning, and capacity strengthening, which would improve agricultural policy, program design, and implementation. The data available and the knowledge flow observed in the course of CAADP implementation suggests an urgent need to undertake institutional mapping of all actors involved in the policymaking process in the agricultural sector. This analysis should include data collection/gathering, policy analysis, and drafting of policy notes or policy dialogues. There is also a need for a full-fledged monitoring and evaluation framework for the agricultural sector with clear individual and institutional responsibilities. Such an M&E framework would need to include (i) data processing and policy analysis; (ii) policy dialogue and advocacy; and (iii) a monitoring and evaluation system.

ANNEX

Description of the Model Used to Simulate Long Term Growth and Poverty Reduction Outcomes

Model Specification and Calibration Data

We used a Dynamic single-country Computable General Equilibrium (DCGE) model for individual ECOWAS member countries for which a Social Accounting Matrix (SAM) was available.[4] The model is a recursive dynamic version of the standard IFPRI Lofgren-Harris-Robinson CGE model coupled with a micro-simulation module.[5] Annex provides a mathematical description of the model specifications. It is designed as a set of simultaneous linear and non-linear equations that represent the first order conditions of the profit and utility maximization behaviors of national economic agents, along with key macroeconomic constraints within a period. The model also specifies the process through which the values of some selected exogenous variables are updated to account for changes in population, labor and land supplies, capital accumulation, total factor productivity and government expenditures between successive periods. This kind of model is appropriate for the analysis of the impacts of alternative policy options on agricultural growth and poverty reduction outcomes as it explicitly takes into account the interactions between disaggregated agricultural and non-agricultural sectors and between the national economy and the rest of world while allowing to follow the distribution of income among factors and among households and other institutions.

In each activity of the national economy, production is carried out following a nested technology in which value-added quantity is a Constant Elasticity of Substitution (CES) function of primary factors, while aggregate intermediate input quantity is a Leontief function of specific intermediate inputs from different sectors, and overall activity output is a Leontief function of value-added and aggregate intermediate input quantities. Primary factors, including land, labor and capital, are fully employed within a period. Land and labor are mobile across activities while capital is activity-specific. Household groups receive income from factor remuneration proportionally to their shares of factor endowment. In addition, they may receive transfers from other household groups, the government and the rest of the world. They spend their income on direct taxes, transfers, and savings and for the consumption of different commodities according to Linear Expenditure System (LES) demand functions, which are derived from maximizing a Stone-Geary utility function. The model uses a Constant Elasticity of Transformation (CET) function to allocate domestic outputs between domestic sales and exports in shares that reflect the ratio of prices in domestic and foreign markets. Armington aggregation of

[4]For The Gambia, Guinea Bissau, Liberia and Sierra Leone for which a SAM was not available, a simplified model was used, instead of the CGE model.

[5]See Löfgren et al. (2002) for a detailed description of the static model version and Löfgren (2001) and Thurlow (2004) for dynamic applications of the model.

Table 7 Values of CES and CET elasticities

	Substitution between capital, labor and land	Substitution between imports and domestic sales	Transformation into exports and domestic sales
Agriculture	0.61	1.5	5.0
Industry	0.70	4.0	3.0
Services	0.80	2.5	1.2

Source: Based on elasticity estimates found in a broad literature review across developing countries by Annabi et al. (2006)

imports and domestic sales of domestic output determines the composite market supply that should meet the sum of demands for private consumption, government consumption, intermediate input, and investment. Government consumption demands of different commodities are exogenous while government savings adjusts to ensure the equality between government expenditures and revenues. Investment is savings-driven, with fixed marginal propensities to save, a fixed current account deficit and a flexible exchange rate.

The data used to calibrate the DCGE model for individual countries are largely derived from their respective SAMs using an income elasticity of 1.0 for household consumption demand and CES and CET elasticities as summarized in Table 7. As mentioned above, the model's dynamics are recursive, in the sense that the model is run as a repetitive static model while updating some exogenous variables between successive periods such as to replicate the economy's observed long term growth patterns. The rate of changes in population, land use, yields and government expenditures are projected from the series of data available on national accounts and agricultural statistical databases over the last decades. These rates are used to update some exogenous variables, including the LES supernumerary income, land and labor stocks, total factor productivity, and government consumption of the different commodities. In each period, the capital accumulation rate is endogenously determined from investment made during a preceding period and new capital is distributed between sectors proportionally to sectoral capital returns, taking into account a depreciation rate of 0.1.

This core DCGE model is linked to the microsimulation module in a top-down relationships (i.e., without feedback effects) through a transmission of changes in per capita household expenditures to the country's household survey data, where standard poverty and inequality measures are re-calculated given a defined poverty line.

Mathematical Model Description

The Tables 8 and 9 below describe the DCGE model utilized for the analysis of growth and poverty reduction scenarios for individual ECOWAS member countries. A comprehensive description of model specifications and closures is provided in Löfgren et al. (2002), Löfgren (2001) and Thurlow (2004).

Table 8 Model sets, parameters, and variables

Symbol	Explanation	Symbol	Explanation
Sets			
$a \in A$	Activities	$c \in CMR(\subset C)$	Regionally imported commodities
$a \in ALEO(\subset A)$	Activities with a Leontief function at the top of the technology nest	$c \in CMNR(\subset C)$	Non-regionally imported commodities
$c \in C$	Commodities	$c \in CT(\subset C)$	Transaction service commodities
$c \in CD(\subset C)$	Commodities with domestic sales of domestic output	$c \in CX(\subset C)$	Commodities with domestic production
$c \in CDN(\subset C)$	Commodities not in *CD*	$f \in F$	Factors
$c \in CD(\subset C)$	Exported commodities	$i \in INS$	Institutions (domestic and rest of world)
$c \in CEN(\subset C)$	Commodities not in *CE*	$i \in INSD(\subset INS)$	Domestic institutions
$c \in CM(\subset C)$	Aggregate imported commodities	$i \in INSDNG$ $(\subset INSD)$	Domestic non-government institutions
$c \in CMN(\subset C)$	Commodities not in *CM*	$h \in H(\subset INSDNG)$	Households
Parameters			
$cwts_c$	Weight of commodity c in the CPI	pwm_c	Import price (foreign currency)
$dwts_c$	Weight of commodity c in the producer price index	$pwmr_{cr}$	Import price by region (foreign currency)
ica_{ca}	Quantity of c as intermediate input per unit of activity a	$qdst_c$	Quantity of stock change
$icd_{cc'}$	Quantity of commodity c as trade input per unit of c' produced and sold domestically	$\overline{qg_c}$	Base-year quantity of government demand
$ice_{cc'}$	Quantity of commodity c as trade input per exported unit of c'	$\overline{qinv_c}$	Base-year quantity of private investment demand
$icer_{cc'r}$	Quantity of commodity c as trade input per exported unit of c' from region r	$shif_{if}$	Share for domestic institution i in income of factor f
$icm_{cc'}$	Quantity of commodity c as trade input per imported unit of c'	$shii_{ii'}$	Share of net income of i' to i (i' ∈ INSDNG'; i ∈ INSDNG)
$icmr_{cc'r}$	Quantity of commodity c as trade input per imported unit of c' from region r	ta_a	Tax rate for activity a
$\text{int}a_a$	Quantity of aggregate intermediate input per activity unit	$\overline{tins_i}$	Exogenous direct tax rate for domestic institution i

iva_a	Quantity of aggregate intermediate input per activity unit	$tins01_i$	0–1 parameter with 1 for institutions with potentially flexed direct tax rates
$\overline{mps_i}$	Base savings rate for domestic institution i	tm_c	Import tariff rate
$mps01_i$	0–1 parameter with 1 for institutions with potentially flexed direct tax rates	tmr_{cr}	Regional import tariff
pwe_c	Export price (foreign currency)	tq_c	Rate of sales tax
$pwer_{cr}$	Export price by region (foreign currency)	$trnsfr_{if}$	Transfer from factor f to institution i
Greek symbols			
α_a^a	Efficiency parameter in the CES activity function	δ_c^t	CET function share parameter
α_a^{va}	Efficiency parameter in the CES value-added function	δ_{fa}^{va}	CES value-added function share parameter for factor *f* in activity *a*
α_c^{ac}	Shift parameter for domestic commodity aggregation function	γ_{ch}^m	Subsistence consumption of marketed commodity c for household h
α_c^q	Armington function shift parameter	θ_{ac}	Yield of output c per unit of activity a
α_c^t	CET function shift parameter	ρ_a^a	CES production function exponent
α_c^m	Shift parameter in the CES regional import function	ρ_a^{va}	CES value-added function exponent
α_c^e	Shift parameter in the CES regional export function	ρ_c^{ac}	Domestic commodity aggregation function exponent
β^a	Capital sectoral mobility factor	ρ_c^q	Armington function exponent
β_{ch}^m	Marginal share of consumption spending on marketed commodity c for household h	ρ_c^t	CET function exponent
δ_a^a	CES activity function share parameter	ρ_c^m	Regional imports aggregation function exponent
δ_{ac}^{ac}	Share parameter for domestic commodity aggregation function	ρ_c^e	Regional exports aggregation function exponent
δ_c^q	Armington function share parameter	η_{fat}^a	Sector share of new capital
υ_f	Capital depreciation rate		
Exogenous variables			
$\overline{CPI}$	Consumer price index	$\overline{MPSADJ}$	Savings rate scaling factor (=0 for base)
$\overline{DTINS}$	Change in domestic institution tax share (=0 for base; exogenous variable)	$\overline{QFS_f}$	Quantity supplied of factor

(continued)

Table 8 (continued)

Symbol	Explanation	Symbol	Explanation
$\overline{FSAV}$	Foreign savings (FCU)	$\overline{TINSADJ}$	Direct tax scaling factor (=0 for base; exogenous variable)
$\overline{GADJ}$	Government consumption adjustment factor	$\overline{WFDIST}_{fa}$	Wage distortion factor for factor f in activity a
$\overline{IADJ}$	Investment adjustment factor		
Endogenous variables			
AWF_{ft}^{a}	Average capital rental rate in time period t	QF_{fa}	Quantity demanded of factor f from activity a
$DMPS$	Change in domestic institution savings rates (=0 for base; exogenous variable)	QG_c	Government consumption demand for commodity
DPI	Producer price index for domestically marketed output	QH_{ch}	Quantity consumed of commodity c by household h
EG	Government expenditures	QHA_{ach}	Quantity of household home consumption of commodity c from activity a for household h
EH_h	Consumption spending for household	$QINTA_a$	Quantity of aggregate intermediate input
EXR	Exchange rate (LCU per unit of FCU)	$QINT_{ca}$	Quantity of commodity c as intermediate input to activity a
$GOVSHR$	Government consumption share in nominal absorption	$QINV_c$	Quantity of investment demand for commodity
$GSAV$	Government savings	QM_c	Quantity of imports of commodity c
$INVSHR$	Investment share in nominal absorption	QMR_{cr}	Quantity of imports of commodity c by region r
MPS_i	Marginal propensity to save for domestic non-government institution (exogenous variable)	QER_{cr}	Quantity of exports of commodity c to region r
PA_a	Activity price (unit gross revenue)	QQ_c	Quantity of goods supplied to domestic market (composite supply)
PDD_c	Demand price for commodity produced and sold domestically	QT_c	Quantity of commodity demanded as trade input
PDS_c	Supply price for commodity produced and sold domestically	QVA_a	Quantity of (aggregate) value-added
PE_c	Export price (domestic currency)	QX_c	Aggregated quantity of domestic output of commodity
PER_{cr}	Export price by region (domestic currency)	$QXAC_{ac}$	Quantity of output of commodity c from activity a

$PINTA_a$	Aggregate intermediate input price for activity a	RWF_f	Real average factor price
PK_{ft}	Unit price of capital in time period t	$TABS$	Total nominal absorption
PM_c	Import price (domestic currency)	$TINS_i$	Direct tax rate for institution i (i ∈ INSDNG)
PMR_{cr}	Import price by region (domestic currency)	$TRII_{ii'}$	Transfers from institution i' to i (both in the set INSDNG)
PQ_c	Composite commodity price	WF_f	Average price of factor
PVA_a	Value-added price (factor income per unit of activity)	YF_f	Income of factor f
PX_c	Aggregate producer price for commodity	YG	Government revenue
$PXAC_{ac}$	Producer price of commodity c for activity a	YI_i	Income of domestic non-government institution
QA_a	Quantity (level) of activity	YIF_{if}	Income to domestic institution i from factor f
QD_c	Quantity sold domestically of domestic output	ΔK^a_{fat}	Quantity of new capital by activity a for time period t
QE_c	Quantity of exports		

Source: Thurlow (2004)

Table 9 Model equations

Production and price equations	
$QINT_{c\,a} = ica_{c\,a} \cdot QINTA_a$	(1)
$PINTA_a = \sum_{c \in C} PQ_c \cdot ica_{ca}$	(2)
$QVA_a = \alpha_a^{va} \cdot \left(\sum_{f \in F} \delta_{fa}^{va} \cdot \left(\alpha_{fa}^{vaf} \cdot QF_{fa} \right)^{-\rho_a^{va}} \right)^{-\frac{1}{\rho_a^{va}}}$	(3)
$W_f \cdot \overline{WFDIST}_{fa} = PVA_a \cdot (1 - tva_a) \cdot QVA_a \cdot \left(\sum_{f \in F'} \delta_{fa}^{va} \cdot \left(\alpha_{fa}^{vaf} \cdot QF_{fa} \right)^{-\rho_a^{va}} \right)^{-1} \cdot \delta_{fa}^{va} \cdot \left(\alpha_{fa}^{vaf} \cdot QF_{fa} \right)^{-\rho_a^{va}-1}$	(4)
$QVA_a = iva_a \cdot QA_a$	(5)
$QINTA_a = inta_a \cdot QA_a$	(6)
$PA_a \cdot (1 - ta_a) \cdot QA_a = PVA_a \cdot QVA_a + PINTA_a \cdot QINTA_a$	(7)
$QXAC_{a\,c} = \theta_{a\,c} \cdot QA_a$	(8)
$PA_a = \sum_{c \in C} PXAC_{ac} \cdot \theta_{ac}$	(9)
$QX_c = \alpha_c^{ac} \cdot \left(\sum_{a \in A} \delta_{ac}^{ac} \cdot QXAC_{ac}{}^{-\rho_c^{ac}} \right)^{-\frac{1}{\rho_c^{ac}-1}}$	(10)
$PXAC_{ac} = PX_c \cdot QX_c \left(\sum_{a \in A'} \delta_{ac}^{ac} \cdot QXAC_{ac}^{-\rho_c^{ac}} \right)^{-1} \cdot \delta_{ac}^{ac} \cdot QXAC_{ac}^{-\rho_c^{ac}-1}$	(11)
$PER_{cr} = pwer_{cr} \cdot EXR - \sum_{c' \in CT} PQ_c \cdot icer_{c'cr}$	(12)
$QE_c = \alpha_c^{e} \cdot \left(\sum_{r \in R} \delta_{cr}^{e} \cdot (QER_{cr})^{-\rho_c^{e}} \right)^{-\frac{1}{\rho_c^{e}}}$	(13)
$\frac{PER_{cr}}{PE_c} = QER_{cr} \cdot \left(\sum_{r' \in R} \delta_{cr'}^{e} \cdot (QER_{cr'}) - \rho_c^{e} \right)^{-1} \cdot \delta_{cr}^{e} \cdot (QER_{cr})^{-\rho_c^{e}-1}$	(14)
$PE_c = pwe_c \cdot EXR - \sum_{c' \in CT} PQ_c \cdot ice_{c'c}$	(15)
$QX_c = \alpha_c^{t} \cdot \left(\delta_c^{t} \cdot QE_c^{\rho_c^{t}} + \left(1 - \delta_c^{t}\right) \cdot QD_c^{\rho_c^{t}} \right)^{\frac{1}{\rho_c^{t}}}$	(16)
$\frac{QE_c}{QD_c} = \left(\frac{PE_c}{PDS_c} \cdot \frac{1-\delta_c^{t}}{\delta_c^{t}} \right)^{\frac{1}{\rho_c^{t}-1}}$	(17)
$QX_c = QD_c + QE_c$	(18)
$PX_c \cdot QX_c = PDS_c \cdot QD_c + PE_c \cdot QE_c$	(19)
$PDD_c = PDS_c + \sum_{c' \in CT} PQ_{c'} \cdot icd_{c'c}$	(20)
$PMR_{cr} = pwmr_{cr} \cdot (1 + tmr_{cr}) \cdot EXR - \sum_{c' \in CT} PQ_c \cdot icmr_{c'cr}$	(21)
$QM_c = \alpha_c^{m} \cdot \left(\sum_{r \in R} \delta_{cr}^{m} \cdot (QMR_{cr})^{-\rho_c^{m}} \right)^{-\frac{1}{\rho_c^{m}}}$	(22)
$\frac{PMR_{cr}}{PM_c} = QMR_{cr} \cdot \left(\sum_{r' \in R'} \delta_{cr'}^{m} \cdot (QMR_{cr'})^{-\rho_c^{m}} \right)^{-1} \cdot \delta_{cr}^{m} \cdot (QMR_{cr})^{-\rho_c^{m}-1}$	(23)
$PM_c = pwm_c \cdot (1 + tm_c) \cdot EXR + \sum_{c' \in CT} PQ_{c'} \cdot icm_{c'c}$	(24)
$QQ_c = \alpha_c^{q} \cdot \left(\delta_c^{q} \cdot QM_c^{-\rho_c^{q}} + \left(1 - \delta_c^{q}\right) \cdot QD_c^{-\rho_c^{q}} \right)^{-\frac{1}{\rho_c^{q}}}$	(25)
$\frac{QM_c}{QD_c} = \left(\frac{PDD_c}{PM_c} \cdot \frac{\delta_c^{q}}{1-\delta_c^{q}} \right)^{\frac{1}{1+\rho_c^{q}}}$	(26)
$QQ_c = QD_c + QM_c$	(27)

(continued)

Table 9 (continued)

Production and price equations	
$PQ_c \cdot (1 - tq_c) \cdot QQ_c = PDD_c \cdot QD_c + PM_c \cdot QM_c$	(28)
$QT_c = \sum_{c' \in C'} (icm_{cc'} \cdot QM_{c'} + icmr_{cc'} \cdot QMR_{c'} + ice_{cc'} \cdot QE_{c'} + icer_{cc'} \cdot QER_{c'} + icd_{cc'} \cdot QD_{c'})$	(29)
$\overline{CPI} = \sum_{c \in C} PQ_c \cdot cwts_c$	(30)
$DPI = \sum_{c \in C} PDS_c \cdot dwts_c$	(31)
Institutional incomes and domestic demand equations	
$YF_f = \sum_{a \in A} WF_f \cdot \overline{WFDIST}_{fa} \cdot QF_{fa}$	(32)
$YIF_{if} = shif_{if} \cdot [YF_f - trnsfr_{row\,f} \cdot EXR]$	(33)
$YI_i = \sum_{f \in F} YIF_{if} + \sum_{i' \in INSDNG'} TRII_{ii'} + trnsfr_{i\,gov} \cdot \overline{CPI} + trnsfr_{i\,row} \cdot EXR$	(34)
$TRII_{ii'} = shii_{ii'} \cdot (1 - MPS_{i'}) \cdot \left(1 - \overline{tins}_{i'}\right) \cdot YI_{i'}$	(35)
$EH_h = \left(1 - \sum_{i \in INSDNG} shii_{ih}\right) \cdot (1 - MPS_h) \cdot \left(1 - \overline{tins}_h\right) \cdot YI_h$	(36)
$PQ_c \cdot QH_{ch} = PQ_c \cdot \gamma^m_{ch} + \beta^m_{ch} \cdot \left(EH_h - \sum_{c' \in C} PQ_{c'} \cdot \gamma^m_{c'h}\right)$	(37)
$QINV_c = IADJ \cdot \overline{qinv}_c$	(38)
$QG_c = \overline{GADJ} \cdot \overline{qg}_c$	(39)
$EG = \sum_{c \in C} PQ_c \cdot QG_c + \sum_{i \in INSDNG} trnsfr_{i\,gov} \cdot \overline{CPI}$	(40)
$YG = \sum_{i \in INSDNG} \overline{tins}_i \cdot YI_i + \sum_{a \in A} ta_a \cdot PA_a \cdot QA_a + \sum_{c \in CMNR} tm_c \cdot pwm_c \cdot QM_c \cdot EXR + \sum_{r \in R} \sum_{c \in CMR} tmr_{cr} \cdot pwmr_{cr} \cdot QMR_{cr} \cdot EXR + \sum_{c \in C} tq_c \cdot PQ_c \cdot QQ_c + \sum_{f \in F} YF_{gov\,f} + trnsfr_{gov\,row} \cdot EXR$	(41)
System constraints and macroeconomic closures	
$QQ_c = \sum_{a \in A} QINT_{c\ a} + \sum_{h \in H} QH_{ch} + QG_c + QINV_c + qdst_c + QT_c$	(42)
$\sum_{a \in A} QF_{fa} = QFS_f$	(43)
${}^{QFS_f} / {}_{QFS} f^0 = \left({}^{RWF_f} / {}_{RWF} f^0\right)^{etals_f}$	(44)
$RWF_f = \left(\frac{YF_f}{QFS_f}\right) / \left(\frac{CPI}{CPI^0}\right)$	(45)
$YG = EG + GSAV$	(46)
$\sum_{c \in CMNR} pwm_c \cdot QM_c + \sum_{r \in R} \sum_{c \in CMR} pwmr_{cr} \cdot QMR_{cr} \cdot \sum_{f \in F} trnsfr_{rowf} = \sum_{c \in CENR} pwe_c \cdot QE_c + \sum_{r \in R} \sum_{c \in CER} pwer_{cr} \cdot QER_{cr} + \sum_{i \in INSD} trnsfr_{i\,row} + FSAV$	(47)
$\sum_{i \in INSDNG} MPS_i \cdot \left(1 - \overline{tins}_i\right) \cdot YI_i + GSAV + EXR \cdot FSAV = \sum_{c \in C} PQ_c \cdot QINV_c + \sum_{c \in C} PQ_c \cdot qdst_c$	(48)
$MPS_i = \overline{mps}_i \cdot (1 + MPSADJ)$	(49)
Capital accumulation and allocation equations	
$AWF^a_{f\,t} = \sum_a \left[\left(\frac{QF_{f\,a\,t}}{\sum_{a'} QF_{f\,a'\,t}}\right) \cdot WF_{f\,t} \cdot WFDIST_{f\,a\,t}\right]$	(50)
$\eta^a_{f\,a\,t} = \left(\frac{QF_{f\,a\,t}}{\sum_{a'} QF_{f\,a'\,t}}\right) \cdot \left(\beta^a \cdot \left(\frac{WF_{f,t} \cdot WFDIST_{f\,a\,t}}{AWF^a_{f\,t}} - 1\right) + 1\right)$	(51)
$\Delta K^a_{f\,a\,t} = \eta^a_{f\,a\,t} \cdot \left(\frac{\sum_c PQ_{c\,t} \cdot QINV_{c\,t}}{PK_{f\,t}}\right)$	(52)

(continued)

Table 9 (continued)

Production and price equations	
$PK_{f\,t} = \sum_{c} PQ_{c\,t} \cdot \frac{QINV_{c\,t}}{\sum_{c'} QINV_{c'\,t}}$	(53)
$QF_{f\ a\ t+1} = QF_{f\,a\,t} \cdot \left(1 + \frac{\Delta K^{a}_{f\,a\,t}}{QF_{f\,a\,t}} - \upsilon_f\right)$	(54)
$QFS_{f\ t+1} = QFS_{f\,t} \cdot \left(1 + \frac{\sum_{a} \Delta K_{f\,a\,t}}{QFS_{f\,t}} - \upsilon_f\right)$	(55)

Source: Thurlow (2004)

References

Annabi, N., J. Cockburn, and B. Decaluwé. 2006. *Functional forms and parametrization of CGE models*. PEP MPIA working papers 2006-04. Québec: Poverty and Economic Policy Research Network.

Badiane, O., S. Odjo, and J. Ulimwengu. 2010. *Building capacities for evidence and outcome policy planning and implementation: The example of the Comprehensive Africa Agriculture Development Programme (CAADP)*. IFPRI Discussion Paper 1019. Washington, DC: International Food Policy Research Institute.

Breisinger, C., X. Diao, J. Thurlow, B. Yu, and S. Kalovali. 2008. *Accelerating growth and structural transformation: Ghana's options for reaching middle income country status*. IFPRI Discussion Paper 750. Washington, DC: International Food Policy Research Institute.

Diao, X., M. Nwafor, V. Alpuerto, K. Akramov, and S. Salau. 2010. *Agricultural growth and investment options for poverty reduction in Nigeria*. IFPRI Discussion Paper 954. Washington, DC: International Food Policy Research Institute.

Fan, S., B. Yu, and A. Saurkar. 2008. Public spending in developing countries: Trends, determination, and impact. In *Public expenditures, growth and poverty: Lessons from developing countries*, ed. S. Fan. Washington, DC and Baltimore, MD: International Food Policy Research Institute and Johns Hopkins University Press.

Löfgren, H. 2001. *Less poverty in Egypt? Explorations of alternative pasts with lessons for the future*. IFPRI Discussion Paper 72. Washington, DC: International Food Policy Research Institute.

Löfgren, H., R. Harris, and S. Robinson. 2002. *A standard CGE model in GAMS*. IFPRI Discussion Paper 75. Washington, DC: International Food Policy Research Institute.

Thurlow, J. 2004. *A dynamic Computable General Equilibrium (CGE) model for South Africa: Extending the static IFPRI model*. Working Paper No. 1-2004. Pretoria: Trade and Industrial Policy Strategies.

World Bank. 2008. *World development indicators*. Washington, DC: World Bank. http://data.worldbank.org/sites/default/files/wdi08.pdf. Accessed 25 May 2009.

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3

Agricultural Policies and their Impact on Poverty Reduction

Manfred Wiebelt, Karl Pauw, John Mary Matovu, Everist Twimukye, and Todd Benson

1 Introduction

With the recent discovery of crude oil reserves along the Albertine Rift, Uganda is set to establish itself as an oil producer in the coming decade. Total oil reserves are believed to be two billion barrels, with recoverable reserves estimated at 0.8–1.2 billion barrels. This is comparable to the level of oil reserves in African countries such as Chad (0.9 billion barrels), Republic of the Congo (1.9 billion barrels), and Equatorial Guinea (1.7 billion barrels) but far short of Angola (13.5 billion) and Nigeria (36.2 billion) (World Bank 2010). Using a conservative reserve scenario of 800 million barrels, peak production, likely to be reached by 2017, is estimated by

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the World Bank to range from 120,000 to 140,000 barrels per day, with a production period spanning 30 years. A more optimistic scenario in this study is based on 1.2 billion barrels and sets peak production at 210,000 barrels per day (see Wiebelt et al. 2011). Although final stipulations of the revenue sharing agreements with oil producers are not yet known, government revenue from oil will be substantial. One estimate, based on an average oil price of US$75 per barrel, puts revenues at approximately 10–15% of GDP at peak production (World Bank 2010). The discovery of crude oil therefore has the potential to provide significant stimulus to the Ugandan economy and to enable it to better address its development objectives, provided oil revenues are managed in an appropriate manner.

If the experience of other resource-abundant countries is anything to go by, the prospects are alarming. Cross-country evidence suggests that resource-abundant countries lag behind comparable countries in terms of real GDP growth (Sachs and Warner 1995, 2001; Gelb 1988; IMF 2003); that the negative relationship between resource abundance and economic growth is stronger for oil, minerals, and other point-source resources than for agriculture; and that this relationship is remarkably robust (Sala-i-Martin and Subramanian 2003; Stevens 2003). Nonetheless, several countries have managed to avoid this so-called resource curse. Indonesia's economy grew by an average of 4% per year during 1965–1990, while oil and gas exports rose quickly in the 1970s, reaching 50% of exports in the early 1980s (Bevan et al. 1999). Botswana achieved double-digit growth in the 1970s and 1980s despite rapidly growing diamond exports since the 1970s, and this development occurred despite the enclave character of the mineral industry (that is, low backward and forward linkages to other sectors) (Acemoglu et al. 2003). Other resource-rich countries, such as Malaysia, Australia, and Norway, have successfully diversified their production structures, laying the ground for broad-based balanced growth.

The anxiety about the effects of resource booms partly reflects reservations about the absorptive and managerial capacity of public sectors—particularly in developing countries—to manage large-scale investment programs or to rapidly step up service delivery without a loss in quality. In part, it also reflects even deeper reservations about resource dependency and the impact of windfall profits on the domestic political economy (Ross 2001; Leite and Weidmann 1999; Easterly 2001). However, more traditional concerns about the macroeconomics of resource booms also figure large, and these are the focus in this study. Dominating these concerns is the fear that the additional foreign exchange arising from the exploitation and exportation of natural resources may cause an appreciation of the real exchange rate. Although a strong domestic currency is good news for importers, Rodrik (2003) warns of the danger an uncompetitive real exchange rate holds for overall economic growth and development. The subsequent loss of competitiveness in the nonresource tradable goods sectors—or Dutch Disease—may hamper growth in traditional export sectors such as manufacturing or agriculture. These sectors are often major employers in developing countries and serve as the engines of growth. Of course, exportation of natural resources does not inevitably have negative consequences for the economy; for example, if the resource flow emanating from the newly exploited natural resource is small relative to overall trade flows, or there are underemployed factors of production that can be used in the expanding natural resource exploitation sectors with little opportunity cost, or both, an expansion in natural resource exports will not necessarily lead to Dutch Disease (see Hausmann and Rigobon 2002; Sala-i-Martin and Subramanian 2003).

This study considers the impact of crude oil extraction and exportation on the Ugandan economy with a specific focus on how it might affect the agricultural sector. We also consider various options open to the Ugandan government for saving, spending, or investing forecasted oil revenues over the coming three decades. For this analysis we modify a recursive-dynamic computable general equilibrium (CGE) model of Uganda by including crude oil extraction and refining industries. These industries are allowed to grow and shrink over time in line with the forecasted oil production trend, while oil revenues accruing to government are either saved abroad in an oil fund (this sterilizes the exchange rate effect) or spent domestically. Several spending scenarios consider the effects of using the balance of oil funds (that is, after deducting amounts saved) to develop public infrastructure. Here we consider scenarios where infrastructure investments only contribute to long-term growth through raising productive capacity, or where they also have productivity spillover effects in targeted sectors (for example, in agricultural or nonagricultural sectors specifically). Scenarios where oil revenues are distributed to citizens in the form of household welfare transfers or used to subsidize prices (for example, fuel subsidies) are also modeled.

The contribution is structured as follows. We first provide an overview on spending options. Particular attention is given to infrastructural investments and their effects in developing countries. Next, we introduce the CGE model and describes the simulation setup and design, then present and discuss the model results. Last, we draw conclusions.

2 Investing Oil Revenues: Options and Challenges

For the past two decades Uganda has managed its public finances and the macro economy in a prudent manner, yet the prospect of a large influx of oil revenue presents a major challenge to government. Even though Uganda's oil reserves are not massive compared to those of the major oil producers of the world, the expected revenue is still substantial relative to the current size of the economy.

There are at least three dimensions to the oil revenue spending challenge that lies ahead: First, there is the issue of how to manage oil price volatility. Volatile prices imply volatile revenue flows from one year to the next, which makes long-term planning difficult. Second, while increased administrative capacity will be required to manage a much larger infrastructural and social spending budget, the danger exists that government becomes too large and undisciplined in its spending. If service delivery becomes inefficient and administrative expenditures (for example, on salaries) grow too much there will ultimately be less funding available for all-important infrastructural spending. Third, infrastructural spending itself may be inefficient due to a lack of administrative or absorptive capacity within government. While spending will contribute to GDP in the current period, thus creating the perception of growth, it may not translate into increased production capacity and higher levels of productivity in future periods, which ultimately hampers the sustainability of oil revenue spending.

2.1 Revenue Stabilization Options

One way to deal with revenue volatility and concerns about spending inefficiency is to transfer oil revenues into a foreign "oil fund" from which a smaller or a more stable revenue flow is extracted. The first option is to set up a budget stabilization fund (SF), which involves allocating a certain share of government oil revenues to a fund that can be tapped when low oil prices cause revenues to drop below projected flows. Examples include the SF of the Russian Federation or the State Oil Fund in Azerbaijan. When using an SF government may still plan to spend all oil revenues during the oil extraction period, in which case the SF is only used to smooth the revenue flow as it deviates from projected revenues. However, such a fund could also be used to extend the spending period beyond the oil extraction period by saving a greater share of annual revenue and continuing to draw on accrued savings that remain at the end of the oil extraction period. A second option is a permanent income fund (PIF) or heritage fund. Here all revenue from oil is transferred to the fund and only the interest earned on accumulated funds is allocated to the government budget. The Norwegian Government Pension Fund and the Kuwaiti Future Generations Fund are good examples of such PIFs. A PIF provides a much smaller flow of revenue compared to the default option of spending all revenues immediately, but the income stream is perpetual, thus having the potential of benefiting future generations. The revenue stream is also likely to be fairly stable or predictable, especially when long-term fixed interest rates are earned on the accumulated funds.

Although the development challenges loom large in Uganda, a prudent spending approach is desirable. This means not succumbing to the temptation of spending too much too soon. Proponents of a spend-all approach may appeal more to the masses, with arguments that the country cannot afford to hoard revenue amidst crumbling infrastructure and developmental backlogs. However, ideally speaking, spending levels should only gradually increase in line with the pace at which government capacity grows. Uganda has taken advice of this nature on board in announcing that an oil fund will indeed be set up and managed by the Central Bank (see Uganda, Ministry of Energy and Mineral Development 2008). The way in which the fund is managed (that is, how funds are deposited or withdrawn over time) should be explicitly governed by the legal and regulatory framework for oil revenue. Such a framework, combined with a gradually enhanced institutional capacity, should cushion the country from pressure from those who would want to see quick but unsustainable gains from oil.

2.2 Investment Spending Options

2.2.1 Investment for Economic Growth and Poverty Reduction

The pace at which public infrastructure is developed is an important determinant of the development process. Numerous studies highlight the importance of the stock of public infrastructure as one necessary ingredient for agricultural productivity growth (Binswanger et al. 1993; Ram 1996; Esfahani and Ramirez 2002). Hulten (1996) argues it is not only the level of public investment that matters, but also the spending efficiency and the effectiveness with which existing capital stocks are used by citizens (see also Calderón and Servén 2005, 2008; Reinikka and Svensson 2002). Microeconomic studies tend to focus more on the latter aspect, and show that improved access to public infrastructure positively influences the adoption of productivity-enhancing technologies by farm households or firms (Antle 1984; Ahmed and Hossain 1990; Renkow et al. 2004). Access to and utilization of public infrastructure also has important welfare effects, including the reduction of rural poverty (Fan et al. 2000; Fan and Zhang 2008; Gibson and Rozelle 2003) and rural inequality (Calderón and Servén 2005; Fan et al. 2003). The strength of these welfare effects, however, depends on the institutional setup in countries (Duflo and Pande 2007), while strong complementarities exist between physical and human capital (Canning and Bennathan 1999). The latter suggests that investments in education, training, or rural extension services would enhance the effectiveness of infrastructural investments.

The overwhelming message is that infrastructural investments matter for development, especially when measures are in place to improve access to that infrastructure. However, it is less clear precisely where to invest in order to maximize growth and poverty outcomes. The agricultural sector stands out as a strong candidate. Agriculture is an important sector in many developing countries in terms of its share of national GDP and employment. Agricultural growth is therefore particularly important in determining the pace of poverty reduction (Diao et al. 2010; Valdés and Foster 2010). In Uganda the agricultural sector is relatively small, contributing less than one-third to national GDP. However, it remains a significant employer, with 81% of the population living in households that are directly involved in agricultural activities (see Benin et al. 2008). Farming is by no means exclusively a rural activity in Uganda (27.8% of urban households are engaged in agricultural activities), but it is clear from population statistics that a focus on rural agriculture is warranted: 9 in 10 farm households live in rural areas, and one in three rural inhabitants are poor, compared to 13.8% of urban people. This implies that growth in the agricultural sector has the potential to significantly reduce poverty in Uganda. Weak historical agricultural growth, low agricultural yields, and poor infrastructure in Uganda all point to the great potential for this sector to grow rapidly should significant public investments, particularly in infrastructure, reach this sector.

Using a recursive-dynamic CGE model, Benin et al. (2008) are able to demonstrate how rapid agricultural growth achieved through yield improvements under the Comprehensive Africa Agricultural Development Programme (CAADP) in Uganda contributes to overall growth and poverty reduction. CAADP aims to achieve 6% agricultural growth by committing countries to allocate 10% of their overall budgets to the agricultural sector in the form of infrastructure investments, research and development, and extension services. In Uganda the 6% growth target implies a doubling of the agricultural growth rate, which, historically, has remained at just below 3%. Benin et al. (2008) show that if agricultural growth is maintained at 6% over the period 2005–2015, the national GDP growth rate in Uganda will increase by 1% point (that is, from 5.1 to 6.1%). Agricultural growth also has spillover effects into the rest of the economy, with agroprocessing or food-processing and trade and transport sectors benefiting from more rapid growth. More importantly, however, are the poverty-reducing effects of rapid agricultural growth. Benin et al. (2008) show that under an accelerated agricultural growth path the poverty rate in 2015 will be 7.6% points lower than the forecasted level under the *business as usual* growth path. This is equivalent to an additional 2.9 million people being lifted out of poverty by 2015.

Benin et al. (2008) extend their analysis to focus on specific agricultural sub-sectors' effectiveness at reducing poverty and generating growth through size and economic linkage effects. In this regard they find that horticultural crops, root crops, livestock, and cereals have the greatest poverty-reducing potential in Uganda. This is due both to the crop choices of resource-poor farmers and to the preferences of poor consumers (increased productivity lowers farmers' unit production costs and benefits consumers via price reductions). Given their initial size, growth potential, and economic linkages, growth in subsectors such as roots, *matooke* (cooking banana), pulses and oilseeds, and export crops contribute most to overall growth.

Using a similar methodology, Dorosh and Thurlow (2009) focus more closely on the relative impacts of rural versus urban public investments in Uganda. In general, they find that improving agricultural productivity generates more broad-based welfare improvements in both rural and urban areas than investing in the capital city, Kampala. Although investing in Kampala accelerates economic growth, it has little effect on other regions' welfare because of the city's weak regional growth linkages and small migration effects. In a study in Peru, Thurlow et al. (2008) find that by investing in the leading (more urbanized) region, that country may be undermining the economy in the lagging (mostly rural) region by increasing import competition and internal migration. The authors also show that the divergence between the leading and lagging regions can only be bridged by investing in the lagging region's productivity through providing extension services and improved rural roads.

This brief overview suggests that public investments in rural areas and agriculture should be a critical part of the development strategy in Uganda if the country is to achieve its goals of reducing (rural) poverty and narrowing the welfare gap between urban and rural areas. Studies cited show that investments in cities or major urban centers such as Kampala, although good for growth there, may in fact be harmful or at best neutral for growth or welfare in rural areas. Either way, such investments will lead to rising rural–urban inequality, which is an undesirable socioeconomic outcome. The challenge is to be strategic about how and where to invest so that productivity gains in priority sectors or subsectors are maximized. Certain types of investments have obvious impacts; for example, investments in rural roads, irrigation infrastructure, or water storage will benefit agriculture, and depending on the exact location (or agronomic zone) of those investments, specific subsectors within agriculture. For other types of investments, such as telecommunications, it is likely that urban-based manufacturing sectors would benefit more, but there may still be intended or unintended productivity spillovers into other sectors. It is also important to realize that there may be a lag from the time the investment in agriculture is made until productivity spillovers materialize and rural poverty declines. The immediate beneficiaries of increased agricultural investment spending are more likely to be those nonpoor workers supplying investment services or producing investment goods rather than poor farming households themselves.

2.2.2 Transferring Rents to Citizens

The massive infrastructural spending backlogs in Uganda mean much of the policy discussion around spending of oil revenue has and will continue to focus on public investments. However, infrastructural spending is not the only option open to government. Some argue that oil revenues should be spent on the provisioning of social protection: Since citizens in effect own the oil resource, the most appropriate approach is to transfer revenues back to them. Social protection can be broadly defined. Benefits transferred to citizens can be in the form of tax breaks (for example, income or consumption tax cuts); subsidies (for example, direct price subsidies, employment subsidies, or investment subsidies); job creation schemes; or direct transfers (Gelb and Grasmann 2010). Not all these transfer mechanisms necessarily involve a direct transfer from government to households; some work indirectly via employment or consumption.

Gelb and Grasmann (2010, 12–16) briefly review the merits of and justification for each of these benefits while Gelb and Majerowicz (2011) consider the strengths and limitations of cash transfers in Uganda. A lower tax burden, they explain, might reduce the deadweight costs of taxation, provided the quality of tax administration does not decline at the same time. Lower taxes, in general, will encourage economic activity, thus compensating export sectors in particular for the adverse effect of a stronger exchange rate. Domestic price subsidies are popular for obvious reasons. A common type of subsidy in oil-producing economies is one on petroleum products; in fact, in many countries petroleum prices are kept far below market levels at a subsidy cost equivalent to "several percentage points of GDP" (Gelb and Grasmann 2010, 13). An approach that is used "more widely in the Middle East than elsewhere" (Gelb and Grasmann 2010, 14) is public-sector job creation. One estimate suggests that around 80% of jobs in Gulf are in the public sector (for example, in Kuwait, employment for nationals is virtually guaranteed).

Very few countries have considered the use of oil revenues to finance direct welfare transfers. However, there is *increasing interest* in distribution mechanisms such as those pioneered in Alaska "as the shortcomings of other approaches become more apparent" (Gelb and Grasmann 2010, 14). Cash transfers or grants have two primary functions: They reduce short-term poverty and inequality, and they provide safety nets that enable households to manage risk (Pauw and Mncube 2007). There are several design options. First, grants can be targeted or universal. Targeted grants are more costly to administer, but targeting improves efficiency in terms of reductions in poverty and inequality. Under a universal grant scheme all citizens have access to a grant, irrespective of their socioeconomic status. Second, grants can be conditional or unconditional. Conditional grants, as the name suggests, are only accessible by households that comply with certain provisions, such as attending school or visiting health clinics.

The successes of conditional programs such as Bolsa Familia in Brazil and Opportunidades in Mexico have been widely reported (see, for example, Adato and Hoddinott 2010). However, just like targeting, conditionality increases the administrative burden of these programs, both for administrators who need to determine eligibility of prospective participants and for health and education service providers who need to deal with the mandatory increase in demand for these services. For this reason conditionality may not always be a good idea, especially in countries where administrative capacity is low or where social service delivery is weak (Pauw and Mncube 2007). The alternative (that is, a nontargeted unconditional grant scheme) is costly, but the large influx of oil revenues in Uganda puts the country in a position where it can probably afford such a *basic income grant*. Although a uniformly distributed grant will not improve inequality, it will reduce poverty, while at the same time policymakers can avoid sensitivities that may arise when oil revenues—seen by all as a national resource—are unequally distributed.

3 CGE Model Simulation Setup

3.1 The Ugandan Recursive-Dynamic CGE Model

This study applies a single-country recursive-dynamic CGE for Uganda (also used by Benin et al. 2008) to investigate the effects of oil production and to consider alternative options for spending oil revenue. This modeling tool is useful as it captures the important direct and indirect effects associated with oil production and the spending of oil revenues. In a similar study to this one, Breisinger et al. (2009) also use a CGE model to examine the potential trade-offs between spending and saving of oil revenues in Ghana. The CGE model is a member of the class of single country neoclassical CGE models first developed by Dervis et al. (1982) and features endogenous prices, market clearing, and imperfect substitution between domestic and foreign goods. Below we highlight some of the key features of the Ugandan model. A detailed model description and equation listing can be found in Thurlow (2004).

3.1.1 Private Production and Consumption

Producers and consumers in the model are assumed to enjoy no market power in world markets, so the terms of trade are independent of domestic policy choices.

Firms in each of the 52 economic sectors (or activities) are assumed to be perfectly competitive, producing a single good that can be sold to either the domestic or the export market. Production in each sector i is determined by a constant elasticity of substitution (CES) production function of the form.

$$Q_i = A_i \, \Sigma_f \left\{ \delta_{fi} F_{fi}^{-\rho i} \right\}^{-1/\rho i}, \tag{1}$$

where f is a set of factors consisting of land, cattle, capital, and different labor categories; Q_i is the sectoral activity level; A_i the sectoral total factor productivity; F_{fi} the quantity of factor f demanded from sector i; and δ_{fi} and ρ_{fi} are the distributional and elasticity parameters of the CES production function, respectively. Only agricultural crop production requires land. Sectoral supply growth of land is fixed. Sector capital endowments are fixed in each period but evolve over time through depreciation and investment. Capital and labor markets are competitive so that these factors are employed in each sector up to the point that they are paid the value of their marginal product. Private-sector output is also determined by the level of infrastructure, which is provided costless by the government. We assume that total sector factor productivity A_i depends on the availability of public infrastructure.

Consumption for each household type is defined by a constant elasticity of substitution linear expenditure system, which allows for the income elasticity of demand for different goods to deviate from unity. The CGE model endogenously estimates the impact of alternative growth paths on the incomes of various household groups. These household groups include farm and nonfarm households and are disaggregated across rural areas, the major city of Kampala, and other smaller urban centers. Each of the households questioned in the 2005/06 Uganda National Household Survey (UNHS5) are linked directly to their corresponding representative household in the CGE model. This is the microsimulation component of the Ugandan model. Changes in representative households' consumption and prices in the CGE model are passed down to the corresponding households in the survey, where standard poverty measures and changes in poverty are calculated.

3.1.2 Macroeconomic Closures and Dynamics

The model has a neoclassical closure in which total private investment is constrained by total savings net of public investment. Household savings propensities are exogenous. This rule implies that any shortfall in government savings relative to the cost of government capital formation, net of exogenous foreign savings, directly crowds out private investment. Likewise, any excess of government savings directly crowds in private investment.

The model has a simple recursive-dynamic structure. Each solution run tracks the economy over 40 periods. Each period may be thought of as a fiscal year (that is, from year 2007 to 2046). Within-year capital stocks are fixed, and the model is solved given the parameters of the experiment (for example, exogenous growth in the oil production or refining sector, or changes in import tariffs on fuels). This solution defines a new vector of prices and quantities for the economy, including the level of public- and private-sector investment, which feed into the equations of motion for sectoral capital stocks. The equation is specified as

$$K_{i,t} = K_{i,t-1}(1 - \mu_i) + \Delta K_{i,t-1}, \quad (2)$$

where $K_{i,t}$ is the capital stock, μ_i denotes the sector-specific rate of depreciation, and $t-1$ measures the gestation lag on investment.

The final element is an externality resulting from public investment in infrastructure. Public investment is assumed to generate an improvement in total factor productivity. Specifically, equation (1) assumes that $\mathrm{A}_{i,t} = \mathrm{A}_i$ for nonspillover sectors, whereas in the spillover sectors, denoted s, total factor productivities evolve according to

$$\mathrm{A_{s,t}} = \mathrm{A_s} \cdot \Pi_{\mathrm{g}}\left\{(\mathrm{I^g}_{\mathrm{t}}/\mathrm{I^g}_0)/\left(\mathrm{Q_{s,t}}/\mathrm{Q_{s,0}}\right)\right\}^{\rho}{}_{\mathrm{sg}}, \quad (3)$$

where g denotes a set of public investments defined over rural and urban infrastructure, health and education, and so on; I^g and Q_s are real government investment and sectoral output levels; and $I^g{}_0$ and $Q_{s,0}$ are the correspondingly defined public investments and output levels in the base period. The terms ρ_{sg} measure the extent of the spillovers. If $\rho_{sg} = 0$, there is no spillover from public investment in infrastructure or health and education. The higher ρ_{sg}, the higher are spillovers.

The total population, workforce, area of arable land, number of livestock, and income from abroad are examples of other variables that evolve over time according to exogenously defined assumptions. The growing population generates a higher level of consumption demand and therefore raises the supernumerary income level of household consumption within the linear expenditure system (LES) specific to each household and subject to the constraints of available income and the consumer price vector. Labor, land, cattle, and foreign capital supply are updated exogenously.

3.2 Simulation Setup

3.2.1 Baseline Scenario

The baseline scenario serves as the counterfactual against which other scenario results are compared. Scenarios are solved over the period 2007–2046, which roughly coincides with the forecasted crude oil extraction period. The baseline (simulation name BASELINE) is a no oil scenario, which assumes a continuation of the *business as usual* growth path for Uganda over the coming decades (that is, without the establishment of crude oil extraction and refining industries). Growth rates for total factor productivity, factor supply, foreign capital inflow, and real government consumption follow recent historical trends or are set at levels such that GDP at factor cost is targeted to grow at an annual average rate of 5.1% until 2046 (see Table 2: Part A). The table further provides a breakdown of this growth into its different components. Absorption, which includes private consumption (5%), investment expenditure (4.4%), and government expenditure (exogenously set to grow at 3%), grows at 4.7% per year. Export growth outpaces import growth, mainly due to domestic factor productivity growth, which makes exporters more competitive in international markets. The result is a declining trade deficit, while the exogenously imposed 3% growth in foreign capital inflows causes the real exchange rate to appreciate on average by 0.9% per year.

The results in *BASELINE* reveal the so-called Balassa-Samuelson effect, where tradable sectors with higher than average productivity increases and lower income elasticities of demand grow less than nontradable sectors, such as services. Thus, as expected under this growth scenario, the economic structure will continue to change in favor of services and industry. Table 2 (Part B) shows that the share of the agricultural sector in total GDP decreases from 22.6% in 2007 to 15.8% in 2046, which is a result of a relative decline in agricultural prices driven primarily by relatively lower domestic demand for agricultural products and domestic terms of trade effects, which cause an appreciation in the real exchange rate. In contrast, the services sector continues to expand, contributing 62.5% of GDP by 2046.

3.2.2 Modeling Oil Production and Refining

Several oil production and refining scenarios are modeled. All involve the same fairly rapid growth path for oil production. Growth is fastest between 2007 and 2017 when peak oil production is reached. Peak production levels are then maintained for about a decade, before production is gradually phased out over the next two decades until recoverable reserves are exhausted by 2046. The expansion is simulated by exogenously raising or lowering the level capital stock available to the crude oil refining sector. The implicit assumption is that capital stock expansion is funded (almost) entirely by foreign direct investment. However, although the decision to invest is made exogenously by foreign investors, the oil sector still has to compete with other sectors for intermediate inputs and, to a much lesser extent, for labor resources. Furthermore, depending on how government spends its oil revenue (for example, government may spend more on public infrastructure or government services), the demand for labor will rise rapidly in those sectors required to satisfy government demand (for example, suppliers of machinery and equipment, construction services, or public service providers). All crude oil is supplied to the refining sector. Supply bottlenecks are avoided by applying a similar capital stock growth rate to the refining sector as the one that determines crude oil production levels.

Profits—or returns to capital stock—generated in the oil production and refining sectors are shared between the foreign owners of capital (their share is repatriated) and the Ugandan government (revenue is transferred via a 74.4% tax on returns to capital). All crude oil is supplied to the oil refineries, and for the sake of simplicity all refined oil is assumed to be exported. Domestic demand for petroleum products is, in turn, met by imports. In reality, some of the refined oil product will be retained for domestic consumption and the country will cease to import petroleum products, but modeling it in this manner is simpler and does not affect results since the balance of payments effect is symmetrical.

3.2.3 Oil Simulation Experiments

In all the oil simulations, oil production and refining capacity is increased and then gradually phased out to replicate the forecasted production path, which assumes peak production of about 210,000 barrels of oil per day between 2017 and 2025. The main objective in this study is not to compare the contributions of alternative oil production and revenue scenarios to the economy, but instead to evaluate economic and socioeconomic outcomes under alternative spending options. All oil simulations therefore assume the same oil production path and government revenue stream, but they differ in terms of how government saves or spends the revenue. A total of six oil scenarios are modeled. We elaborate below, and Table 1 summarizes.

We start off with a set of basic investment scenarios where we assume all oil revenue is invested domestically, or, alternatively, part of oil revenue is invested and the balance is transferred to a foreign oil fund. Also included in this set of scenarios is one where part of the revenue is transferred to households in the form of a welfare grant. The first simulation, named FND00INV, is a typical Dutch Disease scenario. It assumes that all public revenue is immediately used to finance public infrastructure investment spending. This means none of the government oil revenue is saved abroad in a fund. In general, in this scenario, additional foreign exchange revenue from oil production and exportation increases national income, which is used by private and public agents for consumption (this is an endogenous effect) and investment (via increased private savings, or by design via the government closure selected). The latter increases the economy's total capital stock until peak oil production is reached, but the increased public capital does not sustain significantly higher output over the entire simulation period, as the capital stock in the oil sector is subsequently reduced to replicate declining output as oil reserves are gradually depleted. The simulation therefore allows the pure demand-side effects of the price boom to be isolated: Absorptive capacity constraints are binding and the demand effects lead to a real appreciation and the typical restructuring of production observed during an oil boom.

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Table 1 Summary of modeled baseline and oil scenarios

Simulation name	Long name	Share of revenue invested	Productivity spillover effects modeled	Share of revenue saved to oil fund
0. BASELINE	"Business as usual" baseline scenario with no oil production and refining capacity	N/A	N/A	N/A
Public investment scenarios with no productivity spillover				
1. FND00INV	Fund 00 investment scenario	100%	No	0%
2. FND50INV	Fund 50 investment scenario	50%	No	50%
3. FND00I&H	Fund 00 investment and household transfer scenario[a]	50%	No	0%
Public investment scenarios with productivity spillover effects				
4. FND50NTR	Fund 50 investment scenario with neutral productivity spillover	50%	Yes	50%
5. FND50AGR	Fund 50 investment scenario with agricultural productivity spillover	50%	Yes	50%
6. FND50NAG	Fund 50 investment scenario with nonagricultural productivity spillover	50%	Yes	50%

Source: Authors' estimations
Notes: (a) Uniform cash grant; 50% of oil revenue distributed to citizens

used by private and public agents for consumption (this is an endogenous effect) and investment (via increased private savings, or by design via the government closure selected). The latter increases the economy's total capital stock until peak oil production is reached, but the increased public capital does not sustain significantly higher output over the entire simulation period, as the capital stock in the oil sector is subsequently reduced to replicate declining output as oil reserves are gradually depleted. The simulation therefore allows the pure demand-side effects of the price boom to be isolated: Absorptive capacity constraints are binding and the demand effects lead to a real appreciation and the typical restructuring of production observed during an oil boom.

The second simulation, *FND50INV*, examines the case where only half of the oil revenue is invested immediately in public infrastructure while the remainder is deposited in a foreign oil fund. Government may choose this option in an attempt to mitigate or *sterilize* the Dutch Disease effects associated with a spend-all approach. Sterilization will reduce the growth effects relative to the experience of a massive spending boom, but at the same time the real exchange rate appreciation will be less pronounced since not all oil revenue from exports is brought back into the domestic economy. Although this may benefit export sectors in the short run, the net effect in the long run is not certain since investment flows and capital stock formation is lower in this scenario.

A third simulation, *FND00I&H*, investigates the option of using oil revenues to finance an unconditional uniform cash transfer scheme. This simulation assumes no deposit in a foreign oil fund; instead, half of oil revenue is spent on infrastructural investments (as in *FND50INV*) and the remainder is distributed equally among Uganda's citizens. The cash transfer is modeled as a nonuniform income tax cut across all household groups. The extent of the tax break varies across household groups in the model such that each citizen, irrespective of his or her age, receives the same per capita transfer in *absolute* terms (that is, initial average income tax rates and the size of household groups are taken into account in the calculation of the applicable tax cuts). In *relative* terms, therefore, poorer citizens receive a much larger welfare transfer than wealthy citizens. Since average tax rates are low in Uganda, several household groups end up with a negative tax rate, which effectively means their earnings from welfare transfers exceed income tax payments. If such a uniform grant scheme ever became a reality in Uganda it could be justified on the basis that each citizen in Uganda is entitled to an equal share of oil revenue. The design of the transfer mechanism implies that household incomes will rise across the board by the same absolute magnitude, causing poverty rates to decline, but income inequality will remain virtually unchanged. In contrast to the earlier scenarios, this simulation will lead to a significant increase in private disposable income, which is used by households to increase consumption and savings. The latter, in turn, finances private investment formation. Low savings rates, however, suggest that most of the additional income will be spent on household consumption.

Whereas the first set of oil simulations assume zero productivity spillover effects from public investments, the second set of simulations explore the importance of such productivity spillover. The aim here is to demonstrate not only the importance, in general, of ensuring that public investments are indeed *productivity-enhancing*, but also to show how investments that aim to raise productivity in specific sectors in the economy (for example, through direct targeting of agricultural or nonagricultural sectors) may ultimately have important growth and welfare or distributional implications. The scenarios all follow the same basic setup as *FND50INV* (that is, half of revenues are saved abroad and the other half is allocated to public infrastructure investments), but now assume that government infrastructure investment raises productivity relative to the growth already assumed in *BASELINE*. In *FND50NTR* the productivity-enhancing effect is uniform or neutral across sectors, whereas in *FND50AGR* and *FND50NAG* total factor productivity growth is biased in favor of agricultural/food-processing and nonagricultural sectors, respectively.

The extent of the total factor productivity spillover effects in each sector is linked directly to the level of spending on each of several budget items. Equation (3) defines this relationship. Thus, as explained before, any increase (or decrease) in the real government investment index $I^g{}_t/I^g{}_0$ in relation to the sector production index $Q_{s,t}/Q_{s,0}$ raises (or reduces) sectoral total factor productivity $A_{s,t}$, with the extent of the increase (reduction) determined by the spillover parameter ρ_{sg}. In the first set of investment simulations ρ_{sg} was set to zero, whereas in the spillover simulations $\rho_{sg} = 0.1$. Since the structure of government spending is likely to have a bearing on sectoral productivity spillover effects (Fan et al. 2009), *FND50AGR* and *FND50NAG* assume both an increase in total government investment spending (as in *FND50INV*) and also a change in the composition of that spending. Data on the current budget composition are obtained from Sennoga and Matovu (2010) and Twimukye et al. (2010). In *FND50AGR* we increase the allocation to agriculture by 20% (or 0.8% points) from 3.8 to 4.6% of total budgetary resources, while at the same the expenditure share to roads is reduced by 0.8% points. In *FND50NAG* we assume the opposite, that is, the expenditure share on agriculture is reduced by 0.8% and vice versa for roads. Next, growth-expenditure elasticities (from Benin et al. 2008) are applied to calculate the marginal effect of the absolute and compositional shift in public expenditure sectoral productivity. The growth-expenditure elasticity for agricultural spending is 1.4, whereas it is 2.7 for roads. The result is that total factor productivities in agriculture and food-processing sectors increase by about 25% in *FND50AGR*, while they decrease by about 10% in other manufacturing and trade and transport sectors (these changes are relative to the growth rate in *BASELINE*). The effects are the exact opposite in *FND50NAG*. In the neutral spending scenario (*FND50NTR*) there is no compositional shift in spending, hence productivity across all sectors grows by the same margin.

4 Model Results

4.1 Public Investment Scenarios with No Productivity Spillover Effects

4.1.1 Spending All Revenues on Infrastructure (*FND00INV*)

The major effects and transmission channels of the oil boom in Uganda are described with reference to the results of scenario *FND00INV*, which serves as the benchmark for other oil scenarios. Public investment expenditures are linked directly to government oil revenue and will therefore increase until peak oil production is reached in 2017. Thereafter these expenditures gradually decline due to declining government oil revenues (which in turn is linked to the real exchange rate appreciation) and the gradual winding down of oil production activities.

Under *FND00INV* the Ugandan economy grows rapidly at 6.9% per year until 2017, mainly because of the large increase in real public-sector investment (see Table 2: Part A). Overall investment grows at 9.5% per year over this period. Household income also rises in these scenarios, which leads to an increase in private consumption (by 5.1% during 2007–2017) and savings. However, private savings as a share of GDP actually declines (not reported in Table 2), which suggests the oil boom crowds out private-sector investment, at least in relative terms. A further factor is the real exchange rate appreciation. Although in general such an appreciation would mean imported capital goods become less expensive,

Table 2 GDP growth, sectoral composition, welfare, and poverty: *No productivity spillover* scenarios during oil expansion period, 2007–2017, and entire oil extraction period, 2007–2046

	Initial value			No productivity oil scenarios					
		BASELINE		*FND00INV*		*FND50INV*		*FND00I&H*	
	2007	2007–2017	2007–2046	2007–2017	2007–2046	2007–2017	2007–2046	2007–2017	2007–2046
Part A: Annual growth rate of demand[a]									
Absorption	26,584	4.2	4.7	5.8	5.2	5.1	5.0	5.7	4.9
Private consumption	18,743	4.5	5.0	5.1	5.5	4.8	5.3	5.7	5.3
Fixed investment	5014	3.6	4.4	9.5	4.9	7.1	4.7	7.2	4.2
Government consumption	2689	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
Exports	3697	6.9	7.0	12.7	7.8	14.0	7.4	12.7	7.3
Imports	−7260	4.7	5.6	7.2	6.2	6.1	5.9	7.2	5.9
GDP at factor cost	21,318	4.5	5.1	6.9	5.6	6.8	5.3	6.8	5.3
Real exchange rate[b,c]		−0.5 (−5.2)	−0.9 (−30.7)	−1.3 (−12.4)	−1.2 (−37.5)	−0.8 (−7.7)	−1.1 (−34.4)	−1.6 (−15.2)	−1.1 (−34.5)
Consumer price index[c]		0.5 (5.0)	0.9 (40.3)	1.2 (12.9)	1.2 (56.2)	0.7 (7.7)	1.0 (48.7)	1.6 (16.9)	1.0 (49.1)
Part B: Sector share of GDP by 2017 and 2046		(2017)	(2046)	(2017)	(2046)	(2017)	(2046)	(2017)	(2046)
Agriculture	22.6	21.1	13.2	16.8	11.2	16.9	12.1	17.2	12.6
Industry	27.3	24.7	20.7	45.6	21.2	42.7	21.0	43.8	19.7
Mining (including crude oil)	0.4	0.3	0.1	17.6	0.2	17.7	0.2	17.7	0.2
Oil refining	–	–	–	1.3	> 0.1	1.3	0.0	1.3	0.0
Services	50.1	54.2	66.1	37.6	67.6	40.4	66.9	39.0	67.7
	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Part C: Equivalent variation[d]		Cumulative growth			Percentage point deviation from BASELINE				
Rural farm	342	56.0	557.8	6.9	109.4	3.1	58.9	24.4	75.4
Rural nonfarm	135	54.9	563.0	9.3	122.9	4.0	65.9	13.6	56.5
Kampala metro	1277	55.4	579.2	9.3	139.8	4.4	74.6	10.0	56.5

Urban farm	1100	50.3	520.9	9.0	126.2	4.6	67.5	17.0	63.5
Urban nonfarm	1249	55.0	575.2	9.6	137.2	4.4	73.3	12.4	59.4
Average	820	54.3	559.2	8.8	127.1	4.1	68.0	15.5	62.2
Part D: Headcount poverty (P_0) (percent)		(2017)	(2046)	(2017)	(2046)	(2017)	(2046)	(2017)	(2046)
National	31.1	22.6	3.5	20.5	1.9	21.7	2.5	16.2	2.4
Rural	34.3	24.8	3.9	22.6	2.2	23.9	2.8	17.7	2.8
Urban	13.8	10.2	1.4	8.5	0.6	9.4	0.9	8.0	0.9

Source: CGE model results

Note:

[a]Initial value in US dollars billions

[b]Trade-weighted real exchange rate

[c]Overall growth rate in parentheses

[d]Initial expenditure per capita in US dollars thousands

capital formation in Uganda is in fact intensive in nontradable goods (for example, nontradable construction goods make up 78% of investments). This means that foreign capital inflows, which are assumed to grow at 3% annually in all scenarios, finance less and less real investment over time. Diminishing oil reserves means the real exchange rate appreciation weakens over time, but this is not sufficient to reverse the trend of declining non-oil exports. In fact, the initial welfare gains associated with the surge in public-sector investment weaken over time as other components of GDP (for example, private investments, consumption, and exports) fail to grow more rapidly when public investments eventually decline.

A comparison of *FND00INV* with *BASELINE* reveals the typical characteristics of Dutch Disease. The consumer price index increases at an average annual rate of 1.2% during 2007–2046, while the (trade-weighted) real exchange rate appreciates by 1.3% between 2007 and 2017 or by 1.2% per year over the entire 2007–2046 period. Relative to *BASELINE*, the spending of windfall revenues leads to a 0.2 and 1.5% point contraction in agriculture and services, respectively, in the medium term. As a result, these two sectors' shares of GDP also decline dramatically by 4.6 and 16.4% points relative to the base (2007–2017; see Table 2: Part B). The services sector regains growth momentum in the long run, but agricultural growth only improves marginally relative to the base. Thus, while real GDP at factor cost increases, the agricultural sector actually suffers a decline in GDP, both absolutely (compared to *BASELINE*) during the oil expansion period and relative to other sectors over the total oil extraction period (Table 2: Part B). The services sector also realizes absolute income losses in the medium term, but a reversal of fortunes sees this sector become the engine of long-term growth.[1]

Table 3 presents more disaggregated sectoral production results (GDP at factor cost), focusing on changes during the oil expansion period (2007–2017). The first column shows the average annual change in *BASELINE*, and the remaining columns show the percentage point changes in production in the various oil scenarios relative to *BASELINE*. The results for *FND00INV* corroborate the picture of Dutch Disease. Crude and refined oil production expand tremendously, while less tradable subsectors in agriculture, industry, and services also expand production. Within agriculture, export-oriented crops and other agriculture (which includes fisheries, a fairly significant exporter) suffer the greatest declines relative to the base, mainly due to the adverse real exchange rate effects on the trade competitiveness of these subsectors. The same is true for sectors such as fish processing and hotels and catering, both of which are highly export-oriented.

Government spending patterns also determine different sectors' relative performance under *FND00INV*. Increased government expenditure on investment goods leads to a sharp increase in demand for construction services (nontraded) and machinery (mostly imported) in particular. This in turn leads to an indirect increase in demand for intermediate input goods typically supplied by manufacturing and

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[1]Of course, the observed structural shift is also a feature of the *BASELINE* scenario, and is, to a large extent, a natural outcome for any developing country's growth path.

Table 3 Annual growth rate of sectoral production (GDP at factor cost): all scenarios during the oil expansion period, 2007–2017

		Percentage point deviation from BASELINE					
		No productivity spillovers		With productivity spillovers			
	BASELINE (%)	*FND00INV*	*FND50INV*	*FND00I&H*	*FND50NTR*	*FND50AGR*	*FND50NAG*
GDP	4.50	2.41	2.32	2.30	3.17	3.26	2.98
Agriculture	3.88	−0.18	−0.11	0.02	0.93	1.32	0.44
Cereals	3.56	−0.07	−0.02	−0.06	1.02	1.33	0.59
Root crops	4.16	0.11	0.05	0.22	1.03	1.39	0.56
Matooke	3.75	0.10	0.05	0.20	1.05	1.34	0.66
Pulses	4.54	−0.03	−0.01	0.01	0.96	1.45	0.38
Horticulture	4.10	0.16	0.07	0.30	1.05	1.35	0.64
Export agriculture	4.49	−0.49	−0.14	−0.70	0.88	1.60	0.05
Livestock	3.95	−0.07	−0.05	0.00	0.98	1.27	0.57
Other agriculture	3.34	−0.50	−0.38	0.12	0.78	1.12	0.34
Industry	3.72	9.00	8.26	8.33	8.80	8.84	8.68
Mining	2.29	55.60	55.60	55.58	55.61	55.61	55.61
Crude oil	1.04	85.19	85.21	85.18	85.19	85.20	85.19
Manufacturing	3.35	2.58	2.65	2.54	3.61	3.72	3.40
Food processing	4.20	−0.07	−0.05	0.35	1.03	1.25	0.74
Fish processing	0.68	−8.15	−4.56	−7.88	−1.93	−1.14	−2.91
Nonfood manufacturing	2.40	5.13	5.22	4.71	6.10	6.12	5.95
Refined oil	1.04	85.19	85.21	85.18	85.19	85.20	85.19
Other industry	3.89	4.03	2.40	2.62	3.24	3.28	3.05
Construction	3.67	5.06	3.02	3.14	3.80	3.85	3.62
Services	5.17	−1.46	−0.89	−1.08	0.18	0.20	0.05
Hotels and catering	13.37	−16.52	−8.63	−16.36	−6.02	−6.87	−5.45
Public services	3.91	0.16	0.09	0.77	0.66	0.67	0.57

Source: CGE model results

services sectors. Despite increased economic activity in nonagricultural sectors (that is, industry in particular), the knock-on effects for nontradable agricultural subsectors is almost negligible.

The contraction of production under *FND00INV* is most pronounced in cotton; tobacco; flowers; coffee; and tea, cocoa, and vanilla, where most or all of total production is exported. These sectors do not benefit from higher prices as a result of increasing domestic demand but are negatively affected by higher factor costs and higher prices for intermediate inputs. The latter also holds true for import-competing cereals (maize, rice, other cereals), pulses (oilseeds and beans), and livestock. Though these sectors are more oriented toward the domestic market and therefore benefit from generally higher domestic income, demand elasticities are fairly low and the demand effect is not strong enough to compensate for the negative supply effect. Moreover, producers of maize, rice, other cereals, and oilseeds face competition from foreign suppliers. Given the high substitution possibilities for agricultural goods in domestic demand, the expansion of domestic demand is insufficient to counter the substitution effect. The assumption of zero productivity spillover effects in this scenario also explains the weak performance of nontradable agricultural subsectors. As later results show, these adverse effects can be offset by using oil revenues to raise agricultural productivity. The contraction of fisheries results from strong forward linkages to fish processing, a highly export-oriented food-processing sector, which suffers from Dutch Disease effects.

Only a select few agricultural subsectors (root crops, *matooke*, and horticultural crops) and forestry realize an increase in production in *FND00INV* relative to *BASELINE*. These benefit from increasing domestic private demand as a result of higher private income. In the former three sectors, private demand expansion is sufficiently strong to induce price increases, which overcompensate cost increases. Forestry is also a pure nontradable, and though not directly consumed, benefits from its forward linkages to the furniture industry, which is an investment-goods industry and therefore directly affected by increased public investment demand.

We next turn to welfare and household poverty results. The equivalent variation (EV) measures welfare improvements after controlling for price changes (see Table 2: Part C). Under *BASELINE* there is a marked improvement in the EV measure, with all household groups experiencing an increase in EV of between 4.8 and 5% on average per year over the 2007–2046 period (or 520–575% on aggregate). Gains are also fairly equally distributed, with rural farm households gaining slightly more thanks to a relatively rapid agricultural productivity growth rate assumed in *BASELINE*. Sustained GDP growth of just over 5% per year will virtually eliminate poverty by 2046 (Table 4: Part D); the national poverty headcount (P0) drops to about 3.5% from 31.1% in the base.[2]

The introduction of oil (*FND00INV*) sees more rapid improvements in EV for higher income urban and nonfarm households than for rural farming households.

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[2]Similar rates of decline are observed for the depth of poverty measure but are not reported in Table 2.

Table 4 GDP growth, sectoral composition, welfare, and poverty: productivity spillover scenarios during oil expansion and peak production period, 2007–2026

	Initial value 2007	No oil (2007–2026)	No productivity spillover (2007–2026)	With productivity spillover (2007–2026)		
		BASELINE	*FND50INV*	*FND50NTR*	*FND50AGR*	*FND50NAG*
Part A: Annual growth rate of demand[a]						
Absorption	26,584	4.3	4.9	5.4	5.5	5.2
Private consumption	18,743	4.7	5.1	5.6	5.7	5.4
Fixed investment	5014	3.8	5.3	5.9	6.0	5.7
Government consumption	2689	3.0	3.0	3.0	3.0	3.0
Exports	3697	6.9	9.4	9.7	9.7	9.7
Imports	−7260	5.0	5.8	6.1	6.1	6.1
GDP at factor cost	21,318	4.7	5.7	6.2	6.3	6.0
Real exchange rate[b,c]		−0.9 (−12.1)	−0.9 (−15.6)	−0.6 (−11.0)	−0.4 (−7.1)	−0.9 (−15.5)
Consumer price index[c]		0.6 (13.8)	0.8 (18.5)	0.6 (12.4)	0.4 (7.2)	0.9 (18.5)
Part B: Sector share of GDP by 2026						
Agriculture	22.6	19.9	16.6	17.0	18.2	15.9
Industry	27.3	23.8	35.3	35.2	35.0	35.5
Mining (including crude oil)	0.4	0.2	11.2	10.2	10.1	10.6
Oil refining	50.1	56.2	48.1	47.8	46.8	48.6
Services	22.6	19.9	16.6	17.0	18.2	15.9
	100.0	100.0	100.0	100.0	100.0	100.0
Part C: Equivalent variation[d]			Cumulative growth	Percentage point deviation from FND50INV		
Rural farm	342		155.2	26.7	35.2	13.2
Rural nonfarm	135		156.0	22.9	28.6	12.3
Kampala metro	1277		159.9	24.4	29.8	13.8
Urban farm	1100		145.7	21.4	27.2	11.0

(continued)

Table 4 (continued)

	Initial value 2007	No oil (2007–2026)	No productivity spillover (2007–2026)		With productivity spillover (2007–2026)					
		BASELINE	*FND50INV*		*FND50NTR*		*FND50AGR*		*FND50NAG*	
Urban nonfarm	1249		158.6		23.3		28.3		13.0	
Average	820		155.1		23.7		29.8		12.7	
Part D: Headcount poverty (*P0*)			(2017)	(2026)	(2017)	(2026)	(2017)	(2026)	(2017)	(2026)
National	31.1		21.7	12.5	17.3	9.7	16.6	8.9	18.4	11.0
	34.3		23.9	13.8	19.0	10.7	18.2	9.9	20.3	12.1
	13.8		9.4	5.6	7.7	4.1	7.7	3.8	8.0	4.9

Source: CGE model results
Note:
[a]Initial value in US dollars billions
[b]Trade-weighted real exchange rate
[c]Overall growth rate in parentheses
[d]Initial expenditure per capita in US dollars thousands

This relates to oil production, construction, and nonfood manufacturing being more capital and skilled-labor intensive, which means increases in factor returns in these sectors tend to benefit higher income and urban households. Self-employed family labor in the agricultural sector is furthermore assumed to remain in the agricultural sector, which means farm households do not benefit much from increasing labor demand and higher wages in nonagricultural sectors, yet they face the same consumer price increases as all other households in the economy. The uneven distributional outcomes under *FND00INV* are also reflected in poverty outcomes. Although the oil boom leads to a larger overall reduction in poverty relative to *BASELINE*, urban poverty declines faster than rural poverty. For example, by 2017 rural poverty is 22.6% in *FND00INV*, an 8.8% drop from the *BASELINE* rate of 24.8%. In contrast, the urban poverty rate is 16.1% lower by in *FND00INV* relative to *BASELINE* by 2017.

Summing up, channeling windfall oil revenue into the Ugandan economy poses a number of challenges. The first one is the likely appreciation of the real exchange rate—the increase in the price of nontradable goods and services, in particular construction—as demand for them increases with windfall revenue in the face of a limited supply response, and its corollary in terms of lost export competitiveness in agriculture and food processing. The second one is the likely drop in overall productivity, as more factors get concentrated in nontradable sectors where potential productivity gains are much scarcer. The third one is the existence of reallocation (investments, migrations) and transition costs (lost markets and know-how), which can make temporary specialization costly overall if the society has to return to its previous specialization patterns. This risk exists with oil in Uganda, given its exhaustible nature, the shape of the likely extraction path, and the possibility that it conducts to an untenable pattern of specialization if government oil revenues are immediately invested and public investments do not confer any spillovers on private-sector productivity.

4.1.2 Transferring Oil Revenues to a Foreign Oil Fund (*FND50INV*)

In the face of severe Dutch Disease effects, Uganda could consider fixing the share of oil revenue to be transferred to the budget and investing the remainder abroad. The impact of such a sterilization strategy is analyzed in scenario *FND50INV*, which assumes that only half of current oil revenue is used to finance public infrastructure investment while the other half is saved in an oil fund abroad. This fund is assumed to be some variant of a permanent income fund (PIF) from which no withdrawals are made during the simulation period. Since none of the invested oil funds make their way back into the economy over the simulation period, we do not explicitly account for interest earned when calculating the cumulative fund value. However, with the nominal exchange rate as numéraire in the model all deposits into the fund are real values; hence, the fund also does not depreciate in value. As a share of GDP the fund reaches more than 50% of GDP by about 2030. After this the fund as a share of GDP declines as no additional oil revenues are deposited into the fund but GDP continues to grow exponentially.

Sterilizing part of the oil revenue and reducing government investment spending leads to less overall investment, less capital accumulation, and lower private consumption and absorption in the medium term (2007–2017). This causes GDP growth to decline marginally in *FND50INV* compared to *FND00INV*, although growth still exceeds that observed in *BASELINE* (Table 2: Part A). Capital outflows (that is, deposits into the oil fund) cause a much smaller real exchange rate appreciation in *FND50INV*, which means the restructuring of supply from trade-oriented sectors with relatively higher total factor productivity growth (for example, agriculture and certain services sectors) toward domestic-market-oriented industrial sectors with lower total factor productivities is less pronounced. This relative productivity gain coupled with the improved export performance almost entirely makes up for the GDP loss associated with the 50% reduction in oil funds invested and the lower level of capital accumulation, at least in the medium term. In the long run, however, total factor productivity effects in *FND50INV* are insufficient to compensate for the lower levels of capital accumulation, with overall GDP growth now deviating more from that in the previous scenario. At the 3% real government consumption growth rate imposed in all these scenarios the adjustment cost falls on private households, with private consumption growing by only 0.2 and 0.3% points more than in *BASELINE* during 2007–2017 and 2007–2046, respectively, compared to 0.5% points in *FND00INV* (both periods).

Tradable and nontradable agricultural subsectors are affected differently by the sterilization of oil revenues. Relative to *FND00INV*, the lower real appreciation improves the competitiveness of export-oriented and import-competing agricultural subsectors. In both types of subsectors, lower costs for nontradable intermediate inputs improve these sectors' domestic terms of trade. In addition, lower price increases on domestic markets, due to less expansion of private domestic consumption, imply that the spread between domestic prices and import and export prices is less pronounced. Thus, on the supply-side, the extent of export reduction is lower in all export-oriented subsectors, whereas on the demand-side, part of the substitution of domestic supply by imports is avoided. Both types of adjustments—export penetration and import substitution—benefit agricultural producers of export crops and agricultural import substitutes. As a result, the contraction of production in these sectors is less pronounced in *FND50INV* compared to *FND00INV* (see Table 3). In contrast, agricultural nontradable goods, such as root crops, *matooke*, and horticulture, are negatively affected by lower private consumer demand, the latter being the result of lower overall income in the Ugandan economy compared to the full spending scenario.

The welfare (EV) results for *FND50INV* in Table 2 (Part C) indicate that, while all households suffer from welfare losses as a result of sterilization, nonfarm households in Kampala and other urban areas will lose out most from the resultant lower levels of public investment. There are two reasons for this result: First, the positive income effect of a higher capital rental rate (for now scarcer capital) is more than offset by lower capital availability; second, wage increases for skilled labor, which is another primary source of income for urban households, are also lower compared to *FND00INV*. The rate of poverty reduction is also lower in all household groups if part of the oil revenue is sterilized (Table 2: Part D). Thus, while sterilization counters Dutch Disease and possibly allows future generations to benefit from increased spending of oil revenues that are saved now, it also means that fewer benefits are transferred to citizens in the medium term.

4.1.3 Transferring Rents to Citizens (*FND00I&H*)

We next consider a scenario where poverty is targeted directly by redistributing part of oil revenues directly to citizens rather than saving funds in an external oil fund. As a variation of *FND00INV*, FND00I&H evaluates the option of investing half of oil revenue in infrastructure while the other half is distributed to citizens as a direct welfare transfer. Each citizen receives the exact same per capita transfer. Households use this windfall to finance additional consumption spending or to save, depending on the average savings propensities specified for different household groups in the CGE model. The grant being uniformly distributed implies that poorer households receive a larger relative transfer. Figure 1 shows the impact of the welfare grant on average per capita income in 2017 when peak production is reached and the transfer value is at a maximum.

The figure shows that prior to receiving the welfare grant, rural farm households have a per capita income of USh900,000 per year in 2017 (approximately $375, or just more than $1 per person per day). The welfare transfer, modeled as a tax rebate, adds a further USh129,000 to their income ($50–60 per person per year); thus, as a share of income the transfer is worth 14.4% to these households. At the other end of the income spectrum are citizens of Kampala with a per capita income of USh5.4 million. To these people the transfer of USh129,000 is worth only 2.4% of their

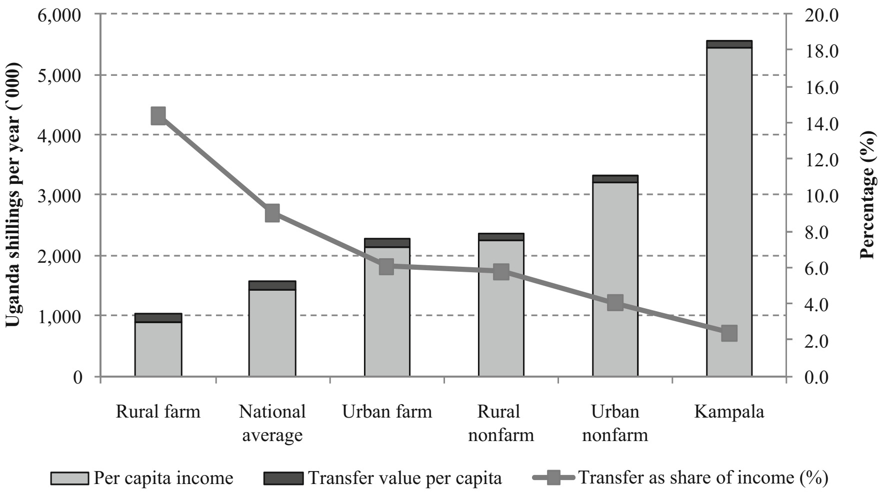

Fig. 1 Average per capita income and per capita transfer values (FND00I&H), 2017. Source: CGE model results

income. About three-quarters of Ugandans live in rural farm households; hence, the national average per capita income is only slightly above that of rural farm households (USh1.4 million), whereas the transfer is worth 9% of income.

Despite price increases, the expansion of private household consumption benefits the agricultural sector as a whole, with overall agricultural GDP growth in *FND00I&H* marginally higher than in *BASELINE* (agricultural growth declined relative to *BASELINE* in both *FND00INV* and *FND50INV*). However, the real exchange rate appreciation accompanying the expansion of private consumption induces structural changes both across and within agricultural subsectors in terms of production for the domestic and world markets. In particular, the expansion of private consumption benefits producers of nontradable agricultural goods such as root crops, *matooke*, horticulture, livestock, and forestry. Export agriculture is now even more negatively affected compared to *FND50INV* due to production cost increases and a stronger real exchange rate. Similarly, import-competing agricultural subsectors, such as cereals and oilseeds, also contract as a result of production cost increases and stronger competition from abroad. In all these subsectors, the demand effect from increased private consumption is not sufficiently strong to compensate for the negative import substitution effect that results from the real exchange rate appreciation. With relatively inelastic demand and strong substitution possibilities between domestic and imported agricultural foodcrops, the substitution effect overcompensates the demand effect.

Compared to the first two experiments, the redistribution of rents creates more employment opportunities in agriculture and leads to significantly higher land rentals and prices for livestock. Thus, a larger share of factor income accrues to rural households, who in turn spend a larger share of their incomes on goods produced domestically and in rural areas. This is corroborated by changes in the EV presented in Table 2 (Part C). These results indicate that welfare improves more rapidly for lower income rural and urban farm households than for higher income nonfarm households. Of course, this result also stems directly from the welfare transfer itself, which in relative terms causes incomes of poorer households to increase more than that of wealthier households (Fig. 1). Moreover, the redistribution of oil rents leads to more consumption by all households, and since production of consumption goods (agricultural and food products in particular) is more land and unskilled-labor intensive, the resulting increases in these factor returns benefit lower income and rural households more.

The uneven distributional impacts are also reflected in poverty outcomes (Table 2: Part D). Between 2007 and 2017 the redistribution of oil rents leads to a significant decline in poverty at the national level, and also relative to *BASELINE* and the first two oil production scenarios. Moreover, rural poverty declines more rapidly than urban poverty. In fact, redistribution is twice as effective at reducing poverty among rural households compared to other rent spending options considered. By 2046, however, poverty outcomes under *FND00INV* are superior to those under *FND00I&H*. This suggests that investments have longer lasting benefits in terms of production capacity and employment in the future. This benefits the poor more in the longer term than welfare handouts in the medium term. Of course, there are several caveats, one of which is the fact that we assume households' expenditure patterns remain unchanged after receiving welfare transfers. In reality, households may choose to invest extra income earned in (say) education, which will raise their productivity and future employability. We also do not consider productivity spillover effects of the investments themselves, which is the focus of the next set of experiments.

4.2 Public Investment Scenarios with Productivity Spillover Effects

In this set of simulations we once again model an increase in public investments, now assuming that these investments have productivity spillover effects in the private sector. All scenarios use *FND50INV* as the basis, with productivity spillover effects determined by both the level of investment spending and its structure. The first simulation, *FND50NTR*, assumes a *neutral* allocation of public investment spending. This assumes increased spending has a uniform productivity-enhancing effect across all sectors of the economy, that is, total factor productivity in all sectors grow by the same margin, in percentage terms, over and above the growth already defined in *BASELINE*. In the second simulation (*FND50AGR*) we model the effect of agricultural-biased public investment spending. This means spending is targeted toward improving agricultural productivity relative to nonagricultural productivity through investing relatively more in (for example) rural and agricultural infrastructure. In this scenario the productivity effects of government infrastructure are restricted to agricultural value-added chains (agricultural sectors and food-processing sectors) and core agricultural inputs, such as communications, banking, and real estate services (this serves to alleviate possible supply constraints in input markets). Finally, *FND50NAG* investigates a restructuring of public investment expenditures toward urban infrastructure at the expense of agriculture-related infrastructure.

In the discussion of results it is important to note that the three scenarios are not necessarily directly comparable as far as overall performance of the economy is concerned. Although a formulaic approach is adopted for determining the productivity shock associated with a certain level and structure of public investment, we do not consider the efficiency of such public spending across different sectors. In reality, cross-sectoral differences in initial productivity rates and productivity growth potential imply that the cost of achieving (say) a 1% increase in productivity may differ from one subsector to the next. What we can (and indeed do) compare are structural differences between the different scenarios. We also compare economic performance in the three productivity spillover scenarios to the no productivity spillover scenario (*FND50INV*).

Table 4 presents the simulation results. Here we only focus on the 2007–2026 period, which includes the run-up to peak oil production as well as the decade during which peak production levels are sustained. All three productivity spillover scenarios assume the same increase in public infrastructural investments as in *FND50INV*. Initially, as public infrastructural investments rise in line with oil revenue increases, the productivity spillover scenarios are exactly the same as *FND50INV*. It is only by 2020 that we assume the productivity spillovers take effect (that is, we allow for a 3-year lag from the time public investments peak in 2017 until a higher level of productivity growth is reached). At this point we observe a fairly substantial additional GDP growth impact in all three scenarios relative to *FND50INV*, such that growth over the 2007–2026 period exceeds growth in *FND50INV* by between 0.3 and 0.6% points across the three productivity spillover scenarios. Even though the same level of oil-funded public investment is assumed in all these scenarios, the increased economic activity means that there is a marked rise in total annual investment as private savings increase.

Real exchange rate and price impacts differ substantially across the three scenarios. Although the real exchange rate appreciates in all these scenarios, it depreciates relative to *BASELINE*, and in *FND50NTR* and *FND50AGR* the real exchange also depreciates relative to *FND50INV*. In contrast, the real exchange rate in *FND50NAG* is virtually unchanged from what was observed in *BASELINE* and *FND50INV*. The combined effect of increased productivity and more favorable terms of trade in at least two of the scenarios mean that export volumes increase in all three productivity spillover scenarios. This is illustrated by the improved performance of sectors such as export-oriented agriculture, livestock, other agriculture, and food processing, all of which grow relative to the decline in GDP observed in *FND50INV* (see Table 3). Other major exporters such as fish processing and hotels and catering show a relative improvement compared to *FND50INV*.

We have previously established that public investment spending in an oil production context and the assumption of no productivity spillovers tends to benefit urban nonfarm households more than rural farm households, since the latter group is largely bypassed as a result of missing backward linkages from rapidly growing industrial and services sectors. The productivity spillover scenarios now suggest a rapid improvement in the outcomes for rural farm households. All households still enjoy increases in welfare (EV) over time if public investment spending does not discriminate between sectors (*FND50NTR*), but, interestingly, the absolute and proportionate gains are now highest for rural farm households (Table 4: Part C). These altered distributional impacts are also reflected in the poverty results (Table 4: Part D), which show that rural poverty declines slightly faster than urban poverty. This relates to the Ugandan economy's ability to produce more tradable and nontradable goods as a result of productivity increases, whereas the reversal of the real exchange rate appreciation shifts the domestic terms of trade in favor of export-oriented and import-competing producers of tradable goods and against producers of nontradable goods. All agricultural sectors now expand their production, whereas export-oriented agricultural sectors increase their export supply. Thus, although many agricultural sectors shrank when public investments were unproductive (for example, in *FND50INV*), the sector is able to expand as a result of productivity spillovers, even when not targeted directly as is the case in *FND50NTR*.

In the case where nonagricultural sectors are targeted (*FND50NAG*), additional public investment spending on urban road infrastructure increases total factor productivity growth in the tradable nonfood-manufacturing sectors (that is, textiles, wood and paper, other manufacturing, machinery, and furniture) and in the trade, hotel and catering, and transport services sectors. At the same time we assume lower levels of spending on rural infrastructure, which reduces total factor productivity growth in all agricultural and food-processing sectors as well as in the less-tradable communications, banking, real estate, and community services sectors. As expected, when productivity growth is lower in sectors that predominantly supply goods for the domestic market (these are also goods that cannot easily be substituted by imports), the spending of oil revenues causes a larger (relative) appreciation of the real exchange rate than in the case of neutral productivity spillovers. Hence, although the manufacturing export performance is slightly stronger in machinery and equipment, hotels and catering, and transport, the agricultural sector is hit relatively hard when productivity gains are biased against it. At 4.1% per year, average agricultural growth in *FND50NAG* is half a percentage point lower than in *FND50NTR*, and the agricultural sector's share in GDP declines by more than a percentage point by 2026 vis-à-vis a neutral allocation of investment spending.

When public investment spending is biased in favor of agriculture and food processing (*FND50AGR*), outcomes are markedly different. Increased supply of agricultural goods and food items is sufficiently strong to more than offset the demand effects of the oil boom, such that the initial real exchange rate appreciation observed in *FND50INV* is reversed within a relatively short time. The effects on exports are a mirror image of those in *FND50NAG*; agriculture exports recover more strongly than in the former experiment, but lower productivity growth in nonfood manufacturing results in a more sluggish recovery in manufacturing exports.

The most striking difference between the two public investment options, though, is the effect on real household disposable incomes, welfare and poverty (Table 4: Parts C and D). Compared to *FND50NTR*, a manufacturing bias (*FND50NAG*) sharply moderates real income and welfare growth in the economy. The total rise in EV relative to *FND50INV* is only 12.7% points in *FND50NAG* compared to 23.7% points in *FND50NTR*. Moreover, the income gain is spread somewhat unevenly across household groups, with rural farm households now faring worse than Kampala households. This contrasts sharply with the outcome under *FND50AGR*, which generates markedly higher aggregate real income gains in the medium term (29.8% points), and one that benefits poorer rural households more. Poverty outcomes for rural and urban households improve in the agricultural-biased scenario relative to the neutral scenario, whereas in the manufacturing-biased scenario poverty rates are higher compared to the neutral growth scenario. In all productivity scenarios, however, poverty rates decline more rapidly than in *FND50INV*.

Given the significant impact on agricultural growth and on the welfare of rural households of the agricultural productivity spillovers from the increased public investments arising from Uganda's oil revenue, it is critical that the Government of

Uganda put in place mechanisms by which these productivity spillovers can be maximized. What is needed, in particular, is a well-coordinated set of interventions aimed at improving competitiveness in the agricultural sector, which would serve as a platform sustainable growth in the economy. However, at 3.8% of the budget, current spending on agriculture in Uganda is well below the 10% target committed to under the Comprehensive African Agricultural Development Program (CAADP). Research by Fan et al. (2009) suggests that agricultural research and development, infrastructure (such as rural roads), and investments in education and skills have the highest payoffs in terms of agricultural productivity gains and increased competitiveness of the sector.

5 Conclusion

Even at conservative prices of $70–80 per barrel, future oil revenue in Uganda will be considerable, potentially doubling government revenue within 6–10 years and constituting an estimated 10–15% of GDP at peak production. The economic impact of oil production on the country's agricultural performance and the livelihood of rural households could be profound, particularly during the first phase of the projected extraction when massive additional inflows of foreign exchange need to be managed by the Ugandan government. The so-called Dutch Disease effects may affect the international competitiveness of export sectors, such as agriculture in particular, and it is likely to make the country's growth strategy—with its emphasis on value-added, export diversification, and manufacturing—harder to achieve. This would threaten to increase, rather than decrease, the urban–rural income gap.

Agriculture and related processing currently contribute about 27% to GDP. Food and agriculture-related processing make up about 50% of household consumption expenditure. Poverty is higher in rural than in urban households and within rural households it is highest among nonfarm households. Even with no oil revenue, agriculture's share of GDP is projected to decrease by 6.8% points from 22.6% in 2007 to 15.8% over the next 40 years, as increasing factor productivities in tradable sectors and increasing per capita income and consumption will be leading toward a restructuring of production in favor of services.

It is important to differentiate between medium- and long-term impacts of oil revenue spending, since structural impacts differ and asymmetric adjustment flexibilities (ratchet effects) in factor markets (investments, migrations) and foreign trade (lost markets and know-how) can make temporary specialization costly if the Ugandan society has to return to its previous specialization patterns because of the exhaustible nature of oil reserves.

The impacts of oil extraction will be felt by Uganda mostly indirectly through higher government expenditures on consumption (largely administration) and investment; direct effects through higher domestic factor income in oil extraction and refining and through backward linkages will be minimal given production technologies and the economic enclave character of the oil industry. Results of this chapter suggest that the extraction and refining of oil will increase overall GDP growth, increase national and rural real household incomes, and benefit the poor in Uganda. In the medium term, that is, from the starting of oil extraction (2011 in this analysis) until reaching peak production (2017), overall average annual GDP growth will be between 2.3 and 3.3% points higher than in a comparable baseline projection without oil. In the long term over the total extraction path of 40 years, the average growth rate will be between 0.2 and 0.5% points higher. The differences depend on how oil revenues are spent, on whether public infrastructure confers any spillovers on private-sector productivity, and in which sectors these spillovers occur.

Several conclusions emerge from the simulations presented in this paper. First, with the projected oil extraction path and recently high oil prices, a real appreciation of the Uganda shilling is almost inevitable. Although policies designed to limit absorption through tight fiscal and monetary policies would reduce the pressure on the exchange rate over the short to medium term, they are unlikely to be sufficient to eliminate it. A rapid buildup of foreign exchange reserves and the accumulation of government oil revenue in some kind of external resource fund could mitigate the pressure but at the expense of domestic investment, the fiscal position, and private household welfare and consumption, as well as poverty reduction. In any case, agriculture and the rural population will be discriminated against by the expected oil boom. As net producers of tradable goods and net consumers of nontradable goods they suffer twice, from increased production costs and higher prices for consumer goods. Only a few select agricultural subsectors that produce exclusively for the domestic market, such as root crops, *matooke*, and horticulture, realize income gains as a result of generally higher income and consumption. Transferring part of the oil rent to citizens—rather than to a foreign oil fund—would directly increase household welfare and accelerate poverty reduction efforts. Moreover, agriculture as a whole would regain growth momentum. However, the real appreciation accompanying the oil-rent-financed expansion of private consumption would induce strong structural changes both across and within agricultural subsectors, which might be difficult to reverse once oil revenues dry out. Thus, there is the real danger of losing long-run competitiveness vis-à-vis foreign suppliers both on world markets for agricultural export commodities as well as on domestic markets for food products.

Second, Uganda's oil discovery comes at an opportune moment as the country battles with the challenges of marked infrastructural backlogs. In this situation of initial scarcity of public infrastructure, oil-funded increases in public infrastructure may lead to potentially large medium-term welfare gains, despite the presence of Dutch Disease effects. This is particularly true when public infrastructure augments the productivity of private factors. Yet, the sectoral and distributional consequences of these investments are highly sensitive to the structure and quality of public investment spending, which has an influence on the location of productivity effects, as well as the characteristics of demand.

Third, a neutral allocation of investment spending, which leads to a balanced sectoral supply response, is broadly beneficial to the Ugandan economy in terms of boosting aggregate growth and investment, welfare, and exports while moderating appreciation of the real exchange rate and reducing poverty on a significant scale, with rural poverty declining even faster than urban poverty. This relates to the Ugandan economy's ability to produce more goods—both tradable and nontradable—as a result of productivity increases, whereas a reversal of the real exchange rate appreciation shifts the domestic terms of trade in favor of export-oriented and import-competing agriculture. Thus, even though many agricultural subsectors would be indirectly discriminated against if there were no productivity-enhancing public infrastructure, these sectors are able to expand as a result of productive public investment, even when not targeted directly. In contrast, agriculture is hit relatively hard when a reallocation of public investment spending leads to a nonagricultural bias in the supply response.

Fourth, outcomes are markedly different when public investment spending is biased in favor of agriculture and food processing. In this case results suggest that (1) the supply response of agriculture would be sufficiently strong to more than offset the demand effects of the oil boom; (2) agriculture exports would recover more strongly than with a neutral or a nonagricultural, industry-biased allocation of investment spending; (3) the supply response would generate higher aggregate real income gains; and (4) poorer rural households will benefit the most, but without sacrificing urban poverty reduction. With respect to the latter, a highly significant outcome is that poverty falls for both rural and urban households under an agriculture-biased public investment spending scenario (relative to a neutral spending strategy), whereas industry-biased spending would lead to comparably higher poverty in both regions.

Although direct comparisons of scenario results should be done with great caution, a simple ranking of public spending options according to growth, real income, and poverty reduction effects suggests an agriculture-biased investment strategy is the preferred option. Such a strategy would not only increase agricultural growth and rural incomes most, but would also have significant and positive spillover effects into the rest of the economy, thereby benefiting all segments of society. The recommendation is less clear in the zero-spillover scenarios. In this case, there is a trade-off between increasing investment (and therefore relatively higher overall growth) and increasing consumption (and therefore relatively higher agricultural growth). The latter (increased consumption), which is achieved by redistributing oil revenues to Uganda's citizens via a welfare transfer scheme, is associated with larger reductions in poverty, at the national level and particularly in poorer rural areas.

These conclusions must, of course, be qualified by a number of caveats. Among these is that absorption capacity and, consequently, the quality and efficiency of public investments for economic growth are critically important. Having oil revenues but then having to incur high economic and social costs in attempting to spend these revenues will lower the net benefits of oil. For balanced growth and poverty reduction to materialize a well-coordinated set of interventions aimed at improving competitiveness in the agricultural sector is needed. These may include investments in agricultural research and development, infrastructure (such as rural roads), and education and skills, with priority afforded to those investment areas that have the highest payoffs in terms of agricultural productivity gains and increased competitiveness of the sector. Any further analysis of the impact of oil in Uganda must pay closer attention to issues of spending efficiency and spending priorities.

References

Acemoglu, D., S. Johnson, and J. Robinson. 2003. Botswana – An African success story. In *In search of prosperity: Analytical narratives on economic growth*, ed. D. Rodrik. Princeton, NJ: Princeton University Press.

Adato, M., and J. Hoddinott. 2010. *Conditional cash transfers in Latin America*. Baltimore: Johns Hopkins University Press.

Ahmed, R., and M. Hossain. 1990. *Developmental impact of rural infrastructure in Bangladesh*. IFPRI Research Report 83. Washington, DC: International Food Policy Research Institute.

Antle, J. 1984. Human capital, infrastructure, and the productivity of Indian rice farmers. *Journal of Development Economics* 14: 163–181.

Benin, S., J. Thurlow, X. Diao, A. Kebba, and N. Ofwono. 2008. *Agricultural growth and investment options for poverty reduction in Uganda*. IFPRI Discussion Paper 790. Washington, DC: International Food Policy Research Institute.

Bevan, D., P. Collier, and J. Gunning. 1999. *The political economy of poverty, equity, and growth: Nigeria and Indonesia, a World Bank comparative study*. New York: Oxford University Press.

Binswanger, H.P., S.R. Khandker, and M.R. Rosenzweig. 1993. How infrastructure and financial institutions affect agricultural output and investment in India. *Journal of Development Economics* 41: 337–366.

Breisinger, C., X. Diao, R. Schweickert, and M. Wiebelt. 2009. *Managing future oil revenues in Ghana. An assessment of alternative allocation options*. IFPRI Discussion Paper 893. Washington, DC: International Food Policy Research Institute.

Calderón, C., and L. Servén. 2005. *The effects of infrastructure development on growth and income distribution*. World Bank Policy Research Working Paper 3643. Washington, DC: World Bank.

———. 2008. *Infrastructure and economic development in sub-Saharan Africa*. World Bank Policy Research Working Paper W4712. Washington, DC: World Bank.

Canning, D., and E. Bennathan. 1999. *The social rate of return on infrastructure investments*. World Bank Policy Research Working Paper W2390. Washington, DC: World Bank.

Dervis, K., J. de Melo, and S. Robinson. 1982. *General equilibrium models for development policy*. Cambridge: Cambridge University Press.

Diao, X., P. Hazell, and J. Thurlow. 2010. The role of agriculture in African development. *World Development* 38 (10): 1375–1383.

Dorosh, P., and J. Thurlow. 2009. *Agglomeration, migration, and regional growth. A CGE analysis for Uganda*. IFPRI Discussion Paper 848. Washington, DC: International Food Policy Research Institute.

Duflo, E., and R. Pande. 2007. Dams. *Quarterly Journal of Economics* 122 (2): 601–646.

Easterly, W. 2001. *The elusive quest for growth. economists' adventures and misadventures in the tropics*. Cambridge, MA: MIT Press.

Esfahani, H., and M.T. Ramirez. 2002. Institutions, infrastructure and economic growth. *Journal of Development Economics* 70: 443–477.
Fan, S., P. Hazell, and S. Thorat. 2000. Government spending, growth, and poverty in rural India. *American Journal of Agricultural Economics* 82 (4): 1038–1051.
Fan, S., T. Mogues, and S. Benin. 2009. *Setting priorities for public spending for agricultural and rural development in Africa*. IFPRI Policy Brief 12. Washington, DC: International Food Policy Research Institute.
Fan, S., and X. Zhang. 2008. Public expenditure, growth, and poverty reduction in rural Uganda. *African Development Review* 20 (3): 466–496.
Fan, S., L. Zhang, and X. Zhang. 2003. *Growth, inequality, and poverty in rural China: The role of public investments*. Research Report No. 125. Washington, DC: International Food Policy Research Institute.
Gelb, A. 1988. *Oil windfalls: Blessing or curse?* New York: Oxford University Press for the World Bank.
Gelb, A., and S. Grasmann. 2010. *How should oil exporters spend their rents?* Working Paper 221. Washington, DC: Center for Global Development.
Gelb, A., and S. Majerowicz. 2011. *Oil for Uganda – Or Ugandans? Can cash transfers prevent the resource curse?* Working Paper 261. Washington, DC: Center for Global Development.
Gibson, J., and S. Rozelle. 2003. Poverty and access to roads in Papua New Guinea. *Economic Development and Cultural Change* 52 (1): 159–185.
Hausmann, R., and R. Rigobon. 2002. *An alternative interpretation of the "resource curse": Theory and policy implications.* NBER Working Paper 9424. Cambridge, MA: National Bureau of Economic Research.
Hulten, C. 1996. *Infrastructure capital and economic growth: How well you use it may be more important than how much you have*. NBER Working Paper 5847. Cambridge, MA: National Bureau of Economic Research.
IMF (International Monetary Fund). 2003, September. *World economic outlook.* Washington, DC: International Monetary Fund.
Leite, C., and J. Weidmann. 1999. *Does mother nature corrupt?* IMF Working Paper 99/85. Washington, DC: International Monetary Fund.
Pauw, K., and L. Mncube. 2007. *Expanding the social security net in South Africa: Opportunities, challenges and constraints.* DPRU Working Paper No. 07/128. Cape Town: University of Cape Town, Development Policy Research Unit.
Ram, R. 1996. Productivity of public and private investment in developing countries: A broad international perspective. *World Development* 24: 1373–1378.
Reinikka, E., and J. Svensson. 2002. Coping with poor public capital. *Journal of Development Economics* 69 (1): 51–69.
Renkow, M., D.G. Hallstroma, and D. Karanjab. 2004. Rural infrastructure, transactions costs and market participation in Kenya. *Journal of Development Economics* 73 (1): 349–367.
Rodrik, D. 2003. What do we learn from country narratives? In *In search of prosperity: Analytical narratives on economic growth*, ed. D. Rodrik. Princeton, NJ: Princeton University Press.
Ross, M.L. 2001. Does oil hinder democracy? *World Politics* 53: 325–361.
Sachs, J. D., and A. M. Warner. 1995. *Natural resource abundance and economic growth.* NBER Working Paper 5398. Cambridge, MA: National Bureau of Economic Research.
Sachs, J.D., and A.M. Warner. 2001. The curse of natural resources. *European Economic Review* 45 (4-6): 827–838.
Sala-i-Martin, X., and A. Subramanian. 2003. A*ddressing the natural resource curse: An illustration from Nigeria*. IMF Working Paper 03/139. Washington, DC: International Monetary Fund.
Sennoga, E. B., and J. M. Matovu. 2010. *Public spending composition and public sector efficiency: Implications for growth and poverty reduction in Uganda*. Research Series No. 66. Kampala: Economic Policy Research Centre.

Stevens, P. 2003. Resource impact—Curse or blessing? A literature survey. *Journal of Energy Literature* 9 (1): 1–42.

Thurlow, J. 2004. *A dynamic computable general equilibrium (CGE) model for South Africa: Extending the static IFPRI model*. TIPS Working Paper 1–2004. Pretoria: Trade and Industrial Policy Strategies.

Thurlow, J., S. Morley, and A. N. Pratt. 2008. *Lagging regions and development strategies*. IFPRI Discussion Paper 898. Washington, DC: International Food Policy Research Institute.

Twimukye, E., J. M. Matovu, S. Levine, and P. Birungi. 2010. *Sectoral and welfare effects of the global economic crisis on Uganda: A recursive dynamic CGE analysis*. Research Series No. 73. Kampala: Economic Policy Research Centre.

Uganda, Ministry of Energy and Mineral Development. 2008. *National oil and gas policy for Uganda*. Kampala: Ministry of Energy and Mineral Development.

Valdés, A., and W. Foster. 2010. Reflections on the role of agriculture in pro-poor growth. *World Development* 38 (10): 1362–1374.

Wiebelt, M., K. Pauw, J. M. Matovu, E. Twimukye, and T. Benson. 2011. *Managing future oil revenue for agricultural development and poverty reduction: A CGE analysis of challenges and options*. IFPRI Discussion Paper 1122. Washington, DC: International Food Policy Research Institute.

World Bank. 2010. *Country assistance strategy for the Republic of Uganda for the period FY 2011–2015*. Washington, DC: World Bank.

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4

National Agricultural Advisory Services (NAADS) Program: Levels of Contamination and Treatment

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An important problem in causal inference and estimation of treatment effects is identifying a reliable comparison group (control observations) against which to compare those that have been exposed to the treatment (treated observations). It is common knowledge that the estimate obtained by the difference in the values of the indicator of interest associated with the two groups could be biased due to lack of overlap in the covariate distributions or common support between the treated and control observations (Dehejia and Wahba 2002; Imbens and Wooldridge 2009). This is especially problematic with non-experimental control observations (Dehejia and Wahba 2002) in which case combining propensity score matching and regression methods has been suggested to yield more consistent estimates of the treatment effect than using either method alone (Imbens and Wooldridge 2009). Matching removes self-selection bias due to any correlation between the observable (pre-treatment) covariates and the dependent variable, while regression isolates the effect of change

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in the covariates on change in the dependent variable over the period of the treatment. Using the combined approach, this paper discusses the effect of using different sets of control groups on estimates of treatment effects of the agricultural extension system in Uganda, the National Agricultural Advisory Services (NAADS) program.

The goal of the NAADS program, which was initiated in 2001, is to increase incomes through increased adoption of profitable agricultural enterprises and improved technologies and practices, agricultural productivity, and marketed output. The program aims at targeting the economically-active poor—those with limited physical and financial assets, skills and knowledge—through farmer groups based on specific enterprises identified by farmers (NAADS 2007). Although the program is a public intervention, farmers have to decide whether to participate in the program or not. When a farmer decides to participate, he or she has to do so through membership of a NAADS-participating farmer group. Then, together with the members of the group, and with members of other NAADS-participating groups, they request for specific technologies and advisory services associated with their preferred enterprises and obtain grants to procure those technologies and related advisory services. The grant is initially used to finance the establishment of a technology development site (TDS) for demonstrations and training, and proceeds (outputs or sale of outputs) from the TDS become a revolving fund for members of the group. The main channel of impact of the program is thus via farmers' access to this grant. Knowledge and skills gained from the activities surrounding the TDS, as well as from select farmers trained to provide follow-up advisory services [community-based facilitators (CBFs)], are also very important.

The program is expected to generate indirect or spillover effects to the extent that the TDSs, NAADS service providers and CBFs are accessible as sources of knowledge and skills to other farmers in the community where the program is implemented. Estimating these indirect effects involves identifying farmers that have benefited from the program in such a manner, which is potentially challenging due to possible misclassification of service providers. For example, the government's regular extension service and NGOs operated in the same areas as the NAADS program. Since some ex-government extension workers and NGOs are occasionally contracted to provide NAADS services, it is possible for them to be wrongly associated with the NAADS program even when they are operating outside the NAADS framework. Spillovers across program boundaries or communities through information flow among farmers and from non-NAADS service providers using the NAADS framework are also possible. We discuss the implications of these from using different controls groups. Next, we present the data and evaluation method, followed by the results, conclusions, and implications.

1 Data and Methods

1.1 Data

The data are from two rounds of household surveys conducted in 2004 and 2007. The 2004 survey served as the baseline on which a stratified sample was based according to the year when the NAADS program was first implemented in the community (sub-county) where the program: began in 2001/02; began in 2002/03; began between 2005 and 2007; or had never been implemented at the time of the 2007 survey. This was done to account for the effect of the rollout of the program that may result in a modified treatment among later entrants to the program due to learning from previous treatments among earlier entrants of the program (supply-side effects of the program), as well as from nonrandom preparedness of later entrants prior to receiving the treatment (demand-side effects). About 400, 300, 100, and 100 households were surveyed from each of the four strata (see Benin et al. 2011 for details). This paper is based on the panel of 719 household observations. The indicator of interest for estimating the treatment effect is agricultural income (INC)—details of this and other variables used are presented later.

1.2 Estimation Approach

What we are interested in is the average treatment effect of the treated (ATT_j):

$$ATT_j = E\left[INC_{1j}|NAADS_j = 1\right] - E\left[INC_{0j}|NAADS_j = 1\right] \quad (1)$$

where INC_{1j} is agricultural income of farm household j due to participation in the program and INC_{0j} is agricultural income of the same farm household j if it did not participate in it. Although, we cannot observe the counterfactual, the underlying estimation problem can be represented as a treatment-effects model of the form:

$$INC_{jt} = \alpha_j + \tau_t + \delta NAADS_j + \boldsymbol{\beta}'\boldsymbol{x}_{jt} + \epsilon_{jt} \quad (2)$$

$$NAADS_j^* = \boldsymbol{\gamma}' w_j + u_j \quad (3)$$

$$NAADS_j = \begin{cases} 1, & \text{if } NAADS_j^* > 0 \\ 0, & \text{otherwise} \end{cases} \quad (4)$$

where: $NAADS_j^*$ is a latent unobserved variable whose counterpart, $NAADS_j$, is observed in dichotomous form; $\boldsymbol{x}_j$ and $\boldsymbol{w}_j$ are vectors of variables determining agricultural income and the decision to participate in the program, respectively; $NAADS_j = 1$ and $NAADS_j = 0$ represent participation (or treatment) and non-participation (or control), respectively; α and τ capture the individual and time specific effect, respectively; β and γ are the vectors of parameters measuring the relationships between the dependent and independent variables; ϵ and u are the random components of the equations with joint normal distribution of means $(\mu, 0)$ and covariance matrix $\begin{bmatrix} \sigma_\varepsilon^2 & \sigma_{\epsilon u} \\ \sigma_{\epsilon u} & 1 \end{bmatrix}$.

We apply a two-stage weighted regression (2SWR) method (e.g. Robins and Rotnitzky 1995). In the first stage, we estimate Eq. (3) by probit to obtain propensity scores, which are used in selecting a matched sub-sample of treatment and control observations. In the second stage, the propensity scores are used as weights in a weighted least squares regression of Eq. (2) on the matched sub-sample according to:

$$\Delta INC_j = \hat{\alpha} + \hat{\delta}_B NAADS_j + INC_{jt0} + e_j \tag{5}$$

$$\Delta INC_j = \hat{\alpha} + \hat{\delta}_F NAADS_j + INC_{jt0} + \hat{\boldsymbol{\beta}}'_{2SWRT} \Delta \boldsymbol{x}_j + e_j \tag{6}$$

where: $\Delta INC = INC_{t1} - INC_{t0}$, and INC_{t0} and INC_{t1} are the incomes in the initial (2004) and later (2007) periods, respectively; $\Delta x = x_{t1} - x_{t0}$, and x_{t0} and x_{t1} are the initial and later period values of the covariates, respectively. Equations (5) and (6) represent specifications without and with the covariates, and the impact of the program is measured by $\hat{\delta}_B$ and $\hat{\delta}_F$ for the two model specifications, respectively. In any two-stage estimation procedure, it is important to address the identification of the second-stage regression or endogeneity of the first-stage regression. A common procedure used is excluding some of the explanatory variables used in estimating the first-stage probit from the second-stage regression (i.e. having $\boldsymbol{x} \subset \boldsymbol{w}$ or $\boldsymbol{x} \neq \boldsymbol{w}$ and corr $(w, \varepsilon/x) = 0$). In general, nonlinearity of the first-stage probit model renders exclusion restrictions unnecessary (Wilde 2000). Further, since we apply a fixed-effect or difference estimator in the second-stage regression, the condition is satisfied in the sense that $\Delta \boldsymbol{x} \neq \boldsymbol{w}$.

Participation is measured using the status observed in 2007 to avoid crossover in different years so that a treatment household is always a treatment household and cannot switch status; the same for a control household. Of the 719 observations, 66 are treated and 653 are controls, which we split into three. The first control sub-group is made up of those in the same area where the program is implemented and claimed to have benefited indirectly from the program, labeled $\text{NAADS}_{\text{NON-1}}$. The second sub-group also is made up those in the area where the program is implemented but did not claim any benefits (labeled $\text{NAADS}_{\text{NON-2}}$), while the third sub-group is made up those in areas where the program was never implemented (labeled $\text{NAADS}_{\text{NON-3}}$). These three sub-groups make up 256, 284, and 113 observations, respectively. Because matching with the nearest neighbor only can limit any potential gain from matching participants with more than one non-participant with similar attributes, we consider and report estimated treatment effects based on matching with one, three, and five nearest neighbors.

1.2.1 Variables

Agricultural income (INC) is agricultural income per adult equivalent and measured as the total gross value of households' crop, livestock, beekeeping and aquaculture output (or agricultural gross revenue) divided by the total number of adult equivalents in the household. The choice of covariates was guided by the principles and design of the NAADS program as well as the literature on agricultural household models (e.g. Singh et al. 1986) and adoption of agricultural technologies (e.g. Feder et al. 1985). The variables used include: human capital (gender, age, education and size structure of household); financial capital (livelihood and income strategies); physical capital [land owned and value of agricultural productive assets (e.g. equipment, livestock, etc.)]; social capital (membership in other organizations); access to infrastructure and services (distance to nearest financial services, road, market); location in the four administrative regions of Uganda (Central, Eastern, Northern and Western); and dummy variables representing the year when the NAADS program was introduced in the sub-county. Physical capital may be potentially endogenous and so we estimate the second-stage regression with and without them to analyze the effect of this problem. All monetary values were converted into year 2000 constant prices to help exclude the influence of inflation and other temporal monetary and fiscal trends.

To improve matching, it is common practice to try different variables and transformations of the variables such as logarithms and higher order and interaction terms, because matching is a nonparametric method of preprocessing data to reduce imbalance between treated and control groups (Imbens and Wooldridge 2009). We follow this practice and use: histograms of the propensity scores between the two groups to select the sub-sample with adequate common support; and balancing tests to check the extent to which any differences that existed between the two groups prior to matching have been reduced in the matched sample.

2 Results

2.1 Determinants of Participation in the Program: Overlap in Covariate Distributions

Selected results on common support and balancing tests for different combinations and transformations (squared and interaction terms) of the covariates using matching with three nearest neighbors are shown in Fig. 1 and Table 1, respectively. We find that different covariates and transformations yield different outcomes of common support and balance between the two groups after matching. The general pattern is a skewness of the propensity scores toward one for participants and zero for non-participants. The situation is most perverse when no transformations of the variables are included or when the covariates on the length of program presence are included (Fig. 1a–c). Regarding the latter, different propensity scores are generated for different controls who are identical in all aspects except location in a NAADS sub-county and several treated observations have to be dropped to improve common support. The models associated with the probits when we include transformations of the covariates and exclude the covariates on the length of program presence are preferred because their results show that there is greater common

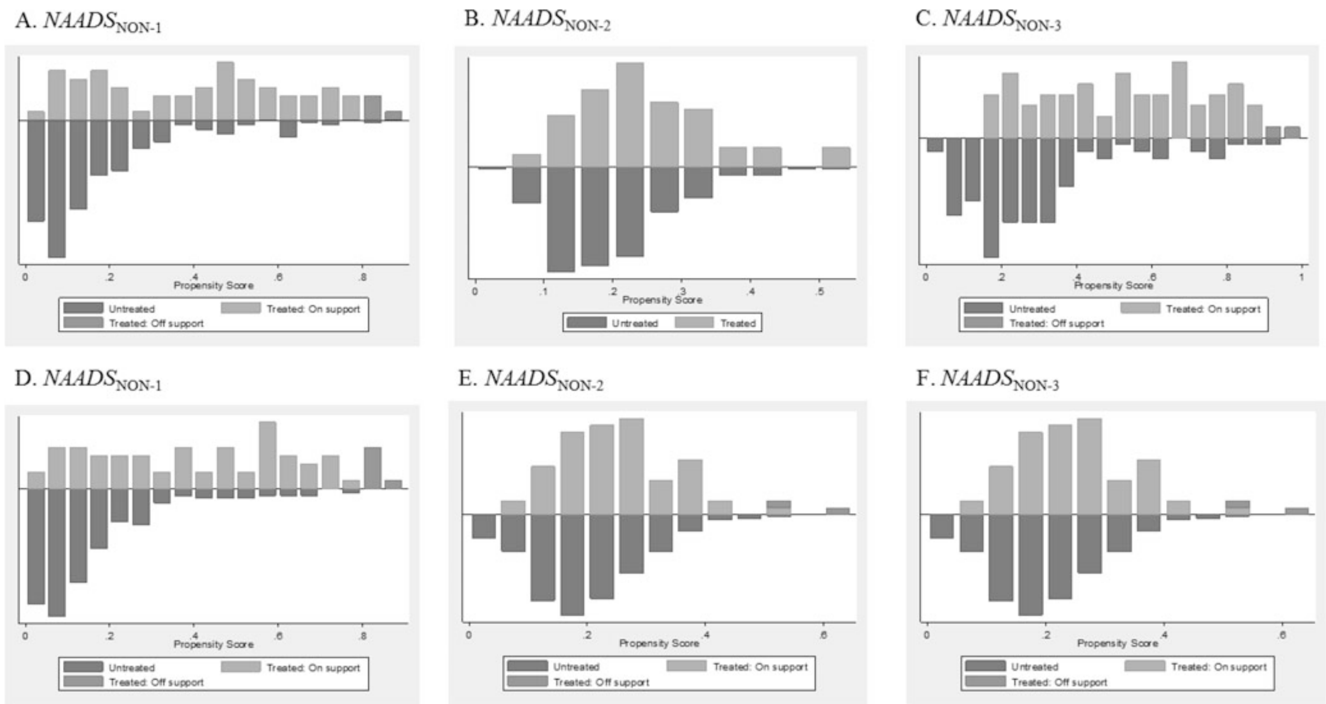

Fig. 1 Histogram of estimated propensity scores between participants and non-participants. Source: Authors' illustration based on probit results. (**a**) to (**c**) excludes squared or interaction terms of the variables in the probits; (**d**) to (**f**) includes them

Table 1 Sample characteristics between NAADS participants (treated observations) and non-participants (control observations)

Variable	Unmatched (mean values)				Matched (% difference in mean values between treated[a] and controls)		
	Treated	$NAADS_{NON-1}$	$NAADS_{NON-2}$	$NAADS_{NON-3}$	$NAADS_{NON-1}$	$NAADS_{NON-2}$	$NAADS_{NON-3}$
Gender of head	0.20	0.13**	0.16	0.24	−3.0	2.7	2.5
Age of head	42.83	45.36**	43.22	42.79	2.3	4.9	−22.8
Primary education	0.64	0.55**	0.66	0.61	−25.0	4.4	5.5
Post-primary education	0.20	0.35***	0.17	0.22	21.3	−10.6	6.4
Household size	4.57	5.41***	4.92*	5.20**	0.7	−0.3	5.5
Membership	0.38	0.83***	0.44	0.44	6.4	3.2	6.4
Income strategy							
Livestock	0.06	0.03*	0.06	0.04	5.2	−4.4	9.3
Other agriculture	0.10	0.17*	0.14	0.16	−6.5	−3.2	4.7
Nonfarm	0.08	0.02***	0.05	0.04*	10.6	−6.4	18.4
Land owned	1.24	3.31	2.61*	1.82	−0.5	−1.5	−4.0
Productive assets	150.00	240.00	290.00	120.00	4.0	2.3	−3.3
Ag revenue per AE	193.14	320.37***	222.86	203.38	11.5	−0.6	8.1
Distance to credit	18.73	19.88	16.78	28.34***	9.6	27.9	7.3
Distance to road	2.61	2.38	2.55	2.75	17.3	9.3	29.2*
Distance to market	6.92	9.35***	7.67	9.24**	−0.3	−3.4	7.8
Eastern region	0.24	0.12***	0.28	0.64***	−8.7	−5.9	−46.4**
Northern region	0.20	0.28*	0.13**	n.a.	−9.1	7.0	n.a.
Western region	0.42	0.42	0.40	0.09***	3.4	4.2	20.8
Number of observations	66.00	256.00	284.00	113.00	93.00	125.00	55.00

Source: Based on probit results including squared and interaction terms of the variables and matching with nearest three neighbors
[a]The numbers of treated observations are 60, 64 and 63 for the sub-samples with $NAADS_{NON-1}$, $NAADS_{NON-2}$ and $NAADS_{NON-3}$, respectively. N.a. means not applicable. *, ** and *** means statistical significance at the 10%, 5% and 1% level, respectively, of the difference in the mean values between treated and control observations

support and only up to six treated observations have to be dropped in any sub-sample (Fig. 1d–f). The sample characteristics in Table 1 also show that any statistically significant differences that existed between the treated and control groups prior to the matching were eliminated or reduced. Together, the results suggest that pooling observations for the different unique control groups as done in Benin et al. (2011) could lead to different policy implications and, as we shall see next, limit any potential gain in knowledge from matching each participant with multiple non-participants that are similar in several attributes but different in others.

2.1.1 Estimated Treatment Effects of the Program on Agricultural Income (INC)

Estimates of the treatment effect are summarized in Table 2 (detailed selected second stage regression results are shown in the annex Table 3). The results show that the NAADS program has had positive impact on agricultural revenue per AE, particularly when participants are compared with those who did not claim any benefits ($NAADS_{NON\text{-}2}$) or with those located where the program was never implemented ($NAADS_{NON\text{-}3}$). The estimated impacts are statistically weak for the former and insignificant for the latter, however. The positive effect on agricultural revenue per AE is consistent with the estimated effects on other outcomes such as adoption of crop and livestock improved varieties, crop and livestock productivity,

Table 2 Estimated treatment effects (% difference between participants and non-participants in 2004–2007 change in agricultural revenue per adult equivalent)

	Sub-sample of control observations		
	$NAADS_{NON\text{-}1}$	$NAADS_{NON\text{-}2}$	$NAADS_{NON\text{-}3}$
2SWR (without covariates)			
1 nearest neighbor	9.3	59.9*	90.3*
3 nearest neighbors	−5.0	47.5*	64.4
5 nearest neighbors	−19.1	40.6*	50.2
2SWR (with covariates, including change in physical capital)			
1 nearest neighbor	−10.5	56.0*	58.7
3 nearest neighbors	−24.2	45.5*	30.4
5 nearest neighbors	−31.1	36.7	30.4
2SWR (with covariates, excluding change in physical capital)			
1 nearest neighbor	5.8	53.1*	69.7
3 nearest neighbors	−7.3	53.3**	30.5
5 nearest neighbors	−10.4	48.1**	30.5

Source: Based on model results. Number of observations: $NAADS_{NON\text{-}1}$ 40, 93 and 119 for matching with nearest one, three and five neighbors, respectively; $NAADS_{NON\text{-}2}$ 53, 125 and 164; and $NAADS_{NON\text{-}3}$ 32, 55 and 69. *, ** and *** means statistical significance at the 10%, 5% and 1% level, respectively. Detail 2SWR results based on model with covariates, excluding change in physical capital, and matching with nearest three neighbors are presented in the annex, Table 3

Table 3 2SWR results of Δ Ln agricultural revenue per adult equivalent

Variable	$NAADS_{NON-1}$	$NAADS_{NON-2}$	$NAADS_{NON-3}$
Participation in NAADS[a]	−0.08	0.43**	0.27
Δ Gender of head	−0.07	0.46	0.56
Δ Ln Age of head	−0.09	0.26	−0.24
Δ Education (reduction)	−0.50	−0.26	0.37
Δ Education (improvement)	−0.14	−0.31	−0.33
Δ Ln household size	0.12	−0.04	−0.49
Δ Income strategy (to crops)	−0.30	−0.41	−0.89**
Δ Income strategy (to livestock)	0.53	1.25**	1.10**
Δ Income strategy (to other ag)	−0.37	0.16	−1.76**
Δ Income strategy (to non-farm)	−0.12	−0.31	0.39
Δ Ln Distance to credit	0.05	−0.40**	−1.10*
Δ Ln Distance to all-weather road	0.47**	0.81***	−1.12***
Δ Ln Distance to markets	0.23	−0.90*	0.15
Ln Agricultural revenue per AE_2004	−0.68***	−0.83***	−0.90***
Intercept	8.45***	9.92***	10.71***
R-squared	0.34***	0.49***	0.46***

Source: Based on model results using matching with nearest three neighbors. Ln is natural logarithm. Δ is difference in 2004 and 2007 values. *, ** and *** means 10%, 5% and 1% statistical significance, respectively

[a]Percentage change in agricultural revenue per AE associated with participation is calculated by: (exponent (coefficient) − 1) × 100

Table 4 Estimated treatment effects in other selected outcomes

Outcome Variable	$NAADS_{NON-1}$	$NAADS_{NON-2}$	$NAADS_{NON-3}$
Adoption of improved crop varieties[a]	−0.19	0.24	0.31*
Adoption of livestock improved breeds[a]	−0.12	0.18	0.18
Value of crop output per hectare[b]	−44.46**	9.53	140.50*
Value of livestock output per tropical livestock unit[b]	−38.43	33.78	166.45**
Percent of crop output that is sold on the market[b]	−1.11	1.01	5.06
Percent of livestock output that is sold on the market[b]	−0.09	3.61	7.82***

Source: Based on model results of second stage regression with covariates, excluding change in physical capital, and matching with nearest three neighbors

[a]Panel random-effects probit regression results of adoption in 2004 and 2007; estimates are difference between participants and non-participants in probability of adoption in 2004 and 2007

[b]Weighted regression results of change between 2004 and 2007 in logarithm of outcome; estimates are % difference between participants and non-participants in 2004–2007 change in outcome. *, ** and *** means 10%, 5% and 1% statistical significance, respectively

and sale of output; although the statistical significance of the estimates are reversed for $NAADS_{NON-2}$ and $NAADS_{NON-3}$ however, which is surprising (see annex Table 4). The estimated effects when direct participants are compared with $NAADS_{NON-1}$ were consistently negative for the different outcomes analyzed, suggesting that the impacts of the program on direct participants were not as large as the change observed for indirect participants. Because farmers in this group are not very familiar with the NAADS program, they may have confused NAADS service providers with agents of other programs, leading to an overestimation of NAADS program effects for this group, as was likely the results in Benin et al. (2011).

The estimates from the model specification without the covariates are generally larger, suggesting that changes in other factors have been important, particularly changes in sources of income and access to infrastructure and services, particularly roads and markets (see annex Table 3).

The lower estimates associated with the model specification with the covariates including change in physical capital suggest that the impact of the program was also via its effect on these assets. The u-shaped or inverted u-shaped relationship between the estimates and increasing number of nearest neighbor matches is consistent with the literature that greater number of matches generally increases precision, but at the cost of increasing bias (Dehejia and Wahba 2002).

3 Conclusions and Implications

In this paper we used different sets of control groups and different propensity score matching specifications combined with regression to estimate the average treatment effect of the agricultural extension system in Uganda on households' agricultural revenue. By breaking up the control observations into sub-groups reflecting likely differences in potential contamination with the treatment, we show how matching each treatment observation with multiple controls that are similar in several attributes but different in others can yield more insights on estimates of average treatment effects. Unfortunately, the results were mixed and weak, in terms of consistent sign and statistical significance across the different methods, model specifications, and outcomes analyzed, making it difficult to draw definitive conclusions regarding the direct impact of the program and, particularly, its indirect impact. Our underlying assumption was that participation in the NAADS program confers benefits via material inputs that will lead to subsequent outcomes. But this assumption was not consistently validated in the results obtained. While changes in other factors (sources of income and access to road and market) are important in raising agricultural revenue, a major limitation with the study is our inability to capture the separate effect of access to non-NAADS extension services.

References

Benin, S., E. Nkonya, G. Okecho, E. Kato, J. Randriamamonjy, G. Lubade, and M. Kyotalimye. 2011. Returns to spending on agricultural extension: the case of the National Agricultural Advisory Services (NAADS) program of Uganda. *Agricultural Economics* 42: 249–267.

Dehejia, R., and S. Wahba. 2002. Propensity score matching methods for non-experimental causal studies. *Review of Economics and Statistics* 84: 151–161.

Feder, G., R. Just, and D. Zilberman. 1985. Adoption of agricultural innovations in developing countries: a survey. *Economic Development and Cultural Change* 30: 59–76.

Imbens, G.M., and J.M. Wooldridge. 2009. Recent developments in the econometrics of program evaluation. *Journal of Economic Literature* 47: 5–86.

NAADS (National Agricultural Advisory Services). 2007. *Facts and figures*. Kampala: NAADS Secretariat.

Robins, J.M., and A. Rotnitzky. 1995. Semi-parametric efficiency in multivariate regression models with missing data. *Journal of the American Statistical Association* 90: 122–129.

Singh, I., L. Squire, and J. Strauss. 1986. *Agricultural household models: extensions, policy and applications*. Baltimore, MD: John Hopkins University.

Wilde, J. 2000. Identification of multiple equation probit models with endogenous regressors. *Economic Letters* 69: 309–312.

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Agricultural Growth, Poverty, and Nutrition Linkages

Karl Pauw, James Thurlow, and Olivier Ecker

1 Introduction

There is widespread agreement that growth is a necessary condition for poverty reduction, although the extent to which poverty declines depends on the level and the structure of growth, and characteristics of the poor (Dollar and Kraay 2002; Ravallion and Datt 1996; Mellor 1999). Agricultural growth has been shown to be particularly effective at contributing to overall growth and reducing poverty in most developing countries, and hence this sector is often afforded priority as a growth sector in developing countries (Diao et al. 2010; Valdés and Foster 2010). This "agricultural growth hypothesis" largely serves as the justification for the Comprehensive Africa Agriculture Development Programme (CAADP), in terms of which signatories agree to allocate at least ten percent of their government budgets to the agricultural sector (for example, in the form of spending on extension services, rural infrastructure, research and development, and so on) with the aim of achieving a target of six percent annual agricultural growth.

While poverty-reduction is one objective of CAADP—and most of the CAADP country-analyses conducted by the International Food Policy Research Institute

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(IFPRI) in recent years used this as one of the key benchmarks against which the policy was evaluated (see Diao et al. 2012)—improved food and nutrition security is arguably equally important as a development goal.

Because agriculture implies food production and because agricultural growth benefits the poor disproportionately in developing countries, there exists a perception among policymakers that the links between agricultural growth and nutrition are inevitably strong. In fact, growth in general is believed to be good for reducing malnutrition in as far as it raises household incomes, thus allowing households to access better or more nutritious food. However, some countries have seen nutrition deteriorate despite growth.[1] In India, for example, rapid income growth has not translated into nutritional improvements, with stunting and wasting remaining widespread and per capita caloric availability declining (Deaton 2010). This is puzzling and hard to explain, confirming, as Timmer (2000) argued a decade before, that the mechanisms through which growth impacts on nutrition are not yet well understood analytically or quantified empirically.

The obvious conclusion is that improved nutrition is not a necessary consequence of growth-induced increases in incomes or reductions in poverty. This reflects the fact that the concept of "food and nutrition security" has several dimensions: "availability" of sufficient quantities of domestically produced or imported food; "access" to sufficient resources to acquire a nutritious diet; and "utilization" of food through adequate diet, water, sanitation and health care (Heidhues et al. 2004). In order to understand how growth impacts on nutrition it is necessary to consider how growth affects all of its dimensions.

This paper compares and summarizes findings from two recent papers, by Pauw and Thurlow (2011) and Ecker et al. (2012) in which at least two of the dimensions of food and nutrition security were modeled (i.e., availability and access). Both studies used a computable general equilibrium (CGE) model complemented with microsimulation nutrition models, and specifically consider how alternative economic growth paths ultimately impact on nutrition. The paper is structured as follows. It first compares the methods used in the respective studies and next summarizes the key results. The chapter ends by drawing general policy conclusions and outlining the way forward for these types of analyses.

2 Methods

2.1 IFPRI's Standard Recursive-Dynamic CGE Model

Both Pauw and Thurlow (2011) and Ecker et al. (2012) use IFPRI's standard recursive-dynamic computable general equilibrium (CGE) model to capture the impact of alternative sectoral growth paths on different households and regions in

[1]See for example Ecker et al.'s (2012) cross-country analysis.

the respective countries.[2] The economywide impact of growth depends largely on the inter-sectoral linkages and the way in which households are linked to different sectors via employment and consumption demand linkages. The social accounting matrix (SAM) underlying a CGE model captures these linkages.

The Tanzania model identifies 58 sectors, 26 of which are in agriculture and 10 in downstream agro-processing. Agriculture is further disaggregated across 20 sub-national regions, which captures variation in agro-ecological conditions and rural livelihood/cropping patterns. The Malawi model, in turn, includes 36 sectors (17 agriculture, 9 industry, and 10 services), while the agricultural sector is disaggregated across eight agroecological zones, urban areas, and small, medium, and large-scale farmers. In both models producers in each sector and region maximize profits when combining intermediate inputs with land, labor and capital. Production is specified using nested constant elasticity of substitution (CES) functions, which reflect region-specific technologies and allow for imperfect substitution between factors. In the Tanzanian model labor markets are segmented into four education groups (i.e., uneducated, primary, secondary, and tertiary), while the Malawi model includes elementary (farm) workers, unskilled workers, and skilled workers.

Economic outcomes are also affected by trade and movements in market prices. The standard CGE model assumes that producers in each region supply their output to national product markets (using a CES aggregation function), which avoids having to model inter-regional trade flows for which data is often unavailable. However, transaction costs separate regional producer and national consumer prices. International trade is captured by allowing production to shift imperfectly between domestic and foreign markets depending on the relative prices of exports and domestic products (constant elasticity of transformation function). Similarly, consumers choose between imported or domestically supplied goods depending on relative import prices (CES Armington function). Since both Tanzania and Malawi are small economies, world prices are fixed. The current account balance is maintained by a flexible real exchange rate.

Household income and expenditure patterns are important in determining how growth and relative price changes affect household incomes in the model. Both models identify farm and non-farm households in rural and urban areas, with further disaggregation by region, per capita expenditure quintiles (in the case of Tanzania) and the extent of households' land holdings (in the case of Malawi). The Tanzania model is highly detailed with 110 representative household groups, while the Malawian model includes 28 household groups. Factor incomes are distributed among households based on their factor endowments. Households save and pay taxes (at fixed rates), and the balance of income is used for consumption expenditure. The latter is based on a linear expenditure system (LES) of demand, which allows for non-unitary income elasticities and fixed marginal budget shares. Income

[2]For a detailed specification of this class of CGE model, see Dervis et al. (1982) and Löfgren et al. (2002).

elasticities determine the responsiveness of demand for different household consumption items to income changes, and are therefore important for determining the nutrition effects of household income changes, at least in the Tanzania model, as we explain further below.

2.2 Macro-Micro Linkages and Microsimulation Modeling

Household poverty and nutrition are affected through both income and expenditure channels. When agricultural production expands, farm households, who derive income from land ownership and on-farm employment, are more likely to benefit from higher crop revenues, although this may be partially offset by falling producer prices and lower returns to factors. Falling prices, in turn, benefit consumers, particularly nonfarm households, but also net-consuming farm households (i.e., those producing less than they consume). We therefore expect that agricultural growth will lead to a decline in both rural and urban poverty, with the relative magnitudes of the changes depending on consumption patterns and price changes faced by either producers or consumers.

In general, however, the use of aggregate household groups in CGE models prevents a nuanced analysis of the differential poverty effects on households. Both the Tanzanian and Malawian models therefore incorporate a poverty module in which changes in prices and consumption at the representative household group level (i.e., as observed in the CGE model) are linked to corresponding member households in the underlying survey data, where changes in standard income poverty measures are computed.

The two studies, however, adopt different approaches to measuring nutrition changes. The Tanzania nutrition module developed by Pauw and Thurlow (2011) is similar to the poverty module already embedded in the CGE model. Specifically, food consumption changes (rather than changes in overall consumption values as in the poverty module) in the CGE model are linked top-down to the household data where changes in caloric availability at the household level are computed based on the nutritional characteristics of different food types. Caloric availability within each household is then compared against a measure of the daily energy requirement, which depends on a household's size and demographic structure. Households below this requirement are deemed calorie deficient or undernourished. The main "nutrition" result in Pauw and Thurlow's (2011) model is therefore changes in the calorie deficiency rate—the term nutrition is therefore used fairly loosely as it only refers to this one dimension—which is expressed either at the national level or for different household subgroups.[3]

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[3]Nutritional characteristics of different food groups are derived from detailed Tanzania-specific data in Lukmanji et al. (2008). Equivalence scales in the nutrition module are from UNU, WHO, and FAO (2004). The Household Budget Survey (HBS) 2001 (NBS 2002) forms the basis of both the poverty and nutrition microsimulation modules.

The UNU, WHO and FAO (2004) recommend that energy needs cannot be considered in isolation of other nutrients as "the lack of one will influence the others." Ecker and Qaim (2011) maintain that micronutrient deficiencies, especially in minerals and vitamins, are often even more widespread in developing countries than calorie deficiencies, which contributes to severe health problems in these countries. Looking beyond caloric availability is therefore critical, particularly when people suffer from multiple nutritional deficiencies as is often the case in developing countries, Malawi included. Hence, in the Malawi microsimulation model, Ecker et al. (2012) focus on a wider range of nutritional indicators.

Rather than using consumption changes observed in the CGE model directly in the nutrition model, Ecker et al. (2012) adopt the two-stage micro-econometric model developed by Ecker and Qaim (2011) to first estimate consumption changes in response to household income changes.[4] In the first stage food demand elasticities are estimated assuming a quadratic almost ideal demand system (QUAIDS). In the second stage the technical coefficients from the first-stage estimation are translated into own-price, cross-price and income elasticities for different nutrients, including calories, protein, iron, zinc, and vitamins A, B3 (riboflavin), B9 (folate), B12, and C. Elasticities are estimated separately for rural and urban households across the different household quintiles. These form the basis of the microsimulation model: CGE results on income changes for different household groups are now fed into the microsimulation model where elasticities are applied to estimate new deficiency levels across the various nutrients.

From the discussion it should be apparent that the main difference between the two model frameworks lies in the specification of the microsimulation components and the way in which results from the "macro" model are linked to the "micro" level. In the Tanzania model caloric availability is calculated directly on the basis of changes in consumption quantities for different consumption items included in the CGE model. As discussed, these consumption changes are determined in an LES demand system, subject to relative price and income changes. In contrast, in the Malawi model, only changes in real household income are passed down to the micro-level. Changes in nutrient availability are calculated on the basis of income elasticities derived from a QUAIDS, a somewhat more flexible and advanced demand system, but one that stands distinct from the CGE model's LES demand system.

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[4]The Integrated Household Survey (IHS) of 2004/05 (NSO 2005) is used as the basis of the microsimulation model (the poverty module embedded in the CGE model also uses the HIS 2004/05).

3 Country Case Studies

3.1 Tanzania[5]

Although Sub-Saharan Africa experienced unprecedented economic growth in recent decades, this did not always translate into less poverty or improved nutrition. The Tanzanian economy is one example of a country that failed to reap the benefits of sustained rapid growth. National gross domestic product (GDP) grew at 6.6% per year during 1998–2007 (MOFEA 2008), while agricultural growth, often regarded as instrumental in lowering poverty rates in agrarian-based developing countries, averaged a respectable 4.4% over the period. Yet, between 2001 and 2007 Tanzania's poverty rate only fell from 35.7 to 33.6%, while the share of the population consuming insufficient calories declined marginally from 25.0 to 23.6% (NBS 2002, 2010).

This outcome raises two questions. First, why did rapid growth not translate into more rapid reductions in poverty and malnutrition? And second, what is the contribution of agricultural growth in reducing poverty and malnutrition in Tanzania? To address these questions, an economywide model of Tanzania is linked with poverty and nutrition modules to (i) show how the current structure of growth resulted in the weak poverty and nutrition outcomes; and (ii) examine how accelerated, broad-based agricultural growth can contribute to higher overall growth and more rapid reductions in income poverty and hunger. Finally, the growth, poverty, and nutrition contributions of agricultural subsectors are examined more closely in order to identify priority sectors.

3.1.1 Notes on the Methodological Framework

The general equilibrium framework used for the Tanzania study incorporates both commodity demand and supply, with the latter made up of domestically produced and imported goods. This means the model is useful for considering the availability and access dimensions of food security. Prices are furthermore treated as endogenous in such models, which is important from a consumption modeling perspective. Consumption behavior is modeled on the basis of income and price elasticities estimated for each household group and commodity type. Both poverty and nutrition are affected by changes in income and relative prices. An analysis of nutrition impacts, however, requires a more in-depth look also at relative food price movements. If, for example, the price of calorie-rich maize increases and that of protein-rich meat declines such that the overall food price index does not change, the calorie

[5]This section was originally published as Chap. 7 of the International Food Policy Research Institute (IFPRI) book *Reshaping Agriculture for Nutrition and Health*, and is included with permission from IFPRI. The original publication is available online at http://dx.doi.org/10.2499/9780896296732 (see Pauw and Thurlow 2012).

Table 1 Calorie contents, calorie prices, and caloric availability in Tanzania, 2001

	Average calories per standard serving[a]	Mean price (TSh) per 100 kcal[b]	Average per capita caloric availability		
			Poor[c]	Non-poor	All
Cereals	294	6.3	1390	1885	1687
Root crops	178	5.5	424	423	423
Pulses and oilseeds	443	10.9	196	411	325
Horticulture	49	19.8	106	240	186
Livestock and processed meat	266	26.0	125	318	241
Sugar and other foods	181	23.5	119	424	302

Source: Pauw and Thurlow (2011), based on Lukmanji et al. (2008)
Notes:
[a]No consumption weights were applied in calculating average calories per food group
[b]Mean price is the total expenditure divided by total calorie content per food item
[c]Poverty line is the 40th percentile of per capita expenditure; *kcal* kilocalories; *TSh* Tanzanian shilling

deficiency rate might decline and the protein deficiency rate might increase, even though the poverty rate remains unchanged. The rich (food) commodity–household specification in the CGE model is useful in this regard, as it captures important differences in consumer spending preferences and responsiveness to income and relative price changes across household types.

To avoid the feeling of hunger poorer consumers often allocate a larger share of their income to food types with high calorie contents and lower costs per calorie. Table 1 compares the calorie content of different foods in Tanzania. It shows how the price per 100 kilocalories (kcal) varies by product, and shows average calories available from different food products for poor and nonpoor households. Livestock products have a higher average calorie content per 100 g serving compared to most other food types, but they also have a higher price that makes them an expensive energy source. Cereals offer a similar amount of calories per serving, but cost considerably less than livestock products.

3.1.2 Tanzania's Recent Growth Performance

An examination of recent production trends suggests that although the agricultural sector as a whole grew rapidly during 1998–2007 (at 4.4% per year), growth has been volatile, while the source of this growth has been concentrated among a few crops. Rice and wheat, for example, dominate cereals production trends, and cotton, tobacco, and sugar production grew almost 10% per year. Larger-scale commercial farmers grow these well-performing crops on farms heavily concentrated in the northern and eastern periphery of the country. In contrast, yield for maize, the dominant staple food crop grown extensively by subsistence farmers, remained low due to primitive farming methods. Despite rice and wheat expansion and generally favorable agroecological conditions, Tanzania remains a net cereals importer because production has failed to keep pace with rising consumer demand.

Roots, such as cassava and potatoes, are also important food sources and account for almost 15% of Tanzania's harvested land. Root crops have performed well recently with more than 4% annual growth. By contrast, higher-value pulses and vegetables have stagnated, with pulses production declining by more than 4% each year. This was partly offset by expanded oilseeds production throughout the country and by fruit production in the northern and eastern regions. Non-cereal food crop production has therefore been characterized by slow growth in widely produced crops, and fast growth in regionally concentrated crops.

Some of the fastest growth rates during 2000–2007 were for export-oriented crops, such as cotton, sugarcane and tobacco. However, these crops are highly concentrated in specific regions. Cotton is mainly produced by smallholders in the western and lake regions (81.5% of national output). Tobacco, another smallholder crop, is produced in the western and highlands regions (82.8%). Sugarcane is mostly produced by larger-scale commercial farmers in the eastern and northern regions (83.8%). Together these three crops generated 17.4% of total merchandise exports in 2007. Coffee and tobacco are also major export crops, but their production has declined in recent years. Growth in export agriculture has therefore been driven by the strong performance of a few regionally concentrated crops. Thus, though the aggregate agricultural sector's substantial expansion in recent years suggests broad-based agricultural growth in Tanzania, a closer examination of agricultural production data suggests the opposite.

3.1.3 Comparing Business-as-Usual Growth to Broad-Based Agricultural Growth

To better understand the poverty and nutritional implications of Tanzania's historical growth path, the CGE model is used to produce a baseline scenario that assumes recent production trends continue over the period 2007–2015. These results are compared to a hypothetical scenario with accelerated agricultural growth ("agriculture scenario") in which agricultural GDP growth averages 5.3%. This scenario assumes a more broad-based agricultural growth path, with yields for crops that have performed well in the past (e.g., rice, wheat, and certain export crops) improving only marginally, while poor-performing crops (e.g., maize, pulses, and vegetables) experience larger yield gains, reflecting their greater growth potential.

The effectiveness of growth achieved under the two scenarios is measured with the aid of two types of elasticity: the poverty–growth elasticity and the calorie–growth elasticity. The poverty-growth elasticity is defined as the percentage decline in poverty caused by a one percent increase in per capita GDP. Similarly, the calorie–growth elasticity is the percentage change in the calorie deficiency rate

Table 2 Modeled poverty– and calorie–growth elasticities for Tanzania, 2007–2015

	Initial deprivation rate (%)	Final deprivation rate (%)	Avg. annual % change in deprivation rate (a)	Annual per capita GDP growth (b)	Deprivation–growth elasticity (a)/(b)
Baseline scenario					
Poverty rate	40.0	29.6	−3.7	3.6	−1.03
Calorie deficiency	23.5	17.6	−3.5	3.6	−0.99
Agriculture scenario					
Poverty rate	40.0	25.7	−5.4	4.1	−1.32
Calorie deficiency	23.5	13.8	−4.8	4.1	−1.57

Source: Results from the Tanzania CGE model and poverty/nutrition modules

divided by the percentage change in per capita GDP. Table 2 reports the deprivation–growth elasticity results from the baseline and agriculture scenarios. Average annual per capita GDP grew by 3.6 and 4.1% under the two scenarios respectively, while poverty declined by 3.7 and 5.4% respectively. This suggests a poverty–growth elasticity of −1.03 in the baseline scenario. In the agriculture scenario the poverty–growth elasticity increases to −1.32. The nutrition module, in turn, shows declines in the malnutrition rate of 3.54 and 4.84% in the two scenarios. This yields a baseline calorie–growth elasticity of −0.99, while in the agriculture scenario the calorie–growth elasticity improves significantly to −1.57.

The results confirm that broad-based agricultural growth greatly strengthens the impact of growth on poverty. The calorie–growth elasticity also rises substantially under the broad-based agricultural growth scenario, which is a reflection of the increased production and consumption of calorie-rich maize, sorghum, millet, and pulses.

3.1.4 Identifying Priority Sectors for Agricultural Growth

While the previous section illustrated the benefits of broad-based agricultural growth, ascertaining whether certain agricultural subsectors are more effective than others in improving the poverty and nutritional outcomes of agricultural growth requires further modeling. Growth within different agricultural subsectors can have different impacts on development outcomes for various reasons. First, poorer households may be more intensively engaged in the production of certain crops or agricultural products. Similarly, some subsectors produce products that poorer households consume more intensively. Growth or price fluctuations in these sectors will therefore have a greater impact on poverty than growth or price fluctuations in other sectors. Second, some subsectors produce products that are particularly important for households' nutritional status, such as those that represent

Table 3 Poverty, nutrition, and growth effects of agricultural subsector growth, 2007–2015

	Poverty-growth elasticity	Calorie-growth elasticity	Size and linkage effects
Maize-led growth	−1.174	−1.477	0.152
Sorghum and millet–led growth	−1.139	−1.348	0.033
Rice and wheat–led growth	−1.106	−1.147	0.106
Root crops–led growth	−1.184	−1.350	0.106
Pulses and oilseeds–led growth	−1.146	−1.161	0.101
Horticulture–led growth	−1.126	−1.092	0.186
Export crops–led growth	−1.097	−1.057	0.098
Livestock-led growth	−1.084	−0.977	0.204

Source: Results from the Tanzania CGE model and poverty/nutrition modules

low-cost sources of calories or are consumed intensively by nutrient-deficient households. While these elasticities are by definition growth neutral, growth itself is crucial for reducing poverty and malnutrition. Thus, a third factor concerns growth itself, and the fact that some sectors, due to their initial size in the economy, downstream production linkages (such as their production multiplier effects), or growth potential (signified by current yield gaps) can have a greater impact on overall growth. These three criteria are taken into account when identifying subsectors most effective at reducing poverty and malnutrition in Tanzania.

Comparative results are presented in Table 3. The simulated growth in each subsector achieves the same target agricultural GDP by 2015 in each simulation, thus ensuring that the poverty– and calorie–growth elasticities are directly comparable across subsectors. The three highest poverty–growth elasticities are for growth led by maize, root crops, and pulses and oilseeds. These crops are important expenditure items for households just below the poverty line and are grown more intensively by poorer farm households. In contrast, the poverty–growth elasticity for rice– and wheat–led growth is lower, mainly because these crops are grown in less poor regions of the country and, in the case of wheat, by larger-scale farmers who are less likely to be poor. The calorie–growth elasticities indicate that maize, sorghum and millet, and root crops raise household caloric availability per unit of growth most effectively. Although pulses and oilseeds have high calorie contents, the poor consume these less intensively since the crops are a fairly expensive source of calories. Livestock products have the lowest elasticity—in spite of the relatively high calorie content of meat products—because they are an expensive source of calories and calorie-deficient households consume them less intensively.

Production multipliers provide a useful indicator of the growth linkages of different subsectors. Multiplying each sector's production multiplier by its initial share in agricultural GDP constructs a simple index of the contribution each unit of additional growth within a sector makes to overall GDP. This index, shown in the last column of Table 2, identifies horticulture, livestock, and maize as sectors with the greatest potential to have a meaningful effect on national GDP in Tanzania within the 8-year timeframe of our simulation analysis.

3.1.5 Policy Recommendations

The analysis here suggests Tanzania's low poverty–growth elasticity results from the current structure of agricultural growth, which favors larger-scale production of rice, wheat, and traditional export crops in specific geographic locations. Accelerating agricultural growth in a wider range of subsectors than those currently leading the growth process can strengthen growth's effectiveness at reducing poverty. Faster agricultural growth would also benefit urban and rural households by increasing caloric availability and the ability to pay for food. Such nutritional improvements are best achieved by improving production of key calorie-laden food crops. The staple maize, already grown extensively by subsistence smallholders in Tanzania, has important size and growth linkages in the economy in addition to having large poverty–growth and calorie–growth elasticities. The analysis therefore identifies this sector as a priority sector for achieving growth, poverty, and nutrition objectives.

The modeling analysis by Pauw and Thurlow (2011) did not explicitly consider how increased agricultural productivity might be achieved or what the cost might be in terms of investments, extension services, or subsidies. However, studies for Tanzania and elsewhere have identified various interventions required to improve smallholders' crop yields, such as investing in rural infrastructure, researching and adopting improved seed varieties, and providing extension services. In recent years the Tanzanian government has allocated a relatively small share of its budget to agriculture. However, current development plans indicate a reprioritization of agriculture as a driver of economic growth and socioeconomic development. Pauw and Thurlow's (2011) results provide some indication of which agricultural sectors should be prioritized within this development plan in order to maximize national growth, poverty, and nutrition outcomes.

3.2 Malawi

While economic growth is generally acknowledged as a necessary precondition for reducing poverty, relatively little is known about how growth and nutrition are related. Therefore, questions persist regarding how to leverage economic policies so that they have a larger impact on nutrition. In recent years the Malawian government allocated a large share of its resources to the Farm Input Subsidy Program (FISP). Subsidized fertilizer and seed mainly for maize production led to rapid GDP growth during 2005–2010. It is obvious that an abundant supply of the calorie-laden staple maize is good for reducing calorie deficiency; however, it is less clear how FISP has affected micronutrient deficiencies, which are high in Malawi. This section explores diverse poverty and nutritional outcomes of recent maize-led growth in Malawi, drawing on the analysis by Ecker et al. (2012). Their study comprises two components: first, a cross-country analysis of the links between growth and nutrition outcomes; and second, a modeling analysis which includes case studies on Yemen and Malawi. We focus on those findings that are relevant to Malawi.

3.2.1 Cross-Country Evidence on the Relationship Between Growth and Nutrition

Ecker et al.'s (2012) cross-country analysis reveals that while some countries have been successful in leveraging growth for improved nutrition outcomes, others have seen nutrition deteriorate despite growth. In general, economic growth positively influences nutrition, but it is often not sufficient. During the early stages of development growth helps reduce calorie deficiency rates in particular, and, in most countries, agricultural growth plays a key role.

Calorie deficiency rates become less responsive to growth as its prevalence declines, and at this stage in the development process economic diversification into manufacturing and services is often necessary to leverage further economic growth, especially as rural-to-urban migration intensifies. Growth is generally insufficient to address all aspects of malnutrition, including child undernutrition and micronutrient deficiencies. Strategic investments and special programs are needed in sectors such as health and education.

3.2.2 Malawi's Farm Input Subsidy Program

The Malawian economy is agriculture-based and features limited economic diversity. Maize and tobacco are dominant subsectors, jointly contributing almost 15% to national GDP, and hence the performance of the agricultural sector and the economy as a whole is highly dependent on these sectors. Growth in the predominantly rainfed agricultural sector is volatile due to frequent droughts and floods. During 1990–2005 Malawi suffered at least three severe droughts and four major floods, with the agriculture sector contracting during 4 of these 15 years. The country has experienced at least two major food deficits since the turn of the millennium, leading to famine in 2002 and a serious food emergency in 2005. Frequent poor harvests combined with poor management of grain stocks contribute to food insecurity in Malawi.

During the 2005–2006 growing season, and in response to particularly severe food supply problems experienced in 2005, the government of Malawi initiated the Farm Input Subsidy Program (FISP), a large scale subsidy scheme that significantly reduces fertilizer and hybrid maize seed costs faced by resource-poor smallholders. The program has been lauded for its success in raising maize yields and contributing to overall economic growth, despite legitimate concerns about its fiscal sustainability (program costs have ranged from 5–16 percent of GDP since inception). Rapid maize output growth improved food security and raised caloric availability.

However, it is less clear how FISP may have impacted on micronutrient deficiencies in iron, zinc, vitamin A, and folate, which historically have been high.

The Malawi case study in Ecker et al. (2012) assesses the ways and extent to which FISP-led growth has contributed to nutrition outcomes in the country, and also considers nutritional outcomes under future growth scenarios. In this analysis, they use an economywide ("macro") model which is linked to household and child nutrition simulation ("micro") models. The combined analytical framework thus permits analyses of the effects of policy shocks on sector-level economic growth and household incomes, and how this in turn affects nutritional status.

3.2.3 Modeled Scenarios and Results

Three scenarios are explored. In the first, the period of rapid maize-led agricultural growth experienced under FISP during 2005–2010 is replicated. Under this scenario national GDP growth averages 6.8%, with growth in cereals driving overall economic growth (Table 4). These estimates are largely consistent with preliminary GDP growth estimates from Malawi national accounts.

Two future scenarios (2010–2020) are also modeled. The first assumes a return to long-term growth of around four percent experienced in the decade prior to FISP. This scenario, which serves as the baseline scenario, assumes the country will be unable to maintain the maize-led growth momentum generated under FISP. A second more optimistic scenario assumes a broad-based agricultural growth path as provided for under Malawi's Agricultural Sector-Wide Approach (ASWAp). This policy document outlines Malawi's vision of transforming the agricultural sector from its current overreliance on maize and tobacco to a more diversified one where a broader range of food and export crops are prioritized, and where rapid growth in downstream industrial and service sectors is encouraged through productivity-enhancing investments.

Table 4 Simulated GDP growth paths for selected sector (2005–2010 and 2010–2020)

	Historical maize-led growth path	Future scenarios			
		Return to long-run growth path		Broad-based agricultural growth	
	2005–2010	2010–2015	2015–2020	2010–2015	2015–2020
National GDP	6.8	4.0	4.1	6.4	6.0
Agriculture	8.5	3.3	3.4	6.5	5.1
Cereals	17.3	3.0	3.0	8.9	4.4
Export crops	4.9	4.1	4.0	5.2	7.7
Industry	5.4	4.6	4.5	6.2	6.8
Services	5.7	4.6	4.6	6.3	6.8

Source: Ecker et al. (2012)

Figure 1 shows changes in poverty and nutrition levels for the historical and future scenarios. Maize is grown extensively by poorer smallholder farmers; hence maize-led growth under FISP contributes to the rapid decline in poverty during 2005–2010. The poverty estimate for 2010 is close to the current official poverty rate of 39% (see NSO 2012). Under the slower growth scenario no further significant reductions in poverty emerge; in contrast, the broad-based growth scenario is associated with significant further reductions in the poverty rate, which drops below 30% by 2020.

The remaining panels in Fig. 1 show changes in calorie and various micronutrient deficiency rates. Historical maize-led growth reduces calorie deficiency from 34.8 to 17.1%. The proportions of people affected by iron, zinc, or folate

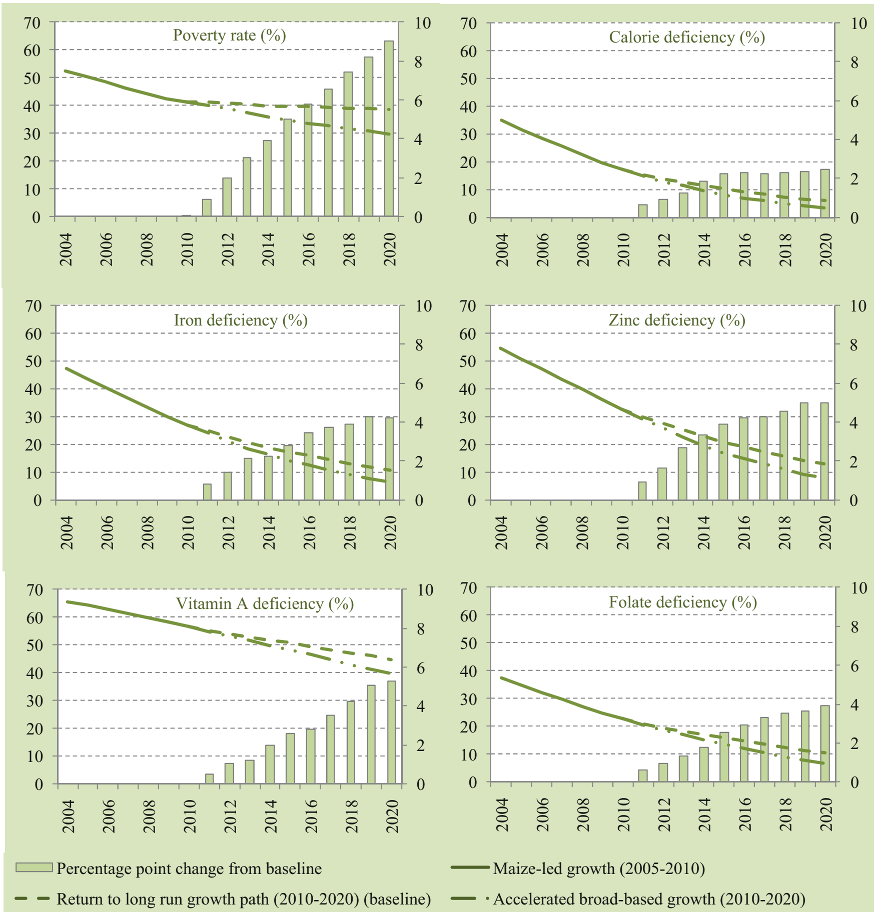

Fig. 1 Poverty and nutritional changes (2005–2020). Source: Based on results in Ecker et al. (2012). Notes: Deficiency rates shown on *left axes*; percentage point difference between slow-growth and accelerated growth paths shown on *right-hand axes*

deficiencies also decline in both absolute and relative terms (i.e., by more than one-third). Vitamin A deficiency, on the other hand, does not decline as rapidly, which reflects limited quantities of meat, fish, vegetable, and fruit in the average diet. In fact, the absolute number of vitamin A deficient people increases by 400,000 over the period. Thus, FISP, coupled with favorable weather conditions, is likely to be successful in reducing calorie and micronutrient deficiencies in relative and absolute terms, with the exception of vitamin A.

The scenarios for 2010–2020 show continued declines in malnutrition rates, albeit generally at a slower pace compared to the historical period. In the baseline scenario the proportion of calorie deficient people drops to under 10% after 2015, while iron, zinc, and folate deficiencies are all estimated to affect less than 15% of the population by 2020. The absolute number of people deficient in calories and most micronutrients also continues to decrease. Vitamin A deficiency, however, remains a concern, with the absolute number of vitamin A deficient people continuing to rise even though their proportion in the total population drops to well below 50% by 2020.

Under the broad-based growth scenario for 2010–2020 nutritional deficiency rates decline considerably faster than in the baseline. Micronutrient deficiencies tend to decline more rapidly than calorie deficiency, at least in percentage point terms. This relates to the high initial incidence of micronutrient deficiencies. From 2015 onwards the rate of decline in calorie deficiency remains stable at around 2% points below the baseline (see bar chart). In contrast, iron, zinc, and vitamin A deficiencies continue to decline at an increasing rate relative to the baseline, such that by 2020 micronutrient deficiency rates will be about 4–5% points below the rates in the baseline. By 2020 the number of people deficient in calories, iron, zinc, and folate is more than one-third lower than in the baseline.

3.2.4 Policy Recommendations

Ecker et al.'s (2012) analysis shows that economic structure and the characteristics of poor or malnourished people determine whether agricultural or nonagricultural growth is more effective at reducing poverty and malnutrition. In countries such as Malawi where agriculture contributes significantly to national income and where the majority of poor people earn a living from farming, agriculture has an important role to play. Nutrition improves not only for those rural households linked to agriculture; urban households also benefit from agricultural productivity growth and the associated reduction in food prices.

However, cross-country evidence shows how the role of growth shifts during the development process. The comparison between the broad-based growth and baseline scenarios for Malawi confirms this and shows how calorie and micronutrient deficiencies become less responsive to growth as prevalence rates decline, at which point economic diversification is needed to leverage further growth and reductions in malnutrition.

Ultimately, however, neither agricultural nor nonagricultural growth is sufficient to eliminate poverty, hunger, or micronutrient malnutrition. For example, in the modeled scenario for Malawi, even after a 15-year period of sustained and rapid agriculture-led economic growth, poverty remains close to 30%. This in part reflects the failure of economic growth to trickle down to all the poor and malnourished households; many individuals simply lack access to jobs or markets and hence fail to benefit from growth. As far as nutrition is concerned, the result also reflects lack of access to information and knowledge about proper nutrition, which diminishes the effect of growth-induced changes in household incomes on nutrition. Individual health status and access to healthcare are equally important for nutrition; if growth is not associated with improvements in health service delivery the nutritional effects of growth will be limited, even if higher incomes mean people can better afford health services. This highlights the need for strategic investments and targeted programs that are complementary to growth policies but explicitly aim to improve health and nutrition outcomes and thus strengthen the growth-nutrition linkages.

4 The Way Forward

The studies by Pauw and Thurlow (2011) and Ecker et al. (2012) are fairly similar in their approach to measuring the links between (agricultural) growth, poverty, and nutrition. The Tanzania analysis explicitly aimed at identifying agricultural subsectors that are most effective at reducing poverty and hunger, while the Malawi study was more focused on how plausible future economic growth paths might affect nutrition across multiple nutrition indicators. Both studies highlight the importance of the structure of growth in determining the pace of poverty reduction and nutritional improvements, with agricultural growth identified as a particularly important sector given its strong ties with rural poor households. Urban households, however, also benefit from increased availability of cheaper food, which is important for countries such as Tanzania where malnutrition levels are higher in urban areas.

Both approaches have strengths and weaknesses. Missing from both is an assessment of how growth affects the "utilization" dimension of food security and nutrition. For example, more rapid growth may be associated with (or the result of) improved infrastructure and better government service delivery in health and education, which either improves nutrition outcomes or raises the responsiveness of nutrition to higher incomes. Such effects are not easily modeled as endogenous outcomes of growth in standard CGE models; moreover, these models typically assume no changes in household consumption behavior over time and hence also not the way in which food is utilized. Analyses that incorporate the utilization dimensions may therefore require a different modeling framework altogether.

A limitation particular to the Malawi study is that it does not consider how consumption responses in the LES (CGE model) compare with those of the QUAIDS (nutrition module); in fact, even the income elasticities are defined and estimated separately. The nutrition module is also not set up to deal with relative price changes (i.e., only real disposable income changes are passed down to the micro-model). Relative prices are therefore implicitly assumed to be unchanged; hence the microsimulation model also disregards changes in the composition of consumption, even if the CGE model's demand system suggests they do change. The model is therefore more suited to analyses of growth-nutrition linkages under a "balanced growth" scenario where relative prices do not fluctuate too much. In essence, therefore, the combined Malawi model framework only considers the demand-side in detail; the supply-side of the nutrition story is reduced to a single measure of income change. In contrast, the Tanzania model explicitly accounts for relative price changes by using the demand system embedded in the CGE model. However, the assumption that all products are gross complements (i.e., cross-price elasticities are negative) is an important limitation of the LES, which means the model is not well suited to analyzing policy shocks leading to large fluctuations in relative prices.

There are, however, some advantages to using a separately-defined demand system for calculating nutrition changes. Whereas demand elasticities in recursive-dynamic CGE models are typically not permitted to change over time, the nutrition demand elasticities in the Malawi microsimulation model are adjusted to account for changes in income levels and the associated behavioral changes (i.e., nutrient demand elasticities are updated to match those of the income cohorts the households move into as their incomes rise). Ecker et al. (2012) are thus able to demonstrate the effect when calorie and micronutrient deficiencies become less responsive to growth as prevalence rates decline over time.

Maize is a widely grown crop in both Tanzania and Malawi, and hence has the potential to significantly contribute to growth and reductions in poverty and calorie deficiency. However, an important question for future research is how a maize-led growth strategy, such as the one followed in recent years in Malawi, might impact on crop diversification and nutrition outcomes across multiple nutrition indicators. The Tanzania study with its narrow focus on calories only cannot answer this question, but neither can the Malawi study, given that the supply of nutrients is not properly accounted for in the microsimulation model (as discussed).

Many of the model limitations can be overcome. Several attempts are underway to introduce a more appropriate demand system into CGE models, specifically one which allows for consumer goods to be treated as genuine substitutes, or a system in which parameters and elasticities can be updated over time to reflect changing consumption behavior (i.e., in recursive-dynamic models). The ultimate aim would be to fully embed a detailed demand system in the CGE model that can be used to evaluate nutrition changes. In the meantime simple model improvements include, in the case of the Malawi model, linking both price and income changes in the CGE model with the microsimulation model, and applying the same set of demand elasticities in both models. The Tanzania model, in turn, can easily be extended to measure changes in the availability of micronutrients as well (data is already available to do so). Ultimately, these studies represent an important step towards better understanding the growth-nutrition linkages.

References

Deaton, A. 2010. Understanding the mechanisms of economic development. *Journal of Economic Perspectives* 24 (3): 3–16.

Dervis, K., J. de Melo, and S. Robinson. 1982. *General equilibrium models for development policy*. New York: Cambridge University Press.

Diao, X., P. Hazell, and J. Thurlow. 2010. The role of agriculture in African development. *World Development* 38 (10): 1375–1383.

Diao, X., J. Thurlow, S. Benin, and S. Fan, eds. 2012. *Strategies and priorities for African agriculture: Economywide perspectives from country studies*. Washington, DC: International Food Policy Research Institute.

Dollar, D., and A. Kraay. 2002. Growth is good for the poor. *Journal of Economic Growth* 7 (3): 195–225.

Ecker, O., C. Breisinger, and K. Pauw. 2012. Chapter 6. In *Reshaping agriculture for nutrition and health*, ed. S. Fan and R. Pandya-Lorch. Washington, DC: International Food Policy Research Institute.

Ecker, O., and M. Qaim. 2011. Analyzing nutritional impacts of policies: An empirical analysis in Malawi. *World Development* 39 (3): 412–428.

Heidhues, F., A. Atsain, N. Hezron, M. Padilla, G. Ghersi, and J. Le Vallée. 2004. *Development strategies and food and nutrition security in Africa. An assessment*. IFPRI 2020 Discussion Paper, 38. Washington, DC: International Food Policy Research Institute.

Löfgren, H., S. Robinson, and R. Harris. 2002. *A standard computable general equilibrium (CGE) model in GAMS*. Washington, DC: International Food Policy Research Institute.

Lukmanji, Z., E. Hertzmark, N. Mlingi, V. Assey, G. Ndossi, and W. Fawzi. 2008. *Tanzania food composition tables*. Dar es Salaam, Tanzania; Boston, MA, Muhimbili University of Health and Allied Sciences (MUHAS); Tanzania Food and Nutrition Centre (TFNC); Harvard School of Public Health (HSPH).

Mellor, J.W. 1999. *Faster, more equitable growth: The relation between growth in agriculture and poverty reduction*. Cambridge, MA: Harvard University Press.

MOFEA (Ministry of Finance and Economic Affairs). 2008. *The economic survey 2007*. Dar es Salaam: Ministry of Finance and Economic Affairs.

NBS (National Bureau of Statistics). 2002. *Tanzania: Household budget survey 2000/01*. Dar es Salaam: National Bureau of Statistics.

———. 2010. *Tanzania: Household budget survey 2007*. Dar es Salaam: National Bureau of Statistics.

NSO (National Statistical Office). 2012. *Integrated household survey 2010/11*. Malawi: National Statistical Office.

Pauw, K., and J. Thurlow. 2011. Agricultural growth, poverty, and nutrition in Tanzania. *Food Policy* 36 (6): 795–804.

———. 2012. The role of agricultural growth in reducing poverty and hunger: The case of Tanzania. In *Reshaping agriculture for nutrition and health*, ed. S. Fan and R. Pandya-Lorch, 55–64. Washington, DC: International Food Policy Research Institute. doi:10.2499/9780896296732.

Ravallion, M., and G. Datt. 1996. How important to India's poor is the sectoral composition of economic growth? *The World Bank Economic Review* 10 (1): 1–26.

Timmer, C.P. 2000. The macro dimensions of food security: Economic growth, equitable distribution, and food price stability. *Food Policy* 25 (3): 283–295.

UNU, WHO, and FAO (United Nations University, World Health Organization, and Food and Agriculture Organization of the United Nations). 2004. *Human energy requirements: Report of a joint FAO/WHO/UNU expert consultation*. Rome, October 17–24, 2001. FAO Food aned Nutrition Technical Report Series 1. Rome: FAO.

Valdés, A., and W. Foster. 2010. Reflections on the role of agriculture in pro-poor growth. *World Development* 38 (10): 1362–1374.

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6

Macroeconomic model with a behavioral micro-simulation: A sequential methodology

Jann Lay

1 Introduction

Analyzing the poverty and distributional impact of macro events requires understanding how shocks or policy changes on the macro level affect household income and consumption. It is clear that this poses a formidable task, which of course raises the question of the appropriate methodology to address such questions. This paper presents one possible approach: A sequential methodology that combines a macroeconomic model with a behavioral micro-simulation. We discuss the merits and shortcomings of this approach with a focus on developing country applications with a short to medium run time horizon.[1]

Most analyses of the poverty and distributional impact of macro shocks have turned to Computable General Equilibrium (CGE) models, which typically incorporate different representative household groups with a given within-group income distribution. Yet, recent empirical findings on distributional change indicate that changes within household groups distributions account for an important share of overall distributional change (Bourguignon et al. 2005a, b). At first sight, an obvious solution to this problem seems to increase the number of household groups, or even to incorporate all households from representative household surveys into

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[1]Davies (2009) reviews applications linking macro models to micro-simulation models in developing and transition country contexts. His focus is on the applicability of different types of such models to specific questions and contexts. A more technical survey including applications is provided by Colombo (2010) who concentrates on alternative methods to link macro and micro models.

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the CGE model. Similarly—yet without providing heterogeneous feedback into the CGE model—micro-accounting techniques on the basis of household survey data that apply changes in factor prices at the individual level using household survey-data could be used to increase household heterogeneity. In an assessment of Russia's accession to the World Trade Organization (WTO), Harrison et al. (2000) however find differences in poverty and distributional outcomes between a model with ten representative household groups and a model with 55,000 households to be negligible.

Such evidence does not imply that household heterogeneity would not matter for a true understanding of the poverty and distributional impacts of macroeconomic shocks. It merely shows that even full heterogeneity of households in terms of factor endowments and consumption patterns does not make a difference in a standard CGE model. Microeconomic evidence on the drivers of changes in income distributions however suggests that applied CGE models (including those combined with household-survey-based micro-accounting models) may fail for a different reason: The importance of individual heterogeneity and decisions taken at the individual level for distributional and poverty outcomes; in other words, the importance of "individual behavior." On the labor market, individual decisions include entry into the labor market, falling into unemployment or switching between sectors or occupations. Of course, CGE models can be extended to include for example unemployment and/or endogenous labor supply. Yet, in order to capture the income distribution implications, decisions would have to be taken by "real" individual household members. This implies to introduce individual "fixed effects" and eventually requires the estimation of structural labor market models (Bourguignon et al. 2005a, b) that would need to be integrated in a general equilibrium framework. The estimation of such structural labor market models is by no means a trivial exercise and embedding them into a general equilibrium framework an additional challenge.[2]

This paper presents a less ambitious and more pragmatic approach. The sequential macro-micro approach that links a macroeconomic model, for example an applied CGE model, to a behavioral micro-simulation model has two distinguishing features. First, it is sequential. A counterfactual scenario is generated in the macro (CGE) model. Then, specific poverty and distribution-relevant link variables, for example wages and employment, are passed to a micro-simulation model. Second, the micro-simulation has behavioral components. For the micro-simulation, individual and household decisions are modeled using microeconometric techniques on household and employment survey data. Through the micro-simulation, the combined model hence incorporates individual "fixed effects" into the analysis.

The paper is structured as follows. We first outline some important characteristics of macro models used as part of a sequential model and present a stylized specification of a labor market that produces the link variables for our illustrative macro-micro model. We then provide a simple representation of household income

[2]See Blundell and MaCurdy (1999) for a survey of structural labor supply models and Creedy and Duncan (2002) for a discussion of their application in micro-simulation models. See Cogneau (2001) and Cogneau and Robilliard (2001) for attempts to integrate such models into general equilibrium models.

generation that forms the core of the of our prototype behavioral micro-simulation. We describe the simulation mechanics of the micro model. The next section presents two applications of this approach before we assess its strengths, weaknesses, and challenges. The final section concludes.

2 A Stylized Macro-Micro Model with a Behavioral Micro-simulation

2.1 *The Macro Model and the Link Variables*

The sequential approach presented in this paper requires a macro model that produces changes in distribution and poverty-relevant (aggregate) variables that are passed to a micro-simulation model. These variables, which we label "link variables," are prices and quantities on factor and goods markets. Link variables from factor markets include real wages for different types of labor, returns to land and different types of capital. Factor quantities, for example the sectoral composition of labor, may also be passed from a macro model to a micro-simulation. Finally, goods prices and quantities may operate as link variables. The developing country applications presented in this paper use applied trade-focused CGE models.[3] Yet, other types of macro models with very different foci and features, including other forms of general equilibrium models (real business cycle models, and stochastic dynamic general equilibrium models) and macroeconometric models, may be more suitable in different contexts and for different questions. The illustrative framework presented in the following is general enough to allow the reader to imagine the application of a sequential macro-micro approach using very different models both at the macro and micro level, and different link variables.

If a macro model is built as part of a sequential macro-micro model, its labor market specification is the key component and will have to be compatible with the micro-simulation model that we present below. The following representation of a labor market should be thought of as being embedded, for example, in an applied multisectoral CGE model that distinguishes between formal and informal production sectors. The associated labor markets are assumed to exhibit structural imperfections with different clearing mechanisms for these sectors. For the simplicity of exposition, we abstract from other factors of production and assume that the formal and informal sector produce the same good. Let total employment be fixed and assume that factors are fully employed. Hence, total employment will be the sum of formal and informal employment, $L = L^f + L^{if}$. In a simple neoclassical world with full mobility of labor between formal and informal sectors, wages in the formal and informal sectors, which produce with different technologies ($f_f(L^f), f_{if}(L^{if})$), will be the same. Employment in formal and informal sector, respectively, and hence the

[3]See Robinson (1989) for a survey and van der Mensbrugghe (2003) and Lofgren et al. (2002) for standard applied model in the tradition of Dervis et al. (1982).

formal labor share in this economy will be determined by the equation of marginal labor products in formal and informal sectors, as expressed in Eq. (1).

$$\frac{w^f}{p} = \frac{w^{if}}{p} = f'_f\left(L^f\right) = f'_{if}\left(L^{if}\right) \tag{1}$$

Now assume that different wage setting mechanisms exist: In the formal sector, wages are rigid, for example due to the presence of bargaining by trade unions or efficiency wages. This rigidity can be represented by a "wage curve," as in Eq. (2) where the real formal sector wage becomes a function of the ratio of formal to informal employment.

$$\frac{w^f}{p} = g\left(\frac{L^f}{L - L^f}\right) \tag{2}$$

Without unemployment, the informal sector will now absorb the remaining workforce and the informal sector wage will adjust such that labor demand by the informal sector equals "residual" labor supply. This is depicted in Fig. 1 below where Ec illustrates the competitive equilibrium and wc/p0 the corresponding wage. With WC, the wage curve, the equilibrium wage and employment levels are represented by E_0. The formal sector wage w_0^f/p_0 will now be higher than the informal sector wage w_0^{if}/p_0. Accordingly, formal sector employment L_0^f will be lower than in the competitive case L_c^f.

Real wages and employment in formal and informal sector, respectively, constitute the link variables in our illustrative macro-micro model.

$$\frac{w^f}{p}, \frac{w^{if}}{p}, L^f, L^{if}$$

We now consider a policy experiment that shifts formal labor demand and leads to a new equilibrium in E1. The formal sector wage increases to w1f/p1 and formal employment to L_1^f. The informal sector wage will increase as well from w_0^{if}/p_0 to w_1^{if}/p_1. Hence, the counterfactual values for our link variables[4] that will be passed to the micro-simulation will be

$$\frac{w_1^f}{p_1}, \frac{w_1^{if}}{p_1}, L_1^f, L_1^{if}.$$

[4]With real data, the base values for wages and employment levels will typically not be empirically consistent between the macro model, i.e. the SAM, and the micro-simulation model. This inconsistency is "resolved" by passing relative changes from the macro to the micro model. In the simple representation here for example an x percent increase in formal employment and a y(z) percent increase in formal (informal) sector wages.

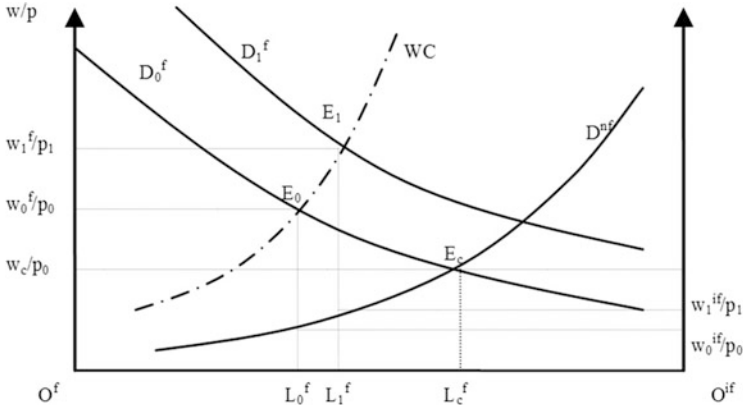

Fig. 1 Formal and informal labor markets. Source: Authors compilation

2.2 A Prototype Income Generation Model: The Micro-simulation

This section describes a prototype micro-simulation model that can be used in combination with the above CGE model to simulate the poverty and distributional impacts of shocks. The basis of the micro-simulation is a household income generation model that needs to be compatible with the above CGE model. For good reasons, we avoid the term consistency here and refer to compatibility instead, as the macro and micro models will not be strictly consistent, neither theoretically nor empirically. We will return to this very important issue in more detail later. The household income generation model is estimated from household survey data with individual-level employment information.

In the micro-simulation, we hence model the household income generation process.[5] This implies that individuals make occupational choices and earn wages or profits accordingly. These labor market incomes plus exogenous other incomes, such as transfers and imputed housing rents, comprise household income. The components of the income generation model are thus an occupational choice and an earnings model. In the choice model, individual agents can choose between wage-employment and self-employment.[6] We thus ignore labor market

[5]The following section borrows from Robilliard et al. (2002). A more detailed discussion of a similar labor market specification can be found in Alatas and Bourguignon (2005).

[6]We will use self-employment and informal sector employment interchangeably.

participation choice in this illustrative model. The occupational choice model is assumed to be slightly different for household heads other household members. Once occupational choices are made, earnings are generated accordingly either in the form of wages or as profits for the self-employed. Being self-employed means being part of what might be called a "household-enterprise," in which all self-employed members of a household pool their incomes. The wage-employment market is segmented: the wage setting mechanisms are assumed to differ for skilled and unskilled labor as well as for females and males, which implies that there are four wage labor market segments.

The following set of equations describes the household income generation model. Household income Y_{hh} is earned by k_{hh} members, who are (and remain) active on the labor market [Eq. (3) below]. They are active either in the formal (with $DF_i = 1$, a dummy variable for formal sector employment) or informal sector ($(DF_i - 1)(-1) = 1$ if $DF_i = 0$) and earn the corresponding wages w_i^f, w_i^{if}. In addition, the household receives an exogenous nominal income $\bar{y}_{hh}$, for example transfers or remittances. All these components are real values, i.e. deflated with prices p. In practice, p will be assumed to be one in the initial situation. Per capital income y_{hh} is obtained by dividing household income by household size $Y_{hh}/hsize$ so that $(y_1, y_2, \ldots, y_n)$ denotes the distribution of income when each observation is weighted with household size.

$$Y_{hh} = \frac{1}{p} \sum_{i=1}^{k_{hh}} \left(w_i^f DF_i + w_i^{if} (DF_i - 1)(-1) + \bar{y}_{hh} \right) \tag{3}$$

Individual occupational choices—between informal and formal activities—can be described by the following functions, which are assumed to be different for household heads (h) and other household members (o). We suppress the individual index here. Equation (4) shows that the household head's probability of being employed in the formal sector is a function of a linear expression with a constant term c^h and personal and household characteristics X^h, which can include for example education, age, and households composition variables.

$$P\left(DF^h = 1 | X^h\right) = g^h\left(c^h + X^h \alpha^h\right) \tag{4}$$

The choices of other household members are assumed to depend not only on their own individual characteristics X^o, but also on the household head's occupational choice.

$$P\left(DF^o = 1 | X^o, DF^h\right) = g\left(c^o + X^o \alpha^o + \gamma^o DF^h\right) \tag{5}$$

Equations (6) and (7) express wages w in the formal (f) and informal (if) sectors, respectively, in log-linear form with X, a vector of personal characteristics, and u, a random error.

$$\ln \frac{w^f}{p} = c^f + X\beta^f + u^f \tag{6}$$

$$\ln \frac{w^{if}}{p} = c^{if} + X\beta^{if} + u^{if} \tag{7}$$

The model just described gives the household income as a non-linear function of observed and unobserved individual and household characteristics. This function depends on two sets of parameters, which include the parameters of the wage equations for informal and formal activities and the parameters in the utility associated with different occupational choices for household heads and other family members. The occupational choice equations as well as the corresponding wage equations can be estimated from standard household survey data. Estimating Eqs. (4) and (5) using discrete choice models (with dichotomous choices hence logit or probit models) and (6) and (7) using Ordinary Least Squares (OLS) (or other adequate estimation techniques[7]) yields the following parameter vector:

$$\left(\widehat{c}^h, \widehat{\alpha}^h, \widehat{c}^o, \widehat{\alpha}^o, \gamma^o, \widehat{c}^f, \widehat{\beta}^f, \widehat{c}^{if}, \widehat{\beta}^{if}\right).$$

In addition, we obtain $\widehat{u}^f$ and $\widehat{u}^{if}$ as observed residuals from the wage equations. However, we only observe formal wages for individuals employed in the formal sector. As the micro-simulation will allow individuals to switch between formal and informal activities, we simulate a residual for the non-observed wage, here by a random draw from a normal distribution with the respective (formal or informal) observed variance.[8] We face a similar problem in the latent utility models necessary to estimate Eqs. (4) and (5). In these models, residuals cannot be observed and are hence generated from the distribution underlying the respective model, here either a normal (probit) or logistic (logit) distribution. Residuals have to be drawn consistent with the observed occupational choice, i.e. the utility an observed formal wage earner relates to formal employment has to be higher than the utility associated with informal employment. Statistically, this implies to draw these residuals conditional on the observed choice. These simulated residuals are denoted $u1_i$ and $u0_i$. With

[7]Selection bias is a problem in estimating earnings equations in different sectors/occupations (corresponding to different labor market choices) that is difficult to resolve. We return to this point later.

[8]This number does not have to be a random number. It may be reasonable to assume that the observed residual has important informational content with regard to unobserved characteristics, such as ability. A possible alternative to a random draw is then to scale the observed residual in accordance with the observed variances of formal and informal wages, respectively.

ind, an indicator function that assumes a value of 1 (0) if the condition in brackets is (not) fulfilled, we thus have.

$$DF_i^h = ind\left(\widehat{c}^h + X_i^h\widehat{\alpha}^h + u1_i > u0_i\right) \tag{8}$$

$$DF_i^o = ind\left(\widehat{c}^o + X_i^o\widehat{\alpha}^o + \gamma^o DF^h + u1_i > u0_i\right) \tag{9}$$

Here DF_i^h and DF_i^o will hence assume their observed values. This implies that the sum of these two dummies—defined either for household heads or other household members—over all individuals will give the total number formal sector employees L_0^f, consistent with the initial value of this link variable from the macro model. This is illustrated in Eq. (10).

$$L_0^f = \sum_{hh} \sum_{i}^{k_{hh}} \left(DF_i^h \oplus DF_i^o\right) \tag{10}$$

Accordingly, average wages in the formal sector can be expressed as follows.

$$\frac{w_0^f}{p} = \frac{\sum_{hh} \sum_{i}^{k_{hh}} \left[\left(DF_i^h \oplus DF_i^o\right) \cdot \exp\left(\widehat{c}^f + X_i\widehat{\beta}^f + \widehat{u}_i^f\right)\right]}{L_0^f} \tag{11}$$

Similar expressions can be written down for informal sector employment and the corresponding wage, such that we can replicate all link variables in the initial equilibrium $w_0^f, w_0^{if}, L_0^f, L_0^{if}$. Remember that this replication is based on the observed characteristics of the individuals (all X), unobserved and partially simulated characteristics (all u), and the estimated parameters.

Based on this micro replication of the initial situation, we can now micro-simulate the distributional and poverty implications of the changes in the link variables given by the macro model. In the simulation, the link variables $\frac{w_1^f}{p_1}, \frac{w_1^{if}}{p_1}, L_1^f, L_1^{if}$ will hence be used as target values. This implies that individual earnings and occupational choices have to change such that they reproduce these targets on the aggregate level. There are a number of ways how this can be achieved. Obviously, the required individual changes in occupational choices can be obtained by varying the coefficients or the observed or unobserved individual characteristics. A typical choice in applied micro-simulation models is to vary the constant(s). Hence, the chosen parameters are adjusted and occupational choices change accordingly, until the results of the micro-simulation are consistent, at an aggregate level, with the given aggregates. Formally, the following constraint describes the consistency requirement where c_1^h is the constant in the heads' occupational choice equation that is consistent with L_1^f.

$$L_1^f = \sum_{hh} \sum_{i}^{k_{hh}} \left[\left(ind\left(c_1^h + X_i^h \widehat{\alpha}^h + u1_i > u0_i \right) \right) \oplus \left(ind\left(\widehat{c}^o + X_i^o \widehat{\alpha}^o + \gamma^o DF_1^h + u1_i > u0_i \right) \right) \right] \tag{12}$$

Varying only the constant $\widehat{c}^h$ (to c_1^h) implies that we assume that the macro shock only induces household heads to switch occupation. Other household members' occupational choices are only affected through the possible change in the head's occupational choice, i.e. in the case of $DF_1^h \neq DF^h$. As this kind of behavior may not be realistic, we can alternatively assume that the constants of both the heads and other household members vary. However, without an additional restriction, changes in the two constants cannot be uniquely determined. A possible solution is to add a variable Δ to the constant term. In practice—when such equations are solved for real households from a household survey—we will typically be able to find a unique solution for Δ in Eq. (13).

$$L_1^f = \sum_{hh} \sum_{i}^{k_{hh}} \begin{bmatrix} \left(ind\left(\left(\widehat{c}^h + \Delta \right) + X_i^h \widehat{\alpha}^h + u1_i > u0_i \right) \right) \\ \oplus \left(ind\left(\left(\widehat{c}^o + \Delta \right) + X_i^o \widehat{\alpha}^o + \gamma^o DF_1^h + u1_i > u0_i \right) \right) \end{bmatrix} \tag{13}$$

Using either approach to adjust the constant (or both constants) in the occupational choices, will thus enable us to replicate the changes in formal as well as formal employment given by the CGE model. Our very simple income generation model allows us to proceed step-wise. We first solve for changes in occupational choices, and simulate wages in the next step. The reason is that wages do not enter the occupational choices of individuals, as they might in a more complex—or structural—income generation model. However, changes in occupational choices enter the equation for aggregate wages, as the (observed and unobserved) characteristics of the individuals in the respective sectors change. As in the case of occupational choices, we can vary the constants in the respective sectors to equate wages given by the CGE model and those in the micro-simulation.[9] For the formal sector, this requires Eq. (14) to hold with c_1^f, the new formal sector wage equation constant.

$$\frac{w_1^f}{p_1} = \frac{\sum_{hh} \sum_{i}^{k_{hh}} \left[\left(DF1_i^h \otimes DF1_i^o \right) \cdot \exp\left(c_1^f + X_i \widehat{\beta}^f + \widehat{u}_i^f \right) \right]}{L_1^f} \tag{14}$$

The equation for the average informal sector wage can be derived accordingly. The solutions for the constants in the choice Eq. (13) and the wage Eq. (14) can be obtained using numerical solution algorithms, for example Gauss-Newton techniques. With counterfactual occupational choices and corresponding wages DF_1, w_1,

[9]Alternatively, we may choose to vary the coefficient for education implying that we expect the macro shock to affect wages through its impact on returns to education.

we can now compute the counterfactual household income Y_{1hh}, as illustrated in Eq. (14). We assume that exogenous transfers $\bar{y}_{hh}$ are constant in nominal terms.

$$Y_{1hh} = \frac{1}{p_1} \sum_{i=1}^{k_{hh}} \left(w_{1i}^{f} DF_{1i} + w_{1i}^{if} (DF_{1i} - 1)(-1) + \bar{y}_{hh} \right) \; with \; DF_1 \\ = DF_{1}{}_{i}^{h} \oplus DF_{1}{}_{i}^{o} \tag{15}$$

With constant household size these counterfactual household incomes now yield a counterfactual income distribution that can be described by $(y_{11}, y_{12}, \ldots, y_{1n})$.

3 Applications

The above prototype macro-micro model is intended to provide an introduction into the basic mechanics of a macro-micro model with a behavioral micro-simulation. Which macro model to choose and which transmission channels to highlight eventually depends on the research or policy question and the context, in which it is placed. The two applications that we present in the following are based on recursive-dynamic, trade-focused national CGE models.[10] The first application examines the possible poverty impacts of a Doha round scenario of further multilateral trade negotiations for the case of Brazil. The second assesses the poverty and distributional implications of the Bolivian gas shock.

As in the above model and most developing country applications, the focus is on the labor market, as reflected by the link variables that include average wages in different labor market segments, employment levels and the occupational composition of employment. The respective specification of the labor market represents the transmission channels considered to be of particular relevance for the policy and shock under consideration. The Brazilian model focuses on movements between agricultural and non-agricultural sectors, while the Bolivian model concentrates on formal-informal segmentation in the urban labor market. In both applications, the labor market is further segmented along skill levels.

The micro-simulation models used in the subsequent applications share the reduced-form character of the above prototype model. Employment volumes in the respective labor market segments, for example unskilled agricultural employment, and wages are adjusted according to the results from the macro model. These adjustments are not triggered by individual responses to prices, for example relative wages—as they would in a (more) structural labor market model. As above, adjustments are obtained by changing the parameters of the estimated household income generation model.

[10]See van der Mensbrugghe (2003) for a technical description of the basic characteristics of the CGE model used in both applications.

3.1 The Poverty Impacts of Trade Liberalization in Brazil

Using this type of sequential model, Bussolo et al. (2006) ex-ante assess the poverty and distributional impacts of different uni- and multilateral trade liberalization scenarios for Brazil.[11] The labor market specification of the CGE model distinguishes between skilled and unskilled labor. While skilled workers are fully mobile across sectors, the labor market for the unskilled is segmented between agriculture and non-agriculture. This dual labor market for unskilled workers is modeled following a simple Harris-Todaro specification where the decision to migrate is a function of expected income in the non-agricultural sectors relative to the expected income in the agricultural sectors.

The micro model is linked to the macro model through changes in the following set of variables: First, changes in agricultural and non-agricultural labor income of unskilled labor; second, changes in labor income of skilled labor; third, changes in the sectoral (agriculture vs. non-agriculture) composition of the unskilled workforce. In addition, the micro-simulation takes into account that unskilled and skilled labor supplies grow at different rates. These rates—also assumed to be exogenous in the CGE model—are derived from past trends of labor supply growth in the respective categories.

In accordance with the structure of the CGE model, the micro model thus simulates the decision to move from agriculture into non-agricultural sectors (or vice versa) only for unskilled workers. This simulation is based on a sectoral mover-stayer model that is estimated for heads and non-heads separately—as in the above prototype model. For this estimation, Bussolo et al. (2006) make use of a distinguishing feature of the PNAD.[12] In contrast to many other household surveys, the PNAD provides information on employment histories, which allows the authors to identify movers between sectors and their characteristics at the time of moving. These characteristics include the type of land right the movers held or whether they were self-employed before they moved out of agriculture. These characteristics enter as explanatory variables into the mover-stayer model. As in the prototype model, the household income generation model is completed by Mincer-type wage equations for unskilled labor in agriculture and non-agriculture as well as for skilled labor. Individual labor incomes are aggregated as described above.

The mover-stayer model can be used to illustrate the behavioral content of the micro-simulation model. For example, Bussolo et al. (2006) find a strong negative influence of own landholdings on the propensity to move. In contrast, higher educational achievements are making individuals more likely to move into non-agricultural employment. In addition, occupational choices of members of the same household are strongly correlated. In the simulation, individuals with no

[11]Changes in global prices and trade flows following multilateral liberalization scenarios are derived from global models. For details see Bussolo et al. (2006).

[12]The Pesquisa Nacional por Amostra de Domicílios (PNAD) is a regularly conducted representative household survey

landholdings, better education and—in case of non-household heads—and moving household heads will hence be the first ones to move from agriculture into non-agricultural employment. Which individuals (landless, but better educated) move first, can make a difference in distributional outcomes. The movers' characteristics will determine the composition of those who remain in agriculture (more with own landholdings, but less educated) as well the earning prospects in the non-agricultural sector (ceteris paribus better with better education).

With these components, the micro-simulation involves two steps: First, unskilled labor moves out of agriculture until the new share of unskilled labor in agriculture given by the CGE is reproduced. Second, wages/profits are adjusted according to the CGE results taking into account the sectoral movements of unskilled labor from agriculture into non-agricultural sectors. Adjustments are achieved through the same procedures as in the above prototype model, i.e. the computation of new constants in the choice and wage equations, respectively, using numerical solution algorithms.

The analysis suggests that the economic effects of multilateral liberalization are rather limited for Brazil. Accordingly, poverty would remain largely unaffected by such reforms. In contrast, a full liberalization scenario implies quite substantial welfare gains that are concentrated among some of the poorest groups of the country, in particular those in agriculture. This scenario is also most interesting from a methodological viewpoint, as it highlights the benefits of a behavioral micro-simulation. Under full liberalization, the rural poor benefit more than proportionately, a result driven—on the macro level—by an export boom in agriculture and agricultural processing industries, growing labor demand and associated higher wages. However, following full liberalization, a larger number of workers remain in agriculture compared to the baseline scenario. Given that moving out of agriculture may substantially improve the income situation of a household, one may expect full liberalization to weaken poverty reduction, an expectation supported by the observation that moving households are on average poorer than those remaining in agriculture (for example because they are landless). However, this is not the case, as the gain in agricultural incomes more than compensates the reduced benefits from lower migration flows (for example because they are better educated than those who stay in agriculture).

3.2 The Poverty Impacts of the Bolivian Gas Boom

Lay et al. (2008) examine the poverty effects of the gas boom Bolivia experienced in the late 1990s and early 2000s. Their analysis attempts to disentangle the effects of the resource-boom/bust from other shocks that the Bolivian economy experienced at the same time. The market for unskilled labor is segmented between rural and urban areas. The two segments are linked through rural-urban migration, modeled as in the Brazilian case as a function of the corresponding wage differential. In contrast, skilled labor is assumed to be fully mobile across all production sectors. Within the urban economy, unskilled workers are mobile between formal and informal sectors, but wage differentials observed in the base period are assumed to persist. These differentials point to systematically lower labor productivity in informal sectors.

Almost as in the prototype model, the macro model is linked to the micro-simulation through the following set of variables: (1) the share of unskilled workers in the formal sector, (2) the share of skilled workers in the formal sector, (3) mean wages for skilled workers, (4) mean wages for unskilled workers, and (5) mean informal profits.[13] Informal profits are understood as mixed income received by self-employed workers. Accordingly, they are calculated as the sum of skilled and unskilled labor income as well as informal capital income.

The two basic components of the income generation model in the Bolivian application are again a model of occupational choices that represents the choice between formal and informal employment as well as earnings functions that correspond to the respective sector of employment. Employment is assumed to be informal if the individual is self-employed/non-remunerated household member and/or works in an enterprise with less than five employees. If individuals happen to be in (or switch to) the formal sector they are assumed to earn a wage, whereas individuals in the informal sector are assumed to be (or become) part of a household enterprise and contribute to the profits earned by this enterprise. The choice between informal and formal activities is modeled separately for household heads, spouses, and other household members. In contrast to the above specifications, the equations of the choice model are interrelated through the head's wage (and choice) that enters the occupational choice model of spouses and other household members. Again, occupational choices are hence assumed to be sequential with the household head deciding first. In line with the CGE model, the micro-simulation distinguishes between unskilled and skilled labor. Separate wage equations for skilled and unskilled labor, respectively, hence describe earnings for individuals employed in the formal sector.[14] The micro-simulation again adjusts the constants to produce counterfactual occupational choices, earnings, and, eventually, household incomes and the corresponding distribution of income.

As in the Brazilian case, the micro-simulation reveals the importance of individual characteristics that determine the sign and the strength of distributional change. Lay et al. (2008) find that—for both unskilled and skilled labor—the very poor are affected most by increasing informality. These results can be rationalized by looking at, first, who moves into informality and, second, the size of the income loss for movers relative to both their initial income and the income losses incurred by other individuals. The size of the income loss depends on individual

[13]The authors note on formal profits (Lay et al. 2008): "Although formal profits account for an important share in value added, they are not passed to the micro-simulation for two reasons. First, most formal profits are retained and invested. Second, capital income is likely to be measured very poorly in household surveys. As formal profits increase considerably during the gas boom, we may systematically ignore an inequality-increasing factor."

[14]Rural incomes are taken into account through a simple micro-accounting exercise.

characteristics (as the returns to these characteristics differ between formal and informal activities) and on whether an individual joins an already existing household enterprise or establishes a new one. The estimation, which underlies the micro-simulation, shows that less educated younger (and hence poorer) individuals tend to move into informality first. With regard to the size of the income losses, the estimation results for wages and profit functions indicate that the income loss of moving into informality is higher for more educated individuals, at least in absolute terms, when they move into an existing household enterprise. However, it may also happen that establishing an informal enterprise increases earnings for a skilled individual—conditional of course on other individual characteristics. For an unskilled individual, by contrast, moving into informality will always imply an income loss.

Overall, Lay et al. (2008) find that the gas boom has both unequalising and equalising distributional impacts that tend to offset each other. As net distributional change is limited, growth generated by the boom also reduces poverty and the boom hence does not completely bypass the poorer parts of the Bolivian population. Poverty reduction with little distributional change can be observed despite increasing informality. Additional stylized micro-simulations by Lay et al. (2008) illustrate that lower formal employment can lead to a significant rise in urban poverty and that the very poor are affected most by increasing informality. Yet, considerable overall increases in informal profits compensate this possible negative impact.

3.3 Strengths and Weaknesses

The macro-micro approach presented above and illustrated by the two case studies brings together two strands of literature, macro models, here applied CGE models, on the one hand, and microeconometric poverty and distributional analyses, on the other, which were largely separated from each other. While CGE analyses tend to suffer from being too stylized and not being well informed by micro data, poverty and distributional analyses are often merely descriptive and lack an assessment of the causes of distributional change and the related transmission channels. The sequential approach that combines a CGE model and a behavioral micro-simulation attempts to get the best out of these two "modeling worlds."[15]

A general advantage of a sequential over more complex models is its tractability: While it remains tractable both at the macro and the micro level, it still allows for sufficiently detailed and disaggregated analyses. This is of course more so when the micro model has behavioral components. The case studies above have illustrated the value added of introducing behavior or "individual fixed effects" into the micro-simulation model. In such a micro-simulation, the poverty and distributional impact of policies, as in reality, depend on the characteristics of the households or even individuals.

[15]This section borrows heavily from Lay (2007).

However, getting the best of two fairly different modeling worlds comes at the cost of a lack of both theoretical and empirical consistency. Sequentially combining a macro and micro model typically implies the imposition of a number of ad-hoc assumptions that are not satisfying from a theoretical perspective. While the "degree of consistency" between the macro and the micro model however differs between applications, the combined model will lack the theoretical consistency of a general equilibrium model and it is difficult—if not impossible—to resolve all the data discrepancies between national accounts, on the one hand, and household survey data, on the other. Individual responses from estimated relationships may not be conforming to theoretical expectations and the combined model may have leakages—in contrast to the consistent system of flows of an applied CGE model. Theoretically, changes in the behavior of economic agents are driven by relative price changes, whereas the micro-simulation typically only features a reduced-form representation of labor market behavior where prices do not appear as explanatory variables. Empirically, problems arise from the large differences in national accounts and household data, in particular with regard to labor value added, although some authors, e.g. Robilliard et al. (2002), manipulate survey weights to reach "empirical consistency."

Furthermore, quite a few economists may argue that the combination of an applied CGE model with a micro-simulation based on a reduced-form labor market representation may not be a good idea after all. Both types of models suffer from serious shortcomings and combining the two may compound these problems by adding new problems and distracting the researcher from the shortcomings of the "single" models. This is a critique that should be taken seriously. From our own experience in building sequential models, we have become increasingly aware that the additional problems that arise from combining the models, for example in terms of empirical consistency, leave less time for the scrutiny needed to estimate a household income generation model from household survey data or less time to do the sensitivity analyses so often called for in applied CGE analyses (Harrison et al. 1993). We therefore dedicate the following paragraphs to the weaknesses of the single components of a combined macro-micro model without, however, forgetting about their strengths.

The shortcomings of the income generation models are very specific to the respective application and they are discussed at length elsewhere, for example in Bourguignon et al. (2005b). We just want to highlight two typical problems: Selectivity and parameter validity. Estimating earnings equations that correspond to different sectoral or occupational choices entail selection problems. In the presence of unobserved heterogeneity, for example in terms of entrepreneurial ability, it is fairly likely the same unobserved characteristics that make you choose a specific sector also determine the earnings in the respective sector. This selection on unobservables biases the coefficients of an Ordinary Least Squares estimation of the respective equations and would have to be accounted for. It is not trivial to correct for selectivity bias, although the so-called Heckman correction or one of its variants is very common in applied work. To be empirically valid, however, an instrument is needed that explains the sectoral choice, but not earnings in the respective sectors. Such a variable is typically very difficult to find.

There may also be reasons for challenging the validity of the estimated parameters in the household income generation model. Typically, the behavioral equations, e.g. those governing occupational choices, are estimated from cross-sectional data. It is hence assumed that the observed variation in behavior between individuals is used to simulate behavioral change of (other) individuals in time, for example in the Bolivian case study.[16] The Brazilian model relies on employment histories and therefore avoids this problem, but the type of information used reflects to a certain extent short-term behavior. Even if panel data was available, constant parameters would have to be assumed for the simulation period, which apparently becomes an increasingly problematic assumption the longer time horizon of the analysis.

Despite these problems, micro-simulation models based on household income generation models provide a powerful tool to assess the final distributional impact of changes in "distributional drivers," as they reflect the welfare implications of discrete changes in individual behavior, such as labor market entry or sectoral movements. The impact of individual transitions out of agriculture in the Brazil study demonstrates the possible magnitude of these discrete individual changes on household welfare. Finally, it should be stressed that the household income generation models of the type presented in this paper have been shown to do fairly well in reproducing historical patterns of poverty and distributional change (Lay 2007).

The applications from above both use CGE models to trace the transmission channels and quantify the magnitude of the effects of the respective shock. Although widely applied, these models have been criticized for a number of reasons. Analytically, most CGE models rely on the neoclassical framework, although a number of structural characteristics and rigidities are incorporated in most developing country applications. Whether and how structural characteristics and rigidities are taken into account differs between country applications and the research question at hand, as illustrated by the case studies above. Two areas where applied CGE models do not capture the economic realities very well, are the rural and the urban informal sector. It is well known that neoclassical price setting and supply responses in agriculture, is at best a very rough approximation of the reality in most developing countries. In addition, disaggregated input-output data for agriculture are typically not available and agricultural surveys suffer from a lot of problems related to measurement, seasonality, and temporary shocks. Furthermore, the insights from agricultural household models regarding non-separability of production and consumption in rural households (Singh et al. 1986) have not yet entered standard models.[17] More research effort also needs to be dedicated to modeling the informal urban sector. Its heterogeneity in terms of technology,

[16]Although this assumption seems to be very restrictive, it can be plausibly made e.g. in the context of occupational choices, which are explained mainly by individual educational attainment, age, and household composition variables.

[17]See Lofgren and Robinson (1999), who integrate a rural household model into a standard CGE model, for an exception.

import penetration, export orientation, and linkages to the formal sector are not reflected in applied CGE models.

However, even with all these improvements, eventually the results of a CGE model will be driven by the assumptions made.[18] Econometricians challenge the empirical relevance of applied CGE models on grounds of the calibration technique based on very restricted functional forms, typically (nested) CES functions. McKitrick (1998) shows the choice of the functional form to make a considerable difference in the results. Yet, in the developing country context, data to estimate these functions is typically not available and the calibration approach overcomes these data restrictions. Furthermore, it is well known that model results are very sensitive to the assumed trade and production elasticities. Harrison et al. (1993) therefore suggest to perform systematic sensitivity analyses and to provide confidence intervals for the results. Such sensitivity analyses, however, are not common in applied work.

Finally, an assessment of the validity of CGE model results also depends on the purpose of the model. If the analysis is expected to provide a precise numerical estimate of the effects of a specific policy change, the above criticisms have to be taken very seriously. In contrast, if CGE models are seen as a rather stylized, yet empirically underpinned, analytical tool to better understand the transmission channels of a shock through counterfactual analysis and approximate their relative importance, the critique is less relevant. This is not to say that the numbers resulting from CGE models are without meaning. They should be taken as the results of a model, given a specific set of assumptions.[19]

4 Conclusions

We have presented and discussed a sequential methodology that combines a macroeconomic CGE model with a behavioral micro-simulation. More specifically, we have shown how micro-simulations based on household income generation models allow the researcher to incorporate individual fixed effects into macro-micro analysis. This is achieved by linking aggregate drivers of poverty and distributional change, such as wages and sectoral employment, to a micro-simulation that is being "forced" to reproduce the changes given by the macro

[18]See De Maio et al. (1999) and the reply by Sahn et al. (1999) for an exemplary discussion on specific aspects of CGE models applied to developing countries. These aspects include the macroeconomic and labor market closures as well as the assumption on price setting mechanisms. De Maio et al. (1999) challenge the results of a study by Sahn et al. (1997) on the poverty impacts of structural adjustment in Sub-Saharan Africa as reflecting only the assumptions made in the CGE models, and not reality.

[19]In some CGE applications, including some of those presented in this paper, there is a tendency to treat CGE results as forecasts.

model. We also explain common empirical operationalizations of this link and the micro-simulation procedures commonly used in the literature.

The presented sequential macro-micro approach has been illustrated using two case studies that examine the poverty and distributional impact of macroeconomic shocks, the typical research and policy research to which this kind of model is and should be applied. Examples from these applications have demonstrated the importance of individual heterogeneity in the analysis of these shocks and have underpinned the value added of such methods with behavioral components.

Beyond its ability to capture individual heterogeneity, one of the merits of the approach is its flexibility. However, this flexibility—embodied in a number of fairly ad-hoc assumptions—comes at the cost of theoretical inconsistency. While the macro models rely on consistent theoretical frameworks, the reduced-form models underlying the micro-simulation do not fulfill the requirements, for example in terms of functional forms. Furthermore, empirical inconsistency between national accounts and household survey data that becomes apparent in macro-micro applications is known to be notorious (Round 2003; Robilliard and Robinson 2003).

Finally, we have argued that combining an applied CGE model and a micro-simulation model does not resolve the problems associated to either of those techniques. These problems include a number of typical microeconometric problems that arise from the estimation of income generation models, the basis of the micro-simulation model. Similarly, CGE models suffer from well-known, often-discussed, but less frequently addressed shortcomings. Despite these problems and challenges, the alternative to the proposed models can only be a general equilibrium model that incorporates heterogeneous individuals. As argued in the introduction, researchers are still far from building an applied model based on a micro-based general equilibrium theory. On the route to building such a model, it may be helpful to improve existing macro-micro models through more and better validation exercises. In addition, micro-simulations may also be linked to more different types of general equilibrium models with a more explicit focus on the operation of labor markets.

References

Alatas, V., and F. Bourguignon. 2005. The evolution of income distribution during Indonesia's fast growth, 1980–1996. In *The microeconomics of income distribution dynamics*, ed. F. Bourguignon, F.H.G. Ferreira, and N. Lustig. Washington, DC: The World Bank and Oxford University Press.

Blundell, R., and T. MaCurdy. 1999. Labor supply: A review of alternative approaches. In *Handbook of labor economics*, ed. O. Ashenfelter and D. Card, vol. 3A, 1560–1695. Philadelphia, PA: Elsevier.

Bourguignon, F., A.S. Robilliard, and S. Robinson. 2005a. Representative vs. real households in the macroeconomic modeling of inequality. In *Frontiers in applied general equilibrium modeling*, ed. T.J. Kehoe, T.N. Srinivasan, and J. Whalley. Cambridge: Cambridge University Press.

Bourguignon, F., F.H.G. Ferreira, and N. Lustig. 2005b. A synthesis of the results. In *The microeconomics of income distribution dynamics*, ed. F. Bourguignon, F.H.G. Ferreira, and N. Lustig. Washington, DC: The World Bank and Oxford University Press.
Bussolo, M., J. Lay, and D. van der Mensbrugghe. 2006. *Structural change and poverty reduction in Brazil: The impact of the Doha Round*. World Bank Policy Research Paper 3833. Washington, DC: World Bank.
Cogneau, D. 2001. *Formation du Revenue, Segmentation et Discrimination sur le Marché du Travail d'une Ville en Développement: Antananarivo Fin de Siècle*. DIAL DT/2001/18.
Cogneau, D., and A. S. Robilliard. 2001. Gr*owth, distribution and poverty in Madagascar: Learning from a microsimulation model in a general equilibrium framework*. TMD Discussion Paper 61. Washington, DC: International Food Policy Research Institute.
Colombo, G. 2010. Linking CGE and microsimulation models: A comparison of different approaches. *International Journal of Microsimulation* 3 (1): 72–91.
Creedy, J., and A. Duncan. 2002. Behavioural microsimulation with labour supply responses. *Journal of Economic Surveys* 16 (1): 1–38.
Davies, J.B. 2009. Combining microsimulation with CGE and macro modelling for distributional analysis in developing and transition countries. *International Journal of Microsimulation* 2 (1): 49–65.
De Maio, L., F. Stewart, and R. van der Hoeven. 1999. Computable general equilibrium models, adjustment, and the poor in Africa. *World Development* 27 (3): 453–470.
Dervis, K., J. de Melo, and S. Robinson. 1982. *General equilibrium models for development policy*. Cambridge: Cambridge University Press.
Harrison, G.W., R. Jones, L.J. Kimbell, and R. Wigle. 1993. How robust is applied general equilibrium analysis? *Journal of Policy Modeling* 15 (1): 99–115.
Harrison, G., T. Rutherford, and D. Tarr. 2000. Trade liberalization, poverty and efficient equity. *Journal of Development Economics* 71: 97–128.
Lay, J. 2007. Poverty and distributional impact of economic policies and external shocks. Three case studies from Latin America combining macro and micro approaches. In *Goettingen studies in development economics*, ed. H. Sautter and S. Klasen, vol. 18. Frankfurt: Peter Lang.
Lay, J., R. Thiele, and M. Wiebelt. 2008. Resource booms, inequality, and poverty: The case of gas in Bolivia. *Review of Income and Wealth* 54 (3): 407–437.
Lofgren, H., R. Lee Harris, and S. Robinson. 2002. *A standard computable general equilibrium (CGE) model in GAMS*. Microcomputers in Policy Research No. 5. Washington, DC: International Food Policy Research Institute.
Lofgren, H., and S. Robinson. 1999. *To trade or not to trade: Non-separable farm household models in partial and general equilibrium*. TMD Discussion Paper 37. Washington, DC: International Food Policy Research Institute.
McKitrick, R.R. 1998. The econometric critique of computable general equilibrium modeling: The role of functional forms. *Economic Modelling* 15 (4): 543–573.
Robilliard, A.S., F. Bourguignon, and S. Robinson. 2002. *Crisis and income distribution: A micro-macro model for Indonesia*. Washington, DC: World Bank.
Robilliard, A.S., and S. Robinson. 2003. Reconciling household surveys and national accounts data using a cross-entropy estimation method. *Review of Income and Wealth* 49 (3): 395–406.
Robinson, S. 1989. Multisectoral models. In *Handbook of development economics*, ed. H. Chenery and T.N. Srinivasan, 885–947. Philadelphia, PA: Elsevier.
Round, J.I. 2003. Constructing SAMs for development policy analysis: Lessons learned and challenges ahead. *Economic Systems Research* 15 (2): 161–183.
Sahn, D.E., P. Dorosh, and S.D. Younger. 1997. *Structural adjustment reconsidered: Economic policy and poverty in Africa*. Cambridge: Cambridge University Press.
———. 1999. A reply to De Maio, Stewart, and van der Hoeven. *World Development* 27 (3): 471–475.
Singh, I., L. Squire, and J. Strauss, eds. 1986. *Agricultural household models. Extensions, applications, and policy*. Baltimore: The Johns Hopkins University Press.

Van der Mensbrugghe, D. 2003. *Prototype model for real computable general equilibrium model for the state development planning commission*. PR China: Mimeo.

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