INTERNATIONAL FOOD POLICY
RESEARCH INSTITUTE

sustainable solutions for ending hunger and poverty

A member of the CGIAR consortium

IFPRI Discussion Paper 01247

February 2013

Evaluating the Local Economywide Impacts of Irrigation Projects

Feed the Future in Tanzania

Mateusz Filipski

Dale Manning

J. Edward Taylor

Xinshen Diao

Angga Pradesha

Development Strategy and Governance Division

INTERNATIONAL FOOD POLICY RESEARCH INSTITUTE

The International Food Policy Research Institute (IFPRI) was established in 1975 to identify and analyze national and international strategies and policies for meeting the food needs of the developing world on a sustainable basis, with particular emphasis on low-income countries and on the poorer groups in those countries. IFPRI is a member of the CGIAR Consortium.

PARTNERS AND CONTRIBUTORS

IFPRI gratefully acknowledges the generous unrestricted funding from Australia, Canada, China, Denmark, Finland, France, Germany, India, Ireland, Italy, Japan, the Netherlands, Norway, the Philippines, South Africa, Sweden, Switzerland, the United Kingdom, the United States, and the World Bank.

AUTHORS

Mateusz Filipski, University of California, Davis
Department of Agricultural and Resource Economics

Dale Manning, University of California, Davis
Department of Agricultural and Resource Economics

J. Edward Taylor, University of California, Davis
Department of Agricultural and Resource Economics

Xinshen Diao, International Food Policy Research Institute
Deputy Division Director, Development Strategy and Governance Division
X.Diao@cgiar.org

Angga Pradesha, International Food Policy Research Institute
Development Strategy and Governance Division

Notices

¹ IFPRI Discussion Papers contain preliminary material and research results. They have been peer reviewed, but have not been subject to a formal external review via IFPRI's Publications Review Committee. They are circulated in order to stimulate discussion and critical comment; any opinions expressed are those of the author(s) and do not necessarily reflect the policies or opinions of IFPRI.

² The boundaries and names shown and the designations used on the map(s) herein do not imply official endorsement or acceptance by the International Food Policy Research Institute (IFPRI) or its partners and contributors.

Copyright 2013 International Food Policy Research Institute. All rights reserved. Sections of this material may be reproduced for personal and not-for-profit use without the express written permission of but with acknowledgment to IFPRI. To reproduce the material contained herein for profit or commercial use requires express written permission. To obtain permission, contact the Communications Division at ifpri-copyright@cgiar.org.

Contents

Abstract	v
Acknowledgments	vi
1. Introduction	1
2. The Model and Data	2
3. Simulations and Results	6
4. Conclusions and Discussion	14
Appendix A: Supplementary Table	15
Appendix B: Social Accounting Matrix Construction	18
References	19

Tables

2.1—The 13 household types in the LEWIE model	3
2.2—Commodity and factor accounts in the LEWIE model for Morogoro	3
3.1—Potential effect of irrigation project on rice yields	6
3.2—Overview of simulation assumptions and impacts on regional total income	7
3.3—Impacts on production and prices by type of commodity (billion TZS and %)	8
3.4—Weighted average effect on nominal land and capital rents	10
3.5—Effects on nominal wages by district and region	10
3.6—Impact of the irrigation projects on nominal and real incomes	11
3.7—Simulated effects of the irrigation projects under alternative factor supply elasticity assumptions	13
A.1—Model statement	15

Figures

1.1—Situational map of the Kilombero and Mvomero districts	1
2.1—Structure of the Tanzanian LEWIE model and market closures in the simulations	5
3.1—Effects of Simulation 1 on production, disaggregated by district (Kilombero, Mvomero, and others)	8

ABSTRACT

Despite years of development interventions, agricultural productivity in Africa south of the Sahara still trails far behind all other continents, leaving many rural populations in dire poverty. This suggests that our understanding of the impacts of agricultural development projects is still imperfect; perfecting it is likely to be a crucial step in achieving development. Projects that raise agricultural productivity, in addition to directly affecting farmers, can have an impact on local prices, wages, and rents, especially in rural areas of Africa, which tend to be less-than-perfectly integrated with outside markets. Price changes, in turn, transmit project impacts to others within the local economy. This paper presents the findings of a local economywide impact evaluation of Feed the Future irrigation projects in the Morogoro region of Tanzania, using a local economy-wide impact evaluation (LEWIE) simulation model. The findings indicate that these irrigation projects can generate important indirect impacts within the region. The structure of local markets, as well as labor and land availability, shapes project spillovers in ways that point to future directions for development assistance in the region.

Keywords: local economy-wide impact evaluation (LEWIE) model, general equilibrium, rice productivity, irrigation, Tanzania

ACKNOWLEDGMENTS

The authors greatly appreciate David Garber for his supports in providing necessary information about the United States Agency for International Development (USAID) Feed the Future initiatives in Tanzania and the government irrigation project documents, which allow the paper to conduct its analysis. The authors also thank James Thurlow and Karl Pauw for their help in updating Tanzanian national social accounting matrix. The views in this paper are the authors' own and do not necessarily reflect those of USAID or the International Food Policy Research Institute.

1. INTRODUCTION

The intervention considered in this paper consists of irrigation projects implemented under the United States Agency for International Development (USAID) Feed the Future (FTF) Initiative in the Kilombero and Mvomero districts of Tanzania (see Figure 1.1). The primary objective of the projects is to improve agricultural productivity, focusing on rice, maize, and horticulture. According to USAID FTF Tanzania (Feed the Future 2011), the interventions are expected to increase production of rice (the main staple crop in the region) by 25 percent; maize, by 10 percent; and horticulture, by 20 percent. Although irrigation development is the major investment under the projects, new technologies and management practices are also introduced along with the development of irrigation. Given that irrigation development is the core investment, the interventions evaluated by this study can be thought of as an “irrigation treatment” that directly benefits agricultural households in the project zones. Naturally, agricultural households in nonproject zones, nonagricultural households, and urban households are not directly affected by the irrigation project. However, economic linkages among treated and nontreated households transfer the impacts of the irrigation treatment beyond the direct-targeted households in the broader economy.

The irrigation projects under FTF Tanzania do not easily lend themselves to the use of randomized control trials for impact evaluation for at least two reasons. First, within a treated region, almost all agricultural households receive the “irrigation treatment.” Regions are heterogeneous, and there is not a sufficient number of target regions to randomize at the regional level. Second, economic linkages transmit impacts from treated (agricultural) to nontreated (nonagricultural) households via local prices. Thus, many of the impacts of these projects are likely to be found among nontreated households, especially if higher yields influence local prices, which is a likely outcome given the imperfect market integration characteristic of these rural economies.

This paper applies a Local Economy-Wide Impact Evaluation (LEWIE) simulation model to analyze the potential of irrigation projects not only in the project zones but also in the surrounding areas and the entire Morogoro region in general.

Figure 1.1—Situational map of the Kilombero and Mvomero districts

Source: Paavola 2008.

2. THE MODEL AND DATA

The immediate impact of the irrigation projects is to increase crop productivity in the treated areas. Moreover, both land and labor productivity are expected to increase significantly when irrigation is combined with the adoption of new technologies and farming practices. For irrigated crops, farmers usually use more modern inputs. Thus, irrigation projects induce increases in farmers' demands for purchased intermediate inputs, such as fertilizer, chemicals, and improved seeds. An increase in crop output triggers higher-order effects through the economy. When staple products are not perfectly substitutable with similar products produced outside the region, the changes in their supply can cause changes in their prices. Through general equilibrium linkages, prices for nontradables, which include both inputs and outputs, can also change. For example, increased demand for labor exerts upward pressure on local wages, whereas an increase in the supply of rice puts downward pressure on local rice prices. Rice farmers and the suppliers of nontradables benefit either from irrigation that increases rice production or from the induced demand effect, which in turn increases their incomes. As a result, their consumption demand for goods and services increases, which further generates price effects, because part of such goods and services are also nontradable.

Some goods either produced by local producers or consumed by local consumers are tradable; their prices are determined outside the region. From a regional economywide point of view, upward pressure on the prices of local nontradables relative to the prices of tradables causes an appreciation in the project region's terms of trade (that is, the ratio of prices for nontradables over tradables). This appreciation, in turn, causes additional resource relocation, increasing production for the local economy while decreasing production for outside markets.

Thus, prices transmit the impacts of the irrigation project through the regional economy. Ultimately, the project's effect on local prices and production depends critically on both the market structure for agricultural products (whether increased production can easily be sold outside the region) and labor mobility (whether local wage is mainly determined by demand for and supply of labor within the local economy). The project's effect also depends critically on the local supply response for outputs as well as inputs, and such supply responses are constrained by available technology and inputs.

The LEWIE model is designed to capture the linkages that transmit project impacts through the local economy. The first LEWIE was developed by Taylor et al. (2013) to evaluate the spillover effects of Kenya's Cash Transfer to Orphans and Vulnerable Children program. The LEWIE model, which has its foundations in general equilibrium theory, consists of a set of equations describing the consumption and production behavior of households interacting in markets. Households in the model respond to price as both producers and consumers. Prices of local nontradables are determined by market-clearing conditions. In many ways, this is akin to a computable general equilibrium (CGE) model, albeit one that portrays a small regional economy containing distinct but interacting agents (households). Our model was designed as an evaluation tool to analyze and quantify the direct and indirect effects of the FTF irrigation projects. The full model statement is provided in appendix A to this paper.

Constructing the LEWIE Model

Identifying the relevant household groups is the first step in modeling the local economywide effects of the irrigation project. The Tanzania LEWIE model was constructed to match both the project locations and the administrative divisions of the Morogoro region. The irrigation projects were carried out in some villages of the Kilombero and Mvomero districts. The model distinguishes these two districts from other districts of Morogoro, and within each district, it distinguishes between households in treated and nontreated villages. The model also distinguishes among agricultural households, nonagricultural rural households, and households in urban areas. The 13 household groups featured in the model are presented in Table 2.1.

Table 2.1—The 13 household types in the LEWIE model

District	Zone	Household Type
Kilombero	Treated	Agricultural
		Other rural
	Nontreated	Agricultural
		Other rural
Mvomero	Treated	Urban
		Agricultural
		Other rural
	Nontreated	Agricultural
Other districts		Other rural
		Urban
	Nontreated	Agricultural
		Other rural
		Urban

Source: Tanzanian LEWIE model.

Households are producers in the model, and they own factors, which are either used in each household's productive activities or traded with other households. The parameters of the production function for a given good are the same across all producers, implying homogeneous technology for producing the same product. The parameters are different across different production activities. Moreover, not all households participate in all productive activities; production is thus defined at the household level, as is factor use. The list of commodities (goods or services) and factors specified in the model was inherited from a Tanzania national social accounting matrix (SAM) (Pauw and Thurlow 2010). Most important, we distinguish paddy rice production and rice processing (milling) in both activities and commodities. The final list of accounts (after some simplification) is reported in Table 2.2.

Table 2.2—Commodity and factor accounts in the LEWIE model for Morogoro

Commodities (goods and services)		Factors
Agriculture	Nonagriculture	Labor
Rice	Rice milling	Labor with no schooling
Maize	Other crop processing	Labor with some primary schooling
Roots and tubers	Trade	Labor with some secondary schooling
Plantains	Local nontradable services	Labor with completed secondary schooling
Pulses	Tradable services	
Fruits	Industry	Capital
Vegetables	Resource extraction	Land
Other local crops	Others	Livestock
Export crops		Agricultural capital
Cattle		Nonagricultural capital
Poultry		
Other livestock		

Source: Tanzanian LEWIE model.

Functional Forms

The consumption demand functions are of the Cobb-Douglas form, which assumes that households spend their income in fixed proportions, with a certain degree of substitutability among different commodities and services. Production functions, which employ factors and intermediate inputs to produce an output, have two components: a Cobb-Douglas component and a Leontief component. The Cobb-Douglas component is the value-added part of the production function, in which factors (land, labor, and capital) are inputs; the Leontief component computes the intermediate input requirements with fixed proportions to total output. For instance, rice is an intermediate input into milling (a fixed amount of rice is required to produce each pound of processed rice).

Market Closures

A challenge in a general equilibrium analysis is that we generally do not know exactly where prices are determined. In real life, changes in prices outside of an economy may be transmitted into the economy. For example, higher world prices for maize might have an effect on domestic prices when maize is imported, and changes in import parity prices may be transmitted to a greater or lesser extent through the rural economy. A number of studies from African countries document imperfect spatial integration and imperfect price transmission in agricultural commodity markets.¹ In contrast, the price for locally produced and consumed cassava, the charge of a cab ride to the neighboring village, or the shadow price for a farmer's family labor might be determined locally, without much outside influence. The same may apply to locally hired labor under poor infrastructure conditions and thus high transaction costs in rural labor markets, as well as to the rental rate (explicit or implicit) on land and other immobile factors. The LEWIE model was set up to accommodate alternative assumptions concerning where market-clearing prices, wages, or rents are set.

Figure 2.1 illustrates the market closure assumptions in the Tanzania LEWIE (commodities and factors are grouped into types for easier interpretation). There are three possible levels of market clearing and thus of price setting: district, regional, or national. Prices for goods and services traded in districtwide markets and isolated from the rest of the country are district specific in the model—that is, they are determined by supply and demand at the district level. For example, in the model, nonexport crops and local services are assumed to be traded within districts, and thus prices for them are district specific. Other goods can be traded within the region, there is a single market for them, and their prices are regional specific. Such prices are determined by the regional total supply and demand. For instance, paddy rice is assumed to be a regional good, and its price depends only on regional supply and demand. On the other hand, milled rice is assumed to be traded with the rest of the country. Morogoro is a rice-producing region, and rice is “exported” to the rest of the country with rather elastic outside demand. In this case, price for milled rice cannot be solely determined by local supply and demand in the region, and rice demand from the rest of the country can affect the price for the milled rice. For some commodities, Morogoro is fully integrated with outside markets (such as for imported goods or export crops); thus, prices for such commodities are fully exogenously determined outside the region.

As with commodities, the factor market closure assumptions determine where factor demand and supply must clear and where the price (or, in the case of labor, the wage) is determined. We consider land and nonagricultural capital as being fixed in their uses—that is, they cannot be reallocated. Rents are thus unique to each activity, household type, and district, which is a plausible assumption in the short run. For example, once the crop is in the ground, it is too late for farmers to plant rice on their maize field. For labor, we assume that workers with no education or some primary schooling face a local labor market (district level). This means that unskilled laborers in, say, Kilombero can work anywhere in that district and receive the same wage, regardless of the activity. However, the unskilled wage in Kilombero is not necessarily the same as the unskilled wage in Mvomero—that is, labor markets are segmented at the district level. We make the same assumption about livestock capital: rents are the same within a district but can differ from those in other districts. On the other hand, we assume that workers who have at least some secondary schooling face a regional market and thus a single, regional wage.

Underemployment is a quintessential feature of poor rural economies. For instance, there may be a surplus of labor, unused land, or underutilized capital, such as tools or machinery. For this reason, factor supplies in LEWIE are treated as elastic, and different supply elasticities for each factor are chosen in different simulations. An elastic labor supply implies a low reservation wage consistent with unemployment in the economy. In this case, an increase in labor demand in one production sector leads some previously unemployed people to be able to work, rather than putting upward pressure on wages via competition with other sectors. For capital, an elastic supply means that the existing capital stock is not being used at full capacity (for example, if tractors can work longer hours or livestock can be bred more

¹ Examples include Barrett (2008) and Abdulai, Sarris, and Hallam (2006).

intensively) or that increasing the capital stock is possible through loans (implying a well-functioning credit market, which is unlikely in the project areas).

The assumptions of market structure can be made separately for different goods and factors in the model; such assumptions can be altered to test their sensitivity to the simulation results. Figure 2.1 illustrates the market assumptions we favored for the simulations presented in this paper. Different sets of factor supply elasticity assumptions are presented below.

Figure 2.1—Structure of the Tanzanian LEWIE model and market closures in the simulations

Source: Tanzanian LEWIE model.

The Data

Data applied to calibrate the Tanzanian LEWIE model come from three sources: (1) the 2007 social accounting matrix (SAM) for Tanzania, in which all regions, including Morogoro Region, are disaggregated; (2) the 2007 national agricultural census, which provides detailed agricultural data at the household level; and (3) official government documents of the Morogoro region irrigation project proposals, which provide irrigation-related data, including expected outcome of yield increases in irrigated crops.

A Morogoro SAM is first constructed using the above three sources of data. Specifically, the regional production and consumption data from the 2007 agricultural census is used to further disaggregate the production and consumption value flows for Morogoro region (included in the national SAM) into 13 types of household groups. Each household group can be treated as a stand-alone SAM with activity and commodity flows. The 13 household SAMs are subsequently integrated into a “meta-SAM” for Morogoro region. The meta-SAM provides a snapshot of all production and consumption accounts in the 13 household groups that is consistent with both the national SAM and the microdata.

The meta-SAM contains all the production, income, and expenditure information necessary to calibrate the LEWIE model with 13 households, with the exception of factor supply elasticities, which had to be set independently.

3. SIMULATIONS AND RESULTS

Four different irrigation projects are considered in the simulations, and each project targets a different zone of Morogoro (Dakawa, Mgongola, Mgugwe, and Udagaji). The projects' primary target is to expand irrigated land used in rice production (the main staple crop in the region) and to a lesser extent other field crops (maize, pulses, oilseeds). Thus, we focus the analysis on rice, which accounts for 95 percent and 92 percent of potential target crop production value in Kilombero and Mvomero districts, respectively. Irrigation has a strong yield-enhancing effect on rice production. Using information drawn from the four irrigation projects (Mgongola, Mgugwe, Udagaji, and Dakawa) proposed by the Tanzanian Ministry of Water and Irrigation, Table 3.1 shows potential yield gains that can be achieved under each of the four specific irrigation projects within the targeted districts.

Table 3.1—Potential effect of irrigation project on rice yields

Irrigation Project	Yield (ton/ha)	
	Actual	Potential
Dakawa	1.5–2.5	6.0
Mgongola	1.5	6.0
Mgugwe	2.5	5.0
Udagaji	2.1	5.0–7.0

Source: Tanzania, Ministry of Water and Irrigation 2010a, 2010b, 2010c, 2010d.

The projects are to be rolled out over five years and will affect 46 percent of the total land cultivated in target crops within the project zone. A doubling of yields in five years on those areas translates into an approximate 18 percent increase in a given project year.² This annual increase in rice productivity is the shock we simulate in the analysis.

The positive impact of irrigation on yields is well-documented. How these increases in yield will affect local markets, prices, incomes, and rural welfare in the project regions is less straightforward. Using simulation methods, we can obtain insight into how the economy may react under a range of possible scenarios.

We first present a core simulation (Simulation 1)—an 18 percent yield increase for rice in the project zones under what we consider to be plausible assumptions about market closures and factor supply elasticities. We then use the model with alternative assumptions to show how factor availability can shape the impact of the irrigation projects.

As described in Table 2.2, the Tanzanian LEWIE model distinguishes among eight categories of factors: land, livestock, agricultural capital, nonagricultural capital, and labor of four different skill levels, which are grouped into two “high-skilled” levels and two “unskilled” levels, depending on secondary schooling.

Supply elasticity for different factors in the base simulation (Simulation 1) is defined as follows: (1) supply of land and nonagricultural capital is fixed (that is, the supply elasticity is 0); (2) supply of agricultural and livestock capital is elastic with an elasticity of 1 (somewhat elastic); (3) supply of high-skilled labor is relatively more elastic, with an elasticity of 3 indicating some unemployment for such type of labor; and (4) supply of unskilled labor is highly elastic (set at 100) with a fixed real wage rate indicating widespread unemployment. Estimates of factor supply elasticities are rare, and none are available for Tanzania. Although we do not have the data to estimate these parameters, we believe the above constitutes a plausible set of assumptions for the rural areas of Tanzania. In the alternative simulations, these assumptions are adjusted to test the sensitivity of the LEWIE model results to the different levels of factor supply elasticity.

² That is an increase of twice 46 percent spread out over five years ($2 * 0.46/5 = 0.18$).

The bottom panel of Table 3.2 shows the overall effect of the simulated increase in crop productivity on regional total income. In nominal terms, the irrigation projects increase aggregate regional income in the simulation year by 0.79 billion Tanzanian shillings (TZS),³ though this ignores the impact of higher yields on local prices. Real effects are much larger than nominal ones, reaching 2.48 billion TZS, because higher yields reduce consumption prices.

The LEWIE model provides considerable detail on the disaggregated local economywide impacts of the irrigation projects on production, prices, factor values, and household incomes. The following sections summarize these disaggregated impacts.

Table 3.2—Overview of simulation assumptions and impacts on regional total income

Treatment Simulated	
Productivity increase	18%
Treated good	Rice
Assumptions about factor supply elasticities	
Land	0 (inelastic)
Agricultural capital	1 (low elastic)
Livestock capital	1 (low elastic)
High skilled labor (2 categories)	3 (more elastic)
Low skilled labor (2 categories)	Highly elastic
Assumptions about exogenous demand for processed rice	
Price elasticity of export demand	–20 (highly elastic)
Income effect of irrigated treatment (billion TZS)	
Total income, nominal	0.79
Total income, real	2.48

Source: Tanzanian LEWIE model.

Productive Spillovers through Rice Processing

The immediate effect of an 18 percent increase in rice productivity is an increase in rice output. However, the projects also trigger a range of secondary impacts through various channels. Producers adapt their input use by shifting their resources toward activities that are made more lucrative by the project (that is, to the extent that they can do so). The shift in supply volumes may affect commodity prices and demand. The shifts in labor demands may affect wages and employment. All of these changes affect nontarget households, which in turn change their consumption and production by responding to changed commodity prices and wage rates. All of these first- and higher-order effects are interdependent, which is why economywide modeling is necessary to simulate net or general equilibrium impacts.

Table 3.3 presents the general equilibrium impact on sectoral production (expressed in billions of the real terms of Tanzanian shillings). The first row of the table reports a sizeable increase in rice output (4.45 billion in the real terms of Tanzanian shillings). Cross-effects influence the output of other activities through several channels. First, most of the paddy rice is processed. Thus, the output of milled rice increases by 3.71 billion in real terms of Tanzanian shillings. Second, both paddy and milled rice are tradable, and trade services can be treated as intermediate inputs for production and processing activities, which partly explains the increase in the output of trade services when rice production increases. In addition, higher incomes in the economy create a demand pull, which also stimulates the output of goods other than rice, such as local crops and local services. On the other hand, some factors are not perfectly elastic, and at least some workers and capital must shift out of their previous uses. This explains why the output of some activities can be negatively affected—for instance, natural resource extraction and other service provision.

³ Garber (2012) conducted a cost-benefit analysis on one of the irrigation projects considered in this paper (the Dakawa irrigation project in Morogoro) and found that the net benefit is expected to be 0.53 billion TZS during the 25 years of the project's life (considering time discount). However, this analysis ignores the price effect both for commodities and input factors.

Table 3.3—Impacts on production and prices by type of commodity (billion TZS and %)

Simulation 1		
	Production Effects (constant prices in billion TZS)	Change in Price (%)*
Paddy rice	4.45	-1.2%
Milled rice	3.71	-0.7%
Local crops	0.10	0.4%
Export crops	0.14	0.00%
Livestock	-0.07	0.02%
Natural resources	-0.38	0.00%
Processed goods	0.08	0.00%
Local trade	0.12	0.13%
Other services	0.00	0.05%
All others	-0.19	0.00%
Total	7.96	

Source: Tanzanian LEWIE model simulation results.

Notes: * Effects on prices that differ between the districts are weighted by production volumes.

For each activity, the net effect reported in Table 3.3 is the result of all the cross-influences previously described—whether the activity is affected directly by the irrigation projects, whether it competes for input and factor resources with rice, whether the demand for its output rises with household incomes, and so forth. Although the production of rice increases by 4.45 billion TZS, the effect of the intervention on the value of total output in the local economy, once all local general equilibrium effects are taken into account, is 7.9 billion TZS, which is 80 percent higher than the increases in rice value. Where this additional production is stimulated and who participates in these activities both help shape the full impact of the rice irrigation project on the entire rural population, not only in the target zones but also in their surroundings.

The numbers reported in Table 3.3 are the net effects aggregated over the entire Morogoro region. The model distinguishes the target districts within the region and offers a window into district-level productive impacts (these impacts are charted in Figure 3.1). Although the projects are carried out in certain target regions of Kilombero and Mvomero, nontarget regions and other districts are affected through general equilibrium effects.

Figure 3.1—Effects of Simulation 1 on production, disaggregated by district (Kilombero, Mvomero, and others)

Source: Tanzanian LEWIE model simulation results.

Figure 3.1 reveals that Kilombero is responsible for most of the productive impact, in terms of both rice production and rice milling. Whereas most paddy rice is milled locally, trade in paddy does exist in the region. Therefore, increases in paddy and milled rice can be different in a location. For example, rice production increases in Mvomero, but changes in rice milling in that district are modest. Other districts increase their rice milling activity more than Mvomero, but their paddy rice production does not necessarily increase (as these districts are not included in the irrigation projects). The spillovers of the project thus trigger some regional specialization—for example, other districts are at a comparative disadvantage in rice production when irrigation is developed outside these districts, but they can benefit from increasing rice processing, especially if Mvomero has limited milling capacity (shown as nonagricultural capital in the model). Food processing also shifts toward other districts. The irrigation project thus encourages some reorganization of Morogoro’s productive landscape.

In addition to productive impacts, Table 3.3 reports the simulated average impact on commodity price in the region (weighted by production volumes). Only the price of paddy rice (the targeted commodity) drops by more than a percentage point. The price of processed rice drops by only 0.7 percent, because of elastic demand from outside the region. Prices of commodities that are not traded outside the region (local crops, livestock, and services) increase slightly. Values of commodities with exogenous prices (export crops and natural resources) are, by definition, unaffected. Since prices faced by consumers change, the value of wages, rents, and incomes is altered. In the following presentation of results, we distinguish real from nominal values when relevant.

Spillovers through Factor Markets

Lurking behind the productive impacts described in the previous section are impacts on the value of factors. We now explore the mechanism behind these impacts—that is, the clearing of factor markets and the setting of wages and rents. The effects of an irrigation project on the demand for factors are not straightforward. On the one hand, the irrigated activity becomes more lucrative, so a farmer may want to intensify production and use factors and intermediate inputs more intensively. On the other hand, the more productive farmer could reduce factor use and still produce more than before the project. In a general equilibrium context, factor supply will also matter. In our model, all of these considerations are reflected in factor rents and wages.

Land and Capital Rents

We assume that land is fixed in each activity, so there is no reallocation in land. This also means that the shadow value of land (the marginal value of its product) is specific to each activity and household type in the model (with 50 different shadow values of land in total). Each land value will be affected differently by the interventions, so Table 3.4 reports weighted averages of impacts on land rental value in each district, distinguishing the target households (agricultural households in target zones) from other households. Land and capital values will tend to increase in activities that are directly or indirectly stimulated by the irrigation projects; the opposite will tend to happen in negatively affected activities. Because some activities are more capital-intensive than others, the net effect on capital can be positive or negative. Increased yields on irrigated land in Kilombero and Mvomero bid up land values for target households by more than 19 percent. In comparison, the spillover effects on all other capital rents are limited (on the order of 1 percent). However, these small changes in capital values contribute toward restructuring the productive landscape. The decrease in rice milling in Mvomero and the increase in other districts mirror the shifts in the values of nonagricultural capital.

Table 3.4—Weighted average effect on nominal land and capital rents

	Target Households	Other Households
Land		
Kilombero	19.82%	–1.49%
Mvomero	19.92%	0.01%
Other	—	–0.53%
Agricultural Capital		
Kilombero	11.66%	–1.01%
Mvomero	11.59%	–0.23%
Other	—	–0.56%
Nonagricultural Capital		
Kilombero	0.02%	0.02%
Mvomero	–0.04%	–0.04%
Other	0.06%	0.06%
Livestock		
Kilombero	–0.31%	–0.31%
Mvomero	–0.28%	–0.28%
Other	0.10%	0.10%

Source: Tanzanian LEWIE model simulation results.

Labor Market Spillovers through Wages

The model assumes different levels of labor market integration for different worker skill types. Workers with no schooling or only some primary schooling supply their labor to district labor markets; thus, they face a local wage. Research from Africa and elsewhere documents a positive effect of schooling on migration and labor market mobility.⁴ In our model, workers with at least some secondary schooling can seek work in the entire region, and thus their labor market clears at the regional level with a regional wage. These assumptions are important because labor markets can carry spillovers of the project to nontargeted households.

Table 3.5 shows that the net effects on wages are modest compared with what we saw for land values in Table 3.4, because labor supply is more elastic and labor can be reallocated between many different activities. The effect on wages is positive for unskilled workers in the two target districts, reflecting a stimulated labor demand in rice production. The total regional demand for workers with at least some secondary education is reflected in slightly higher wages. In other districts, the effect is negative for less-skilled laborers, which is consistent with a shift away from low-skill activities (such as rice production) and toward higher-skill activities (such as rice processing).

Table 3.5—Effects on nominal wages by district and region

Wage Effects at All Levels		Simulation 1
No schooling	Kilombero	0.24%
	Mvomero	0.05%
	Other districts	–0.03%
Some primary	Kilombero	0.98%
	Mvomero	0.75%
	Other districts	–0.35%
Some secondary	Morogoro region	0.05%
Completed secondary	Morogoro region	0.10%

Source: Tanzanian LEWIE model simulation results.

⁴ See, for example, Taylor and Martin (2001).

Impacts on Target and Nontarget Household incomes

The shifts in production volumes, rents, and wages discussed in the previous section all have ramifications for household incomes. However, price impacts cause real income effects to deviate from nominal ones. Thus, Table 3.6 reports both nominal incomes and real incomes that take into account local price inflation or deflation.

Table 3.6—Impact of the irrigation projects on nominal and real incomes

Nominal Income Change (in billion TZS)			Simulation 1
Kilombero	Target zone	Agricultural	1.14
		Rural nonagricultural	0.02
	Nontarget zone	Agricultural	−0.39
		Rural nonagricultural	0.00
		Urban	0.08
Mvomero	Target zone	Agricultural	0.38
		Rural nonagricultural	0.00
	Nontarget zone	Agricultural	0.04
		Rural nonagricultural	0.00
		Urban	0.04
Other districts		Agricultural	−0.56
		Rural nonagricultural	0.01
		Urban	0.04
CPI Change			
Kilombero			−0.31%
Mvomero			0.03%
Other districts			−0.06%
Real Income Change (in billion TZS)			
Kilombero	Target zone	Agricultural	1.21
		Rural nonagricultural	0.13
	Nontarget zone	Agricultural	0.00
		Rural nonagricultural	0.03
		Urban	0.72
Mvomero	Target zone	Agricultural	0.38
		Rural nonagricultural	0.00
	Nontarget zone	Agricultural	0.01
		Rural nonagricultural	−0.01
		Urban	0.03
Other districts		Agricultural	−0.34
		Rural nonagricultural	0.16
		Urban	0.17

Source: Tanzanian LEWIE model simulation results.

The top panel of Table 3.6 shows nominal income changes in the three simulations. Looking at both target zones, it appears the project would create a little more than 1.5 billion TZS in additional income for agricultural households. Most of these benefits (1.14 billion TZS) are in Kilombero, because the projects affect a larger population there. However, this actually represents roughly a 12 percent income gain for both target groups.

Table 3.6 shows nominal income spillovers for nontargeted agricultural households. In nontarget zones of Mvomero, the spillovers are positive (0.04), but in Kilombero and other districts they are negative (–0.39 billion and –0.56 billion, respectively). Nonagricultural households in all zones and districts benefit somewhat. Production in the irrigated target zones bids down the local prices of rice, thus hurting some agricultural households in the nontarget zones. On the other hand, increased production in the target zones draws agricultural laborers from surrounding areas, which generates spillover income effects. The net income effect is positive for most households but is negative for agricultural households that did not receive irrigation in Kilombero and other districts.

Nominal incomes, however, give an incomplete picture of the welfare effects of the irrigation projects. Shifts in prices transmit spillovers and alter the real value of incomes. The central panel of Table 3.6 reports changes in consumer price indexes (CPIs) for the three districts. CPI's are computed using household expenditure shares and price shifts at the district level. In Mvomero, the CPI increases only slightly (+0.03 percent), and in the other districts, it drops slightly (−0.06 percent). In Kilombero, the CPI drops by less than half a percentage point (−0.31 percent). The CPI reflects both price levels and consumption patterns. The larger drop in Kilombero is not due to large price shifts; rather, it reflects the fact that the most impacted crop (paddy rice) represents a higher share of expenditures for Kilombero households (about 20 percent, versus about 5 percent in Mvomero and the other districts).

Compared with the change in production discussed in Table 3.1 and displayed in Figure 3.1, the household income effect displayed in Table 3.6 seems to be much more modest. In fact, production output (measured in constant prices) includes both a value-added component (which is the income to the factor-owner households) and an intermediate component. While intermediate inputs contribute only a small portion of the output value for primary agriculture, this share is very large for rice processing: paddy rice as an intermediate accounts for more than 90 percent of milled rice production value. Moreover, to be comparable with the changes in production value, the price effect should be taken into consideration. As shown in the second panel of Table 3.6, the income effect in real terms is much larger than in nominal terms (at 2.34 billion TZS in total), due to the decline in most commodity prices, which results in a negative change in CPI. Thus, at the same level of nominal income, a household can buy more of the commodities it wishes to consume. For target households (that is, agricultural households in target zones), real incomes are slightly higher than nominal ones in Kilombero and barely lower in Mvomero. Even for households that see no nominal income change whatsoever, a negative change in CPI is beneficial. In target zones of Kilombero, rural nonagricultural households barely see any benefits from the irrigation projects in nominal terms (0.02 billion TZS); however, cheaper commodities on the local market translate into a gain of 0.13 billion TZS in real terms for them.

Outside the target zones, the difference between nominal and real incomes is more pronounced. In Kilombero, the lower prices eliminate the negative nominal income effect (from −0.39 billion TZS to 0). Urban households of Kilombero, which are not much affected in nominal terms (0.08 billion TZS), gain 0.78 billion TZS in real terms. Similar observations can be made about the other districts, where the CPI drops slightly. The opposite is true in Mvomero, where the CPI hurts households on the consumption side, though only by a small magnitude.

Factor Supply and the Size of Spillovers

The simulation results reveal that the irrigation projects can generate sizeable spillover effects from target to nontarget households and from target districts to their surroundings. These results were obtained using assumptions that we think are most plausible for a rural region such as Morogoro. If we repeat the simulations with altered assumptions, we can verify the robustness of our results. In this section, we present two simulations with alternative sets of assumptions. In Simulations 2 and 3, we chose extremely high or low elasticity values, so that the results of the two simulations bracket the likely impacts of the irrigation project. The assumptions and results are summarized in Table 3.7.

Simulation 2 represents a scenario in which all factors are in fixed supply. Factors can still be reallocated between uses, but the only way to increase factor use in one activity is to reduce it in other activities. Conversely, Simulation 3 assumes very high elasticity values for all factors, meaning activities hardly need to compete for factor resources.

The production results in Table 3.7 show that factor supply elasticity has a certain impact on the total production response to the projects. In Simulation 1, which is the one we consider most plausible, total production increases by 7.96 billion TZS. In Simulation 2, when factor supply is fixed and its elasticity is all 0, this total gain is reduced by 10 percent to 7.19 billion TZS. Conversely, with the very high elasticities under Simulation 3, production increases by 9.3 percent to 8.7 billion TZS. Thus, limited or inelastic factor supply reduces the irrigation project's productive impact.

Different assumptions on factor supply elasticity affect the impact on households' real income much more modestly than the effect on production output. For example, in Simulation 2, when factor supply is fixed and its elasticity is all 0, change in households' real income becomes 2.34 billion TZS, which is slightly lower than the result of Simulation 3 (2.49 billion TZS) when very high elasticities are assumed for the factor supply. This finding suggests that our simulations are rather robust to the ad hoc assumptions we made about factor supply elasticities.

However, Table 3.7 also reveals that supply elasticities have an effect on the distribution of those total impacts. It reports the effects on real incomes of beneficiary and nonbeneficiary households. When factor supply is most constrained (Simulation 2), almost one-third of the productive response to the treatment is attributable to nontarget households (2.13 billion of 7.19 billion TZS). When factor supplies are very elastic, this share is less than 10 percent (0.7 billion of 8.7 billion TZS). Similarly, in real income terms, nontarget households gain much more under Simulation 2 than under Simulation 3 (1.06 billion versus 0.51 billion TZS). This finding underscores the importance of factor supply in determining the size of spillovers that an intervention can generate. If factors are unavailable, the target households must rely on their neighbors (for instance, to hire workers and mill rice), thus sharing the benefits of the irrigation project. Factor availability increases the productive impacts generated by the project, while also keeping the benefits in the target households.

Table 3.7—Simulated effects of the irrigation projects under alternative factor supply elasticity assumptions

	Simulation 1 Most plausible	Simulation 2 Very inelastic	Simulation 3 Very elastic
Assumptions about factor supply elasticities			
Physical capital	1	0	10
Livestock	1	0	10
High skill labor	3	0	100
Low skilled labor	100	0	100
Total production effect (billion TZS)			
In all of Morogoro, of which:	7.97	7.19	8.7
<i>All beneficiary households</i>	6.35	5.06	8.01
<i>All nonbeneficiary households</i>	1.62	2.13	0.7
Total real income effect (billion TZS)			
Nominal income in all of Morogoro	0.79	0.8	0.64
Real income in all of Morogoro, of which:	2.48	2.34	2.49
<i>All beneficiary households</i>	1.59	1.28	1.97
<i>All nonbeneficiary households</i>	0.89	1.06	0.51

Source: Tanzanian LEWIE model simulation results.

4. CONCLUSIONS AND DISCUSSION

Starting with the Morogoro accounts in the Tanzanian national social accounting matrix (SAM), we used production and consumption data for the five zones to create 13 household-type SAMs. To calculate household-type agricultural proportions for production and commodity accounts, we used production data from each group to assign a proportion of production to each group. In a given group, only agricultural households participate in agricultural production, as this gave us a proportion of regional production by each of the 13 household types. We multiplied the corresponding proportion by each agricultural commodity and activity column of the regional SAM for each of the 13 households, giving us 13 distinct accounts for each activity and commodity. Livestock sales data allowed us to create proportions of livestock production in each of the agricultural households. Since we did not have direct production data on olive and poultry production, we used average agricultural production to disaggregate these accounts.

To disaggregate nonagricultural activities, we used a similar process. We first assumed that agricultural households did not participate in nonagricultural activities. We used data on urban populations in the region to break nonagricultural activities into urban and rural households. Next, dividing up the factor inputs required several assumptions. Low-skilled labor went exclusively to agricultural activities and in the same proportions as agricultural capital. These proportions came from household average agricultural production (averaged across activities). Higher-skilled labor and nonagricultural capital went to nonagricultural activities, and proportions came from average production of nonagricultural output. Households used mining capital in proportion to their mining output.

Finally, we combined consumption data by group and by demographic data about proportions of populations that participate in agriculture and that live in rural and urban populations. We used this to assign each of the 13 households a proportion of consumption in the region. Consumption, like production data, was commodity specific.

After dividing production, factor demands, and consumption across the 13 household types, we calculated marketed surplus for each household and for each commodity. Households within the region could be either net producers or net consumers of each commodity. Marketed surplus was split between trade within the region and trade with the rest of the country. The proportion of surplus that goes to (or comes from) the rest of the country equals regional marketed surplus divided by the sum of household marketed surplus (including only the surpluses that have the same sign as the regional surplus). The remaining proportion goes to other households in the region that have a marketed surplus of a different sign than the region as a whole. In practice, this means we assume that if a region exports a crop, that crop is mixed in a local market, and some proportion of all households' production goes to exports. If the region imports, then its imports are mixed with local production, and households consume a mix of regional and imported production. This process gave us two shared accounts: one represents trade within the region, and the other represents exogenous trade with the rest of the country.

To conclude the disaggregation, we nested each of the 13 household-specific SAMs into a regional mega-SAM, with each household on a block diagonal. The regional and rest-of-country trade accounts spanned all households and ensured that the mega-SAM balanced, with row totals equal to column totals.

The model can be calibrated straight from the meta-SAM. To achieve a more manageable model size, some commodities and activities were reaggregated in the General Algebraic Modeling System (GAMS) code, reducing the commodity number from 58 to 19.

APPENDIX A: SUPPLEMENTARY TABLES

Table A.1—Model statement

Name	Equation
Price Block	
EQ_PH(g,h)..	$PH_{g,h} = [PZ_g]_{g \in gtz \cup gtw} + \left[\sum_{d \in maphd(h,d)} PD_{g,d} \right]_{g \in gtd}$
EQ_PVA(g,h)..	$PVA_{g,h} = PH_{g,h} - \sum_{ga} idsh_{ga,g,h} \times PH_{ga,h}$
Production Block	
EQ_QVACOB(g,h)..	$QVA_{g,h} = a_{g,h} \times \prod_f (FD_{g,f,h})^{\beta_{g,f,h}}$
EQ_FDCOB(g,f,h)..	$\begin{aligned} & [R_{g,f,h}]_{f \in fk} + [WZ_f]_{f \in ftz} + \left[\sum_{d \in maphd(h,d)} WV_{f,d} \right]_{f \in ftd} \\ & = \frac{PVA_{g,h} \times QP_{g,h} \times \beta_{g,f,h}}{FD_{g,f,h}} \end{aligned}$
EQ_QP(g,h)..	$QP_{g,h} = QVA_{g,h} / vash_{g,h}$
EQ_ID(gg,g,h)..	$ID_{ga,g,h} = QP_{g,h} \times idsh_{ga,g,h}$
Consumption and Income Block	
EQ_QC(g,h)..	$\begin{aligned} QC_{g,h} &= \frac{\alpha_{g,h}}{PH_{g,h}} \\ &\times \left(Y_h - TROUT_h - SAV_h - EXPROC_h \right. \\ &\quad \left. - \sum_{ga} PH_{ga,h} \times cmin_{ga,h} \right) + cmin_{g,h} \end{aligned}$
EQ_Y(h)..	$\begin{aligned} Y_h &= \sum_{g,fk} (R_{g,fk,h} \times FD_{g,fk,h}) \\ &\quad + \sum_{g,ftz} WZ_{ftz} \times HFSUP_{ftz,h} \\ &\quad + \sum_{ftd} \sum_{d \in maphd(h,d)} WD_{ftd,d} \\ &\quad \times HFSUP_{ftd,h} + \sum_{ftw} WZ_{ftw} \times HFSUP_{ftw,h} \end{aligned}$
EQ_TROUT(h)..	$TROUT_h = troutsh_h \times Y_h$
EQ_EXPROC(h)..	$EXPROC_h = exprocsh_h \times Y_h$

Table A.1—Continued

Name	Equation
EQ_SAV(h)..	$SAV_h = savsh_h \times Y_h$
EQ_CPI(h)..	$CPI_h = \sum_g PH_{g,h} \times \alpha_{g,h}$
EQ_RY(h)..	$RY_h = \frac{Y_h}{CPI_h}$
Market-Clearing Block for Commodities	
EQ_HMKT(g,h)..	$HMS_{g,h} = QP_{g,h} - QC_{g,h} - \sum_{ga} ID_{g,ga,h}$
EQ_DMKT(g,d)..	$DMS_{g,d} = \sum_{h maphd(h,d)} HMS_{g,h}$
EQ_ZMKT(g)..	$ZMS_{g,d} = \sum_d DMS_{g,d}$
EQ_DMKTfix(gtd,d)..	$DMS_{gtd,d} = dmsfix_{gtd,d}$
EQ_ZMKTfix(gtz)..	$ZMS_{gtz} = zmsfix_{gtz}$
Market-Clearing Block for Factors	
EQ_HFD(f,h)..	$HFD_{f,h} = \sum_g FD_{g,f,h}$
EQ_FCSTR(g,fk,h)..	$FD_{g,fk,h} = fixfac_{g,fk,h}$
EQ_HFMKT(ft,h)..	$HFMS_{ft,h} = HFSUP_{ft,h} - \sum_g FD_{g,ft,h}$
EQ_HFSUP(ft,h)..	$\frac{HFSUP_{ft,h}}{hfsup^0_{ft,h}} = \left[\sum_{d maphd(h,d)} (WD_{ft,d})^{\zeta_{ft,h}} \right]_{f \in ftd} + \left[(WZ_{ft,d})^{\zeta_{ft,h}} \right]_{f \in ftz \cup ftw}$
EQ_DFMKT(ft,d)..	$DFMS_{g,d} = \sum_{h maphd(h,d)} HFMS_{g,h}$
EQ_ZFMKT(ft)..	$ZFMS_{ft} = \sum_d DFMS_{ft,d}$
EQ_DFMKTFIX(ftd,d)..	$DFMS_{ftd,d} = dfmsfix_{ftd,d}$
EQ_ZFMKTFIX(ftz)..	$ZFMS_{ftz} = zfmsfix_{ftz}$

Table A.1—Continued

Sets		Subsets	
g or ga	commodities	gtd	Goods tradable in the district
F	factors	gtz	Goods tradable in the region
h or hh	households	gtw	Goods integrated to world markets
D	districts	Fk	Fixed factors
		ftd	Factors tradable in the district
		ftz	Factors tradable in the region
		ftw	Factors integrated to world markets
Mappings			
maphd(h,d)	Mapping of households to the district they live in		
Variables			
Values		Consumption and Income	
PD(g,d)	price of a good at the district level	QC(g,h)	quantity of g consumed by h
PZ(g)	price of a good at the regional level	Y(h)	nominal household income
PH(g,h)	price as seen by household h (=PV or PZ)	RY(h)	real household income
PVA(g,h)	price of value added net of intermediate inputs	CPI(h)	consumer price index
			transfers given by a household of others
R(g,f,h)	rent for fixed factors	TROUT(h)	household savings
WD(f,d)	wage at the district level	SAV(h)	household expenditures out of the region
WZ(f)	wage at the regional level	EXPROC(h)	
Production		Trade	
QP(g,h)	quantity produced of a good by a household	HMS(g,h)	household marketed surplus of good g
FD(g,f,h)	factor demand of f in production of g	DMS(g,d)	district marketed surplus of good g
ID(g,gg,h)	intermediate demand for production of g	ZMS(g)	Regional marketed surplus of a good
			factor marketed surplus from the household
QVA(g,h)	quantity of value added created	HFMS(f,h)	factor marketed surplus out of the district
HFD(f,h)	factor demand in the household	DFMS(f,d)	factor marketed surplus out of the region
	labor supply from the household (elastic endowment)	ZFMS(f)	
Parameters			
Production		Consumption	
a(g,h)	production shift parameter for the CD	alpha(g,h)	consumption share parameters in the LES
beta(g,f,h)	factor share parameter for the CD	cmin(g,h)	minimal consumption in the LES
vash(g,h)	share of value added	exinc(h)	exogenous income of household
idsh(gg,g,h)	intermediate input share	dmsfix(g,d)	fixed marketed surplus at the district level
fixfac(g,f,h)	fixed factor endowment	zmsfix(g)	fixed marketed surplus at the zoi level
dfmsfix(f,d)	factors fixed at the district level (family labor)		
zfmsfix(f)	factors fixed at the zoi level (hired labor)	Transfers	
hfsupzero(f,h)	initial factor supply	troutsh(h)	share of transfers in the households expenditures
		exprocsh(h)	share of expenditures outside of the region
Factorsupply		savsh(h)	share of income saved
hfsupel(f,h)	factor supply elasticity from household	trinsh(h)	share of total transfers received by a given household

Source: Authors' compilation.

APPENDIX B: SOCIAL ACCOUNTING MATRIX CONSTRUCTION

Starting with the Morogoro accounts in the Tanzanian national social accounting matrix (SAM), we used production and consumption data for the five zones to create 13 household-type SAMs. To calculate household-type agricultural proportions for production and commodity accounts, we used production data from each group to assign a proportion of production to each group. In a given group, only agricultural households participate in agricultural production, as this gave us a proportion of regional production by each of the 13 household types. We multiplied the corresponding proportion by each agricultural commodity and activity column of the regional SAM for each of the 13 households, giving us 13 distinct accounts for each activity and commodity. Livestock sales data allowed us to create proportions of livestock production in each of the agricultural households. Since we did not have direct production data on olive and poultry production, we used average agricultural production to disaggregate these accounts.

To disaggregate nonagricultural activities, we used a similar process. We first assumed that agricultural households did not participate in nonagricultural activities. We used data on urban populations in the region to break nonagricultural activities into urban and rural households. Next, dividing up the factor inputs required several assumptions. Low-skilled labor went exclusively to agricultural activities and in the same proportions as agricultural capital. These proportions came from household average agricultural production (averaged across activities). Higher-skilled labor and nonagricultural capital went to nonagricultural activities, and proportions came from average production of nonagricultural output. Households used mining capital in proportion to their mining output.

Finally, we combined consumption data by group and by demographic data about proportions of populations that participate in agriculture and that live in rural and urban populations. We used this to assign each of the 13 households a proportion of consumption in the region. Consumption, like production data, was commodity specific.

After dividing production, factor demands, and consumption across the 13 household types, we calculated marketed surplus for each household and for each commodity. Households within the region could be either net producers or net consumers of each commodity. Marketed surplus was split between trade within the region and trade with the rest of the country. The proportion of surplus that goes to (or comes from) the rest of the country equals regional marketed surplus divided by the sum of household marketed surplus (including only the surpluses that have the same sign as the regional surplus). The remaining proportion goes to other households in the region that have a marketed surplus of a different sign than the region as a whole. In practice, this means we assume that if a region exports a crop, that crop is mixed in a local market, and some proportion of all households' production goes to exports. If the region imports, then its imports are mixed with local production, and households consume a mix of regional and imported production. This process gave us two shared accounts: one represents trade within the region, and the other represents exogenous trade with the rest of the country.

To conclude the disaggregation, we nested each of the 13 household-specific SAMs into a regional mega-SAM, with each household on a block diagonal. The regional and rest-of-country trade accounts spanned all households and ensured that the mega-SAM balanced, with row totals equal to column totals.

The model can be calibrated straight from the meta-SAM. To achieve a more manageable model size, some commodities and activities were reaggregated in the General Algebraic Modeling System (GAMS) code, reducing the commodity number from 58 to 19.

REFERENCES

- Abdulai, A., A. Sarris, and D. Hallam. 2006. "Spatial Integration and Price Transmission in Agricultural Commodity Markets in Sub-Saharan Africa." In *Agricultural Commodity Markets and Trade: New Approaches to Analyzing Market Structure and Instability*, edited S. Alexander and D. Hallam, 163–186. Northampton, MA: Edward Elgar Publishers.
- Barrett, C. B. 2008. "Smallholder Market Participation: Concepts and Evidence from Eastern and Southern Africa." *Food Policy* 33 (4): 299–317.
- Feed the Future. 2011. "Tanzania FY 2011–2015 Multi-Year Strategy." www.feedthefuture.gov/sites/default/files/country/strategies/files/TanzaniaFTFMulti-YearStrategy.pdf.
- Garber, D. 2012. "Cost-Benefit Analysis of Irrigation Rehabilitation in Dakawa, Tanzania." Mimeo, United States Agency International Development, Washington D.C.
- Paavola, J. 2008. "Livelihoods, vulnerability and adaptation to climate change in Morogoro, Tanzania." *Environmental Science & Policy*,(11) 7: 642–654
- Pauw, K., and J. Thurlow. 2012. "Tanzania." In *Strategies and Priorities for African Agriculture: Economywide Perspectives from Country Studies*, edited by X. Diao, J. Thurlow, S. Benin, and S. Fan. Washington, DC: International Food Policy Research Institute (forthcoming)
- Tanzania, Ministry of Water and Irrigation. 2010a. *Project Proposal Dakawa Irrigation Project*. Dar es Salaam, Tanzania: Ministry of Water and Irrigation.
- _____. 2010b. *Project Proposal Mgongola Irrigation Project*. Dar es Salaam, Tanzania: Ministry of Water and Irrigation.
- _____. 2010c. *Project Proposal Mgugwe Irrigation Project*. Dar es Salaam, Tanzania: Ministry of Water and Irrigation.
- _____. 2010d. *Project Proposal Udagaji Irrigation Project*. Dar es Salaam, Tanzania: Ministry of Water and Irrigation.
- Taylor, J. E., and P. L. Martin. 2001. "Human Capital: Migration and Rural Population Change." In *Handbook of Agricultural Economics*, Volume I, edited by B. Gardener and G. Rausser, 457–511. Amsterdam: Elsevier.
- Taylor, J. E, M. Filipowski, K. Thome, J. Kagin, and B. Davis. 2013. "Agricultural Spillover Effects of Cash Transfers: What Does LEWIE Have to Say?" *American Journal of Agricultural Economics* (forthcoming).

RECENT IFPRI DISCUSSION PAPERS

For earlier discussion papers, please go to www.ifpri.org/pubs/pubs.htm#dp.
All discussion papers can be downloaded free of charge.

1246. *Factor endowments, wage growth, and changing food self-sufficiency: Evidence from country-level panel data*. Keijiro Otsuka, Yanyan Liu, and Futoshi Yamauchi, 2013.
1245. *Impact of food price changes on household welfare in Ghana*. Nicholas Minot and Reno Dewina, 2013.
1244. *Parametric decomposition of the Malmquist Index in an output-oriented distance function: Productivity in Chinese agriculture*. Bingxin Yu, Xiyuan Liao, and Hongfang Shen, 2013.
1243. *Extreme weather and civil war in Somalia: Does drought fuel conflict through livestock price shocks?* Jean-Francois Maystadt, Olivier Ecker, and Athur Mabiso, 2013.
1242. *Evidence on key policies for African agricultural growth*. Xinshen Diao, Adam Kennedy, Ousmane Badiane, Frances Cossar, Paul Dorosh, Olivier Ecker, Hosaena Ghebru Hagos, Derek Headey, Athur Mabiso, Tsitsi Makombe, Mehrab Malek, and Emily Schmid, 2013.
1241. *A global assessment of the economic effects of export taxes*. David Laborde, Carmen Estrades, and Antoine Bouët, 2013.
1240. *The Women's Empowerment in Agriculture Index*. Sabina Alkire, Ruth Meinzen-Dick, Amber Peterman, Agnes R. Quisumbing, Greg Seymour, and Ana Vaz, 2012.
1239. *Food price volatility in Africa: Has it really increased?* Nicholas Minot, 2012.
1238. *The comprehensive Africa agriculture program as a collective institution*. Shashidhara Kolavalli, Regina Birner, and Kathleen Flaherty, 2012.
1237. *Mechanization in Ghana: Searching for sustainable service supply models*. Xinshen Diao, Frances Cossar, Nazaire Houssou, Shashidhara Kolavalli, Kipo Jimah, and Patrick Aboagye, 2012.
1236. *Differential export taxes along the oilseeds value chain: A partial equilibrium analysis*. Antoine Bouët, Carmen Estrades, and David Laborde, 2012.
1235. *The role of rural producer organizations for agricultural service provision in fragile states*. Catherine Ragasa and Jennifer Golan, 2012.
1234. *Cash, food, or vouchers?: Evidence from a randomized experiment in Northern Ecuador*. Melissa Hidrobo, John Hoddinott, Amber Peterman, Amy Margolies, and Vanessa Moreira, 2012.
1233. *Public expenditures, private incentives, and technology adoption: The economics of hybrid rice in South Asia*. David J. Spielman, Deepthi Kolady, Patrick Ward, Harun-Ar-Rashid, and Kajal Gulati, 2012.
1232. *Malaria and Agriculture: A global review of the literature with a focus on the application of integrated pest and vector management in East Africa and Uganda*. Benjamin Wielgosz, Margaret Mangheni, Daniel Tsegai, and Claudia Ringler, 2012.
1231. *Did using input vouchers improve the distribution of subsidized fertilizer in Nigeria?: The case of Kano and Taraba states*. Lenis Saweda O. Liverpool-Tasie, 2012.
1230. *The supply of inorganic fertilizers to smallholder farmers in Tanzania: Evidence for fertilizer policy development*. Todd Benson, Stephen L. Kirama, and Onesmo Selejio, 2012.
1229. *The supply of inorganic fertilizers to smallholder farmers in Mozambique: Evidence for fertilizer policy development*. Todd Benson, Benedito Cunguara, and Tewodaj Mogues, 2012.
1228. *The supply of inorganic fertilizers to smallholder farmers in Uganda: Evidence for fertilizer policy development*. Todd Benson, Patrick Lubega, Stephen Bayite-Kasule, Tewodaj Mogues, and Julian Nyachwo, 2012.
1227. *Taxation policy and gender employment in the Middle East and north Africa region: A Comparative analysis of Algeria, Egypt, Morocco, and Tunisia*. Ismaël Fofana, Erwin Corong, Rim Chatti, Sami Bibi, and Omar Bouazouni, 2012.
1226. *Policy reform toward gender equality in Ethiopia: Little by little the egg begins to walk*. Neha Kumar and Agnes R. Quisumbing, 2012.
1225. *Improving the Measurement of food security*. Derek Headey and Olivier Ecker, 2012.

**INTERNATIONAL FOOD POLICY
RESEARCH INSTITUTE**

www.ifpri.org

IFPRI HEADQUARTERS

2033 K Street, NW
Washington, DC 20006-1002 USA
Tel.: +1-202-862-5600
Fax: +1-202-467-4439
Email: ifpri@cgiar.org