Why the Poor Care About Partial Versus General Equilibrium Effects Part I: Methodology and Country Case

Peter Wobst[1]

International Food Policy Research Institute
Trade and Macroeconomics Division
2033 K Street, Washington, D.C. 20006, USA
e-mail: p.wobst@cgiar.org — fax: +1 (202) 467-4439

Abstract

The paper compares the effects of productivity growth in agriculture in a standard CGE model and an adjusted CGE model with special features in order to replicate partial equilibrium behavior of traded agricultural sectors within a general equilibrium framework. The fixed-price, partial equilibrium CGE model shows a strong multiplier effect so that total GDP, factor earnings, and household incomes increase with the productivity growth in agriculture. In comparison, the standard CGE model generates much more diverse sectoral behavior, stronger trade through shifts in the exchange rate, and a less equitable income distribution among farm and non-farm households.

Keywords: CGE, Partial Equilibrium, Southern Africa, Tanzania

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1. Introduction

The paper compares the impact of an increase in agricultural productivity on sectoral economic performance and household welfare under partial *versus* general equilibrium frameworks in the Southern African context. The study applies a computable general equilibrium (CGE) model that employs a standardized 12-sector social accounting matrix (SAM) for Tanzania.[2] The model specifies alternative sectoral trade regimes and hence allows comparison of partial and general equilibrium effects, taking into account (a) perfect substitutability *versus* imperfect substitutability—the Armington assumption of different degrees of tradability between traded and domestic products; (b) the law of one price *versus* domestic price transmission mechanisms which results from perfect *versus* imperfect substitutability; (c) fixed employment *versus* factor market mobility as well as unemployment; and (d) fixed *versus* flexible exchange rate assumptions.

The paper addresses the extensive literature on the role of the agricultural sector in overall economic development in LDCs, e.g., Mellor (1966); Mellor (1976); and Eicher and Staatz (1984), that has been surveyed by Timmer (1988). In particular, it is motivated by Winters et al. (1998) who analyze "the impact of a productivity gain in agriculture on the agricultural surplus in an archetype net food-importing African country" and its transfer to the industrial sector.[3] Although, this analysis does not provide an explicit accounting framework like Winters et al., it captures the full range of general equilibrium effects and contributes to earlier discussions in two ways. First, the optional regime switch between perfect and imperfect substitutability for any desired sector within a CGE modeling framework and, second, the application of a real country

[2] The project "Macroeconomic Reforms and Regional Integration in Southern Africa" coordinated by the Trade and Macroeconomics Division at the International Food Policy Research Institute, Washington, D.C., constructed SAMs for 5 Southern African countries, namely, Malawi, Mozambique, Tanzania, Zambia, and Zimbabwe. Part II of this paper will be concerned with comparative analysis of all 5 economies.

[3] Advancing Morrisson and Thorbecke's (1990) SAM-based approach to a CGE approach and thus taking into account not only physical quantities at fixed prices (visible transfers), but also invisible transfers through government interventions or overvalued exchange rate and consequently depressed domestic prices of tradables.

database for a Southern African economy moving beyond the archetype case.

The objective of the study is to provide an appropriate framework for comparing partial (direct) effects with economywide repercussions, intersectoral linkages and feedbacks, as well as secondary (indirect) effects in order to determine the different levels of impact that agricultural productivity growth has on household welfare within alternative analytical environments. The general question is how partial equilibrium results differ from general equilibrium results, including household welfare indicators.

The methodology applied in this study is an economywide, multi-sector CGE model that extends the approach by Dervis, de Melo, and Robinson (1982) and accommodates an aggregated 12-sector 1992 SAM for Tanzania. The data differentiate export agriculture, imported food crops, and other agriculture with insignificant trade and thus capture intersectoral changes through productive factor shifts.

The results show that common partial equilibrium analysis overstates both the sectoral and economywide impacts of productivity growth in agriculture because it ignores price transmissions and factor market linkages. CGE models capture these links and show how the benefits of agricultural productivity growth are dampened throughout the economy.

The following section briefly describes the CGE modeling approach and discusses the extensions for this particular application. It also highlights some characteristics of the 1992 SAM database for Tanzania and presents the simulations. Section 3 explains the results, while the last section draws conclusions.

2. Incorporating partial equilibrium features in a CGE framework

This section first sketches out the standard general equilibrium approach applied to Tanzania in this paper and then highlights the particular

features incorporated in order to adopt partial equilibrium analysis in the CGE framework. Further, the section describes the main characteristics of the database employed and the simulations carried out to compare partial and general equilibrium effects generated by a productivity increase in agriculture.

2.1 The standard general equilibrium approach

A CGE model captures both stabilization and structural adjustment features because it specifies macroeconomic key determinants as endogenous variables and also allows for any degree of sector disaggregation that is suitable for the analysis of intersectoral shifts. Complex product differentiation in a CGE model captures a variety of sector and market linkages within the economy and linkages with the rest of the world. The CGE approach reflects Chenery's (1975) view of "neoclassical structuralism". On the one hand, the model has a neoclassical foundation, and, on the other hand, it incorporates structural rigidities. The major rigidities of the applied model are (a) foreign trade specification following the Armington assumption where imports and exports are imperfect substitutes for domestic produce, (b) high import dependency due to fixed relative input-output ratios, (c) segmented factor markets, which restrict migration between agricultural and non-agricultural sectors, (d) fixed sectoral capital, which captures the rigid investment structure of the economy, and (e) minimum quantities of marketed and non-marketed household demand in order to guarantee minimum levels of food consumption. Furthermore, one single good in a CGE model appears in a variety of states, namely as domestic produce, export, domestic supply, import, composite aggregate, and final consumption good. In capturing product differentiation, a CGE model incorporates the variety of (endogenous) prices associated with respective goods markets.

Taking into consideration the differentiated functional specification of a CGE model including the wide variety of endogenous variables, it is the most appropriate tool to analyze the impact of macroeconomic policies

on markets and sectoral adjustment processes as well as their impact on individual household welfare. The microeconomic foundation of the CGE specification guarantees the simultaneous interaction among the micro, market, and macro levels of the economy which capture all horizontal and vertical linkages among sectors, factors, households, and other agents of the economy. Although the CGE approach is neoclassical in structure and solves for relative prices under market-clearing conditions, it allows the specification of additional market constraints in order to capture the broad variety of market imperfections, rigidities, and inefficiencies which are typical of developing economies.

The model applied in this paper follows the approach in Dervis, de Melo, and Robinson (1982). In addition, it incorporate two country-specific features in order to capture Tanzania's particular regional and national economic conditions. First, the model incorporates own-household consumption which considers the production of non-marketed food crops and their contribution to total household consumption and nutrition. In an economy where 85 % of the population lives in rural areas and is mainly engaged in food cropping, the appropriate specification of own-household consumption behavior is essential for household-specific welfare analysis. Second, the model contains explicit marketing margins for domestic supply, export, and import commodities in order to capture the extreme differences between producer and consumer prices due to high transportation and other marketing costs in an economy with poor infrastructure and long transit distances.

2.2 Incorporating sectoral partial equilibrium behavior into a CGE

For this paper, we allow for perfect substitutability in case of major export and import agricultural commodities. On the import side, the Constant Elasticity of Substitution (CES) or Armington function which specifies imperfect substitutability between domestic produce and imports in a CGE model, is replaced by the following composite commodity aggregation function with perfect substitutability:

$$(1) \qquad QQ_C = QM_C + QD_C$$

where QQ_C is the composite good supply quantity,
QM_C is the imports quantity, and
QD_C is the domestic sales quantity of commodity c.

Furthermore, the import demand function derived from the first order condition of cost minimization, which depends on relative prices between domestic and import commodities in the CGE model, is replaced by the identity between the two prices in the case of perfect substitutability—the law of one price in partial equilibrium:

$$(2) \qquad PDD_C = PM_C$$

where PDD_C is the demand price for c produced and sold domestically and
PM_C is the domestic import price of commodity c.

On the export side, the Constant Elasticity of Transformation (CET) function combining exports and domestic sales in the CGE approach with imperfect transformability is replaced by perfect transformability:

$$(3) \qquad QX_C = QE_C + QD_C$$

where QX_C is the output quantity and
QE_C is the export quantity of commodity c.

Simultaneously, the export supply function of the CGE specification is replaced by the identity of domestic supply and domestic export prices:

$$(4) \qquad PDS_C = PE_C$$

where PDS_C is the supply price for c produced and sold domestically and
PE_C is the domestic export price of commodity c.

Substituting the CES/CET trade specification with equations (1) to (4) for the major import and export agricultural commodities allows a partial equilibrium treatment for these sectors within the CGE framework, in the following referred to as CGE/PE specification. First, equations (1) and (3) define perfect substitutability between domestic supply and imports and perfect transformability between domestic supply and exports respectively. Second, equations (2) and (4) define the applicability of the

law of one price, i.e., world market prices directly determine domestic prices. Third, the model can specify a fixed exchange rate in order to reflect the common partial equilibrium assumption on the foreign exchange market. Fourth, factor markets are segmented between the agricultural and non-agricultural aggregate sectors, limiting the possibility of adjustment through factor movements.

In order to replicate partial equilibrium behavior in a general equilibrium framework—which does not necessarily translate to realistic economic behavior—some further technical adjustments have to be made regarding the factor market treatment in the model: (a) agricultural labor is mobile among the three agricultural sectors and the related food processing sector and its total supply is fixed; (b) agricultural capital is mobile among the three agricultural sectors and its total supply is fixed; (c) land use is fixed per agricultural sector; (d) non-agricultural labor (four types) and capital markets are unrestricted in their sectoral demand and aggregate supply. Wages and rent are assumed fixed which implies no aggregate factor supply constraint.

What makes the model partial equilibrium in agriculture is to fix non-agricultural prices which can be done by fixing the wages in non-agricultural sectors. The production of commodity x as a function of capital K and labor L, $x = f (K, L)$, can be written as a cost function of wage W_L and rent W_K, $P (x) = F (W_K, W_L)$. Fixing wages and rents, fixes the production price (except for changes in intermediate demand prices) and hence turns the model into a fixed-price model with unrestricted resources, i.e., factor markets with fixed wages can absorb existing unemployment or lay off productive resources according to changing factor productivities. The treatment of unconstrained resources turns the CGE model with partial equilibrium features into a classical multiplier model where an increase in one sector’s productivity generates additional income, which translates to more demand (and supply) of all commodities according to household budget shares and respective income elasticities, and the increased supply in turn generates additional income in these sectors, and so on and so forth.

2.3 Database and simulations

The CGE model is calibrated to replicate a 12-sector social accounting matrix (SAM) for Tanzania for the base year 1992. The SAM features 3 agricultural sectors, of which one comprises major exports, one comprises agricultural sub-sectors with substantial imports (larger than 5 % of total absorption), and one comprises non-traded (or nearly non-traded) sub-sectors. In the CGE/PE specification, the domestic components of export and import agriculture are perfect substitutes with their respective traded components, and the third agricultural sector remains an imperfect substitute. In order to capture another typical partial equilibrium feature and also to avoid inconsistent model behavior, some minor data adjustments were made to eliminate cross-hauling in all three agricultural sectors.

The SAM features 9 non-agricultural sectors, namely, mining, food processing, final consumption items, intermediates, construction, trade and transportation, business services, public administration, and other private services. Food processing is the only sector that is directly linked to agriculture through the agricultural labor market. There is one agricultural labor market, the SAM specifies 4 urban labor markets, segmented capital markets for agriculture and non-agriculture, as well as a land market. The SAM also distinguishes 4 household types: rural farmers, rural non-farmers, urban farmers, and urban non-farmers. The structure of the economy by sector in the base is presented in Table 1.

The basic simulation is a 5 % total factor productivity (TFP) increase in all 3 agricultural sectors under both model specifications. Under the CGE/PE specification (a) the exchange rate is fixed at its base value; (b) wages and rents in non-agricultural factor markets are fixed and their sectoral demand and total supply unrestricted; and (c) major agricultural export and import commodities are perfect substitutes while all other traded commodities are imperfect substitutes. Under the full CGE specification the same 5 % TFP shock is simulated with (a) flexible exchange rate and fixed foreign capital inflow; (b) fixed total supply in

Table 1: Structure of the 1992 base year economy of Tanzania by sector (in %)

	GDP f.c.	Exports	Imports	Absorp.	Exp. share[1]	Imp. share[2]	CET elast.	CES elast.
CAGEX	3.9	22.2		3.1	41.2		2.5	
CAGIM	2.1		1.0	0.9		20.1		3.0
CAGNO	32.8	2.5		15.3	1.0		2.5	
CMINE	2.9	1.0	2.3	2.1	2.8	18.4	2.5	0.8
CFOOD	6.4	2.0	10.7	13.0	1.0	15.4	4.0	1.3
CFICO	2.3	23.4	5.7	5.6	30.0	24.2	4.0	0.5
CINTE	1.8	4.5	65.1	17.8	4.7	69.8	4.0	0.5
CCONS	5.4			5.8				
CTTRA	20.2	5.6	0.9	14.8	1.8	1.0	1.0	0.5
CBUSI	6.3	0.0	4.6	5.2	0.0	14.1	1.0	0.5
CPUBL	7.2	0.1		8.6	0.1		1.0	
CPRIV	9.0	38.7	9.6	7.8	29.5	26.0	1.0	0.5
Total ag	38.7	24.7	1.0	19.3				
Total non-ag	61.3	75.3	99.0	80.7				
Total	100.0	100.0	100.0	100.0				

Note: CAGEX = agricultural exports; CAGIM = agricultural imports; CAGNO = non-trade agriculture; CMINE = mining; CFOOD = food processing; CFICO = final consumption items; CINTE = intermediates; CCONS = construction; CTTRA = trade and transportation; CBUSI = business services; CPUBL = public administration; CPRIV = other private services

1 Exports as share of production

2 Imports as share of absorption

non-agricultural labor markets and fixed sector demand for non-agricultural capital; and (c) imperfect substitutability for all traded commodities including agriculture. The following section compares the simulation results for CGE/PE *versus* full CGE specifications.

3. Results

Results from the simulations indicate that the CGE/PE specification leads to much more balanced effects among sectoral growth, factor earnings, household incomes, and sectoral trade behavior in the economy as a whole when compared to the effects of the full CGE specification where sectoral prices vary and there is more adjustment of the sectoral structure of production. Table 2 presents the major results of the 5 % TFP shock in agriculture, comparing the CGE/PE and full CGE specifications as percentage changes from the base, presenting the base in value terms.[4]

[4] Note that the base run for the partial equilibrium specification replicates the base run in the full CGE specification.

Table 2: Base values and results for partial and general equilibrium model specifications as %-age change to the base of a 5 % total factor productivity increase in agriculture

	Base	Partial	General
General results			
Exchange rate a)	1.000	1.000	1.031
Foreign savings	158.2	9.6	0.0
CPI, numeraire a)	1.000	1.000	1.000
DPI a)	1.000	1.000	1.032
Gov. revenue	341.7	2.5	4.2
Gov. expenditure	359.2	4.3	2.8
Household consumption spendings			
Urban farmers	165.3	4.6	2.6
Urban non-farmers	260.6	5.4	8.9
Rural farmers	705.1	4.3	0.7
Rural non-farmers	55.5	5.4	7.8
Factor earnings			
Urban professional	117.6	4.8	8.6
Urban white collar	62.8	4.8	9.2
Urban blue collar	122.2	5.0	6.4
Urban unskilled	57.2	4.9	9.3
Rural labor	518.9	4.7	-4.2
Capital non-agriculture	508.6	4.9	7.7
Capital agriculture	28.5	4.9	-4.7
Land	40.5	4.9	-4.6
Real GDP at f.c.	1456.2	4.9	1.9
Real GDP at f.c. agriculture	563.2	5.0	4.3
Nominal GDP at f.c. agriculture	563.2	4.8	-4.9
Final consumption			
Real private consumption	913.2	4.7	3.0
Real investment consumption	419.5	4.7	-1.4
Real govenment consumption	331.6	4.7	-0.4
Real exports	163.8	6.1	2.4
Real imports	551.5	4.6	0.7
Trade balance	-387.7	3.9	0.0
Real GDP at market price	1276.7	4.9	1.6

Note: a) Exchange rate, CPI, and DPI are in value term for base and scenarios

Because we simulate the partial equilibrium environment for the major agricultural trade commodities within a CGE framework (CGE/PE), the model features the full GE linkages through the income side. Real GDP at factor cost in agriculture increases with the 5 % TFP increase. This initial income effect induces a multiplier effect in the non-agricultural sectors that finally increases total GDP at factor cost by 4.9 % revealing the linkage of agriculture with the rest of the economy through its increasing demand for non-agricultural intermediates and through increasing final household demand for non-agricultural commodities.

Intersectoral linkages and endogenous price feedbacks within the applied CGE/PE approach are capturing the full repercussion mechanisms in the economy, showing the full multiplier effect of sectoral productivity growth under unconstrained resources.[5] The wage of the rural labor market and the rent of the agricultural capital market increase simultaneously (by 4.7 % and 4.9 % respectively) and spill over to the agro-processing food sector, which over-proportionally increases its demand for non-agricultural factors at fixed wages.

In the full CGE specification, the immediate effect on agricultural real GDP at factor cost (4.3 % increase) is dampened through larger factor movements into food processing and total GDP at factor cost increases by only 1.9 %. Considering agriculture's GDP share of nearly 40 %, non-agriculture still enjoys a real GDP at factor cost increase of about 0.4 %, but this is less than a tenth of its increase under the CGE/PE specification.

The agricultural productivity increase causes the following sectoral changes for the CGE/PE specification: (a) export agriculture employs 2.1 % more labor, increases its output by 7.0 %, and exports 11.0 % more following the vent for surplus argument; while (b) import agriculture employs 2.6 % more labor, increases its output by 7.5 %, and hence imports 14.3 % less following the import substitution argument. All other sectors increase their exports and imports according to the total GDP effect of 4.9 %—due to fixed prices, the import ratio is fixed and, since the economy demands more of all commodities in general (income effect), it also imports more of all commodities; and (c) non-traded agriculture, facing imperfect substitutability, behaves similarly to non-agricultural sectors. As a consequence, total real exports increase by 6.1 %, while total real imports increase by 4.6 % on a much larger base, and thus the net effect on the trade balance is a 3.9 % increase of the trade

[5] Total factor supplies of all non-agricultural factor markets increase with the total GDP increase while total factor supply constraints in agricultural factor markets and leakages through the trade balance slow down the combined employment/GDP effect.

deficit (worsening of the trade balance), keeping the nominal exchange rate fixed.

In comparison, for the full CGE specification, export agriculture can sell its increased output abroad at fixed world prices and, therefore, employs 10.3 % more labor, increases output by 14.8 %, and exports one third more than in the base. In the flexible exchange rate scenario, the trade balance is fixed and one observes a depreciation of the exchange rate along with an increase of total exports of only 2.4 %, import agriculture employs only 0.8 % more labor, increases production by 5.8 %, and reduces imports by the same 14.3 % as in the CGE/PE specification. However, total imports still increase by 0.7 %, through increased imports of non-agricultural commodities. This is due to the general income increase and the same productivity increase in the relatively large non-traded agricultural sector as in the major agricultural trade sectors. Therefore, the net effect on the exchange rate is theoretically unclear. In the case of Tanzania, the increase of TFP in all agricultural sectors depreciates the exchange rate by 3.1 % compared to the base while the trade balance is fixed.

So far, one can conclude from the comparison of production and trade data that general equilibrium effects severely dampen partial equilibrium results because factor markets in the full CGE specification are supply constrained and hence do not allow for the same degree of multiplier effect. In any case, some spillover effects of a TFP growth in agriculture into the non-agricultural sector can be detected and interlinkages between the two market segments are crucial. However, in order to address the poverty reduction issues, one has to scrutinize the distributional effects of economic growth which turns out to be very different for the 2 model specifications. In the CGE/PE case, the impact on incomes and expenditures for the 4 household types is rather balanced ranging from 4.3 % to 5.4 % increase. This is a result from the full multiplier effect working in this model specification which simultaneously and similarly effects all sectors' production, factor

earnings, and consequently household incomes. In the full CGE case, all households still gain, but farmers gain much less and rural farmers lose the most compared to the CGE/PE specification—1.6 % gain for urban farmers and 0.6 % gain for rural farmers. On the other hand, non-farm household are much better off, gaining 8.2 % and 7.5 % for urban and rural respectively.

This result may appear counterintuitive on first sight, but can be explained through the development of factor wages in the full CGE specification. In a scenario where non-agricultural factor markets are supply constrained, their wages increase along with increasing output and consumer prices in reaction to increased demand for their produce by the growing agricultural sector. Agriculture, on the other hand, enjoys increased TFP while facing limited demand because the rest of the economy does not grow at the same rate and therefore does not significantly increase its demand. Agricultural prices fall, and, consequently, agricultural wages fall accordingly. In other words, we observe a severe negative terms of trade effect between agricultural and non-agricultural prices in the wake of a general agricultural productivity increase.

4. Conclusions

The approach developed in this paper supports the comparison of partial and general equilibrium analysis in one modeling framework with two different model specifications. The results indicate that a fixed-price, fixed-wage, partial equilibrium model with unconstrained non-agricultural factor markets generates strong multiplier effects and, consequently, overestimates the economywide impact of sectoral growth in agriculture. The spillover effects of agricultural growth on non-agricultural sectors, although relevant, are much lower than suggested by partial equilibrium and multiplier analysis. A major reason is that factor markets typically are constrained in the short to medium term and therefore equilibrate through wage adjustments which in turn work through the economy via linkages with other labor and product markets. In this context, the

analysis shows that links of agricultural labor markets with agricultural-related (food processing) sectors are important. The CGE/PE specification features full income linkages, but misses intersectoral linkages through price effects because of its fixed-price nature. Although common partial equilibrium models do not account for the economywide multiplier effect observed in the CGE/PE specification, they typically overestimate sectoral benefits because they do not account for the negative repercussions analyzed in this paper. Pure multiplier models overestimate economywide effects of sectoral growth, because they also operate under implicit fixed-price assumptions. In comparison, the full CGE specification accounts for economywide intersectoral linkages and repercussions through relative price changes in commodity and factor markets, including exchange rate effects. The 2 approaches give diverse views of how agricultural productivity increases affect aggregate welfare and the distribution of income.

References

Chenery, H.B. 1975. The Structuralist Approach to Development Policy. *American Economic Review*, 65(2):310-316.

Dervis, K., J. de Melo, and S. Robinson. 1982. *General Equilibrium Models for Development Policy*. Cambridge University Press: Cambridge.

Eicher, C.K. and J.M. Staatz, eds. 1984. *Agricultural Development in the Third World*. The Johns Hopkins University Press: Baltimore and London.

Mellor, J.W. 1966. *The Economics of Agricultural Development*. Cornell University Press: Ithaca and New York.

_____ 1976. *The New Economics of Growth: A Strategy for India and the Developing World*. Cornell University Press: Ithaca and New York.

Morrisson, C., E. Thorbecke. 1990. The Concept of Agricultural Surplus. In *World Development*, 18:8(1081-95).

Timmer, C.P. 1988. The Agricultural Transformation. In *Handbook of Development Economics*, Vol. 1, ed. H. Chenery and T.N. Srinivasan. North Holland: Amsterdam and New York.

Winters, P., A. de Janvry, E. Sadoulet, and K. Stamoulis. 1998. The Role of Agriculture in Economic Development: Visible and Invisible Surplus Transfers. In *The Journal of Development Studies*, 34:5(71-97).