TMD DISCUSSION PAPER NO. 40

**PARAMETER ESTIMATION FOR A
COMPUTABLE GENERAL EQUILIBRIUM MODEL:
A MAXIMUM ENTROPY APPROACH**

Channing Arndt
Purdue University

Sherman Robinson
International Food Policy Research Institute

Finn Tarp
University of Copenhagen

Parameter Estimation for a CGE Model

Abstract:

We introduce a maximum entropy approach to parameter estimation for computable general equilibrium (CGE) models. The approach applies information theory to estimating a system of nonlinear simultaneous equations. It has a number of advantages. First, it imposes all general equilibrium constraints. Second, it permits incorporation of prior information on parameter values. Third, it can be applied in the absence of copious data. Finally, it supplies measures of the capacity of the model to reproduce the historical record and the statistical significance of parameter estimates. The method is applied to estimating a CGE model of Mozambique.

JEL classification codes: C51 and C68

Keywords: maximum entropy, computable general equilibrium, CGE, prior information, Mozambique.

This paper is forthcoming in *Economic Modelling.*

Table of Contents

**ARAMETER ESTIMATION
FOR A COMPUTABLE GENERAL EQUILIBRIUM MODEL:
A MAXIMUM ENTROPY APPROACH**

1. Introduction

Computable general equilibrium (CGE) models have become workhorses for policy analysis. Despite their popularity, CGE models are frequently criticized for resting on weak empirical foundations, particularly for estimates of behavioral parameters (Shoven and Whalley 1992; McKitrick 1998). The problem is not confined to CGE models, but has been recognized for complex simulation models in general (Schmalensee, Stoker, and Judson 1998).

For developed countries, some major microeconometric exercises have been undertaken to estimate behavioral parameters, notably trade parameters. These include efforts by the IMPACT project, the U.S. International Trade Commission, and the U.S. Central Intelligence Agency (Goodman 1973; Alaouze 1976, 1977; Alaouze, Marsden, and Zeitsch 1977; Shiells, Stern, and Deardorff 1989; Shiells 1991; Shiells and Reinert 1991; Shiells, Roland-Holst, and Reinert 1993). Despite these and other efforts, the microeconometrics literature is widely viewed as providing only spotty coverage of the parameters of interest (Hansen and Heckman 1996; McKitrick 1998). In addition, it is far from clear that results from microeconometric studies can be appropriately applied to the more aggregate sectoral and household representations usually present in CGE models (Hansen and Heckman 1996; Dawkins, Srinivasan, and Whalley, 1999). For developing countries, the lack of an empirical basis for behavioral parameters is even more severe. As a result, debate over appropriate values for behavioral parameters remains highly contentious. This is particularly true for trade parameters in CGE models employing Armington type trade assumptions.

The dearth of estimates of behavioral parameters has generally led analysts to specify functional relationships that require relatively few behavioral parameters. Hence, the ubiquity of the constant elasticity of substitution (CES) functional form in applied general equilibrium analysis. This parsimony with respect to number of behavioral parameters comes at a cost in terms of flexibility in representing technology or preferences (Jorgenson 1984; Uzawa 1962; McFadden 1963).

Direct econometric approaches to estimating CGE models have been used (Jorgenson 1984; Jorgenson and Slesnick 1997; McKitrick 1998). However, lack of data, computational and conceptual difficulties in estimation, and uncertainty concerning the validity of resulting estimates have comprised formidable barriers to application of the econometric approach. Existing applications reflect these difficulties. First, econometric estimates, such as those obtained by Jorgenson (1984), are almost always obtained using annual data. The elasticities obtained are thus short run. However, many CGE analyses consider a significantly longer adjustment time frame, often three to five years. Short run elasticities are likely to understate the response capacity of agents over this longer time frame. Second, given the large number of parameters to be estimated, long time series data for numerous variables are required to provide sufficient degrees of freedom for estimation. In many cases, the economy is likely to have undergone structural changes over the period, which may or may not be appropriately reflected in the estimation procedure.

Finally, even those econometric estimates designed specifically to feed parameter estimates to CGE models (e.g. Jorgenson 1984; Jorgenson and Slesnick 1997; McKitrick 1998) undertake estimation without imposition of the full set of general equilibrium constraints. While the estimated parameters might provide a highly plausible description of historical production and consumption data sets, the estimated values will not be fully compatible with the general equilibrium system they are designed to represent. For example, predicted values from separate econometric production and consumption systems have the potential to grossly violate product balance conditions for some years of historical data.

As an alternative to the econometric approach, some CGE researchers employ a simple "validation" procedure by which they run a model forward over an historical period and compare results for some variables. The results can provide a basis for revising estimates of some important parameters, recalibrating the model in a kind of informal Bayesian estimation procedure. Examples of this approach include Gehlhar (1994); Kehoe, Polo, and Sancho (1995); and Dixon, Parmenter, and Rimmer (1997). Unlike econometric approaches, this approach makes very limited use of the historical record and provides no statistical basis for judging the robustness of estimated parameters.

In this article, we introduce a maximum entropy (ME) approach to estimation of behavioral parameters for a CGE model. The ME approach is similar to the econometric

approach of Jorgenson (1984) in that (i) the full historical record can be employed, and (ii) statistical tests for estimated parameter values are available. It is similar to the multi-period validation/calibration approach in that (i) the full model tracks the historical record, and (ii) the ME approach can be applied in the absence of copious data. The ME approach allows one to use all available data, take into account all relevant constraints, employ prior information about parameter values, and apply variable weights to alternative historical targets. Available information does not need to be complete or even internally consistent. The philosophy of the ME approach is to use all available information, but do not assume any information you do not have (such as strong assumptions about the distribution of error terms).

In the following, section two introduces maximum entropy estimation. Section three describes the ME approach as applied to a CGE model. Section four presents an application to Mozambique. A final section concludes and provides suggestions for future research.

2 Maximum Entropy Estimation.

The maximum entropy approach is motivated by "information theory" and the work of Shannon (1948), who defined a function to measure the uncertainty, or entropy, of a collection of events, and Jaynes (1957a; 1957b), who proposed maximizing that function subject to appropriate consistency relations, such as moment conditions. The maximum entropy (ME) principle and its sister formulation, minimum cross entropy (CE), are now used in a wide variety of fields to estimate and make inferences when information is incomplete, highly scattered, and/or inconsistent (Kapur and Kesavan 1992). In economics, the ME principle has been successfully applied to a range of econometric problems, including non-linear problems, where limited data and/or computational complexity hinder traditional estimation approaches. Theil (1967) provides an early investigation of information theory in economics. Mittelhammer, Judge, and Miller (2000) provide a recent text book treatment which is focused more tightly on the ME principle and its relationships with more traditional estimation criteria such as maximum likelihood.

In general, information in an estimation problem using the entropy principle comes in two forms: (1) information (theoretical or empirical) about the system that imposes constraints on the values that the various parameters can take; and (2) prior

knowledge of likely parameter values. In the first case, the information is applied by specifying constraint equations in the estimation procedure. In the second, the information is applied by specifying a discrete prior distribution and estimating by minimizing the entropy distance between the estimated and prior distributions—the minimum cross entropy (CE) approach. The prior distribution does not have to be symmetric and weights on each point in the prior distribution can vary. If the weights in the prior distribution are equal (e.g., the prior distribution is uniform), then the CE and ME approaches are equivalent.

Golan, Judge, and Miller (1996) bring the general regression model into the entropy/information framework by specifying an error term for each equation, but not assuming any specific form for the error distribution. In estimation, they do specify a support set for the error distribution and a prior on the moments of that distribution (usually symmetric about zero). The entropy framework also allows specification of a prior distribution for the parameters (again, through specifying a support set). When prior distributions on parameters are specified, the ME/CE objective function has two terms. The first accounts for deviations of the estimated parameters from the prior. The second accounts for differences between predicted and observed values of variables (the error terms). Golan and Judge (1996) define the first term as "precision" and the second term as "prediction" (within sample). The optimal solution reflects tension between choosing parameter values that allow the model to closely fit the data (prediction) and parameter values that are close to their priors (precision). The analyst can choose the relative weight between the two terms in the objective.[1]

The result is a flexible estimation framework that supports the use of information in many forms and with varying degrees of confidence. The framework also supports statistical inference. Imbens (1997) proves consistency and asymptotic normality of the ME estimator of the general linear model. Asymptotically valid test statistics are developed. For more general nonlinear cases, Golan and Vogel (1997) develop a Chi-square (χ^2) statistic, similar to a likelihood ratio, which can be employed for hypothesis testing. A brief description of the statistic is presented in an appendix. For most applications, the real power of the framework is that it makes efficient use of scarce information in estimating parameters.[2]

3. Estimation Approach

View a classic static CGE model in the following form:

$$F(X, Z, B, \delta) = 0 \qquad (1)$$

where F is an I-dimensional vector valued function, X is an I-dimensional vector of endogenous variables such as prices and quantities,[3] Z is a vector of exogenous variables such as endowments and tariff rates, B is a K dimensional vector of behavioral parameters such as Armington substitution parameters (to be estimated), and δ is a second vector of behavioral parameters whose values are uniquely implied by choice of B, the exact form of F, and data for the base year. The elements of F capture economically coherent production and consumption behavior as well as macroeconomic constraints. Static CGE analysis proceeds by changing the vector of exogenous variables, Z, and examining the resulting vector of endogenous variables, X, which satisfies (1).

In the entropy estimation formulation, the static model attempts to track the historical record over T (t=1,2,…,T) time periods. To reflect the historical record, the Z vector is partitioned into exogenous variables observable from historical data, Z_t^o, and exogenous variables not observable from historical data, Z_t^u. The vector Z_t^o would typically contain historical data on elements such as tax rates, endowments, world prices, and government spending. The vector Z_t^u might contain rates of technical change, implicit or unknown tax or subsidy rates, and other items, which are not available from the historical record. As mentioned above, the model is calibrated to a base year, which can be labeled year t'. Due to calibration to the base year and the restrictions imposed on the function, F, a unique relationship between δ and B exists which permits the model in (1) to reproduce the base year conditional on the choice of behavioral parameters B,

$$\delta = \Phi(Z_{t'}, B). \qquad (2)$$

Note that the full vector $Z_{t'}$ is assumed observable in the base year.

Estimation occurs in the context of the CGE model. Consequently, the relationship:

$$F(X_t, Z_t^o, Z_t^u, B, \delta) = 0 \quad \forall \quad t \in T \tag{3}$$

must hold for estimated values B and Z_t^u, imposed values Z_t^o, and calibrated values δ. The solution to the CGE model implies a predicted historical time path for variables of interest. Note that, in the current formulation, the historical time path could be viewed as multiple solves of a static CGE model. There are no forward looking dynamic elements. This "series of solves" traces a time path which can be compared with actual historic time paths for key variables in the following manner:

$$Y_t = G(X_t, Z_t^o, Z_t^u, B, \delta) + e_t \tag{4}$$

where Y_t is an N dimensional vector of historical targets, G is a function producing the vector of model predicted values for the targets, and e_t is an N dimensional vector representing the discrepancy between historical targets and predicted values. Calibration to the base year implies that $e_{t'} = 0$.

The estimation problem is set up in the manner suggested by Golan, Judge, and Miller (1996). We treat each B_k (k=1,…,K) as a discrete random variable with compact support and $2 \leq M < \infty$ possible outcomes. So, we can express B_k as:

$$B_k = \sum_{m=1}^{M} p_{km} v_{km} \tag{5}$$

where p_{km} is the probability of outcome v_{km} and the probabilities must be non-negative and sum to one. Similarly, treat each element of e_t, e_{tn}, as a finite and discrete random variable with compact support and $2 \leq J < \infty$ possible outcomes. We can express e_{tn} as:

$$e_{tn} = \sum_{j=1}^{J} r_{tnj} w_{tnj} \tag{6}$$

where r_{tnj} is the probability of outcome w_{tnj}. In actual applications, support sets are typically specified with three or more points, supporting recovery of information about higher moments of the distribution. Elements of Z_t^u may undergo the same reparameterization; however, we forgo this step for simplicity. This corresponds to assuming either that all elements of Z_t are known or that elements of Z_t^u are being estimated without the imposition of a prior distribution.

Since we specify prior distributions on parameters, the objective contains the two terms, precision and prediction, discussed above. Each term can be given a weighting factor, $á_1$ and $á_2$. Within both terms in the objective, we specify the more general cross entropy prior allowing for non-uniform weights, q and s, on the discrete

support points for parameters and error terms respectively. This CE formulation may be written as follows:

$$\underset{p,r,Z_t^u}{Min} \quad a_1 \sum_{k=1}^{K} \sum_{m=1}^{M} p_{km} Log\left(\frac{p_{km}}{q_{km}}\right) + a_2 \sum_{t=1}^{T} \sum_{n=1}^{N} \sum_{j=1}^{J} r_{tnj} Log\left(\frac{r_{tnj}}{s_{tnj}}\right) \tag{7}$$

s.t.

$$F\left(X_t, Z_t^o, Z_t^u, B, \delta\right) = O \quad \forall t \in T$$

$$Y_t = G\left(X_t, Z_t^o, Z_t^u, B, \delta\right) + e_t \quad \forall t \in T$$

$$\delta = P\left(Z_T, B\right)$$

$$B_k = \sum_{m=1}^{M} p_{km} v_{km} \quad \forall k \in K$$

$$e_{tn} = \sum_{j=1}^{J} r_{tnj} w_{tnj} \quad \forall t \in T, n \in N$$

$$\sum_{m=1}^{M} p_{km} = 1 \quad \forall k \in K$$

$$\sum_{j=1}^{J} r_{tnj} = 1 \quad \forall t \in T, n \in N.$$

If the priors are chosen with uniform weights, the minimum CE objective collapses to the maximum entropy formulation. Consider the case where $q_{km}=q$ and $s_{tnj}=s$:

$$\underset{p,r,Z_t^u}{Max} \quad -a_1 \sum_{k=1}^{K} \sum_{m=1}^{M} p_{km} Log\left(p_{km}\right) - a_2 \sum_{t=1}^{T} \sum_{n=1}^{N} \sum_{j=1}^{J} r_{tnj} Log\left(r_{tnj}\right)$$

$$+ Ka_1 Log(q) + TNa_2 Log(s). \tag{8}$$

Note the objective direction reversal and the sign switch on each term when comparing (8) with (7) and note that the third and fourth terms in (8) are constants and not relevant to the optimization problem. The CE formulation in (7) corresponds to the Kullback-Liebler measure of deviation of the estimated weights from the prior (see Kapur and Kesavan 1992). This measure of deviation is minimized.[4] The constrained optimization problem in (7) chooses distributions for parameters and error terms that are closest to the prior distributions, using an entropy metric, and satisfy the full set of conditions required by a CGE model $\forall \ t \in T$. In addition, the model endogenously calibrates itself to the base year.[5]

It should be emphasized that the model being estimated is structural rather than reduced form. Decades of experience with this class of economy-wide model provide some prior information on relevant ranges for parameter values and likely parameter estimates. Furthermore, while the support of any imposed prior distribution for a parameter is a maintained hypothesis (the estimate must fall within the support), the shape of the prior distribution over that support (e.g., the weights on each support point) is not. Unless the prior is perfect, the data will push the estimated posterior distribution away from the prior. The direction and magnitude of these shifts are, in themselves, informative. Also, note from (7) that, increases with the number of data points, the second term in the objective ("prediction") increasingly dominates the first term ("precision"). In the limit, the first term in the objective becomes irrelevant. The prior distributions on parameters are only relevant when information is scarce.

Finally, since this structural model is, in principle, a complete representation of the economy in question, estimation through periods of structural change can be valid. For example, trade policy reform within the estimation period can be accounted for through appropriate adjustment of the elements of Z_t^o. This is what CGE models were initially designed to do. In fact, if the trade policy reform induces major shifts in relative prices, estimating through this period may be helpful as the price changes aid in identifying underlying technology and preference parameters. In contrast, structural changes, such as trade policy reform, pose difficulties for reduced form approaches (Hendry 1997) since no levers are available to model policy changes.

Like the econometric approach of Jorgenson (1984), the estimation problem in (7) is highly non-linear in parameters. The potential for multiple local optima exists. In our empirical experience with this estimation procedure to date, the model converges to the same point over a wide range of starting values.

4. An Application to Mozambique

4.1 Background

Mozambique is one of the poorest countries in the world. Following independence from Portugal in 1975, a combination of a vicious civil war and inefficient socialist policies paved the way to complete economic collapse in 1986. In early 1987, a stabilization and structural adjustment program was launched, with civil war still ongoing. As might be expected, the civil war severely limited the scope and

impact of initial reform measures. However, following cessation of hostilities in 1992, a vigorous economic reform program was launched; and economic indicators improved considerably (from a dismal base). Despite recent improvements, the main development challenges lie ahead (Arndt, Jensen and Tarp 2000). To help in identification of key development constraints and to aid in elaboration of a coherent development strategy, a CGE model of Mozambique was developed.

4.2 A CGE for Mozambique

The model developed for Mozambique is a relatively standard CGE model in the tradition of Dervis, de Melo, and Robinson (1982) and Devarajan, Go, Lewis, Robinson, and Sinko (1997).[6] Two unique features have been added in order to reproduce some salient aspects of the Mozambican economy. First, available data indicate that marketing margins are very large, amounting to 40% or more of the final sale price for many commodities (National Institute of Statistics 1997; Arndt, Jensen, Robinson, and Tarp 2000). Accordingly, marketing margins are modeled in careful detail. A separate commerce activity, which accounted for about 20% of GDP at factor cost in 1995, provides margin services (National Institute of Statistics, 1997). Margins are imposed on imports (cost of delivery from the border to the consumer), exports (cost of delivery from the farm or factory gate to the border), and domestic transactions (cost of delivery from the farm or factory gate to the consumer).

Second, due to high transactions costs, many products, particularly agricultural products, are produced and consumed on location. This home consumption evades marketing margins. The value of home consumption amounted to nearly 20% of the value of total consumption in 1995 (National Institute of Statistics, 1997). Since the value of home consumption avoids marketing margins and purchased consumption is margin laden, home consumption accounts for an even higher proportion of real commodity consumption. In the CGE model, home consumption is modeled explicitly. Specifically, home produced and marketed commodities enter separately into a linear expenditure system. Minimum consumption levels for home produced and marketed commodities comprise parameters to be estimated.

Remaining aspects of the model are relatively standard. There are three factors of production: agricultural labor, non-agricultural labor, and capital.[7] Agricultural labor is used exclusively in agricultural activities while non-agricultural labor is used exclusively in all remaining activities. Due to the importance of agriculture and the

informal sector, full employment is assumed for both types of labor. Labor and capital combine in a Cobb-Douglas fashion to produce value added. Value added combines in a Leontief fashion with intermediate products to produce final goods. Domestic products are differentiated from imports and exports via a constant elasticity of substitution (CES) function on the import side and a constant elasticity of transformation (CET) function on the export side. The model contains a rural and an urban household. As discussed in more detail below, exchange rates are fixed to observed historical levels. More details on the model are available in Arndt, Jensen, Robinson, and Tarp (2000).

4.3 Data and Estimation

Economic collapse and war have not been kind to data gathering and analysis systems in Mozambique. As one might expect, data quality is often exceedingly poor and large information holes persist. Nevertheless, enormous efforts have been made to collect and analyze data since the cessation of hostilities in 1992. In particular, a newly created National Institute of Statistics has produced coherent, survey based national accounts data for the period 1991-1996. This information is the primary data source employed for estimation. Product balance statements for 184 commodities are available for the period and provide information on imports, exports, tariff revenue, total production, marketing margins, intermediate consumption, and household consumption (split between the rural and urban sectors as well as home versus marketed consumption). Value added and additional tax information are also available for 26 sectors. These data are supplemented by data from the Mozambique *Anuário Estatístico* (National Institute of Statistics, various years). This source provides information on exchange rates, government expenditure (broken between recurrent and investment), government tax revenues, remittances, and aid in the government budget.

In the model to be estimated, the data are aggregated to six commodities (food, cash crops, processed food, fish, manufactures, and services) and seven activities, which correspond one to one to the commodities plus the commerce activity. The base year for the model is 1995, which corresponds to the most recent year for which a detailed social accounting matrix is available. Detailed information on the social accounting matrix underlying the CGE model is available in Arndt, Cruz, Jensen, Robinson, and Tarp (1998). In 1991, civil war was ongoing and data quality is thought to be exceedingly poor. As a result, this year is excluded from the analysis. The data set thus comprises five years (1992-96), including the base year. The paucity of time series

data implies that annual observations must be employed in estimation. The estimated elasticities apply to this relatively short time frame. Note that the lack of data effectively precludes application of the econometric approach of Jorgenson (1984).

The GDP deflator is used to convert all data to real 1995 values. The following historical data series are imposed upon the model (elements of Z_t^o): the exchange rate (Mt/USD),[8] total non-governmental organization activity, total government expenditure and government investment, subsidies to enterprises, social security payments, net remittances, tariff rates by commodity, and world price changes for exports and imports by commodity. Indices of world prices for imports and exports are derived from national accounts data. These indices are shown in Figures 1 and 2. The indices exhibit considerable price variation for most commodities, which bodes well for identifying trade parameters.

Data are not available on the evolution of the stock of labor and capital. Agricultural and non-agricultural labor stocks are assumed to vary proportionately with rural and urban population respectively. Rural and urban population estimates are derived from Bardalez (1997). Estimates for the capital stock were obtained using a variant of the perpetual inventory method of Nehru and Dhareshwar (1993). They describe the evolution of the capital stock as:

$$K_t = (1-\varphi)^t K_0 + \sum_{i=0}^{t-1} I_{t-1}(1-\varphi)^i \qquad (9)$$

where K_0 is the initial capital stock, I_t is investment in period t, and φ is the rate of geometric decay. Unfortunately, neither a long series of investment data nor an estimate of an initial capital stock is available. An estimate of the capital stock in 1995, the base year, was obtained by dividing total payments to capital, derived from national accounts data, by an assumed rate of return to capital. An annual rate of return of 0.17 was assumed which accords with the high rates of return to capital experienced over the period and simple growth accounting equations. Remaining capital stocks can then be determined by applying the capital stock evolution equation under an assumed rate of decay. Nehru and Dhareshwar apply a rate of decay of 0.04 to all countries in their sample. However, they admit that developing countries are likely to have higher rates of decay. For Mozambique, rapid rates of decay can be expected for road investment, which claims a relatively high share of total investment. A rate of decay of 0.075 was applied.

11

Finally, some exogenous parameters, derived from the 1995 social accounting matrix, are held constant throughout the estimation period. These include input-output coefficients; income, enterprise, factor, and consumption tax rates; most output tax rates; household and enterprise savings rates; commodity cost shares in government consumption and investment; and commodity cost shares in private investment. In these cases, either time series data on these coefficients are unavailable or the coefficients are small and have remained relatively constant throughout the period.

Eight sets of variables are targeted. As shown in equation (4), an error term measures the difference between values predicted by the model and the value of the historical targets. Historical target variables include: (a) gross domestic product, (b) total sales by activity, (c) value of imports by commodity, (d) value of exports by commodity, (e) consumption tax revenue, (f) value of total private investment, (g) value of home consumption by commodity and household type, and (h) value of marketed consumption by commodity and household type. For example, the relationship between actual and predicted GDP determines the value of the error term associated with GDP as follows:

$$GDP_t^a = GDP_t^p + e_t \quad \forall\; t \in T \tag{9}$$

where GDP_t^a is actual GDP in period t and GDP_t^p is predicted GDP in period t.

Support sets on error terms set the maximum divergence of the predicted value from the historical target. Golan, Judge, and Miller (1996) recommend setting upper and lower bounds for error terms approximately three standard deviations from the expected value (in this case zero). Monte Carlo tests undertaken by Preckel (2000) indicate that parameter estimates are relatively insensitive to bounds on error terms specified wider than three standard deviations but can be quite sensitive to bounds on error terms that are less than three standard deviations from the mean value. The incentive is thus to specify relatively wide bounds. Table 1 illustrates upper and lower support points for predicted values of imports by commodity as a percentage of historical targets. These support sets are typical of those employed for almost all target variables excepting GDP.[9] As is clear from the Table, support sets are relatively wide. In addition, because data quality is believed to be poorer for 1992 and 1993 than for subsequent periods, support sets are widened for these periods. The support sets on the error for GDP are significantly tighter—error in predicting GDP can be no larger than 15% of actual GDP for all periods. All support sets on error terms are symmetric three

point (lower, upper, and zero) prior distributions indicating an expected error term mean value and skewness of zero.

Prior distributions for parameters were set wide in order to contain all possible parameter values. For trade parameters associated with the CES aggregator functions, three point prior distributions were set on elasticities with the lower point set at 0.3, the central point set at 1.5, and the upper point set at 9.0. The central point, which corresponds to the prior, was given a weight of 0.5. Weights on the upper and lower points were set such that the expected value of the prior distribution was 1.5.[10] This distribution reflects our priors on likely Armington elasticity values. The estimates cannot be less than 0.3 or more than 9.0. We expect estimated elasticities to be around 1.5 for each commodity, which is why the central point receives a relatively heavy weight of 0.5. Due to the paucity of information on parameter values for Mozambique, we apply the same prior distribution for each commodity. The standard deviation on the parameter implied by this prior distribution is 2.1, which reflects the high level of uncertainty concerning these parameter values.

The support set is the same for the CET excepting the upper point, which is set at five rather than nine reflecting the limited export capacity of the economy. This placement of the upper bound closer to the mode of the distribution reduces the standard deviation on CET elasticity parameters implied by the prior to 1.5. Given that the prior involves unequal weights on the support set, estimates of the CES and CET function elasticities employed a cross entropy formulation such that the implied prior value on all elasticities equaled 1.5. Table 2 presents the three point prior distributions on elasticity values actually employed, as well as the estimated elasticity values, for export (CET) and import (CES) trade functions respectively. Prior weights associated with each point in the cross entropy formulation appear in parentheses below the point.

On the consumption side, estimation focused on minimum consumption levels in the linear expenditure system. Other parameters of the linear expenditure system are implied by choice of minimum consumption levels and base year data. Very little information is available on appropriate values for these parameters. As a result, equally weighted three point prior distributions (a flat prior) for minimum home and marketed consumption levels were centered on one third and one fifth of base year consumption levels respectively for all households and commodities. Lower and upper limits on the prior distributions were set at 50% and 150% of these central levels.

Equally weighted two point support sets for prior distributions were set on parameters for technical change. Rates of Hicks-neutral technical change over the estimation period were calculated for manufactures and services—the two activities where weather or other external factors do not play a major role in determining productivity levels. These support sets were set quite wide with lower point set at –20% per annum and the upper point set at 24% per annum, implying a prior mean value on technical progress of 2% per annum. For agricultural activities (food and cash crops) and for the fishing activity in 1993, technology parameter support sets were specified for each year reflecting significant variation in climatic conditions over the estimation period.[11] Lower and upper points on technology parameters were set at 25% and 250% respectively of the level observed in 1995. Weights on support set points were chosen so that the prior value for the technology parameter was exactly the 1995 level.

Finally, some elements of the Z_t^u vector were estimated without any prior distributions. In particular, levels for output subsidies to food processing and manufacturing activities were set as free variables with no prior for the years 1992-94. This choice reflects subsidies in the form of soft loans from state run banks (or the central bank itself) directed towards these activities over this period.[12] The soft loans permitted selected firms in manufacturing and food processing to pocket the inflation-induced increase in product price over the period (if they repaid the loan, which they often did not). Since inflation rates hovered around 50% over the period, easy access to low cost credit represents a potentially large subsidy (Arndt, Jensen, and Tarp, 2000). This subsidy appears to have manifested itself in the national accounts in the form of reduced input costs. Failure to account for implicit state subsidies to manufacturing and food processing industries implies rapid technological regress over the estimation period—a highly implausible result.

Allowing net capital inflows to adjust endogenously closes the model. The exchange rate is fixed to the historical target. Thus, net capital inflows expand or contract depending on the gap between domestic savings and non-government investment. Given the large volumes of aid made available to Mozambique over the period 1992-96, this specification appears to be a reasonable assumption.[13] In addition, while macroeconomic closure is a contentious issue in CGE models generally, in this case, a number of major macro variables (government recurrent spending, government investment and the exchange rate) are fixed to historical values dampening the closure issue. This is appropriate given the focus on behavioral parameters.

4.4 Results

      This section examines first some measures of goodness of fit between actual and predicted values. We follow Kehoe, Polo, and Sancho (1995) in employing simple correlations and pseudo R-squared measures to determine goodness of fit.[14] Discussion of estimated parameter values follows. This discussion focuses on estimates for trade parameters.

4.4.1 Measures of Fit

      Table 3 illustrates correlations and a pseudo R-squared measure between predicted and actual macro-aggregates over the estimation period. Movement of macro aggregates correlates nicely with the historical data. Values for the pseudo R-squared tend to be substantially lower than the correlations. Unlike linear regression, which forces the sum of the error terms to equal zero, predicted values in this maximum entropy procedure can consistently diverge from actual values by either a positive or negative amount. All of the predicted values for aggregates illustrated in the Table, excepting total imports, exhibit a tendency towards either positive or negative consistent divergence from the actual value. For example, consider Figures 3 and 4, which illustrate total exports and total imports respectively. The model tends to over-predict exports prior to 1995 but is reasonably close to the level of imports.

      Table 4 illustrates measures of goodness of fit for exports and imports by commodity. Performance in terms of correlation and R-squared varies substantially from more than 0.9 to negative values. For the major import commodity (manufactures with a 53% share) and export commodity (services with a 52% share), predicted values track historical values quite closely. Small flows, such as exports of food and imports of cash crops, tend to be predicted with a lesser degree of accuracy. General equilibrium models are predicated on the belief that general equilibrium feedbacks matter. For example, for the important traded commodities in an economy, macro constraints, such as the balance of payments conditions, can substantially influence behavior. However, for small flows within an economy, general equilibrium feedbacks can be relatively unimportant. This logic underpins the ceterus paribus assumption present in partial equilibrium models. As a result, one would expect that the model should be more adept at predicting larger flows.

      Two prominent exceptions to this rule of thumb are exports of fish and processed food. The share of each commodity in total exports is significant;

nevertheless, correlations are small or negative and R-squared is negative for each commodity. These poor performances probably indicate that exogenous factors, operating outside of the model, had a stronger impact on exports of fish and processed food than the factors contained within the model. In the case of fish, exports are materially affected by weather and ocean conditions conducive to catching fish, particularly prawns. Regarding processed food, exports of this commodity are comprised primarily of sugar, cashew nuts, and cotton fiber. Each of these constituent industries operated in a complex and rapidly evolving regulatory environment over the estimation period (World Bank 1996). These policy constraints and shifts, which are impossible to incorporate into the model at this level of aggregation, have clearly affected export performance in cashew nuts and sugar and quite likely have affected export behavior in cotton fiber.

On the positive side, the model does a good job of tracking structural shifts in the shares of import volumes over the 1992-96 period. In particular, the nominal value of food imports declined from 18% of total import value in 1992 to 4% of total import value in 1996. While the food share of import values declined, the share of manufactures and services in nominal import values increased over the same period. As indicated in Table 4, the model does a good job of tracking these structural shifts in import composition. The model also tracks very closely the rise in food production that permitted the decline in food import volumes.

The final column of Table 4 presents a weighted average of correlations and R-squared with the weights corresponding to 1995 export or import shares as appropriate. For the three cases of negative R-squared, these values were set to zero for the purposes of the weighted R-squared calculation. Using this criterion, model predictions of import behavior perform well with a weighted correlation of 0.81 and a weighted R-squared of 0.75. Model predictions of export behavior are less favorable, with a weighted correlation of 0.50 and a weighted R-squared of 0.46 (with the truncation of R-squared measures at zero). In sum, the model is capable of explaining a number of salient aspects of the performance of the Mozambican economy in the post civil war period. This is remarkable given the tumultuous changes, which characterized the period, and the relative paucity of good information on economic performance. We conclude that the fit of the model is adequate to allow us to turn attention to estimated behavioral parameters. [15]

16

4.4.2 Trade Parameter Estimates

Estimated export elasticities for four commodities (food, fish, processed food, and manufactures) are low. For services and cash crops, estimated export elasticities move substantially above the prior. Since services comprised more than half of exports in value terms in 1995, the elastic transformation estimate is interesting. A statistical test was conducted to determine if the prior elasticity of 1.5 is consistent with the data. The χ^2_1 statistic of 2.2 fails to reject the null hypothesis.[16] The basic story emerging from the estimates is that Mozambique is an economy with little capacity to shift production between domestic and export markets for many export commodities. The loss of contact with export markets, which occurred during the civil war period, appears to have restricted the capacity of firms to access export markets. In addition, the structural changes brought about by the economic reform program have harmed some traditional exporters, such as cashew nut processors, and opened export opportunities in other sectors such as food. For example, Mozambique has begun exporting small quantities of maize. However, a lack of well-established export institutions hinders export capacity in maize and other commodities (Miller 1996; World Bank 1996). The export elasticity estimates indicate that, for most commodities, similar difficulties exist in tapping export markets.

While economic collapse and civil war profoundly affected export volumes, import volumes remained substantial thanks to large influxes of foreign aid. As a result, importing institutions functioned throughout the estimation period. In addition, firms operating in domestic markets became accustomed to competing with imports and consumers regularly faced choices between domestic and foreign produced goods. Substitution possibilities between domestic and imported food appear to be particularly strong. Substitution elasticities between imports and domestics for other goods appear to be smaller.

The large elasticity on food is interesting as yellow maize comprised a substantial portion of food imports, particularly in the early post-war period. For example, in 1993, maize comprised approximately 60% of food imports with the vast bulk of maize imports coming in the form of yellow maize as food aid (National Institute of Statistics 1997; Donovan, 1996). Even though Mozambican consumers express a clear preference for white maize, substitution possibilities appear to be strong.

A test of null hypothesis of an import elasticity on food of three was rejected by the data at the 95% confidence level (χ^2_1 statistic of 5.9).

This result accords with available microeconomic evidence. The Ministry of Agriculture in cooperation with Michigan State University (1994) conducted a study of white versus yellow maize consumption. They found that, with equal prices, consumers overwhelmingly favor white maize. However, when presented with a hypothetical maize purchasing game, consumers indicated that they would switch rapidly to yellow maize if its price fell relative to white maize. Low-income consumers, who comprise the bulk of the population, indicated the greatest degree of price sensitivity.

Manufactures represent a second interesting case. Manufactures claimed by far the largest import share in 1995 (see Table 4). In addition, domestic manufactures production is small accounting for less than two percent of value added at factor cost in 1995. On the basis of volume alone, domestic manufactures cannot substitute substantially for imported manufactures. However, this does not necessarily imply that the degree of substitutability between existing domestic manufactures and imported manufactures is small. Estimation results indicate an elasticity slightly lower than one. This is within the range of values frequently employed in developing country contexts. However, a statistical test fails to reject the null hypothesis of an elasticity of two. The χ^2_1 statistic is only 0.1 indicating reasonable consistency of the data with a wide range of possible values for the import elasticity for manufactures.

The χ^2 statistic provides some useful insights into the robustness of the estimation results (explicit sensitivity analysis is also presented in the next section). For example, the statistic indicates that the data strongly point to a relatively high value for the import elasticity for food while the data provide little insight into the appropriate value for the import elasticity of manufactures. While this test statistic adds to the utility of the entropy approach, it should be noted that neither the philosophy of the entropy estimation approach nor the properties of the χ^2 statistic lead one to place heavy emphasis on hypothesis testing within this framework. With respect to properties, the χ^2 statistic is known to have weak power. With respect to estimation philosophy, the focus is on using all available information (and no additional information) to estimate unknown parameters. Once satisfied that one has employed all available information from theory, data, and prior experience in the estimation procedure, information theory dictates that one should use the parameter estimates obtained. Doing anything else

would imply the existence of additional information—a possibility that has already been ruled out.

4.4.3 Sensitivity Analysis

In developing the prior distributions on parameters, we drew on our collective intuition and experience. Nevertheless, in facing the same problem, reasonable economists could easily differ on the exact shape of the parameter prior distributions. It is thus worthwhile to ask how alternative assumptions on prior distributions would influence parameter estimates. Table 5 illustrates trade parameter estimates for the base case (prior distributions and estimates shown in Table 2) and two additional parameter priors. In Prior 1, support points are the same as in the base case except that the upper support point is reduced to six for the import elasticities and three for export elasticities. As in the base case, the central support point (value of 1.5) receives a prior weight of 0.5 and prior weights on upper and lower support points are set such that the mean of the prior distribution is 1.5. In Prior 2, upper and lower support points are the same as in Prior 1. The central support point is set to 0.9 and receives a prior weight of 0.5. Prior weights on upper and lower support points are set such that the mean of the prior distribution is 0.9. Table 5 also provides the first three moments for each of the three prior distributions.

As is clear from Table 5, the choice of parameter prior distributions does influence the parameter estimates. For both export and import elasticities, Prior 1 exhibits reduced variance and strongly reduced skewness relative to the base. The mean remains the same. The effect of this is to tend to draw the estimates towards the mean. This is what occurs in nine of the 11 cases. Note that the larger elasticity estimates, such as services on the export side and food on the import side, tend to be pulled more strongly towards the mean due to the combined effect of reduced variance and reduced skewness. Comparing the moments of Prior 1 versus Prior 2, the main difference lies in the reduction in the mean value. This tends to simply lower all of the estimated elasticities from Prior 1 to Prior 2, which is what occurs in 10 of the 11 cases.

While the elasticity estimates do change with changes in the prior distribution, the qualitative story remains essentially unchanged across the various prior distributions. Across all distributions, the estimates indicate limited capacity to transform domestic production to exports for all commodities other than services. On

the import side, the estimated import transformation elasticity for food is high for all distributions. Finally, the rank ordering of the estimates from lowest to highest remains essentially the same across all the distributions for both the export and import elasticity groups.

5. Conclusions and Suggestions for Future Research

The maximum entropy approach offers strong promise as a formal method of parameter estimation. The estimated trade parameters for Mozambique point strongly to the need for development efforts to aid in the transformation of domestic products into export products. It also indicates high transformation elasticities between imported and domestically produced food. The application illustrates the power of the ME approach to derive useful economic implications from limited data. This property is extremely valuable, particularly in developing country contexts. Nevertheless, in terms of future research, it would be of interest to apply the method to a country with a longer and more reliable series of data.

6. References

Alaouze, C.M., 1976. 'Estimation of the elasticity of substitution between imported and domestically produced intermediate inputs'. IMPACT Project Paper OP-07.

Alaouze, C.M., 1977. 'Estimates of the elasticity of substitution between imported and domestically produced goods classified at the input-output level of aggregation'. IMPACT Project Paper O-13.

Alaouze, C.M., J.S. Marsden and J. Zeitsch, 1977. 'Estimates of the elasticity of substitution between imported and domestically produced commodities at the four-digit ASIC level'. IMPACT Project Paper OP-11.

Arndt, C., A. Cruz, H. Tarp Jensen, S. Robinson, and F. Tarp, 1998. 'Social accounting matrices for Mozambique: 1994-95'. International Food Policy Research Institute, Trade and Macroeconomics Division Paper No. 28.

Arndt, C., S. Robinson, and F. Tarp, 1999. 'Parameter estimation for a computable general equilibrium model: A maximum entropy approach'. International Food Policy Research Institute, Trade and Macroeconomics Division Working Paper.

Arndt, C., H. Tarp Jensen, F. Tarp, 2000. 'Stabilization and structural adjustment in Mozambique: An appraisal'. *Journal of International Development*, 12:3.

Arndt, C. H. Tarp Jensen, S. Robinson, and F. Tarp, 2000. 'Marketing margins and agricultural technology in Mozambique'. *Journal of Development Studies,* 37:1.

Bardalez, J., 1997. 'Mocambique: Projeccoes da populacao total do pais a nivel provincial, distrital e cidades periodo 1991-2000'. Technical Report, Instituto Nacional de Estatistica, Maputo, Mozambique.

Castro, R., 1995. Mozambique, 'Impediments to industrial sector recovery', Report No. 13752-MOZ, The World Bank, Washington D.C.

Dawkins, C., T.N. Srinivasan, and J. Whalley, 1999. 'Calibration.' University of Warwick, unpublished paper.

Devarajan, S., D.S. Go, J. D. Lewis, S. Robinson and P. Sinko, 1997. 'Simple general equilibrium modeling' in *Applied methods for trade policy analysis: A handbook*. J.F. Francois and K.A. Reinert, eds. Cambridge: Cambridge University Press.

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

Dixon, P.B., B.R. Parmenter, and M.T. Rimmer, 1997. 'The Australian textiles, clothing and footwear sector from 1986-87 to 2013-14: Analysis using the Monash model'. September, Centre of Policy Studies and IMPACT Project. University of Monash.

Donovan, C., 1996. 'Effects of monetized food aid on local maize prices in Mozambique' Ph. D. Dissertation, Michigan State University, USA.

Gehlhar, M.J., 1994. 'Economic growth and trade in the pacific rim: An analysis of trade patterns' Ph.D. Dissertation; Purdue University, Department of Agricultural Economics.

Golan, A. and G. Judge, 1996. 'A maximum entropy approach to empirical likelihood estimation and inference' Unpublished paper, University of California, Berkeley.

Golan, A., G. Judge, and D. Miller, 1996. *'Maximum entropy econometrics: robust estimation with limited data'* Chichester: Wiley.

Golan, A. and S.J. Vogel, 1997. 'Estimation of stationary and non-stationary social accounting matrix coefficients with structural and supply-side information' Unpublished Technical Report, American University, Department of Economics.

Goodman, S.H., 1973. 'Overview of the CIA trade flow model project' Office of Economic Research, Central Intelligence Agency, Washington, D.C., April 1974; Paper presented to the Winter Meeting of the Econometric Society, 27-30th December.

Hansen, L.P., and J.J. Heckman, 1996. 'The empirical foundations of calibration' *Journal of Economic Perspectives* 10: 87-104.

Hendry, D., 1997. 'The econometrics of macroeconomic forecasting' *Economic Journal*. 107: 1330-57.

Imbens, G., 1997. 'One-step estimators for over-identified generalized method of moment models' *Review of Economic Studies* 64: 359-383.

Jaynes, E.T., 1957a. 'Information theory and statistical mechanics II' *Physics Review* 108: 171-190.

Jaynes, E.T., 1957b. 'Information theory and statistical mechanics I' *Physics Review* 106: 620-630.

Jorgenson, D., 1984. 'Econometric methods for applied general equilibrium analysis' In Scarf, Herbert E. and Shoven, John B. (eds.) *Applied General Equilibrium Analysis.* New York, Cambridge University Press.

Jorgenson, D.W. and D.T. Slesnick, 1997. 'General equilibrium analysis of economic policy' in *Welfare*. Jorgenson, D.W., ed. Volume 2. Cambridge, The MIT Press.

Kapur, J.N. and H.K. Kesavan, 1992. *Entropy optimization principals with applications.* Academic Press Boston, p. 1-76.

Kehoe, T.J., C. Polo, and F. Sancho, 1995. 'An evaluation of the performance of an applied general equilibrium model of the Spanish economy' *Economic Theory* 6: 115-141.

McFadden, D., 1963. 'Constant elasticity of substitution production functions' *Review of Economic Studies* 30: 73-83.

McKitrick, R.R., 1998. 'The econometric critique of computable general equilibrium modeling: The role of parameter estimation' *Economic Modelling* 15: 543-573.

Miller, E.H. 1996. 'Maize marketing strategy for Mozambique' A Report to the United States Agency for International Development/Maputo, Mozambique.

Ministry of Agriculture, National Directorate of Agricultural Economics and Michigan State University, 1992. 'The determinants of household income and consumption in rural Nampula province: implications for food security and agricultural policy reform' Maputo.

Ministry of Agriculture, National Directorate of Agricultural Economics and Michigan State University, 1994. 'Who eats yellow maize? Some preliminary results of a survey of consumer maize meal preferences in Maputo' Working Paper No. 18.

Mittelhammer, R.C., G.G. Judge and D.J. Miller, 2000. *Econometric Foundations*. Cambridge University Press Cambridge, pp. 313-336.

National Institute of Statistics, various years. *Anuário Estatístico* (Statistical Yearbook), Maputo, Mozambique.

National Institute of Statistics, 1997. National accounts data in electronic form. Maputo, Mozambique.

Nehru, V. and A. Dhareshwar, 1993. 'A new database on physical capital stock: Sources, methodology and results' *Revista de Analisis Economico*, 8: 37-59.

Preckel, P.V., 2000. 'Least squares and entropy: A penalty function perspective' *American Journal of Agricultural Economics*, forthcoming.

Roberts, B.M., 1994. 'Calibration procedure and the robustness of CGE models: Simulations with a model for Poland' *Economics of Planning* 27: 189-120.

Schmalensee, R., T.M. Stoker, and R.A. Judson, 1998. 'World carbon dioxide emission: 1950-2050' *The Review of Economics and Statistics,* 80: 15-27.

Shannon, C.E., 1948. 'A mathematical theory of communication' *Bell System Technical Journal,* 27: 379-423.

Shiells C.R., D.W. Roland-Holst, K.A. Reinert, 1993. 'Modeling a North-American free-trade area – estimation of flexible functional forms' *Weltwirtschaftliches Archiv*, 129: 55-77.

Shiells C.R and K.A. Reinert, 1991. 'Armington models and terms-of-trade effects – some econometric evidence for North America' *Canadian Journal of Economics*, 26: 299-316.

Shiells C.R., 1991. 'Errors in import-demand estimates based upon unit-value indexes' *Review of Economic and Statistics*, 73: 378-382.

Shiells C.R., R.M. Stern, and A.V. Deardorff, 1989. 'Estimates of the elasticities of substitution between imports and home goods for the United States: Reply' *Weltwirtschaftliches Archives* 125: 371-374.

Shoven, J.B. and Whalley J., 1992. *Applying General Equilibrium*, Cambridge University Press, Cambridge.

Theil, H., 1967. *Economics and Information Theory,* North-Holland Pub. Co., Amsterdam.

Uzawa, H., 1962. 'Production functions with constant elasticities of substitution' *Review of Economic Studies,* 29: 291-99.

World Bank, 1996. 'Agricultural sector memorandum: Mozambique' Washington, D.C.

Zellner, A., 1988. 'Optimal information processing and Bayes theorem'. *American Statistician,* 42: 278-284.

7. Appendix

Denote z_u as the objective value for the maximization problem in (7) unencumbered by any hypothesis test and denote z_e as the objective value for the maximization problem in (7) when a constraining hypothesis, such as the Armington import elasticity on food is equal to three, has been added to the constraint set. The test statistic, 8, is then:

$$\lambda = 2z_u\left(1 - \frac{z_c}{z_u}\right)$$

which converges in distribution to χ^2_k with k degrees of freedom in large samples. Degrees of freedom correspond to the number of constraints imposed (see Golan and Vogel 1997).

The ME objective is a measure of information content in the constraints. If a constraining hypothesis is imposed and results in a large reduction in the objective value, this implies that the constraint is highly informative. In other words, the constraint adds significant information beyond the information content derived from the data. In these cases, the null hypothesis represented by the constraint is rejected.

Extension of the test statistic to the CE formulation is straightforward (see Golan and Vogel 1997).

Table 1: Support Set End Points on Predicted Values for Imports as a Percentage of Actual Values.

	Low	High
1996	42%	158%
1994	42%	158%
1993	28%	172%
1992	14%	186%

Note: Since 1995 is the base year, predicted values always equal actual values in 1995.

—

Table 2: Trade Parameter Support Sets and Estimates.[1]

	Export Elasticity				Import Elasticity			
	Estimate	Prior Value	High	Low	Estimate	Prior Value	High	Low
Food	0.72	1.50	5.00	0.30	5.54	1.50	9.00	0.30
		(0.500)	(0.128)	(0.372)		(0.500)	(0.069)	(0.431)
Cash Crops	2.20	1.50	5.00	0.30	0.69	1.50	9.00	0.30
		(0.500)	(0.128)	(0.372)		(0.500)	(0.069)	(0.431)
Fish	0.74	1.50	5.00	0.30	NA	NA	NA	NA
		(0.500)	(0.128)	(0.372)				
Processed Food	0.33	1.50	5.00	0.30	0.57	1.50	9.00	0.30
		(0.500)	(0.128)	(0.372)		(0.500)	(0.069)	(0.431)
Manufactures	0.56	1.50	5.00	0.30	0.87	1.50	9.00	0.30
		(0.500)	(0.128)	(0.372)		(0.500)	(0.069)	(0.431)
Services	2.84	1.50	5.00	0.30	1.85	1.50	9.00	0.30
		(0.500)	(0.128)	(0.372)		(0.500)	(0.069)	(0.431)

[1]Prior weights for each point in the support sets are shown in parentheses below each point.

Table 3: Correlations and Pseudo R-Squared for Macro Aggregates.

	Correlation	R-Squared[1]
GDP	0.99	0.81
Private Investment	0.92	0.83
Value of Intermediate Consumption	0.97	0.84
Total Sales	0.97	0.55
Total Exports	0.80	0.62
Total Imports	0.62	0.65

[1]The pseudo R-squared measure employed is simply 1 – ESS/TSS where ESS is the error sum of squares and TSS is the total sum of squares.

Table 4: Measures of Fit for Exports and Imports.

		Food	Cash Crops	Fish	Processed Food	Manufactures	Services	Weighted Average[1]
Exports	Share in 1995	0.01	0.04	0.21	0.17	0.05	0.52	NA
	Correlation	0.35	0.91	0.14	-0.48	0.60	0.91	0.50
	R-Squared[2]	0.10	0.96	-2.03	-0.66	0.39	0.76	0.46
Imports	Share in 1995	0.06	0.00	0.00	0.22	0.53	0.18	NA
	Correlation	0.87	-0.60	NA	0.51	0.90	0.89	0.81
	R-Squared[2]	0.79	-0.08	NA	0.43	0.92	0.63	0.75

[1] For the cases of negative R-squared in the export row, these two values were set to zero for the purposes of the weighted R-squared calculation.

[2] The pseudo R-squared measure employed is simply $1 - ESS/TSS$ where ESS is the error sum of squares and TSS is the total sum of squares.

Table 5: Trade Parameter Estimates Under Alternative Prior Distributions

	Export Elasticity Estimates			Import Elasticity Estimates		
	Base	Prior 1	Prior 2	Base	Prior 1	Prior 2
Food	0.72	0.90	0.66	5.54	4.83	4.74
Cash Crops	2.20	1.88	1.52	0.69	0.70	0.57
Fish	0.74	0.91	0.61	NA	NA	NA
Processed Food	0.33	0.31	0.37	0.57	0.51	0.50
Manufactures	0.56	0.66	0.53	0.87	0.95	0.64
Services	2.84	2.13	1.76	1.85	1.69	1.42
Mean	1.50	1.50	0.90	1.50	1.50	0.90
Variance	2.10	0.90	0.63	7.74	2.70	1.53
Skewness	4.85	0.27	0.95	53.36	8.91	6.89

Notes:

Prior 1: Support points are the same as the base except that the upper support point is reduced to six for the import elasticities and three for export elasticities. The central support point (value of 1.5) receives a prior weight of 0.5 and prior weights on upper and lower support points are set such that the mean of the prior distribution is 1.5.

Prior 2: Upper and lower support points are the same as in Prior 1. The central support point is set to 0.9 and receives a prior weight of 0.5. Prior weights on upper and lower support points are set such that the mean of the prior distribution is 0.9.

Hypothesis test results are essentially the same across the alternative priors.
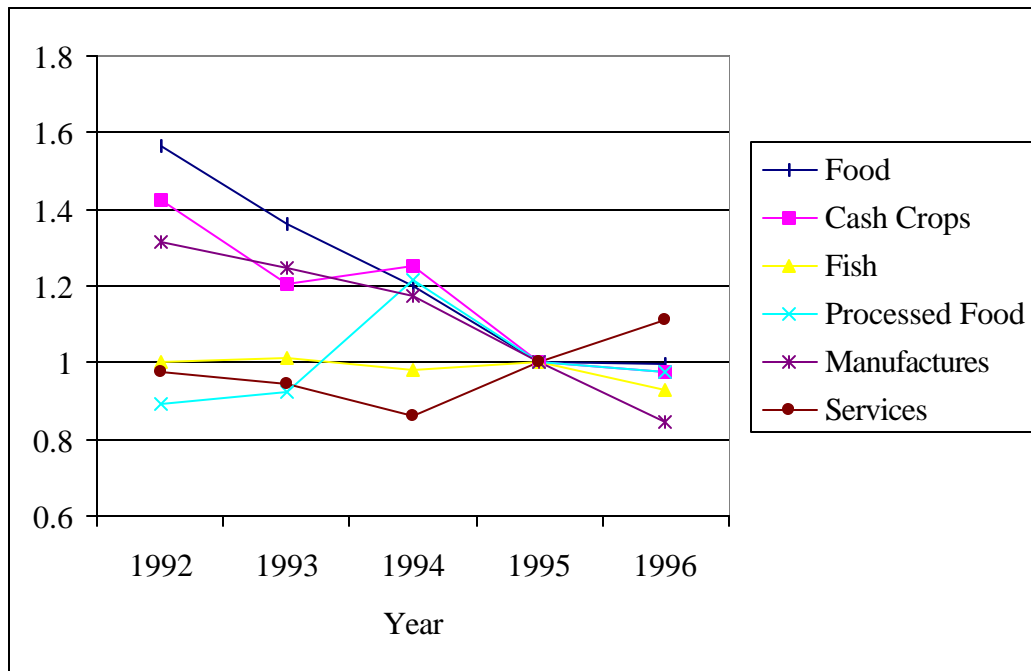
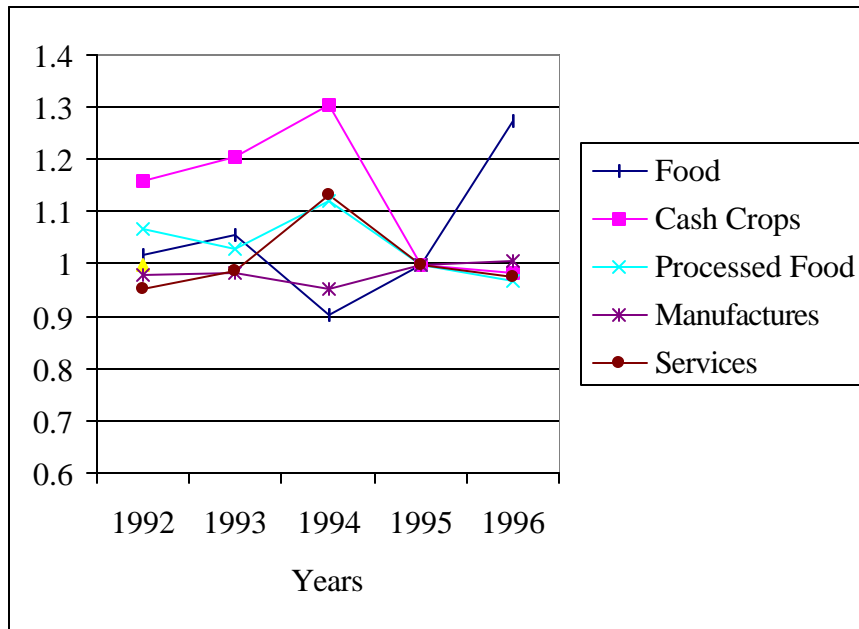Figure 1: Export Price Indices

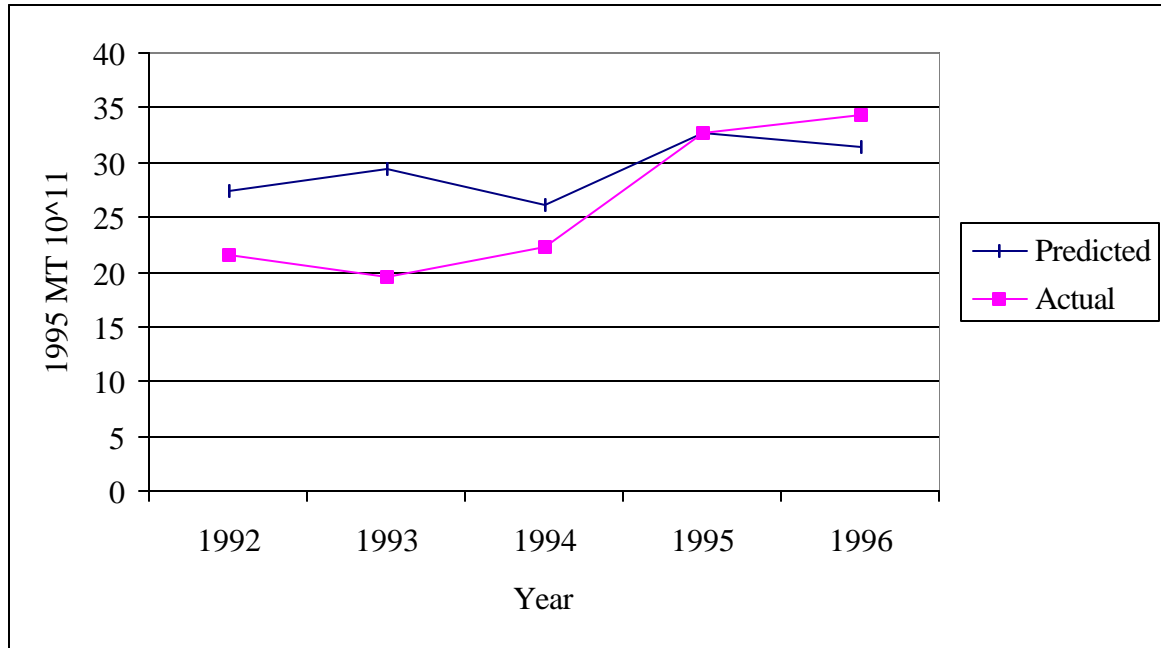Figure 2: Import Price Indices
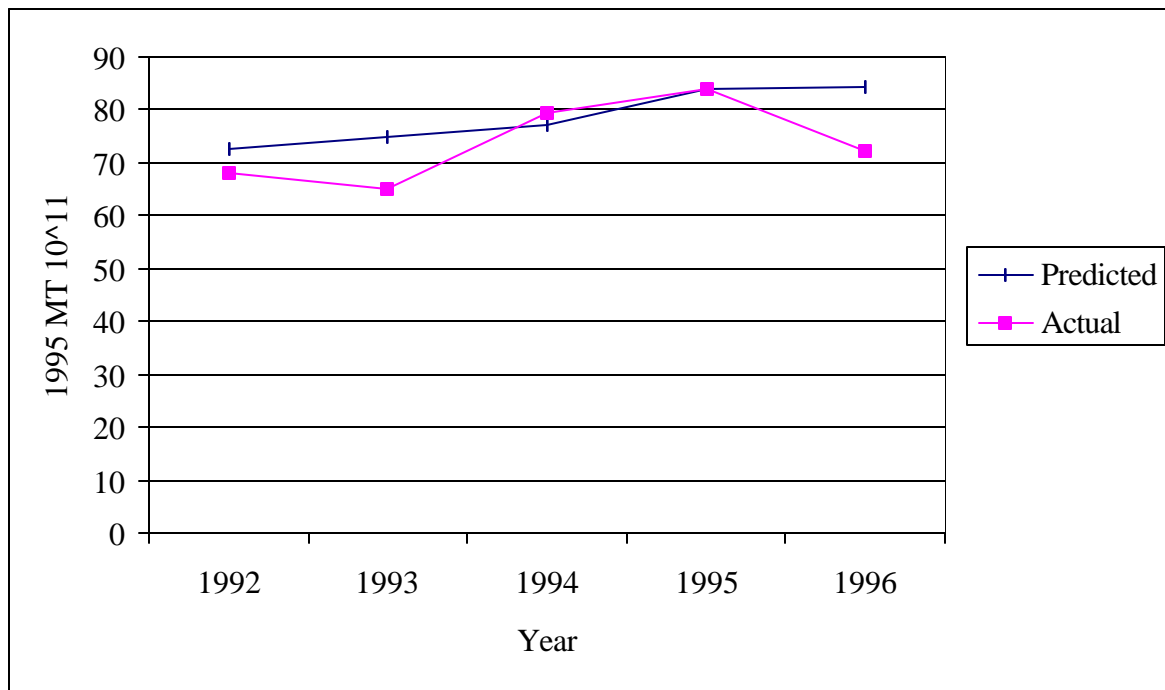
Figure 3: Total Exports

Figure 4: Total Imports

8. Endnotes

---

[1] One option is to dispense with parameter priors altogether (zero weight on precision). In ME estimation of the general linear regression model (GLM) with a "wide" support set specified for the error terms and zero weight on precision, parameter estimates derived from the ME approach will be very similar to parameters obtained using OLS in small samples.

[2] Golan, Judge, and Miller show that the ME/CE approach is an "efficient" information processing rule, as described by Zellner (1988).

[3] The vector X contains a slack variable as a check on Walras' law.

[4] Non-negativity constraints apply to the estimated weights, p and r. In the limit, 0log(0)=0. In practice, estimated weights, p and r, are bounded below to small values to prevent numerical difficulties.

[5] According to McKitrick (1997), one of the benefits of the econometric approach is that it allows the analyst to dispense with exact calibration to a base year. Others, such as Roberts (1994), find that choice of base year matters relatively little to model results while choice of parameter values matter a great deal.

[6] A full description of the model is available upon request.

[7] Land is relatively abundant and data on returns to land non-existent. There is some work indicating that returns to land are positive, not zero as is often assumed (Ministry of Agriculture, 1992). However, the cost share of land is surely small and reasonably lumped into returns to capital.

[8] Even though Mozambique conducts very little direct trade with the United States, the Mt/USD exchange rate was chosen. Three reasons underpin this choice. First, the value of aid flows, which are extremely important, and remittances, which are somewhat important, are recorded in U.S. dollars. Second, many international transactions are denominated in dollars even if the U.S. plays no part in the transaction. Third, the Mt/USD exchange rate behaved similarly to a trade weighted exchange rate index over the estimation period.

---

[9] For some very small flows, support points are set very wide. For example, small but positive imports of cash crops occur in each year. Support sets on these flows are set very wide.

[10] The CES import aggregator function is not defined numerically for an elasticity of one. To permit estimation, the import elasticities were bounded initially to be greater than one. If an elasticity estimate struck its bound, the bounds were shifted to the elasticity range less than one. This processed continued until an interior solution (no import elasticities on bounds) was found. Prior distributions remained the same for all solves.

[11] Use of data on climatic conditions (e.g., rainfall) as instrumental variables in estimation of agricultural technology parameters would be an interesting extension.

[12] To the extent that subsidization of certain industries through the banking system continued into 1995, this subsidization is inadequately captured in the available social accounting matrix. However, by 1995, it had become clear that the banking system had been a conduit for subsidies to state enterprises, and steps had been taken to minimize the flow (Castro, 1995).

[13] It is also the only feasible closure. Credible data on capital inflows are non-existent. Official capital inflow data corresponds with a different (and lower quality) set of national accounts (Arndt, Jensen and Tarp, 2000). The two sets of national accounts differ substantially in levels for almost all aggregates of importance, such as GDP, export, imports, and export minus imports, as well as trends in these aggregates.

[14] The pseudo R-squared measure employed is simply $1 - ESS/TSS$ where ESS is the error sum of squares and TSS is the total sum of squares. Ordinary least squares (OLS) imposes conditions on error term estimates which imply various properties for R-squared. These properties are not present in the ME estimator. For example, OLS estimation implies that $RSS/TSS = 1 - ESS/TSS$ where RSS is regression sum of squares. The ME procedure employed does not impose this relationship.

[15] It should be noted that many important aspects are hidden. For example, the structural adjustment program may be expected to force non-competitive formerly state subsidized manufacturers to

35

contract while it is hoped that other manufacturers will expand. The net effect on aggregate

manufacturing is unclear particularly in the short run. Since we focus on aggregate manufacturing,

we cannot capture this compositional effect.

[16] Imposing an export elasticity of one for services results in failure of the routine to find a feasible

solution with the optimal solution as starting values.

List of Discussion Papers

No. 1-   "Land, Water, and Agriculture in Egypt: The Economywide Impact of Policy Reform" by Sherman Robinson and Clemen Gehlhar (January 1995)

No. 2-   "Price Competitiveness and Variability in Egyptian Cotton: Effects of Sectoral and Economywide Policies" by Romeo M. Bautista and Clemen Gehlhar (January 1995)

No. 3-   "International Trade, Regional Integration and Food Security in the Middle East" by Dean A. DeRosa (January 1995)

No. 4-   "The Green Revolution in a Macroeconomic Perspective: The Philippine Case" by Romeo M. Bautista (May 1995)

No. 5-   "Macro and Micro Effects of Subsidy Cuts: A Short-Run CGE Analysis for Egypt" by Hans Löfgren (May 1995)

No. 6-   "On the Production Economics of Cattle" by Yair Mundlak, He Huang and Edgardo Favaro (May 1995)

No. 7-   "The Cost of Managing with Less: Cutting Water Subsidies and Supplies in Egypt's Agriculture" by Hans Löfgren (July 1995, Revised April 1996)

No. 8-   "The Impact of the Mexican Crisis on Trade, Agriculture and Migration" by Sherman Robinson, Mary Burfisher and Karen Thierfelder (September 1995)

No. 9-   "The Trade-Wage Debate in a Model with Nontraded Goods: Making Room for Labor Economists in Trade Theory" by Sherman Robinson and Karen Thierfelder (Revised March 1996)

No. 10-   "Macroeconomic Adjustment and Agricultural Performance in Southern Africa: A Quantitative Overview" by Romeo M. Bautista (February 1996)

No. 11-   "Tiger or Turtle? Exploring Alternative Futures for Egypt to 2020" by Hans Löfgren, Sherman Robinson and David Nygaard (August 1996)

No. 12-   "Water and Land in South Africa: Economywide Impacts of Reform - A Case Study for the Olifants River" by Natasha Mukherjee (July 1996)

No. 13-   "Agriculture and the New Industrial Revolution in Asia" by Romeo M. Bautista and Dean A. DeRosa (September 1996)

No. 14-   "Income and Equity Effects of Crop Productivity Growth Under Alternative Foreign Trade Regimes: A CGE Analysis for the Philippines" by Romeo M. Bautista and Sherman Robinson (September 1996)

No. 15-   "Southern Africa: Economic Structure, Trade, and Regional Integration" by Natasha Mukherjee and Sherman Robinson (October 1996)

No. 16-   "The 1990's Global Grain Situation and its Impact on the Food Security of Selected Developing Countries" by Mark Friedberg and Marcelle Thomas (February 1997)

No. 17-   "Rural Development in Morocco: Alternative Scenarios to the Year 2000" by Hans Löfgren, Rachid Doukkali, Hassan Serghini and Sherman Robinson (February 1997)

No. 18-   "Evaluating the Effects of Domestic Policies and External Factors on the Price Competitiveness of Indonesian Crops: Cassava, Soybean, Corn, and Sugarcane" by Romeo M. Bautista, Nu Nu San, Dewa Swastika, Sjaiful Bachri and Hermanto (June 1997)

No. 19-   "Rice Price Policies in Indonesia: A Computable General Equilibrium (CGE) Analysis" by Sherman Robinson, Moataz El-Said, Nu Nu San, Achmad Suryana, Hermanto, Dewa Swastika and Sjaiful Bahri (June 1997)

No. 20-   "The Mixed-Complementarity Approach to Specifying Agricultural Supply in Computable General Equilibrium Models" by Hans Löfgren and Sherman Robinson (August 1997)

No. 21-   "Estimating a Social Accounting Matrix Using Entropy Difference Methods" by Sherman Robinson and Moataz-El-Said (September 1997)

No. 22-   "Income Effects of Alternative Trade Policy Adjustments on Philippine Rural Households: A General Equilibrium Analysis" by Romeo M. Bautista and Marcelle Thomas (October 1997)

No. 23-   "South American Wheat Markets and MERCOSUR" by Eugenio Díaz-Bonilla (November 1997)

No. 24-   "Changes in Latin American Agricultural Markets" by Lucio Reca and Eugenio Díaz-Bonilla (November 1997)

No. 25*-   "Policy Bias and Agriculture: Partial and General Equilibrium Measures" by Romeo M. Bautista, Sherman Robinson, Finn Tarp and Peter Wobst (May 1998)

No. 26-   "Estimating Income Mobility in Colombia Using Maximum Entropy Econometrics" by Samuel Morley, Sherman Robinson and Rebecca Harris (Revised February 1999)

No. 27-   "Rice Policy, Trade, and Exchange Rate Changes in Indonesia: A General Equilibrium Analysis" by Sherman Robinson, Moataz El-Said and Nu Nu San (June 1998)

No. 28*-   "Social Accounting Matrices for Mozambique - 1994 and 1995" by Channing Arndt, Antonio Cruz, Henning Tarp Jensen, Sherman Robinson and Finn Tarp (July 1998)

No. 29*-   "Agriculture and Macroeconomic Reforms in Zimbabwe: A Political-Economy Perspective" by Kay Muir-Leresche (August 1998)

No. 30*-   "A 1992 Social Accounting Matrix (SAM) for Tanzania" by Peter Wobst (August 1998)

No. 31*-   "Agricultural Growth Linkages in Zimbabwe: Income and Equity Effects" by Romeo M. Bautista and Marcelle Thomas (September 1998)

No. 32*-   "Does Trade Liberalization Enhance Income Growth and Equity in Zimbabwe? The Role of Complementary Polices" by Romeo M. Bautista, Hans Lofgren and Marcelle Thomas (September 1998)

No. 33-   "Estimating a Social Accounting Matrix Using Cross Entropy Methods" by Sherman Robinson, Andrea Cattaneo and Moataz El-Said (October 1998)

No. 34-   "Trade Liberalization and Regional Integration: The Search for Large Numbers" by Sherman Robinson and Karen Thierfelder (January 1999)

No. 35-   "Spatial Networks in Multi-Region Computable General Equilibrium Models" by Hans Löfgren and Sherman Robinson (January 1999)

No. 36*-   "A 1991 Social Accounting Matrix (SAM) for Zimbabwe" by Romeo M. Bautista and Marcelle Thomas (January 1999)

No. 37-   "To Trade or not to Trade: Non-Separable Farm Household Models in Partial and General Equilibrium" by Hans Löfgren and Sherman Robinson (January 1999)

No. 38-   "Trade Reform and the Poor in Morocco: A Rural-Urban General Equilibrium Analysis of Reduced Protection" by Hans Löfgren (January 1999)

No. 39-   " A Note on Taxes, Prices, Wages, and Welfare in General Equilibrium Models" by Sherman Robinson and Karen Thierfelder (January 1999)

No. 40 -   "Parameter Estimation for a Computable General Equilibrium Model: A Maximum Entropy Approach" by Channing Arndt, Sherman Robinson and Finn Tarp (Revised version March 2001)

TMD Discussion Papers marked with an "" are MERRISA-related papers.

Copies can be obtained by calling, Maria Cohan at 202-862-5627 or e-mail
m.cohan@cgiar.org