ASSESSING THE SUITABILITY OF PARTIAL EQUILIBRIUM MODELLING IN ANALYZING THE FOREST SECTOR OF DEVELOPING COUNTRIES: METHODOLOGICAL ASPECTS WITH REFERENCE TO TANZANIA

Ngaga[1*] Y. M. and Solberg[2] Birger

[1] *Department of Forest Economics, Sokoine University of Agriculture*
P.O. Box 3011, Chuo Kikuu
Morogoro, Tanzania.

Email: ngaga@suanet.ac.tz, yngaga@yahoo.co.uk
[2]*Resource Economics and Planning Section, Department of Forest Sciences*
Agricultural University of Norway
P.O. Box 5044, N-1432 Ås, Norway.
* Corresponding author

ABSTRACT

This paper evaluates the strengths and weaknesses of applying partial equilibrium modeling for forest sector analysis in Tanzania. The aim of the evaluation is to determine the usefulness of this model framework in analyzing the impact of various policies on the development of the forest sector. The structure and specifications of the model, and the data input requirement and availability are examined. The results of a partial equilibrium model are examined against the findings from separate interviews conducted with the main stakeholders in the Tanzania forest sector. Based on the evaluation, the paper gives some recommendations regarding model improvements and areas of future research. The main assumptions of a perfect competitive market hypothesis underlying the Tanzania Trade Model (TTM) are violated especially on the supply of round wood, the existence of monopoly situation in wood-based panels and paper industry, and lack of a competitive transport market. However, there is competition in the domestic market between imports and local manufacturers, and for products such as sawn wood. Despite these violations, the quantitative analyses with the model together with the findings from stakeholders in the forest sector of Tanzania provide some useful lessons on the key deciding factors and the competitiveness of the forest industry products.

Keywords: Forest sector – Forestry - Forest products - Partial equilibrium model - Tanzania.

INTRODUCTION

Development in the forest sector of Tanzania is decided by the nature of forest resources, forest-based industry, international trade in forest products, economic growth and government policies. Several factors from inside and outside the forest sector are involved in shaping the performance and development of the sector. Understanding these factors and their linkages is critically important for planning and decision making. Different quantitative approaches are available for modeling the forest sector at regional, national and global levels in the determination of current and future possible development direction. The major approaches which have been in use include linear programming models, econometric models, general and partial equilibrium models, market share models and pure simulation models. Each of these models has its advantages and limitations and the decision of which model to use depends on the objectives of the study. The most famous and comprehensive among forest sector models are Timber Assessment Model (TAMM), Price Endogenous Linear Programming Systems (PELPS) and International Institute for Applied Systems Analysis-Global Trade Model (IIASA GTM) models (Moiseyev 1997). All these models are built in a spatial equilibrium framework, and perform forest sector analyses in a similar way although the forestry sector is represented differently in each model. Previous studies have focused on developed countries. There has been no or little attempt to use this approach for forest sector analysis in developing countries. The first national forest sector model developed for Tanzania (Tanzania Trade Model) was tailored for developing countries (Ngaga and Solberg 2001).

The link between forest-based industry and international trade in forest products, and its role in economic development in Tanzania made it of interest to use a spatial equilibrium model as a tool for analyzing the forest sector development and the impacts of policies which have a direct bearing on the sector (Ngaga and Solberg 2001). However, the degree of abstractness in this kind of modeling is high particularly when the forest sector is aggregated at national level, and some variables may be omitted. In addition, other analytical approaches are useful to gauge the reliability of the model and to complement what the model cannot capture. In view of this, a special survey was undertaken through administered questionnaires to map the opinions of four main stakeholders, i.e., the producers, traders, forest and trade administrators, and end-users, with regard to the main problems and challenges of the forest sector in Tanzania (Ngaga, Solberg and Monela 2001).

Theoretical considerations, model experimentation and sensitivity analyses are important parameters in judging the relevance and usefulness of any modeling work. It is against this background that this paper assesses the suitability of the model as a tool in predicting/simulating the effects of policy decisions or options on the forest sector of a developing country like Tanzania.

The main objective of the paper is to evaluate the strengths and weaknesses of applying a partial equilibrium model for forest sector analysis in Tanzania. It evaluates the structural features and data input requirement for the model. Also it compares the results of the partial equilibrium model against the findings from the stakeholders' interviews with the view of determining the usefulness of the model in analyzing the impact of various policies on the development of the forest sector. Based on the evaluation, the paper gives some recommendations aimed at model improvements and areas of future research.

General and Partial Competitive Spatial Equilibrium

The conditions which satisfy the definition of a general spatial competitive equilibrium are as follows (after Takayama and Judge (1971): (1) Market equilibrium; This is satisfied by the conditions of homogeneity and uniqueness of commodity prices for all consumers and producers in each country or region, homogeneity and uniqueness of transportation costs on any transportation circuit, no excess demand for any commodity in any country and that the market should provide an efficient pricing, there should be no excess demand for transportation activities, and efficient transportation activity, and locational price equilibrium. (2) Consumer equilibrium (consumption efficiency). The utility being maximized subject to income evaluated at the equilibrium point. (3) Producer equilibrium (production efficiency). Each producer maximizes his profit subject to his production, technological and institutional constraints and (4) Balance of payments equilibrium. This condition is an essential part of any international trade general competitive argument, and the transportation activity is implicitly taken care in the definition. Also, the products involved in international trade are measured using a common unit of measurement.

In most cases we are forced to work with situation which demands less specification in which case some of the above conditions are relaxed or not required to hold. An economy in a partial competitive spatial equilibrium must satisfy all the conditions mentioned above except that the condition on consumer equilibrium is relaxed. This makes the definition less binding since the income formulation rule is not specified and that gives an opportunity to develop a class of mathematical programming models that are capable of attaining this equilibrium state. This possibility has enabled various models including partial equilibrium forest sector models to be developed for specific sectors depending on the scope and objectives of individual research studies.

Brief Description of the Tanzania Trade Model (Ttm)

Structure of the TTM

The model applied for studying the forest sector of Tanzania is named the "Tanzania Trade Model (TTM)" described in detail in Ngaga (1998). The TTM was adapted and modified from the Norwegian Trade Model (NTM) (Trømborg and Solberg 1995, 1996a&b) which resembles the Finnish version, SF-GTM (Ronnila 1995). All versions are based on the framework of the Global Trade Model (GTM) developed at the International Institute for Applied Systems Analysis (IIASA) (Kallio, Dykstra and Binkley 1987).

The TTM consists of 5 domestic regions and 2 regions representing the rest of the world for export and import respectively. The characteristics for rest of the world regions are presented in less detail relative to the domestic regions because most trade of forest products takes place in the domestic market. There are 17 products of which seven are primary products namely: natural forest sawlogs, other natural forest roundwood, softwood sawlogs, hardwood sawlogs, pulpwood (hardwood and softwood) and recycled paper. The remaining 10 products are classified as final products and they include softwood sawnwood, hardwood sawnwood, newsprint paper, packing and wrapping papers, other writing and printing papers, plywood, hardboard, chipboard, charcoal and fuelwood.

The model is a partial equilibrium market model for which a solution is obtained within each period by maximising the net social pay-off, i.e., the sum of consumers and producers surpluses less the transportation cost resulting from trade for all products and regions. The model takes into account the constraints on resources, industrial capacity and budget. At any given time period t, the model searches for market-equilibrium solutions for all products such that the demand and supply are equal for each forest product in each region. The solution of each period is used for updating the data on which the solution for the subsequent period is based. The TTM has 4 periods of 5 years each, from 1998 to 2018.

Conceptually the structure of the model is made up of several hierarchical levels, i.e., sectoral, regional and global levels, linked together. At the sectoral level, we have the sector agents (i.e. consumer sector, production sector, export and import trade sectors) which maximises their social welfare under specific constraints. Together they form the second hierarchical level, a regional module that may be a sub-module of a large regional module. The principle of linking together sectoral agents and regions requires choosing regional and world market prices that equates demand and supply in all markets. The regional modules are linked together via trade to form the global module which is the top level of the hierarchy. To equate demand and supply to determine the partial equilibrium price, π^*, and consumption, q^*, is equivalent to maximising the area between the demand and supply curves (i.e. the consumers' surplus and producers' surplus). The intuition behind this is given in a mathematical programming framework developed from the work by Samuelson (1952).

A detailed description of the sectoral, regional and global levels and how they are linked to each other is presented in Sections 3.1.1 to 3.1.3.

Sectoral agents

Consumers

Assuming that consumers are trying to maximise their welfare depending on the consumption of the final products, given the demand functions of the products, we derive the mathematical formulation of the consumer sector for the case of one product, k. In a given region i, let $q = (q_k)$ be a vector of the product demands, k ($k = 1, ..., n$), and $P_k\ (q_k)$ be the inverse demand function for product k. Let $P_k\ (q_k)$ be differentiable and non-increasing. Furthermore, let $\pi = (\pi_K)$ be a vector of product prices, and let Q denote the consumption possibility set (closed, convex and nonempty). Then the consumption sector's problem is given as follows:

$$\max_{q \in Q} \sum \int_0^{q_k} P_k\ (q_k)\, dq_k - \pi q \quad \text{Eq. 3.1)}$$

Production sector

As for the consumers, producers such as timber growers and forest industry firms, of a given region i are assumed to maximise their profit defined as producer's surplus and submit this information to the regional level of hierarchy.

Let $z = (z_k)$ be a vector of product supply for products k, let $c_k\ (z_k)$ be the marginal cost function for product k, and V is the production possibility set (closed, convex and nonempty). Under competitive markets, the vector of product prices $\pi = (\pi_K)$ is not perceived as being dependent on net output volumes by any individual producer. Thus, the producer's problem is set as follows:

$$\max_{z \in V} \pi z - \sum_k \int_0^{Z_k} c_k\,(z_k)\, dz_k \quad \text{(Eq. 3.2)}$$

Export and import sector

The export-import sector can be conceptualised by assuming that the producers and consumers account only for domestic prices and that the trade agents deal with exports and imports among regions. We derive a mathematical programming formulation of the trading agents operating in region i as follows:

$$\max_{e_{ijk}, e_{jik}} \sum[(\pi_k^j - \pi_k^i - D_{ijk})\, e_{ijk} + (\pi_k^i - \pi_k^j - D_{jik})\, e_{jik}] \quad \text{(Eq. 3.3)}$$

Where π_k^i is the price for product k in domestic region i, π_k^j is the price for product k in region j; e_{ijk} are exports for product k from region i to j; e_{jik} are imports from region j to i; D_{ijk} is transportation cost for a unit of product k from region i to j. Exports and imports may be restricted exogenously.

Regional models

The sectoral agents described by Eqs. 3.1 to 3.3 are combined in order to specify the objective function for region i and the feasible set for the region problem consists of sectoral agents' constraints and the material balance equations:

$$q_k + \sum_j e_{ijk} = z_k + \sum_j e_{jik} \quad \forall\, k \quad \text{(Eq. 3.4)}$$

The sectoral agents are assumed to take prices as given and otherwise behave as though their decision variables are independent of other sectors. At equilibrium the Eq. 3.4 holds and the regional objective function can be reduced to Eq. 3.5, where the vector π^i of domestic prices no longer appears. Thus, the whole problem can be defined as :

$$\max \sum_k \int_0^{q_k} P_k\,(q_k)\, d\, q_k - \sum_k \int_0^{Z_k} c_k\,(z_k)\, dz_k + \sum_{jk} [(\pi_k^j - D_{ijk})\, e_{ijk} - (\pi_k^j + D_{jik})\, e_{jik}] \quad \text{(Eq. 3.5)}$$

subject to

$$q_k + \sum_j e_{ijk} = z_k + \sum_j e_{jik} \quad \forall\, k \quad \text{(Eq. 3.6)}$$

$$q \in Q \quad \text{(Eq. 3.7)}$$

$$z \in V \quad \text{(Eq. 3.8)}$$

3.1.3 The global model

The regional models represented by Equation 3.5 are mathematically independent because they have independent variables and constraints. Thus, in the global model, the objective functions of each region are summed up jointly within a single optimisation problem subject to all regional constraints represented by Eq. 3.6 to Eq. 3.8. Since the imports of product k to region i from region j equals the respective exports from j to i, the import variables match the export variables. The global problem can be stated as follows:

$$\max \ [\sum_{ik} \int_0^{q_k^i} p_k^i (q_k) dq_k - \sum_{ik} \int_0^{z_k^i} c_k (z_k) dz_k - \sum_{ijk} D_{ijk} \ e_{ijk}] \qquad \text{(Eq. 3.9)}$$

subject to;

$$q_k^i + \sum_j e_{ijk} = z_k^i + \sum_j e_{jik} \ \forall \text{ k, i} \qquad \text{(Eq. 3.10)}$$

$$q^i \in Q^i \ \forall \text{ i} \qquad \text{(Eq. 3.11)}$$

$$z^i \in V^i \ \forall \text{ i} \qquad \text{(Eq. 3.12)}$$

The optimality conditions for the stated problem equal the equilibrium conditions for global competitive market (Samuelson 1952). The optimisation conditions governing the sectoral agents, regional and global models satisfy the partial equilibrium conditions of the TTM.

Strengths and Weaknesses of Partial Spatial Equilibrium Models in Forest Sector Analysis

General strength of partial spatial equilibrium models

Some of the strengths of partial equilibrium models in analytical context include the following (after Kallio, Dykstra and Binkley 1987; Trømborg and Solberg 1994):

i. Large number of products and several market levels (such as logs and final products) are readily accommodated in this framework with little additional solution cost or increase in model complexity. This is an attribute that is lacking in any of the other general modelling approaches.
ii. The possibility of having a multi-regional representation with interregional flows at all levels. The multi-regional representation and the presence of several market levels provide an opportunity to study the complex linkages that characterize forest sector markets, and the possibility for trade analysis.
iii. This approach is useful where variations in data availability or market structure across regions require the use of highly diverse functional representations of demand and supply relations. This allows the use of functions ranging from continuous functions to simple activity analyses, and use of linear and non-linear programming algorithms (Buongiorno 1996). Also, the underlying theme of optimization in spatial equilibrium models of the forest sector has indicated to be a powerful way of organizing the data (Buongiorno 1996).
iv. These models are transportable and adaptable to meet varying computational capabilities of potential users because the models use solution codes which are readily available or easily adaptable to the available computing facilities.
v. Partial equilibrium models are also useful in the analysis of long-term trends in the forest sector and the likely impact of alternative policy scenarios, as they are flexible enough to be able to accommodate a wide range of simulations. The flexibility in modelling is important because sometimes at the beginning of modeling work, the full extent of policy simulations or scenario analysis may not be clear. Therefore somewhere in the process some adjustments may be needed by means of constraints and/or changes in the objective function to reflect the intended policy or scenario environment.

General weaknesses of partial spatial equilibrium models

Some of the weaknesses of the models compared to the real world situation include the following (after Kallio, Dykstra and Binkley 1987; Cardellichio and Adams 1988):

i. These models fail to explain “minor” bilateral flows and may error in predicting the size of large flows. This is because spatial equilibrium models embody some structural features which fail to explain some of the bilateral trade flows. These features include the high level of aggregation both in region and product dimensions, and the economic assumptions that drive the model behaviour. For instance, large region sizes increase the probability that one area of the region could import a product while another part of the same region is exporting the same product. Similar argument can be said for product aggregation. Products are defined in broad terms that they encompass many distinct commodities and it is possible even for a narrowly defined region to import and export the same product.
ii. These models also ignore the heterogeneity of goods within a given commodity class and consumer preferences. For example in natural forests where there are many species of different classes but all aggregated in a few classes such as fine hardwood and general utility hardwood or simply sawn-hardwood. Also the consumer preferences for example on certain tree species (Ngaga, Solberg and Monela 2001) may be the cause for the observed bilateral trade flows. Trade may be influenced by other factors such as traditional market arrangements, long-term trading agreements, delivery performance and expectations regarding future markets. These factors add to the difficulty of predicting bilateral trade flows. The observation on bilateral flows notwithstanding, predictions of total trade, production, consumption and prices may still be good which makes these models potential for use and application.
iii. Partial equilibrium models also assume certainty and hence abstract from policies of some importers of diversifying sources so as to limit the impact of trade or domestic disruptions, or where exporters do so for reasons other than profit.
iv. In economies where the forest sector plays a significant role it can be argued that partial equilibrium models overlook important interactions between the forest sector and the general economy (Trømborg and Solberg 1994).

Strengths and weaknesses with reference to the Tanzanian forest sector

The assumption of perfect competitive market

One of the main assumption underlying the Tanzania Trade Model (TTM) is that of a perfect competitive market hypothesis (Ngaga and Solberg 2001). That is, producers and consumers operate at a single unit market price. Further, this assumes that the market operates under the following qualitative conditions (Kreps 1990): (1) The good is undifferentiated and/or is a commodity; (2) The producers (or consumers) have perfect information about the prices being paid or charged by consumers (or producers); (3) Each producer or consumer of the good takes as given the market price for the good in question. Based on the above conditions along with those discussed under competitive spatial equilibrium, the analysis of the forest sector in Tanzania has indicated that there are some main and minor violations of this assumption regarding both the producers (supply) and the consumer (demand) sides. This is further discussed in sections 4.3.1.1 through 4.3.1.3.

Roundwood supply and demand

The roundwood inventory projections made with the TTM are based on estimates of forest resources and growth rates available. This information is more reliable for industrial plantation forests managed by the state, than for private plantation forests, which have no reliable data. In addition, the actual stock in natural forests cannot be established with certainty because no recent inventory has been conducted in Tanzania to cover the whole country. Thus, roundwood supply from private plantation and natural forests are estimates based on the reports provided by the Forestry and Beekeeping Division.

To assess if the inventory projected by the TTM is reasonable we make comparison with the general state and trends in forest resource development in Tanzania available in several reports including the Forest Resource Assessment by FAO (1990) and the TFAP report by MTNRE (1994). Based on this comparison, the levels projected by the TTM were found to be reasonable for the purpose of sectoral-level forest policy analysis. However, the chances of having a margin of error in the absence of actual inventories cannot be ruled out.

One of the shortcomings with the roundwood supply model for the Tanzania case is that the marginal cost curve for roundwood supply is defined as a function of elasticity. Tanzania lacks empirical studies on timber price elasticities. The timber price elasticities used in TTM are based on those used in the Global Trade Model (GTM) (Kallio, Dykstra and Binkley 1987), and there could be a margin of error.

In addition, the supply elasticity in TTM just like in the GTM is assumed to be identical for all roundwood assortments. However, the fact that marginal sawlogs can always be downgraded to pulpwood when pulpwood prices rise demands more elastic supply for small roundwood assortments. Nevertheless, the present set-up of identical supply elasticity is appropriate in the sense that it suggests that sawlogs and pulpwood are in direct competition in the regions of Tanzania.

The government owns almost all forest resources. This is about 33.3 million hectares of natural forests, and 80 000 hectares of industrial plantations which all together form about 99% of the total forest land area. Very little is owned privately. This indicates that there is only one source that supplies roundwood in Tanzania representing a monopoly situation.

The royalty fees for roundwood are centrally set by the government and are not reviewed regularly. Roundwood prices (except from natural forests) used in the quantitative study is the sum of royalty fee, harvesting and delivery costs to the mill sites within the region (Ngaga and Solberg, 2001). However, harvesting and delivery costs vary from one region to another which makes roundwood prices to vary regionally.

The demand for roundwood is high and competitive in some regions and less competitive in other regions. This is largely due to the distribution of forest-based industries which is geographically uneven and has concentrated in few regions (Ngaga *et al.*, 2001). In those regions, for instance Arusha, Kilimanjaro and Tanga there is competition for roundwood, and in the same regions or other regions the situation is exacerbated by the closure of some of the natural forests.

The demand for roundwood from natural forest is high for certain species, (Ngaga *et al.*, 2001). Therefore, preference and tastes influence the demand for roundwood from natural forests. Some of the forest plantations lack competition on the demand side because they are remotely located and infrastructural constraint prohibits entrepreneurs to invest in those areas. Other forest plantations like Sao Hill forest plantation whose allowable cut is around 600 000 m^3/year (Dallu, 1996) mainly served two customers, the Southern Paper Mills (SPM) and the Sao Hill Sawmill which do not run at their full capacities. The priority in this case was given to the two mills although there are many other customers seeking to harvest in Sao Hill forest plantation (ibid). Hence, the assumption of a perfect competition is violated.

Generally, the demand for roundwood is high in some places which could have brought competition if there were more actors on the supply side. The government (owner) has the control on who and how many should be allowed to harvest not on the competitive basis or the monopoly hypothesis but based on other criteria such as employment and/or to guarantee the availability of raw material for particular industries. The standard theory of monopoly states that the monopoly sets the quantity of output less and price higher than in a competitive market.

However, the ownership of forest resources and the demand for roundwood in Tanzania exhibits a monopoly situation and hence violation of the perfect competition hypothesis.

Forest industry production and costs

In TTM, forest industry production was modelled by using production costs for individual mills. The implication here is that one must have access to reliable cost data and also be able to maintain a significant level of disaggregation for the curves to provide accurate and appropriate representation of the industry behaviour. This type of forest product supply curves is also used in PAPYRUS (Gilless and Buongiorno 1987), GTM (Kallio, Dykstra and Binkley 1987), SF-GTM (Ronnila 1995) and in NTM (Trømborg and Solberg 1995) but at different aggregate levels of cost data. These data are usually not available in public statistics and most firms in many places particularly in the private sector still regard them as sensitive and treat them with an element of confidentiality. Data from state managed industries were readily available and some of them well documented. Private forestry industries are quite often reluctant to release correct information particularly financial data. In such cases, data from private individuals were adjusted using data obtained from parastatal industries provided they have similar conditions (for example installation capacity and market conditions). Also, various reports and studies on forest industries in Tanzania have been used in adjusting some of the statistics. The data used here are fairly reliable.

Furthermore, in TTM, there is a reasonably high level of product aggregation because of compromising with data availability and consistency. The level of aggregation is discussed by Ngaga and Solberg (2001). For example, sawnwood is produced in different sizes and from many species of different prices, and the prices of sawnwood also vary by species and size. To model these details in the supply functions would have increased the complexity and realism of the model but certainly the exercise would be cumbersome. Because of this aggregation, it is possible for the model to generate prices which are different from the actual prices.

Estimation of industrial capacities was based on Kowero (1989), Jaakko Pöyry (1992), Tanzania Wood Industry Corporation (TWICO) and mill reports. The current production level in pitsawing industry is assumed to be at capacity limit. This is because at the moment there is an over exploitation of the commercial tree species in natural forests based on the fact that pitsawing has concentrated in few areas and tend to be very selective on tree species. The reason for this tendency is the skewed market preference for a few popular indigenous tree species (Ngaga and Kowero 1992). Consequently, less than 30% of the mill's capacity that rely on these hardwoods is utilized due to shortage of the raw material which is no longer easily available in some of the areas (O'Kting'ati and Kowero 1990).

Proposed new investments in sawmilling, wood based panels, and pulp and paper industries are within the limits of the economic growth of the country particularly the industry sector. Individual mill plans and their current status, including some studies on the forest industry sector have been used in planning for new capacities. The proposed new capacities are mainly in form of renovation and repairs rather than consideration for new plants because most of the industries already in operation are working below their rated capacities.

Supply and demand for final products

Demand functions

The primary requirement in TTM is that the demand functions for each region, product, and time step must depend only on the product price in the region at that time. This is done by using the approach of updating demand functions overtime based on the assumption that demand curves will shift overtime as a result of economical growth, population growth via demand growth and technological changes. However, more appropriate demand functions should have been based on end-user sectors like housing and industrial buildings. This is because final products are primarily consumed by the end-user sectors of the economy. One could start by analyzing the demand in those sectors by looking on indicators like volume of output and the share of various forest products among all inputs used in the sector, and use that information to develop the demand functions. Nevertheless, this approach was not possible due to lack of data on end-user sectors.

Except for the average substitution effects embodied in the direct price elasticities, the cross-price elasticities have been omitted in the TTM due to unavailability of data on substitution. Since price trajectories differ markedly across products, this is likely to be seen as simplification because there is no opportunity for commodity substitution. However, TTM is a medium-term simulation model and the degree of substitution in Tanzania is very minimal. Thus, the power of the model as a medium-term simulation tool is not weakened by this omission.

The TTM employs linear approximation of demand functions in the simulation of actual model solutions. Linear demand curves may cause problems in simulating market behaviour in the sense that they tend to choke off final products demand too rapidly when product prices are rising (Cardellichio and Adams 1990). Thus, if demand curves are thought to be non-linear, linearization of curves will lead to projections or policy simulations with unintended demand responses (ibid).

Price elasticities

The elasticities used in the model are estimates adjusted based on those proposed by Kallio and Wibe (1987) for low income countries having less that USD 750 per year. Tanzania falls under low income category and its annual income per capita is very low (i.e. USD 250 per capita). Based on this low income, price elasticities had to be adjusted using information from some studies in Tanzania such as Openshaw (1971). Elasticities tend to change with income over time and the use of constant elasticities for a longer period than 10 years may lead to unrealistic forecasts. There is still room for some improvements on this subject in future. We think the uncertainty is rather high with regard to elasticities used in TTM and this uncertainty should be tested through sensitivity analysis.

Prices

The reference prices for 1993 are average or weighted annual price nearly for all products. There are several reasons for using averages. In some cases several related products have been grouped together (through product disaggregation). For example, while sawn hardwood is treated as a single product there are many species of hardwood sold at different prices depending on the size. Such detailed breakdown was not possible and would have made the analysis difficult. Therefore in this case, within each region, the prices taken to determine the average/weighted price were those of the most popular and available tree species and sizes. In wood based panels (i.e. plywood, hardboard and chipboard), there were several grades for each product and each grade had its own price although the factory does not differentiate costs of production by grade. Consequently, all grades had to be treated as one grade and take the average price. A similar situation was found in paper and paperboard products and had to be treated using the same approach.

On roundwood prices, the Central Government is responsible for setting royalties for roundwood products, but cannot have very much influence to the delivery and transportation costs. Hence, there is a chance of having a margin of error in roundwood prices used, particularly where the source of information on transportation cost depended solely on private owners. There is also a possibility that these costs may change relatively fast from time to time as private businesspersons try to adjust with inflation.

Consumption, exports and imports

There is no sufficient and accurate data on trade and consumption for most of the products. Statistics on consumption of products like fuelwood and charcoal are often crude and subjective. This is because consumption of fuelwood is concentrated in rural areas where most of the fuelwood is collected and consumed directly without any record. Fuelwood and charcoal demand data have been estimated from few scattered demand studies and regional reports.

Trade with the rest of the world has been on few forest products, mainly sawnwood, paper and log products. The data used in the model comes from official statistics that may be underestimated as certain amount is traded illegally due to difficulties in monitoring private businessmen and rent seeking. All these factors together may affect the reliability of data used.

Exports in forest industry products have declined due to the constraints faced by forest-based industries and the trade sector in general although there was significant increase in log export in 2003 and 2004. On the other hand, imports particularly on wood-based panels and paper products have increased. Recently, much of the imports have come from Kenya because it is nearer and hence minimum transportation costs. In addition, the revival of the East African Co-operation (EAC) and minimization of trade barriers among the member countries have eased trade and communication.

The main assumption of the model with regard to trade is that it assumes a surplus of the product. However, many companies in Tanzania, for example the paper industries when interviewed indicated that they export mainly because of the need for foreign currency to purchase raw material and spare parts in addition to pure profit maximization. This might look like a violation of the assumption but assuming foreign currency is a constraint for profit maximization the main assumption still holds. That notwithstanding, the condition for a competitive spatial equilibrium which requires no excess demand for any commodity in any of the countries involved in trade still holds.

Sawnwood

The supply of sawnwood in Tanzania is rather competitive since the forest-based industry is characterized by many small sawmills and a substantial amount of pitsawn timber. However, the location of sawmills is geographically skewed and hence the degree of competition vary regionally. Pitsawn timber is available in all regions because pitsawyers are scattered all over the country. Pitsawn timber adds to consumer's choice depending on need and ability to buy. The results from the interviews also did not indicate that sawnwood availability in the domestic market was a problem, and that the number of sawmills and traders has increased (Ngaga, Solberg and Monela 2001).

The domestic demand for sawnwood is also high particularly in regions with high construction and building activities, and high population such as Dar es Salaam, Arusha and Mwanza regions. That means in those regions there is a relatively efficient market pricing of sawnwood.

Wood-based panels

There is only one hardboard mill, one chipboard mill and one active plywood mill in Tanzania (Ngaga, Solberg and Monela 2001). As such there is a monopoly situation and before trade liberalization, there was no competition in the domestic market. However, following trade liberalization and free market pricing, imports particularly from Kenya, are increasing making the supply of panel products competitive especially in the Northern part of Tanzania, and manufacturers complained that their share in the domestic market has declined (Ngaga, Solberg and Monela 2001). Also, following the economic reforms, construction and building activities are growing fairly fast and increasing the demand for wood-based panels. Similarly, Jaakko Pöyry (1992) forecast an increase in demand and imports of wood-based panels for Tanzania in the next ten years.

Paper and paperboard products

There are only three major paper mills in Tanzania producing few different types of paper products (Ngaga and Solberg 2001, Ngaga, Solberg and Monela 2001). For instance, newsprint, and writing and printing papers were only produced by Southern Paper Mills Company (SPM). In view of this, the domestic supply of paper products is not competitive but monopolistic. The competition in the domestic market has mainly come from imports following trade liberalization and waives of import duty on some of the papers. The supply of paper has increased mainly from imports and the demand has increased as well due to the growing population and the economy. The domestic paper manufacturers complained on the decline in the domestic market share because of imported papers (Ngaga, Solberg and Monela 2001).

Charcoal

The supply and demand for charcoal in Tanzania is competitive in places of high consumption. Charcoal makers are widely scattered in the woodlands of Tanzania particularly in forests close to the roads. The woodlands are characterised by small dimension woods rendering them particularly suitable for charcoal making. In addition, the cost of producing charcoal is relatively small and there is lack of alternative means of income generation in rural areas. These factors have attracted many villagers to engage themselves in charcoal making. The demand for charcoal is high particularly in towns due to high tariff charges for electricity and low income for most people.

Transport competition

Ideally, separate transportation costs should be estimated for each mode and route, and the combination of least cost selected. Due to limitation of data this approach was found to be inappropriate for this study. Instead, the model uses a simplified method for treating transportation costs. The total transportation cost for each product is the product of the transportation cost parameter and the distance units between regions. The variable transportation cost per unit per kilometre is the same for all methods of transportation (i.e. truck or railway), and that distances between regions are measured from the city centres. This simple approach is justified by the difficulties involved in getting actual data for each method of transportation, by product and by region. The approach however, has the advantage of consistency among all routes, and useful for forecasting and simulation purposes. Also, the differences in transport charges among regions are reflected. In some cases this simplification may lead to projections or simulations with biased results. However, with limited alternative modes of transport to various regions in Tanzania this shortcoming does not weaken the strength of the transportation model.

Roundwood logging is done either by the Forestry and Beekeeping Division or individual sawmillers including delivery to the road side. In most cases, transportation of timber to the mill site is done by the mills or in some cases hired contractors. Consequently, transportation costs vary from place to place even within the region and not very reliable. However, our judgement is that the data used are fairly good.

Comparison of model results and stakeholder's views

Comparison of the results from sensitivity analyses using partial equilibrium model (Ngaga and Solberg, 2001) and the findings from the stakeholder's views based on interviews (Ngaga *et al.*, 2001) is presented in sections 4.3.3.1 through 4.3.3.6. The aim of the discussion is to illustrate the realm of the model.

The alternative scenarios conducted with the TTM include the increased electricity price, increased transportation costs, increased timber costs, restrictions on harvesting natural forests/limited growth in timber supply, changes in foreign exchange rates and changes in demand growth forecasts (Ngaga and Solberg, 2001).

On increased electricity price

The price of electricity was increased by 25%, 50% and 100% to test its effects on production and prices of products. The results from the analysis indicated that the paper industry would be affected most followed by wood-based panel and sawmills. For example, at 25% increase in electricity price production of newsprint decreased by 40%, writing and printing paper decreased by 50% in some of the periods. Production of paper products decreased even further as costs of electricity increased (Ngaga and Solberg, 2001). Also, the prices of products increased significantly to compensate for increased costs (ibid). The implication from these results concurred with the findings from the stakeholders' interviews that unreliable power supply was one of the major problems affecting production and hence causing high production costs among other reasons (Ngaga *et al.*, 2001). In addition, it was indicated by interviewed end-users that lack of reliable electricity and high tariff charges are among the main reasons for high production costs (Ngaga *et al.*, 2001).

The observation on power supply and its implication on cost by the respondents indicate that the scenario was relevant. This indicates that reliable supply of electricity is one important component of the infrastructure in relation to production costs and the competitiveness of the Tanzanian manufactured products in the international market.

On increased transportation costs

The simulation of 25% and 50% increased transportation costs on production, consumption, price and trade indicated that all products were sensitive to the changes, particularly paper and panel products (Ngaga and Solbetrg, 2001). The most negatively affected product however was other writing and printing paper whereby production declined by over 20% from the base scenario at 50% increase in transportation costs. The analyses of the stakeholders opinions on factors affecting production and trade in forest products especially producers, traders and end-users' views, all cite transportation costs as one of the main problem (Ngaga *et al.*, 2001).

On increased timber costs

The scenario of increased timber costs by 25%, 50% and 100% indicated that roundwood supply will decrease as well as some of the final products produced from the category of the decreased roundwood (Ngaga and Solberg, 2001). The results indicate that as timber costs increased by 25%, the natural forest sawlogs and pulpwood from both softwood and hardwood declined by 1 to 2%. Similarly, at 50% and 100% increased timber costs, the same products declined in the range of 1 to 4% per year (Ngaga and Solberg, 2001). In addition, prices of roundwoods would fall because of decreased harvests. Production of hardwood sawnwood decreased by 1% and 2% as timber costs increase by 25% and 50% respectively. Similarly, high timber cost was mentioned by producers and forest owners interviewed on the factors affecting production and trade in forest-based industries, and supply of raw material (Ngaga *et al.*, 2001). Respondents indicated that timber costs increased mainly due to harvesting costs caused by increased distances, accessibility and search for known species (Ngaga *et al.*, 2001). This indicates that the scenario is relevant and that the observations are reasonable.

Restrictions on harvesting natural forests/supply of roundwood

This scenario assumed a decrease of 20% and 30% on supply of roundwood from natural forests, and the results indicated that supply of natural forest sawlogs and other industrial roundwood will decrease proportionately with the level of restriction imposed (Ngaga and Solberg, 2001). Consequently production and consumption of sawn hardwood and charcoal would decrease, and prices of roundwood and final products would increase because of harvesting, delivery and production costs (ibid). For example, at 20% restriction, price of sawlogs increased relative to the base scenario by 44% and at 30% restriction the increase was by 71%. A similar trend was observed in other roundwood where the percentage increases in price relative to the base scenario were 3 and 65 at 20% and 30% restrictions on harvesting respectively. Also, at 30% restriction, production of hardwood sawnwood decreased by 10% from 90 000 m^3/year in period one to 80 000 m^3/year in period two (Ngaga and Solberg, 2001).

In the analysis of factors affecting production and trade based on the stakeholders interviewed, respondents in forest-based industries and those in forest offices indicated increasing difficulties in procurement of natural forest sawlogs due to either closure of some natural forests or increasing distances in search for known species (Ngaga *et al.*, 2001). This translated into high timber costs. Therefore, this scenario was relevant to be tested and the results in both reports provide some insights on the effects of restricting supply of logs from natural forests. The order of magnitude of the impacts estimated by the model seems reasonable as compared with views of the interviewed stakeholders.

Changes in foreign exchange rates

In the foreign exchange rate scenario, the Tanzania shilling was devalued by 10%, 20% and 30% and its impact on production, prices and trade evaluated (Ngaga and Solberg, 2001). The results indicated that devaluation would generally benefit the domestic producers particularly the paper industry, and that the volume of exports will most likely increase. At 20% increase in foreign exchange rates, newsprint, other writing and printing papers, and hardwood sawnwood exports to the rest of the World increased by 1 000 t/year in 2018. The same increase in volume of exports was observed with 30% increase in foreign exchange. In addition, the results indicated that exchange rate changes would have some impact on the prices and profitability of all domestic production (Ngaga and Solberg, 2001).

Theoretically, weak currency makes exports attractive because they become cheaper when valued at border prices and hence stimulate domestic production, and discourage imports. Nevertheless, the analysis of the responses from the stakeholders' interviews on the effects of structural adjustment programmes (SAPs) has indicated different views (Ngaga *et al.*, 2001). The views of traders and manufacturers are that exports have either stagnated or declined mainly because of the constraints surrounding production and the trade sector, while imports have increased due to trade liberalisation and laxity in tax collection. This observation highlights the need to take into account the effects of other policies when evaluating the likely outcome of model results. Furthermore, the implication is that other important factors not covered by the model and its underlying assumptions may invalidate some of the predictions.

The main factors which influence forest sector development in Tanzania in relation to the TTM variables and parameters

The findings from interviews with the main stakeholders in the Tanzania forest sector have indicated that despite of many factors which affect and influence production and trade in forest products of Tanzania, four of them are the main ones (Ngaga *et al.*, 2001). These factors include financial constraint, infrastructure constraint, inadequate incentives and institutional set-up. It can be said that the financial constraint which is the most important factor singled out, is implicitly taken care by the model through capital and investment, production and transportation costs, income elasticity, and other variables such as base year production and recovery rates. The base year production indicates capacity utilization. The recovery rate is a function of the machinery, technical skills and operation techniques. There are many factors which determine the capacity utilization and mill recovery rates in Tanzania and these factors are mostly contributed by financial constraint (Ngaga *et al.*, 2001; Moyo and Kowero, 1987; Kowero, 1988; Moyo and Kowero, 1986). The infrastructure constraint is taken care by the model via transportation cost parameters and the distance matrix, and cost of power (i.e. electricity, heat/steam and fuel).

The institutional set-up factor leads to high bureaucracy and transaction costs; a problem which is pertinent in Tanzania and in many developing countries with regard to poor performance in international trade. Bureaucratic activities represent the real costs although they do not appear in official accounting figures (Markusen *et al.* 1995). However, the institutional set-up factor is captured by the TTM only indirectly through high production costs. A factor not captured by the model is that of incentives to attract investment in production and trade, and salary and other remunerations to increase the morale for work among employees. The institutional set-up and incentive factors cannot be translated into direct costs/prices by economic rules as they are largely overheads and it is difficult to have quantitative variables in the model to account for their effects.

The financial constraint, infrastructure constraint, incentives and institutional set-up factors, operate alone and in conjunction with other factors to cause small volume and high costs in both the production and the trade sector. Similarly, the results of the TTM indicated a modest increase in both production and trade (Ngaga *et al.*, 2001). These factors also cause high production, transportation and marketing costs, raw material availability and limitations on the consumption of forest industry products (Ngaga, Solberg and Monela 2001).

CONCLUSIONS AND FUTURE RESEARCH

Conclusions

The TTM is of interest in analyzing the Tanzanian forest sector due to its ability in accounting for the regional aspects and the forest sector representation up to a firm level. Also, the model has the capability of economic consistency in the optimization algorithm in each scenario, and it can generate solutions within a relatively short time. Some of its shortcomings are: the aspect of linearization of demand functions might give too large changes in demand when prices change, the fact that demand functions are not based on end-user indicators may to some extent simplify the circumstances surrounding the market behaviour; and the data input required is rather demanding.

Generally, statistics on forestry related parameters in Tanzania are available in varying degrees of abundance and accuracy. Also, information on some of the needed parameters is not available because such studies are yet to be conducted in Tanzania. The institutional set-up of forestry and forestry related activities in the country and the fact that they are not co-ordinated to some extent affect storage, availability, and level of accuracy of the data used in this model.

Based on a comparative analysis of the model results and the findings from the stakeholder's interviews, the model appears to be a useful tool which can be used to provide some insights on the forest sector of Tanzania. The model is appealing from the structural point of view particularly the representation of the main stakeholder in the forest sector - producers, traders, consumers and the government on policies as well as products coverage. Another strong feature of the model is the coverage on the spatial or regional aspects. This makes the framework appropriate for examining policies which have international repercussions.

Despite the violations of some main assumptions however, the TTM still represents strong characteristics of the Tanzanian forest sector and can provide some useful insights when used in the analysis of the sector. In addition, the model could also serve as an ideal model, in the perfect competitive hypothesis sense, to indicate the likely scenarios in the case of a competitive market particularly based on the on-going economic and market reforms. Another contribution of the TTM is that it provides a logical and consistent framework to study forest sector issues in Tanzania though in an experimental setting. This may assist planners in the forest sector address appropriate or important questions concerning the future of the national forest sector.

Future research

Based on the present study, the following areas may be suitable for further research: Improvement of the data base, particularly on parameters which are not yet available in Tanzania such as technological coefficient, elasticities of prices, income, harvesting and substitution between products.

Testing other models such as non-competitive and econometric models to compare their relative weak and strong points for various kinds of analyses. Also, the possibility of combining these methods in order to benefit from the strong features of each approach.

Study on products substitution and it's effects on production in forestry.With the ongoing economic and market reforms, it will be interesting to study how will the markets for forest industry products function and what factors will guide the behaviour of firms.

Assessment of the already privatised forest-based industries in Tanzania to investigate the changes and the effect on the management practises on the forest industry.

REFERENCES

Buongiorno, J. 1996. Forest sector modelling: a synthesis of econometrics, mathematical programming, and system dynamics methods. *International Journal of Forecasting* 12:329-343.

Cardellichio, P. A. and D. M. Adams, 1988. Evaluation of the IIASA model of the global forest sector. Working paper No. 13, CINTRAFOR. 142 pp.

Cardellichio, P.A. and D. M. Adams, 1990. An appraisal of the IIASA model of the Global forest sector: Advances, shortcomings, and implications for future research. *Forest Science*, 36:2.

Dallu, A.I.M. 1996. Wood supply situation for Sao Hill forest project. Ministry of Natural Resources and Tourism, Forestry and Beekeeping Division. 3 pp.

FAO, 1990. Forest resources assessment: Country briefs. Rome.

Gilless, J. K. and J. Buongiorno, 1987. PAPYRUS: A model of the North American pulp and paper industry, *Forest Science monograph*, No. 28.

Jaakko Pöyry, 1992. Industrial restructuring study on wood and paper industry in Tanzania. Fact book. SIDA, Helsinki. 308 pp.

Kallio, M. and S. Wibe, 1987. Demand functions for forest products. In: Kallio, M., D. P. Dykstra and C. S. Binkley (eds.), 1987. The Global Forest Sector: An Analytical perspective. London: John Wiley & Sons. 560-568 pp.

Kallio, M., D. P. Dykstra and C. S. Binkley (eds.), 1987. The global forest sector: An analytical perspective. John Wiley & Sons. 703 pp.

Kowero, G. S. 1988. An economic evaluation of the mobile sawmills industry in Tanzania. Winrock International Institute for Agricultural Development, Arkansas. 56 pp.

Kowero, G. S. 1989. Forestry statistics in Tanzania: Case study. Seminar on forestry statistics in Africa, Blantyre, Malawi. 12th-15th November. FAO, Rome. 65 pp.

Kreps, D. M. 1990. A course in microeconomic theory. Princeton University Press. 839 pp.

Krutilla, K. 1991. Transportation specification in forest sector models. *Forest Science* 37(1): 284-295.

Markusen, J. R., J. R. Melvin, W .H. Kaempfer and K. E. Maskus, 1995. International trade: Theory and evidence. New York: MacGraw-Hill, Inc. 471 pp.

Moiseyev, A. 1997. Approaches to modelling international forest sector. In: Saastamoinen, O. and S. Tikka (eds.). *Proceedings of the Biennial Meeting of the Scandinavian Society of Forest Economics,* Mekrijärvi, Finland, March 1996. Scandinavian Forest Economics No. 36: 99 - 119. Joensuu.

Moyo, C. L. and G. S. Kowero 1986. Mingoyo sawmill: A sawmill with a promising export potential. *Faculty of Forestry Record No. 36.* 11 pp.

Moyo, C. L. & G. S. Kowero 1987. The performance of some coastal hardwood sawmills in Tanzania. *Faculty of Forestry Record No. 39.* 14 pp.

MTNRE 1994. Tanzania forestry action plan 1990/91-2007/08. Update 1994. Forestry and Beekeeping and Division, Ministry of Tourism, Natural Resources and Environment, Dar es Salaam. 122 pp.

Ngaga, Y. M. 1998. Analysis of Production and Trade in Forest Products of Tanzania. Doctor Scientiarum thesis, Report No.1. Department of Forest Sciences, Agricultural University of Norway. 37 pp.

Ngaga, Y. M. and B. Solberg 2001. Analysis of Medium - term Development of the Forest Sector in Tanzania using a Partial Equilibrium Model. *Tanzania Journal of the Forestry and Nature Conservation, Vol. 74: 100-116.*

Ngaga, Y. M., B. Solberg and G.C. Monela 2001.Stakeholder's views on Economic and Institutional Factors Affecting Performance of the Tanzania Forest Sector. *Tanzania Journal of the Forestry* *and Nature Conservation, Vol. 74: 134-148.*

Ngaga, Y. M. and G. S. Kowero, 1992. Present consumption of sawnwood in the municipalities of Arusha and Dodoma in Tanzania. *Faculty of Forestry Record* No. 56.

O'Kting'ati, A. and G. S. Kowero, 1990. Natural forests in Tanzania and the national economy. A methodological approach. *Faculty of Forestry Record 43:131-135.*

Openshaw, K. 1971. Present consumption and future requirement of wood in Tanzania. FAO Technical report No. 3, SF/TAN 15, Rome. 47 pp.

Ronnila, M. 1995. Medium-term scenario for the Finnish pulp and paper industry. Working paper, 95-38, International Institute for Applied Systems Analysis (IIASA). Laxenburg, Austria. 105 pp.

Samuelson, P. A. 1952. Spatial price equilibrium and linear programming. *The American Economic Review* 42:283-303.

Takayama, T. And G. G. Judge, 1971. Spatial and temporal price and allocation models. North-Holland Publishing Company, Amsterdam . London. 528 pp.

Trømborg E. and B. Solberg, 1994. Evaluation of some forest sector models - assumptions, strengths and weaknesses. In: Helles, F. and M. Linddal, (eds.). *Proceedings of the Biennial Meeting of the Scandinavian Society of Forest Economics*, Gilleje, Denmark. Scandinavian Forest Economics No. 35: 237-249. Joensuu.

Trømborg, E. and B. Solberg, 1995. Beskrivelse av en partiell likevektsmodell anvendt i prosjektet "Modellanalyse av norsk skogsektor". Rapport fra Skogforsk 14/95: 1-35.

Trømborg, E. and B. Solberg, 1996. Data brukt i prosjektet "Modellanalyse av norsk skogsektor". Rapport fra Skogforsk 1-96: 1-60.

Trømborg, E. and B. Solberg, 1996b. Resultater fra projektet "Modellanalyse av norskskogsektor". Rapport fra Skogforsk 2-96: 1-80