AGRICULTURAL TRADE LIBERALIZATION, PRODUCTIVITY GROWTH AND POVERTY ALLEVIATION: A GENERAL EQUILIBRIUM ANALYSIS

Nadia Belhaj Hassine Veronique Robichaud Bernard Decaluwé

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Abstract

Computable General Equilibrium (CGE) models have gained continuously in popularity as an empirical tool for assessing the impact of trade liberalization on agricultural growth, poverty and income distribution. Conventional models ignore however the channels linking technical change in agriculture, trade openness and poverty. This study seeks to incorporate econometric evidence of these linkages into a CGE model to estimate the impact of alternative trade liberalization scenarios on welfare, poverty and equity.

The analysis uses the Latent Class Stochastic Frontier Model (LCSFM) and the metafrontier function to investigate the influence of trade openness on agricultural technological change. The estimated productivity gains induced from higher levels of trade are combined with a general equilibrium analysis of trade liberalization to evaluate the direct welfare benefits of poor farmers and the indirect income and prices outcomes. These effects are then used to infer the impact on poverty using the traditional top-down approach. The model is applied to Tunisian data using the social accounting matrix of 2001 and the 2000 household expenditures surveys.

1. Introduction

The Uruguay Round commitments and the current Doha Round of agricultural trade talks have raised the interest in understanding the main channels through which trade affects the livelihood of the poor in developing countries. The transmission mechanisms linking international trade to poverty are complex and challenging to predict. Among the important mechanisms documented in the literature, economic growth is advocated to be one of the main conduit through which trade liberalization can lead to sustained poverty alleviation (Winters, 2004; Winters *et al*., 2004; Nissanke and Thorbecke, 2006).
The link from agricultural trade openness to poverty reduction is presumed to operate partly by promoting the transfer of new technology and enhancing farming productivity. Agricultural productivity growth is vital for spurring broader economic growth through its strong linkages to the wider economy and for overcoming poverty particularly in countries with predominantly rural poverty profiles. Evidences provided by Thirtle *et al*. (2003), Ravallion and Chen (2007), and Self and Grabowski (2007) illustrate the fundamental role of agricultural development in generating economic growth, in alleviating poverty and in improving well being.

The poverty issues of agricultural trade reforms have been widely investigated using Computable General Equilibrium (CGE) models. The popularity of these models is due to their ability to produce disaggregated results at the microeconomic level, within a consistent macroeconomic framework. Even though most of the simulations show welfare gains from the removal of trade barriers, the estimated benefits greatly diverge across the studies (Bouët, 2006). The difficulty of assessing the true poverty impacts of trade reforms is in part explained by the complexity of the dynamic implications of external trade liberalization. CGE analyses generally ignore or deal poorly with the productivity and growth mechanisms (Winters, 2005; Porto, 2007). While these dynamic responses to international openness are gradually being incorporated in some CGE applications, the most influential frameworks in the policy debate are at quite some distance from fully integrating these forces (Vos, 2007).

This paper tempts to explore the poverty implications of agricultural trade liberalization in Tunisia. The study incorporates econometric evidence of the productivity linkages into a general equilibrium model to capture the additional poverty alleviation that could be expected from the dynamic growth effects induced by higher levels of trade.

Agriculture is an economically and socially important sector in Tunisia and remains among the most distorted sectors due to the heavy use of trade barriers and support policies. Historically, attempts by the Tunisian government to achieve food self-sufficiency have led to the implementation of important development projects and regulation measures of the agricultural and rural activities. The development policy targeted the modernization of the farming sector, the intensification of the production and the promotion of strategic commodities. The regulating mechanisms were notably aimed at ensuring adequate income levels for farmers by reducing their exposure to the food price instability in the world markets, as well as at preventing consumers from the risk of scarcity in staple commodities. The government interventions were mainly channeled via the control of prices and the protection of the domestic market by tariffs and non-tariff barriers.

Faced with structural economic difficulties and mounting financial and sectoral imbalances, it became evident that large budgetary outlays for the agricultural sector and urban consumers were losing support on efficiency and affordability grounds. Consequently, the government started the reform of agricultural policy, which culminated with the adoption and implementation of the Agricultural Structural Adjustment Programme (ASAP) in 1986 that aimed particularly at shifting prices closer to those in world markets and reducing production subsidies.

The economic reform strategy was accompanied by a gradual liberalization of the overall economy and the promotion of private-sector initiative. The broad trend towards a deeper integration into the free trade and open market-based world economy was accelerated after the signature of the General Agreement on Tariffs and Trade (GATT) and joining the World Trade Organization in the early 1990s. The signing of the partnership agreement with the European Union in mid-1995, stands for an important step for intensifying the Tunisian's economic and financial relations with Europe. While currently limited to the removal of tariff and non-tariff barriers on manufactured goods, the agreement called for a gradual agricultural liberalization. A comprehensive free trade in the agriculture sphere is not envisaged at the present time, the agreement aims simply at consolidating, and in some cases improving, the existing preferential mutual access for specific agricultural products. Freeing agricultural trade is however at centre stage of the current Doha Development Agenda negotiations and Tunisia is actively participating in the actual negotiations.

Despite these positive developments in terms of market liberalization and reduced State intervention in the Tunisian economy, the effective protection remains high in the farming sector, dominated by unskilled wage-workers and family farmers that are overly dependent on trade protection and government support.

In a country with limited natural resources, agricultural growth will depend more and more on yield-increasing technological change. Trade openness offers great opportunities through technology transfer and export promotion. A less optimistic view cannot however deny the challenges facing the most vulnerable rural populations for which rain-fed farming is the essential livelihood source and that may suffer adverse social and economic consequences from the growing competitive pressures, increases in agricultural and food prices and tariff preferences erosion.

To shed some light on these issues, we base our approach on two steps. In the first step, we start by sketching a conceptual framework for exploring the role of international trade in promoting technology transfer from more advanced trading partners of Tunisia and in enhancing agricultural productivity growth. For this purpose, we compute agricultural total factor productivity (TFP) indexes for Tunisia and its main trading partners. We use panel data for 14 countries involved in the EU-Mediterranean partnership and estimate a latent class stochastic frontier model to account for cross country heterogeneity in production technologies. We evaluate the contribution of trade openness to agricultural productivity growth using the distance from the technological frontier to capture the potential for technology transfer.

In the second step, we incorporate econometric evidence of the productivity effects into a CGE model to arrive at a comprehensive calculation of alternative trade liberalization scenarios on commodity prices, as a basis for then calculating the corresponding impact on poverty and inequality.

The structure of the paper is as follows. Section 2 outlines the plan for empirical investigation and presents the procedure to measure total factor productivity. Section 3 describes the CGE model and explains how the link between productivity and trade policy is incorporated. Section 4 reviews the data, and section 5 reports the empirical results. Finally, section 6 synthesizes the main findings and draws some conclusions.

2. Econometric Model

2.1. Agricultural Productivity Measurement: Panel Data Specification of a Latent Class Stochastic Frontier Model

Among the several alternative conceptual approaches to estimating agricultural efficiency and multifactor productivity, stochastic frontier models have become very popular. Based on the econometric estimation of the production frontier, the efficiency of each producer is measured as the deviation from maximum potential output. Evenly productivity change is computed by aggregating over technology change, factor accumulation, and changes in efficiency.

According to the frontier approach all producers use a common underlying production technology. However, agricultural producers that operate under various production and environmental conditions might not share the same production possibilities. Ignoring the technological differences in the stochastic frontier model may result in biased efficiency estimates as unmeasured heterogeneity might be confounded with producer-specific inefficiency (Orea and Kumbhakar, 2004).

The recently proposed latent class stochastic frontier model (LCSFM) has been suggested as suitable for modeling technological heterogeneity. This approach combines the stochastic frontier model with a latent sorting of individuals into discrete groups. Producers within a specific group are assumed to share the same production possibilities, but these are allowed to differ between groups. Heterogeneity across producers is accommodated through the simultaneous estimation of the probability for class membership and a mixture of several technologies (Orea and Kumbhakar, 2004; Greene, 2005).

The latent class framework assumes the simultaneous coexistence of J different production technologies. Producers in the sample are grouped into different clusters, each using one of these technologies. The number of groups and the class membership are a priori unknown to the analyst. The technology for the j^{th} group is specified as:

$$\ln(y_{it}) = \ln\ f(x_{it}, \beta_j) + v_{it|j} - u_{it|j} \qquad (1)$$

subscript i indexes producers (or countries) (i: $1 \ldots N$), t (t: $1 \ldots T_i$) indicates time and j (j: 1, …, J) represents the different groups. β_j is the vector of parameters for group j, y_{it} and x_{it} are, respectively, the production level and the vector of inputs. For each group, the stochastic nature of the frontier is modeled by adding a two-sided random error term $v_{it|j}$, which is assumed to be independent of a non-negative inefficiency component $u_{it|j}$.

In order to estimate (1) by the maximum likelihood method we assume the noise term $v_{it|j}$ to follow a normal distribution $N(0,\sigma^2_{v_j})$ and the inefficiency term $u_{it|j}$ to be a non-negative truncation of a normal random variable:

$$u_{it|j} = \exp(z_{it}'\delta_j)\omega_{it|j} \qquad (2)$$

where z_{it} is a vector of country's specific control variables associated with inefficiencies including: land distribution, land quality, water resources, land fragmentation, climatic variables…., δ_j a vector of parameters to be estimated, and $\omega_{it|j}$ a random variable with a half normal distribution.

In a latent class model, the unconditional likelihood for country i is obtained as a weighted average of its j-class likelihood functions, with the probabilities of class membership used as the weights:

$$\ln LF = \sum_{i:1}^{N} \ln \left\{ \sum_{j:1}^{J} P_{ij} \prod_{t:1}^{T} LF_{ijt} \right\} \qquad (3)$$

where LF and LF_{ij} are respectively the unconditional and conditional likelihood functions for country i, and P_{ij} the prior probability assigned by the researcher on this country to belong to class j. The salient feature of the latent class model is that the class membership is unknown to the analyst, the probabilities in this formulation reflect the uncertainty that the researchers might have about the true partitioning in the sample. To constrain these probabilities to sum to unity, we parameterize P_{ij} as a multinomial logit model:

$$P_{ij} = \frac{exp(\lambda_j ' q_i)}{\sum_j exp(\lambda_j ' q_i)} \qquad (4)$$

where q_i is a vector of country's specific, but time-invariant, variables explaining the probabilities and λ_j are the associated parameters.

Various algorithms for the maximum likelihood estimation have been proposed. The conventional gradient methods and the expectation maximization (EM) algorithm are among the most used approaches (Greene, 2001; Caudill, 2003; Orea and Kumbhakar, 2004). Using the parameters estimates and Bayes' theorem, we compute the conditional posterior class probabilities from:

$$P_{j|\mathrm{i}} = \frac{LF_{ij} P_{ij}}{\sum_{j} LF_{ij} P_{ij}} \quad (5)$$

Every country is assigned a specific class according to the highest posterior probability i.e., country i is classified into group k (: 1,..., J) if $P_{k|\mathrm{i}} = \max_{j} P_{j|\mathrm{i}}$. Furthermore, the estimated posterior probabilities help to compute the efficiency scores. Given that there are J groups, the latent class model estimates J different frontiers from which the inefficiencies of the producers can be computed by two methods. The first method estimate technical efficiency using the most likely frontier (the one with the highest posterior probability) as a reference technology. This approach results in a somewhat arbitrary selection of the reference frontier that can be avoided by evaluating the weighted average efficiency score as follows:

$$\ln TE_{\mathrm{it}} = \sum_{j:1}^{J} P_{j|\mathrm{i}} \ln TE_{it|\mathrm{j}} \quad (6)$$

where $\mathrm{TE}_{\mathrm{it}}|_{\mathrm{j}} = \exp(-u_{it}|_{\mathrm{j}})$ is the technical efficiency of country i using the technology of class j as the reference frontier.

2.2. International trade and agricultural productivity growth

From the estimated LCSFM we obtain technical efficiency measures for each country. We turn then to examining the role of international trade in promoting technology transfer, as well as in facilitating productivity growth and catch up with the frontier technology.

We begin by evaluating productivity change before moving to the analysis of the relationship between trade openness and agricultural TFP growth. Productivity growth is composed of technological progress, efficiency improvement and scale economies[1]. Consequently, TFP growth can be computed from:

$$\dot{\mathrm{A}} = TC + \dot{TE} + Scale \quad (7)$$

where $\dot{\mathrm{A}}$ is the growth rate of agricultural TFP, $TC = \frac{\partial \ln f}{\partial t}$ is technical change which measures the rate of outward shift of the best-practice frontier, $\dot{TE} = \frac{-\partial u_{it}|_{j}}{\partial t}$ is efficiency

[1] See Kumbhakar and Lovell (2000) for the tri-partite decomposition of productivity growth.

change over time, and $Scale = \frac{(\varepsilon_j - 1)}{\varepsilon_j} \sum_k \varepsilon_{kj} \dot{x}_k$ is the scale effect when inputs expand over time. ε_j is the sum of all the input elasticities[2] ε_{kj}.

TFP growth is explicitly related to change in efficiency which is assumed to be a function of a set of variables including international trade. The expression for productivity change can be extended to incorporate technology transfer as a source of convergence in agricultural growth among Mediterranean countries. Griffith *et al.* (2004) and Cameron *et al.* (2005) emphasize the importance of technology transfer, international trade and human capital for productivity growth in countries behind the technological frontier. In these models technology gap is used to capture the potential for technology transfer, and is included as an interaction term to capture an effect on the speed of technology transfer. Following these authors we derive an equation for agricultural productivity growth in the subsequent non linear form:

$$\dot{A}_{it} = \alpha_i + \alpha_1 H_{it}^{\alpha_G} + \alpha_2 IT_{it}^{\alpha_t} H_{it}^{\alpha_G} - \alpha_2 IT_{it}^{\alpha_t} H_{it}^{\alpha_G} GAP_{it} + \upsilon_{it} \quad (8)$$

where *H* is the human capital level of the country, *IT* is a measure of international trade, and *GAP* is the technology gap[3]. α_i is a country-specific constant and υ_{it} is an error term.

Technology gap indicates the deviation of country frontiers from the best practice technology labeled as metafrontier (Battese *et al*., 2004). We estimate the metafrontier by taking the outer envelop of the group specific frontiers, $f(x_{it}, \beta^*) = \max_j f(x_{it}, \beta_j)$. Then we measure the technology gap as the ratio of the output for the frontier production function for group *j* relative to the potential output defined by the metafrontier, $GAP_{it} = \frac{f(x_{it}, \beta_j)}{f(x_{it}, \beta^*)}$.

3. The General Equilibrium Model

The analysis of the impact of agricultural trade liberalization on poverty and inequality in Tunisia rely on a CGE approach. The model draws from Van der Mensbrugghe (2005), Rattsø

[2] Since input elasticities vary across groups, productivity change estimates from equation (7) are group-specific. Unconditional productivity measures can be obtained as a weighted sum of these estimates.

[3] $\dot{TFP}$ in equation (7) can be considered as the empirical counterpart of *GTFP*.

and Stokke (2005), and Diao *et al*. (2005). The framework includes productivity dynamics in order to capture the long run transmission mechanisms from trade reforms to poverty.
The model distinguishes 33 production sectors, including 23 agricultural and food activities with 10 urban industries and services. Factors of production are classified as capital, land, labor and natural resources. Land is further differentiated according to the perennial features of the crops, the irrigation intensity and the varieties grown. Labor is classified by the level of qualification (skilled and unskilled) and is disaggregated in five components. Institutions include households, companies, government and foreign trading partners. The household bloc is disaggregated into rural and urban households. The trading partners are decomposed into European Union countries and rest of the world.
The model is calibrated to data from a Tunisian social accounting matrix for 2001. The modeling analysis in this work is static by nature. The CGE model is completed by a micro-simulation methodology to measure the distributional and poverty effects of agricultural trade policy changes using the 2000 expenditures household survey. We use endogenous poverty lines to minimize the potential bias in the measurement of the poverty outcomes that results from using exogenous poverty lines. The CGE and micro-simulation models are linked in a top-down fashion.
This section provides an overview on the model structure, a more complete specification is given in Appendix 2.

3.1 The model structure

The model's production functions are of the nested structure. Perfect complementarity is assumed between value added and the intermediate consumptions in each sector. Value added is a Cobb Douglas (CD) function of labor, land, capital and natural resources. Labor is a CES bundle of skilled and unskilled labor. Land is also decomposed by type in a CES nest. Land is agriculture specific and labor is assumed to be fully mobile. Capital and natural resources are assumed to be sector specific.
In the demand side, the preferences across sectors are represented by the LES (Linear Expenditure System) function to account for the evolution of the demand structure with the changes in income level.
The consumption choices within each sector are a nesting of CES functions. The subutility specifications are designed to capture the particular status of domestic goods, together with product differentiation according to geographical origin.

Total demand is made up of final consumption, intermediate consumption and capital goods. Sectoral demand of these three compounds follows the same pattern as final consumption.

The methodological approach in this study is designed to take account of the productivity effects, triggered by technology transfer and trade, in the analysis of the inequality and poverty outcomes of trade reforms in Tunisia. The productivity dynamics formulation is based on Diao *et al*. (2005, 2006) and is consistent with the technology gap specification, suggested in the precedent section, where the productivity growth rate increases with the distance to the technological frontier.

We express agricultural TFP as a function of labor augmenting technical progress A_L, and land augmenting technical progress A_D:

$$A_a = A_L^{\beta_s^L} A_D^{\beta_a^{Ld}} \tag{9}$$

where β_a^L and β_a^{Ld} are the labor and land elasticities respectively.

TFP in the manufacturing sector is: $A_m = A_L^{\beta_m^L}$.

Subscript *a* indexes agricultural crops and *m* indexes agri-food and manufacturing products[4].

Technology transfer and own innovation are assumed to be the major sources generating productivity growth. Technology transfer (or absorptive capacity) is assumed to combine the gap to the technological leader, defining the learning potential through imitation; human capital, indicating the ability to exploit foreign technology; and the level of foreign trade which represents the channel transmitting the new technology to domestic producers. The basic idea behind this model has been developed by Nelson and Phelps (1966) in the context of a simple neoclassical growth model. Different modified specifications of this model have been empirically documented by Benhabib and Spiegel (2003), Griffith *et al.* (2004), Rattsø and Stokke (2005) and Cameron *et al.* (2005). An equation for TFP growth of the following form is incorporated in the CGE model:

$$\dot{A} = \alpha_1 \left(\frac{G}{GDP}\right)^{\alpha_G} + \alpha_2 \left(\frac{G}{GDP}\right)^{\alpha_G} \left(\frac{Trade}{XS}\right)^{\alpha_T} \left(-GAP\right) \tag{10}$$

where *G* is public expenditure, *Trade* is total trade, *GDP* gross domestic product, *XS* is aggregate output, and *GAP* is the technology gap. α_1, α_2, α_G, and α_T are constant parameters.

[4] See Diao *et al*. (2005, 2006) for similar specification.

The first term on the right-hand side of equation (1) captures the contribution from innovation that depends on the level of human capital. The second is an interaction term that captures the absorptive capacity. The further a country lies behind the technological frontier, the greater the potential for international trade and human capital to increase TFP growth through technology transfer from more advanced countries. Human capital is measured by the share of public expenditure in GDP and international trade is measured by the share of total trade in total production.

As increased openness may lead to skill biased productivity growth, we investigate this effect through the following CES specification of aggregate labor demand. Following Rattsø and Stokke (2005) aggregate labor demand is specified as:

$$L_i = \left[\gamma_{1,i} A_L^{\rho_l - 1/2\beta} UL^{\rho_l} + \gamma_{2,i} A_L^{\rho_l + 1/2\beta} SL^{\rho_l}\right]^{\frac{1}{\rho_l}} \qquad (11)$$

The direction and degree of technological bias is introduced through the parameter β, which gives the elasticity of the marginal productivity of skilled relative to unskilled labor with respect to labor augmenting technical progress. For β equal to zero, technical change is neutral and does not affect the relative efficiency of the three labor types. With a positive value of β technical change favors skilled workers, while negative values imply that improvements in technology are biased towards unskilled labor.

The reduced form specification of technological bias is assumed to be an increasing and convex function of trade share:

$$\beta = \lambda\left(\left(\frac{\dot{TRADE}}{XS}\right)^2 - 1\right) \qquad (12)$$

where λ is a constant parameter.

3.2 Income distribution and poverty

This section discusses incomes distribution and attempt to provide a brief overview on the methodology used to analyze the external choc effects on poverty.

The common poverty measures can be formally characterized in terms of per capita income and relative income distribution as follows:

$$P = P(Y, L(p)) \tag{13}$$

where *Y* is per capita income and *L(p)* is the Lorenz curve. *P* denotes the poverty measure which we assume to belong to the Foster-Greer-Thorbecke class (1984):

$P_\theta = \int_0^z \left(\frac{z-y}{z}\right)^\theta f(y)\,dy$, where θ is a parameter of inequality aversion, *z* is the poverty line, *y* is income, and *f(.)* is the density function of income. P_0, P_1 and P_2 are respectively the headcount ratio, the poverty gap and the squared poverty gap.

The CGE model, including the linked micro-simulation approach is the core methodology of the analysis of the poverty impacts of agricultural trade liberalization and productivity growth. The calibration of the model entails constructing a Social Accounting Matrix (SAM) and estimating the parameters of the productivity dynamics specification[5].

The model is designed of such way to capture the direct and indirect effects of agricultural trade liberalization on commodity and factor prices as a basis for then calculating the corresponding impact on poverty. The poverty implications of alternatives trade liberalization scenarios are inferred using the traditional "top-down" approach.

The model is solved using the SAM for 2001. The simulation of alternative trade liberalization scenarios generate new vectors of commodity and factor prices which are then fed into a micro-simulation framework to conduct a detailed analysis of income distribution and poverty at the household level using the Tunisian household survey of 2000[6].

Following Bibi and Chatti (2006), we use the concept of equivalent income defined as the level of income that would allow achieving the same utility levels under different budget constraints. Assuming a Stone Geary utility function, the equivalent income for each household *m* within the group *h* and at each period *t* can be written as:

$$Y_e(p_0, p_t, y_t^{h,m}) = \prod_i \left(\frac{p_{i,0}}{p_{i,t}}\right)^{\beta_{h,i}} \left(y_t^{h,m} - \sum_i p_{i,t} C_{i,h}^{min}\right) + \sum_i p_{i,0} C_{i,h}^{min} \tag{14}$$

where $p_{i,t}$ is the price of commodity *i* at period t, $y_t^{h,m}$ the income of household *m* within the group *h*, $C_{i,h}^{min}$ is the minimum level and $\beta_{h,i}$ the budget share devoted to the consumption of commodity *i* by household *h*.

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[5] Part of the structure of the econometric model is simplified to allow for statistical feasibility.

[6] The access to the household survey of 2000 was impossible. We use the 1990 and 1995 household surveys and the INS publications on the 2000 survey to generate the missing data. Our procedure is similar to that of Bibi (2005).

In order to better capture the effects of prices and income variations on poverty, we write the poverty measures in terms of equivalent income as follows:

$$P_\theta = \frac{1}{N}\sum_{m\in \mathrm{P}} n_{m,h}\left(\frac{z - Y_e^{m,h}}{z}\right)^{\theta} \tag{15}$$

where $n_{m,h}$ is the household size, N is the population size and P is the set of all poor individuals.

The basic requirement for the measurement of poverty is the definition of a poverty line in order to delineate the poor from the non-poor. We follow Decaluwé *et al.*(1999) and Sánchez Cantillo (2004), by using endogenous poverty lines produced by the CGE model in order to reduce the potential bias in the measurement of the poverty outcomes that results from neglecting the effects of trade policy on basic consumption. The poverty line is estimated as

$$z = \sum_f p_f C_f^{\mathrm{basic}} \tag{16}$$

where C_f^{basic} and p_f are the quantities and prices of the basic needs by commodity[7].

4. Data

Our study requires an important database to conduct the econometric and the CGE analysis. The following sections give an overview of the data used to conduct the analyses.

4.1 The econometric analysis

The econometric application considers panel data at the national level for agricultural productions in several south Mediterranean countries involved in the partnership agreements with the EU and different EU Mediterranean countries presenting a strong potential in agricultural production. The data set include observations on the main crops grown in these countries, inputs use, determinants of market competition and countries characteristics. The variables used in the empirical analysis are summarized as follows:

The econometric application is based on panel data at the national level for agricultural and agro-food production in the main trading partners and competitors of Tunisia with demonstrated performance in agriculture, namely Algeria, Egypt, Israel, Jordan, Lebanon, Morocco, Syria, Turkey, France, Greece, Italy, Portugal and Spain during the period 1990-2005. Our data set includes observations on the main commodities produced in these

[7] We assume that the basic needs correspond to the minimum vital needs and are inferior to the minimum consumption level in the utility function.

countries, inputs use, international trade, human capital, agricultural research effort, land distribution, land quality, climatic conditions, and institutional factors. These variables are grouped in different sets to estimate the stochastic production function in (1), the parametric function of the inefficiency component in (2), the class probabilities in (4) and the productivity change equation in (8). The data are the FAO (FAOSTAT), World Bank (WDI), AOAD, Eurostat, CEPII, AMAD, ASTI, UN-WIDER, Barro and Lee (2000), Pardey *et al*. (2006), and Kaufmann *et al*. (2007) databases as well as from the different reports of the FEMISE, FAO, CIHEAM and ESCWA. The characteristics of the data used in are summarized in Table A1 in Appendix 1.

The variables used to estimate the stochastic production frontier consist of thirty six agricultural commodities belonging to six product categories (fruits, shell-fruits, citrus fruits, vegetables, cereals, and pulses) and five inputs (cropland, irrigation water, fertilizers, labor and machines). We construct aggregate output and input indices for each product category using the Tornqvist and EKS indexes (Rao *et al*., 2004). The agricultural product categories include the main produced and traded commodities in the Mediterranean region. Substantial protection measures exist in the form of entry prices, customs tariffs, quotas, and safeguard clauses. These measures aim at restricting the exchange of commodities considered as a potential source of strong competition in the Mediterranean basin, and for which greater openness may have serious domestic economic and social consequences. The data for the input use by crop for each country are constructed according to the information collected from recently published reports from the sources above. All the input and output variables are measured in quantity.

The inefficiency effect model and the productivity growth equation incorporate an array of control variables representing openness to trade, human capital, land holdings, agricultural research effort, land quality, and institutional quality. Tow different measures are used to proxy the degree of openness of each country, the ratio of agricultural exports plus imports to agricultural value added and agricultural trade barriers. Agricultural commodities are currently protected with a complex system of ad-valorem tariffs, specific tariffs, tariff quotas, and are subject to preferential agreements. The determination of the appropriate level of protection is a fairly complex task. The MacMaps database constructed by the CEPII provides ad-valorem tariffs, and estimates of ad-valorem equivalent of applied agricultural protection, taking into account trade arrangements (Bouët *et al*. 2004). Our data on agricultural trade barriers are drawn from this database[8].

Human capital is measured by average years of schooling in the population over age 25 and is included to capture the labor quality and the ability to absorb advanced technology. Land quality, land fragmentation and the distribution of agricultural holdings are often cited as sources of inefficiency in agriculture (Vollrath, 2007). The inefficiency model includes land quality, which is measured by the percent of land under irrigation; land fragmentation, which is controlled for by the percent of holdings under five hectares; and inequality in operational holdings measured by the land Gini coefficient to capture these effects. Agricultural research effort is measured by public and private R&D expenditures. Institutional quality includes various institutional variables considered as indicators of a country's governance, namely, political stability, government effectiveness, and control of corruption. These variables reflect the ability of the government to provide sound macroeconomic policies and impartial authority which protects property rights and enforces contracts.

Regarding the determinants of the latent class probabilities, we consider country averages of five separating variables related to natural and modern input endowments as well as to climatic conditions. The variables included in the class probabilities are total number of wheel and crawler tractors, total applied fertilizers, total agricultural land, average farm size, and rainfall levels. Tractors and fertilizers help to identify countries endowed with modern production factors. Average farm size captures the differences in the scale of agricultural holdings across countries and distinguishes countries with important small farms (Vollrath, 2007). Total agricultural land and rainfall levels capture the influence of resources endowments and climatic conditions on class membership.

4.2 The CGE analysis

The calibration of the base-year solution of our CGE model requires a consistent data set, reflecting the structure of the Tunisian economy. As existing SAMs for Tunisia are unlikely to adequately reflect the structural features of the national agricultural sector, we compiled a new SAM for the year 2001. Building a completely new SAM requires however gathering a huge amount of data; we use a top-down approach to carry out the compilation of the new SAM. Our procedure follows two main steps. First, we construct a Macro SAM from national accounts. Second, we disaggregate the Macro SAM by activity and commodity to generate a Micro SAM. The disaggregation mainly relates to agriculture and agri-food processing

[8] Available at http://wits.worldbank.org/witsweb/default.aspx.

commodities and is implemented using the Input-Output (IO) table of 2001, the national-accounts and different complementary sources such as the surveys conducted by the National Institute of Statistics (INS), the different reports of the Ministry of Finance and Planning, and the Ministry of agriculture[9]. This step is carried out in order to match with the commodity structure of the Tunisian household expenditures, and in a way that is consistent with the national accounts and coefficients from a prior SAM. As the data discrepancies in the micro matrix may cause unbalances, we apply the cross-entropy approach to generate a balanced SAM table. Table 1 displays the macro SAM for the year 2001.

[9] Mainly « Les Enquêtes Agricoles de base », « Annuaire des statistiques agricoles » and « Enquête sur les structures des exploitations agricoles ».

TABLE 1. THE 2001 MACRO SAM FOR TUNISIA (MILLION OF TD)

	Activities							Commodities							Factors		Institutions				Fiscal Instruments			SAV	TOT
	AGR	AGRF	WAT	MIN	MANUF	NMAN	SERV	AGRC	AGRFC	WATC	MINC	MANUFC	NMANC	SERC	LAB	CAP	HS	ENTR	GOV	ROW	DTAX	ITAX	TIMP		
AGR								4493.3																	4493.3
AGRF									5843.4																5843.4
WAT										170.5															170.5
MIN											393.3														393.3
MAN												16500.9													16500.9
NMAN													7458.9												7458.9
SERV														18019.6											18019.6
AGRC	206.1	2417.5		3.2	126.8	2.1	209.4										2033.9			185.0				209.4	5393.5
AGRFC	477.3	922.3			65.8	1.3	664.9										3859.9			534.1				-0.4	6525.1
WATC	17.3	7.0	1.4	1.9	17.3	9.3	32.8										83.5								170.5
MINC		8.5		0.5	362.2	0.0	8.1										3.4			79.8				6.4	469.0
MANC	103.3	573.6	13.1	32.2	9005.6	2318.6	945.4										5588.8			7622.9				3198.6	29402.1
NMANC	91.5	138.1	14.6	44.0	749.3	939.6	762.3										765.1			892.9				4405.8	8803.1
SERVC	53.5	179.7	22.6	64.8	948.3	806.5	2689.8										4947.2		4745.3	4578.0				83.9	19119.4
LAB	508.7	525.4	63.3	110.7	2299.1	729.3	5958.3													69.6					10264.3
CAP	3033.9	460.3	37.3	135.0	2500.3	1920.5	6206.2																		14293.5
HS															10201.1	8929.9		1402.3	1757.6	1464.1					23755.0
ENTR																5363.6	850.0		6.8	244.5					6464.9
GOV																	2087.1	855.9		94.0	1893.4	2332.4	1686.1		8948.9
ROW								772.3	497.2		70.2	11603.8	1273.4	1099.8	63.2		101.0	657.5	902.9						17041.2
DTAX																	1160.2	672.8	33.7	26.6					1893.4
ITAX	1.8	611.0	18.3	0.9	426.2	731.7	542.5																		2332.4
TIMP								128.0	184.5		5.5	1297.4	70.7												1686.1
SAV																	2275.0	2876.4	1502.6	1249.8					7903.7
TOT	4493.3	5843.4	170.5	393.3	16500.9	7458.9	18019.6	5393.5	6525.1	170.5	469.0	29402.1	8803.1	19119.4	10264.3	14293.5	23755.0	6464.9	8948.9	17041.2	1893.4	2332.4	1686.1	7903.7	

The macro SAM is disaggregated into micro SAM by breaking down the activity (and commodity) accounts into the 33 accounts that correspond to the model production activities described in Table 2.

The main impediment at this level was the disaggregation of intermediate consumption in the agricultural and agri-food activities, as only the total value spent by each of these activities was available in the IO table. We used the information contained in the technical sheets from the Ministry of agriculture and the national institute of agronomic research (INRAT) to estimate these values. We made some minor adjustments to constrain the sum of the intermediate consumption of agricultural and agri-food sub activities to add up the corresponding aggregated values in the Macro SAM.

Table 2 Classification of the accounts in the Micro SAM

LABELS	ABBREVIATIONS
Activities and commodities	
Tender wheat	TWHEAT
Hard wheat	HWHEAT
Barley	BARLEY
Other cereals	OCER
Leguminous	LEGUM
Olives	OLIV
Citrus fruits	CITR
Dates	DAT
Other fruits	OFRUITS
Vegetables	VEG
Livestock	LVST
Industrial cultures	INDCUL
Other crops	OCROPS
Fish and fishery (mollusks, crustaceans …)	FISH
Meat	MEAT
Dairy products	DAIRY
Flour	FLOUR
Olive oil	OOIL
Other oil	OGR
Canned	CANNED
Sugar and biscuits	SUGAR
Beverages	BEVER
Other agri-food products	OAGRI
Construction material, ceramic and glass industries	MCV
Mechanical and electrical industries	IME
Chemical industries	CHEM
Textiles and leathers industries	TEXT
Other manufacturing industries	OMAN
Mining industries	MINING
Urban water	WATERNA
Irrigation water	WATERA
Non manufacturing industries	NMAN
Services	SERV
Production Factors	
Family agricultural workers	FAW

Unskilled wage workers in the agricultural sector	UWA
Skilled wage workers in the agricultural sector	SWA
Unskilled wage workers in the non-agricultural sectors	UWNA
Skilled wage workers in the non-agricultural sectors	SWNA
Annual irrigated agricultural land	AIAL
Annual dry agricultural land	ADAL
Perennial irrigated agricultural land	PIAL
Perennial dry agricultural land	PDAL
Natural resources	NRES
Capital	CAP
Institutions	
Rural households	RUR
Urban households	URB
Enterprises	ENTR
Government	GOV
European Union	EU
Rest of the world	ROW
Fiscal instruments	
Indirect taxes	ITAX
Direct taxes	DTAX
Import taxes from EU	TUE
Import taxes from. ROW	TROW
Saving-Investment	ACC

5. Main Estimation Results

5.1. The latent class model

This empirical application involves basically a three-step analysis of agricultural productivity performance across Mediterranean countries. First, a Cobb Douglas parameterization of the technology frontier is employed and the latent class model of equation (1) is estimated using maximum likelihood via the EM algorithm[10]. Second, efficiency and productivity levels and growth are computed for each country. Third, the technology gap among the different countries is measured, and the determinants of agricultural productivity growth are investigated focusing on the role of international trade.

We estimated several groups. First, we started by appraising the results for each agricultural commodity group. Second, we stacked the different groups in one model and reported the results.

In estimating the latent class model, we begin by examining the class selection issue. The *SBIC* and *AIC* test results support the segmentation of the model and indicate that the model with four classes is preferred for citrus fruits, shell fruits, vegetables and for the pooled model, while the preferred number of classes for the remaining product categories is three[11]. Thus, we limit the discussion to the results of estimating a mixture of stochastic frontiers to these numbers of classes.

Table 3 presents the results of estimating the input elasticities of the production frontier. In the interest of space limitation, we describe the results using pooled data and report the probability weighted average of the different classes' parameter estimates for specific crop groups, namely fruits, citrus, cereals, shell fruits, pulses, and vegetables in Table A2 in the Appendix.

TABLE 3: LATENT CLASS MODEL PARAMETER ESTIMATES: TOTAL POOL

	Class 1	**Class 2**	**Class 3**	**Class4**
Production Frontier				
Land	0.309***	0.261***	0.444***	0.216***
Water	0.275***	0.289***	0.276***	0.333***
Labour	0.236***	0.26***	0.141*	0.144**
Fertilizers	0.107*	0.092*	0.127*	0.111*
Machines	0.097*	0.16*	0.136**	0.327***
Time	0.017***	0.06**	0.009**	0.008*
Intercept	0.55**	0.76**	0.022	0.12
Efficiency term				
Land Gini	0.212***	0.169***	0.175***	0.123***
Land fragmentation	0.038**	0.002*	0.058**	0.02*
Land quality	-0.04**	-0.04*	-0.05***	-0.011*
Trade openness[1]	-0.157***	-0.135***	-0.268***	-0.165***
Human capital	-0.095***	-0.098**	-0.156**	-0.149**

[10] The estimation procedure was programmed in Stata 9.2.
[11] The results are available from the authors upon request.

R&D	-0.004*	-0.002*	-0.002**	0.001*
Government effectiveness	-0.026	-0.0034*	-0.01**	0.003***
$\Gamma = \sigma_e^2/\sigma_s^2$	0.72***	0.829***	0.784***	0.891***
Probabilities				
Fertilizers consumption		-0.073	0.144**	-0.99**
Agricultural machinery		0.079*	-0.03	0.472***
Agricultural land		0.0367***	0.045**	0.408***
Average holdings		-0.026**	0.35*	0.093**
Rain		-0.006*	0.01**	0.262**
Intercept		-1.36	-1.359*	-3.29**
Log-likelihood		-274.33		
Number of Obs.		1344		

Notes: the variables in the production frontier and efficiency function are in natural logarithm. The significance at the 10%, 5% and 1% levels is indicated by *, ** and *** respectively. A negative sign in the inefficiency model means that the associated variable has a positive effect on technical efficiency.

The results show relatively important differences of the estimated factor elasticities among classes and seem to support the presence of technological differences across the countries. The input elasticities are globally positive and significant at the 10% level. Water and cropland have globally the largest elasticity, indicating that the increase of Mediterranean agricultural production depends mainly on these inputs.

The estimated technology frontiers provide a measure of technical change. A positive sign on the time trend variable reflects technical progress. Significant shifts in the production frontier over time were found in the pooled and specific commodity models, indicating gains in technical change for the selected countries.

Next, we examine the determinants of agricultural production efficiency among the selected countries. The estimated coefficients of the inefficiency function in Table 3 are statistically significant at conventional levels and have globally the expected signs. International trade seems to exert a significant impact on improving efficiency in the Mediterranean farming sector. Educational attainment, land quality, agricultural research effort and institutional factors appear also to contribute to enhancing efficient input use. As expected, the unequal distribution of agricultural land and to a lesser extent land fragmentation have significant adverse effects on efficient resource use.

The investigation of the estimation results of the latent class probability functions shows that the coefficients are globally significant, indicating that the variables included in the class probabilities provide useful information in classifying the sample. We had no apriori expectation about the sign of these coefficients, as positive values on the separating variables' coefficients in one class indicate that higher values of these variables increase the probability of assigning a country into this class, while negative parameters suggest that the probability of class membership decrease with an increase of the corresponding variables. For example, increasing total applied fertilizers increases the probability of a country to belong to class three. Wider total agricultural areas increase the probability of membership in the three last classes, while higher average farm size reduces the probability of belonging to the second class.

The average efficiency scores and TFP changes, estimated using equations (6) and (7) respectively, are reported in Table 4. The results show productivity increases in the Mediterranean agricultural sector, on average, with SMC registering relatively better average rates of productivity gain than EU countries. Significant differences in technical efficiency performance are apparent among commodity groups and countries. On average, over the period under consideration, EU countries exhibited better efficiency levels than SMC.

TABLE 4: EFFICIENCY SCORES AND TFP INDEX GROWTH

	FRUITS		CITRUS		SHELL		VEGETABLES		CEREALS		PULSES		POOL	
	TE[a]	TFPG[b]	TE	TFPG	TE	TFPG	TE	TFPG	TE	TFPG	TE	TFPG	TE	TFPG
ALGERIA	0.543	2.88	0.415	2.39	0.601	-1.19	0.683	0.62	0.546	1.78	0.639	-0.58	0.596	1.14
EGYPT	0.577	1.37	0.664	1.64	0.587	-0.9	0.44	4.9	0.582	-0.14	0.593	1.61	0.598	1.16
FRANCE	0.917	1.08	0.832	-1.18	0.961	0.601	0.986	0.55	0.994	1.21	0.981	1.09	0.981	0.96
GREECE	0.629	1.473	0.706	1.73	0.629	-1.65	0.646	-0.85	0.663	1.91	0.678	1.03	0.684	0.85
ISRAEL	0.683	1.54	0.787	1.19	0.667	1.74	0.714	2.13	0.482	-0.74	0.642	2.74	0.667	1.82
ITALY	0.893	1.51	0.753	1.55	0.705	0.74	0.81	1.41	0.741	1.79	0.785	1.1	0.807	1.45
JORDAN	0.608	0.97	0.666	1.22	0.627	1.74	0.785	1.66	0.351	-0.89	0.645	1.72	0.659	1.34
LEBANON	0.878	1.31	0.768	1.28	0.871	1.62	0.822	1.95	0.612	1.98	0.808	-0.47	0.789	1.61
MOROCCO	0.617	-0.46	0.861	1.12	0.67	2.94	0.768	1.45	0.633	-0.25	0.631	1.32	0.737	1.05
PORTUGAL	0.534	0.38	0.627	1.39	0.512	0.24	0.714	-0.41	0.638	1.92	0.558	-0.25	0.613	0.79
SPAIN	0.785	1.59	0.848	1.01	0.678	-2.37	0.876	1.78	0.757	1.63	0.694	0.73	0.799	0.96
SYRIA	0.648	1.33	0.788	0.99	0.702	3.04	0.736	2.45	0.768	2.76	0.762	1.42	0.738	2.01
TUNISIA	0.638	0.74	0.641	1.03	0.685	0.31	0.734	1.62	0.684	0.93	0.654	1.58	0.657	1.07
TURKEY	0.878	1.79	0.881	2.19	0.883	2.08	0.819	1.87	0.853	1.89	0.793	2.26	0.834	2.08

[a]: Technical efficiency score, [b]: TFP growth (%).

Variation of performance across countries opens the possibility of investigating the factors contributing to productivity improvement and facilitating the catching up process between high-performing and low-performing countries. Two of the key concerns here are the relevance of international trade as a channel for technology spillovers and the importance of human capital for absorbing foreign knowledge and driving rates of productivity growth. To tackle this issue, we first measure the technology gap ratio (*GAP*), defined in section 2, using the metafrontier approach, and then estimate the model in equation (8) that links agricultural productivity growth to technology gap, international trade, and human capital.

The estimation of this model poses several challenges relating to unobserved heterogeneity, potential endogeneity, and measurement error. To deal with these potential problems we include country specific fixed effects and use instrumental variables estimation.

Table 5 reports the estimation results considering two measures of international trade, namely the ratio of agricultural exports plus imports to GDP (column 1), and agricultural trade barriers (column 2).

TABLE 5: IMPACT OF INTERNATIONAL TRADE ON AGRICULTURAL TFP GROWTH

	TRADE VOLUMES	TRADE BARRIERS
α_1	0.05**	0.04***
α_2	0.17*	-0.13***
α_t	0.34***	-0.14***
α_G	0.35***	-0.14**
N. of observations	1260	1260
R^2 adjusted	0.62	0.53

Notes: *, ** and *** denote statistical significance at the 10%, 5% and 1% levels respectively.

Regardless of the international trade measure, the results lend strong support to the positive effect of trade openness on agricultural productivity growth. Across the regressions, TFP growth rate increases with higher trade shares and decreases with more trade barriers. These estimates provide interesting insights into the agricultural productivity dynamics. They highlight the role of international trade in promoting technology transfer and point to the importance of education in facilitating the assimilation of foreign improvement of technology. The findings suggest that countries lying behind the frontier enjoy greater potential for TFP growth through the speed of technology transfer.

5.2 Simulation of trade policy reform

In this section we evaluate three sets of scenarios:

1. Scenario 1: Cutting tariffs on manufactured products imported from the European Union and 50% decrease of tariff barriers on agricultural imports from the European Union.
2. Scenario 2: In addition to scenario 1 this simulation assumes cutting tariffs on agricultural imports from the European Union and 30% decrease of tariff barriers on agro-food imports from the European Union.

3. Scenario 3: This scenario extends Scenario 2 to agricultural and agro-food imports from the non-EU countries.
4. Scenario 4: In addition to Scenario 3, we assume an average increase of 20% in agricultural and agro-food international prices.

The simulation analysis focuses only on selected key variables, the choice of which relies on the mechanisms through which trade policy affects inequality and poverty. The results are reported using the percentage deviation from the model's base-line.

TABLE 6. PRODUCTIVITY

Commodities	Total Factor Productivity					Labor Productivity					Land Productivity				
	Initial	Scen.1	Scen.2	Scen.3	Scen.4	Initial	Scen.1	Scen.2	Scen.3	Scen.4	Initial	Scen.1	Scen.2	Scen.3	Scen.4
TWHEAT	1.02	0.45	0.90	1.46	0.05	0.24	0.15	0.17	0.20	0.15	0.51	1.17	2.55	4.26	-0.08
HWHEAT	1.02	0.44	0.82	1.29	-0.04	0.12	0.67	1.18	1.79	0.05	0.33	0.86	1.76	2.85	-0.29
BARLEY	1.02	0.21	0.30	0.31	-0.87	0.12	0.26	0.31	0.32	-0.33	0.46	0.41	0.67	0.68	-2.82
OCER	1.02	0.24	0.23	0.50	-0.77	0.12	0.30	0.30	0.49	-0.39	0.43	0.47	0.44	1.20	-2.41
LEGUM	0.85	0.19	0.18	5.53	3.36	0.10	0.45	0.44	8.79	5.40	0.26	0.23	0.19	16.28	9.74
OLIV	0.68	0.17	0.18	0.19	0.23	0.24	0.31	0.32	0.34	0.31	0.21	0.08	0.08	0.10	0.59
CITR	1.10	0.30	0.32	0.38	1.14	0.28	0.83	0.90	1.03	3.04	0.32	0.46	0.50	0.59	2.04
DAT	1.10	0.29	0.31	0.35	0.94	0.32	0.93	0.98	1.12	2.95	0.26	0.54	0.57	0.66	2.03
OFRUITS	0.72	0.73	6.26	6.26	5.78	0.51	-1.33	11.04	11.04	3.06	0.35	3.47	6.44	6.42	10.10
VEG	1.08	0.28	0.35	0.24	-0.67	0.29	0.61	0.74	0.54	-1.32	0.56	0.29	0.38	0.24	-0.99
LVST	1.09	0.23	0.49	0.48	0.53	0.11	0.90	1.90	1.87	2.06	0.66	1.62	4.50	11.91	7.86
INDCUL	0.68	0.19	0.24	0.37	0.31	0.10	-0.15	-1.14	-3.68	-2.28	0.34	1.04	2.23	2.39	-0.60
OCROPS	0.68	0.19	0.23	0.24	0.17	0.51	0.16	0.11	0.11	0.26					
FISH	1.15	0.26	0.29	0.31	0.30	0.25	2.44	2.72	2.92	2.85					
MEAT	1.09	0.26	0.33	0.34	0.35	0.13	0.86	1.12	1.15	1.18					
DAIRY	1.09	-0.03	0.63	0.63	0.66	0.46	-0.04	0.86	0.85	0.89					
FLOUR	1.09	0.20	0.65	0.59	0.77	0.37	0.31	1.00	0.92	1.18					
OOIL	1.09	0.17	0.17	0.19	0.18	0.15	0.54	0.55	0.58	0.56					
OGR	1.09	0.25	0.31	0.35	0.30	0.15	0.77	0.96	1.08	0.95					
CANNED	1.09	0.24	0.50	0.51	0.51	0.22	0.54	1.12	1.14	1.16					
SUGAR	1.09	0.06	0.25	0.07	0.21	0.34	0.10	0.41	0.12	0.34					
BEVER	1.09	0.17	0.77	0.77	0.79	0.24	0.36	1.61	1.62	1.66					
OAGRF	1.09	0.16	0.21	0.11	0.29	0.44	0.22	0.29	0.16	0.40					
MCV	1.09	1.10	1.31	1.32	1.32	0.27	2.11	2.51	2.51	2.52					
IME	1.09	0.24	0.23	0.24	0.24	0.30	0.42	0.42	0.42	0.42					
CHEM	1.09	0.50	0.51	0.53	0.53	0.22	1.11	1.13	1.16	1.16					
TEXT	1.09	0.29	0.30	0.31	0.31	0.31	0.51	0.52	0.54	0.54					
OMAN	1.09	0.98	1.09	1.10	1.10	0.46	1.33	1.48	1.50	1.50					
MINING	1.09	0.37	0.38	0.39	0.39	0.20	0.87	0.89	0.92	0.91					
WATERNA	1.09	0.17	0.18	0.19	0.19	0.45	0.24	0.24	0.26	0.25					
WATERA	1.09	0.17	0.18	0.19	0.19	0.32	0.29	0.30	0.31	0.31					
NMAN	1.09	0.18	0.15	0.16	0.16	0.18	0.46	0.40	0.43	0.43					
SERV	1.09	0.26	0.27	0.28	0.28	0.29	0.47	0.49	0.52	0.51					

Results in Table 6 show that reducing trade barriers contributes significantly to productivity growth especially in the agricultural sector. It appears form the simulation of scenario 3 that the removal of agricultural trade barriers will help to greatly improve the farming performance. An increase in the international prices of agricultural products seems however to thwart the beneficial effects of trade openness in the cereal sector. An increase of the international food prices appears to have a negative impact on the cereal imports and to adversely affect the productivity growth in this sector.

TABLE 7. SUPPLY AND DEMAND

	TOTAL PRODUCTION					DOMESTIC DEMAND					COMPOSITE PRICE				
	Initial	Scen.1	Scen.2	Scen.3	Scen.4	Initial	Scen.1	Scen.2	Scen.3	Scen.4	Initial	Scen.1	Scen.2	Scen.3	Scen.4
TWHEAT	46.99	-3.77	-7.60	-12.74	0.30	46.99	-3.77	-7.60	-12.74	0.30	1.14	-3.82	-8.28	-14.31	1.62
HWHEAT	207.41	-2.58	-2.63	-2.97	-1.88	207.41	-2.58	-2.63	-2.97	-1.88	1.04	-2.53	-4.81	-8.57	2.39
BARLEY	47.27	-3.17	-3.66	-2.77	7.30	40.85	-3.66	-4.26	-3.46	6.21	1.03	-1.44	-2.59	-3.99	10.85
OCER	96.71	1.78	2.49	1.09	13.34	87.28	1.86	2.59	0.91	13.04	1.03	-0.19	-0.32	-4.21	10.86
LEGUM	51.05	1.09	1.38	-13.95	-8.98	50.23	1.09	1.38	-14.37	-9.44	1.10	-0.69	-0.84	-35.89	-18.07
OLIV	207.65	1.79	1.93	2.49	1.57	207.60	1.79	1.93	2.49	1.57	1.00	0.06	-0.02	-0.89	0.86
CITR	118.86	0.82	0.92	1.60	2.15	107.25	0.76	0.83	1.45	0.65	1.00	-1.39	-1.81	-3.13	-1.28
DAT	307.70	0.97	1.18	2.19	6.69	204.40	0.77	0.93	1.68	1.32	1.00	-1.37	-1.71	-3.24	-2.45
OFRUITS	482.15	-0.53	-24.20	-24.01	-5.84	474.70	-0.54	-24.03	-23.84	-6.00	1.01	-1.00	25.50	25.38	6.54
VEG	848.52	0.77	0.96	1.70	0.23	842.94	0.77	0.95	1.69	0.15	1.00	-0.94	-1.50	-2.70	2.37
LVST	1590.50	0.48	0.75	1.05	0.57	1564.78	0.47	0.74	1.03	0.56	1.00	-0.78	-1.86	-2.31	-1.30
INDCUL	17.68	-2.60	-15.21	-47.49	-30.69	15.56	-2.98	-16.80	-52.10	-35.19	1.48	-3.98	-13.22	-36.02	-22.13
OCROPS	215.12	-0.75	-1.95	-1.84	1.75	206.69	-0.84	-2.08	-1.98	1.14	1.01	-2.50	-3.63	-4.19	-0.89
FISH	405.76	0.35	0.48	0.56	0.49	387.30	0.37	0.47	0.57	0.49	1.00	0.17	-0.46	-0.31	-0.45
MEAT	1168.80	0.63	1.15	1.47	0.93	1167.44	0.63	1.15	1.47	0.93	1.00	-0.65	-1.71	-2.01	-1.28
DAIRY	538.25	2.55	3.15	3.48	3.02	529.04	2.54	3.11	3.44	2.98	1.05	-2.52	-6.13	-6.27	-6.04
FLOUR	1186.45	1.73	3.57	5.05	1.53	1113.72	1.70	3.45	4.90	1.46	1.03	-1.87	-5.84	-7.63	-3.08
OOIL	270.14	1.81	1.97	2.53	1.59	75.07	5.78	6.28	6.97	6.31	1.02	2.48	2.72	2.37	3.47
OGR	254.90	1.54	1.66	2.20	1.37	239.22	1.59	1.67	2.23	1.36	1.09	-0.10	-1.46	-1.36	-1.52
CANNED	340.38	1.59	1.18	1.55	1.10	169.44	1.83	0.25	0.64	0.21	1.13	-0.79	-4.14	-4.38	-4.02
SUGAR	302.09	2.56	3.20	5.26	3.66	296.85	2.57	3.18	5.24	3.63	1.10	-1.21	-4.32	-5.41	-4.65
BEVER	577.33	0.90	1.49	1.65	1.41	532.98	0.84	1.21	1.37	1.14	1.18	-1.46	-6.43	-6.58	-6.32
OAGRF	1430.88	1.65	2.27	3.78	1.32	1315.39	1.57	2.14	3.59	1.24	1.15	-2.50	-3.81	-6.01	-2.33
MCV	1420.06	-3.85	-5.38	-5.54	-5.49	1270.21	-5.44	-6.94	-7.12	-7.07	1.10	-14.83	-15.98	-16.00	-15.99
IME	4183.44	-0.25	-0.42	-0.57	-0.56	2427.50	-3.74	-3.81	-4.03	-4.02	1.10	-8.09	-8.13	-8.12	-8.12
CHEM	2515.54	0.63	0.37	0.45	0.43	1362.79	-2.54	-2.92	-2.82	-2.84	1.10	-8.69	-9.32	-9.34	-9.33
TEXT	6818.32	1.85	1.92	1.98	1.93	2814.69	1.37	1.42	1.52	1.44	1.04	-2.47	-2.57	-2.57	-2.57
OMAN	2256.17	-1.65	-2.60	-2.44	-2.66	1961.71	-2.88	-3.87	-3.70	-3.94	1.10	-11.73	-12.86	-12.89	-12.86
MINING	394.04	-0.16	-0.30	-0.26	-0.28	299.73	-0.49	-0.69	-0.65	-0.68	1.02	-1.74	-1.92	-1.94	-1.96
WATERNA	137.84	0.76	0.67	0.77	0.67	137.84	0.76	0.67	0.77	0.67	0.98	-1.82	-1.94	-1.94	-1.96
WATERA	15.33	-1.49	-14.43	-15.89	-1.48	15.33	-1.49	-14.43	-15.89	-1.48	2.26	-1.32	-10.27	-11.29	-1.34
NMAN	7561.00	-3.75	-4.13	-4.46	-4.35	6633.53	-4.82	-5.19	-5.57	-5.44	1.07	-6.65	-6.62	-6.81	-6.75
SERV	16806.9	0.71	0.71	0.78	0.73	12281.5	0.61	0.58	0.66	0.60	1.04	-0.93	-1.09	-1.11	-1.09

Note : values in the base year are in Million TD.

TABLE 8. HOUSEHOLD CONSUMPTION

	HOUSEHOLD CONSUMPTION									
	RURAL					URBAN				
	Initial	Scen.1	Scen.2	Scen.3	Scen.4	Initial	Scen.1	Scen.2	Scen.3	Scen.4
TWHEAT	0.83	2.19	5.24	7.71	0.78	0.71	1.85	3.48	6.32	-0.91
HWHEAT	10.33	1.56	3.67	5.12	0.43	8.76	1.23	1.93	3.76	-1.25
BARLEY	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
OCER	3.06	0.47	1.65	3.15	-3.39	17.70	0.16	-0.08	1.81	-5.03
LEGUM	8.87	0.70	1.88	17.44	9.66	37.06	0.39	0.16	15.95	7.88
OLIV	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CITR	12.51	1.03	2.32	2.66	2.08	81.17	0.70	0.59	1.33	0.38
DAT	44.85	1.02	2.27	2.71	2.61	159.77	0.69	0.54	1.38	0.91

OFRUITS	65.30	0.85	-10.00	-10.19	-1.44	364.15	0.53	-11.60	-11.39	-3.10
VEG	121.12	0.82	2.18	2.47	0.44	518.74	0.50	0.45	1.14	-1.25
LVST	52.71	0.74	2.34	2.29	2.09	250.93	0.43	0.61	0.96	0.39
INDCUL	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
OCROPS	8.01	1.55	3.14	3.14	1.91	63.16	1.22	1.40	1.80	0.21
FISH	43.58	0.48	2.69	2.19	2.69	253.04	0.00	-0.02	0.11	0.03
MEAT	146.65	1.07	3.57	3.39	3.27	851.44	0.58	0.85	1.31	0.60
DAIRY	54.19	2.46	6.71	6.42	6.65	326.11	1.93	3.95	4.30	3.94
FLOUR	159.85	1.97	6.50	7.38	4.55	610.00	1.45	3.75	5.25	1.87
OOIL	21.29	-1.12	0.43	0.29	-0.09	69.09	-1.58	-2.25	-1.77	-2.73
OGR	19.37	0.68	3.40	2.94	3.45	69.22	0.19	0.68	0.85	0.77
CANNED	26.35	1.17	5.30	5.07	5.22	107.50	0.68	2.55	2.97	2.53
SUGAR	47.04	1.48	5.43	5.80	5.66	189.72	0.98	2.68	3.69	2.96
BEVER	48.70	1.67	6.92	6.63	6.85	187.44	1.16	4.16	4.51	4.14
OAGRF	152.01	2.43	5.06	6.23	4.02	663.67	1.91	2.32	4.11	1.34
MCV	9.40	13.05	13.68	13.31	13.70	68.36	12.34	10.86	11.12	10.92
IME	99.07	6.89	8.12	7.72	8.12	1354.72	6.30	5.35	5.59	5.40
CHEM	91.75	7.41	8.97	8.59	8.98	630.02	6.80	6.19	6.44	6.25
TEXT	301.16	2.42	4.18	3.79	4.19	1826.77	1.90	1.46	1.70	1.51
OMAN	118.95	10.10	11.48	11.11	11.48	831.75	9.45	8.67	8.94	8.72
MINING	0.44	1.87	3.72	3.35	3.76	3.02	1.36	1.00	1.26	1.08
WATERNA	11.10	1.93	3.74	3.35	3.76	64.09	1.42	1.01	1.26	1.08
WATERA	4.61	1.56	9.64	9.97	3.32	0.00	0.00	0.00	0.00	0.00
NMAN	91.15	5.70	7.06	6.80	7.15	625.93	5.12	4.30	4.67	4.44
SERV	583.54	1.22	3.00	2.63	3.00	4091.02	0.74	0.40	0.64	0.45

Note : values in the base year are in Million TD.

TABLE 9. EXTERNAL TRADE

	EXPORT SUPPLY										IMPORT DEMAND									
	EU					ROW					EU					ROW				
	Initial	Scen.1	Scen.2	Scen.3	Scen.4	Initial	Scen.1	Scen.2	Scen.3	Scen.4	Initial	Scen.1	Scen.2	Scen.3	Scen.4	Initial	Scen.1	Scen.2	Scen.3	Scen.4
TWHEAT	0	0	0	0	0	0	0	0	0	0	109.49	5.74	16.53	4.54	-5.10	90.26	-8.91	-14.55	7.78	-2.15
HWHEAT	0	0	0	0	0	0	0	0	0	0	36.43	6.39	19.88	13.29	-7.32	33.79	-6.77	-8.80	12.83	-7.69
BARLEY	0	0	0	0	0	6.42	-0.09	0.16	1.60	14.24	84.90	-2.96	-0.69	-2.89	-13.00	47.40	-6.97	-8.81	-2.92	-13.03
OCER	0	0	0	0	0	9.42	1.06	1.54	2.73	16.16	5.24	5.85	11.34	4.52	-4.97	170.25	1.00	1.26	4.37	-5.11
LEGUM	0	0	0	0	0	0.82	1.14	1.40	11.70	19.35	0.00	0.00	0.00	0.00	0.00	9.44	-0.74	-0.83	51.0	57.62
OLIV	0.02	0.65	0.77	1.66	14.47	0.03	0.65	0.77	1.66	14.47	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CITR	10.83	1.39	1.74	3.01	15.97	0.77	1.39	1.74	3.01	15.97	0.00	-2.02	-2.79	-4.80	-29.93	0.01	-2.02	-2.79	-4.80	-29.93
DAT	66.82	1.38	1.70	3.19	17.33	36.48	1.38	1.70	3.19	17.33	0.04	-1.97	-2.50	-4.80	-31.16	0.18	-1.97	-2.50	-4.80	-31.16
OFRUITS	2.70	0.12	-34.77	-34.60	4.40	4.74	0.12	-34.77	-34.60	4.40	7.38	52.24	542.30	541.98	138.78	0.00	0.00	0.00	0.00	0.00
VEG	4.65	1.04	1.53	2.78	12.73	0.93	1.04	1.53	2.78	12.73	20.70	0.95	2.17	0.39	-22.76	0.00	0.00	0.00	0.00	0.00
LVST	0.07	0.77	1.61	2.05	1.13	25.65	0.77	1.61	2.05	1.13	16.77	-1.12	8.54	7.87	9.64	3.01	-1.12	-2.64	-3.25	-1.66
INDCUL	0.00	0.00	0.00	0.00	0.00	2.12	0.18	-3.58	-13.76	2.28	18.20	39.45	97.42	10.15	6.26	73.15	-6.30	-19.28	8.90	5.05
OCROPS	6.46	1.42	1.28	1.69	16.59	1.97	1.42	1.28	1.69	16.59	20.05	6.03	18.03	17.09	-14.29	2.24	-5.16	-6.18	16.69	-14.58
FISH	16.51	0.00	0.55	0.46	0.55	1.96	0.00	0.55	0.46	0.55	8.41	0.73	3.72	4.15	3.74	12.67	0.73	-0.38	0.03	-0.36
MEAT	0.76	0.72	1.69	2.02	1.28	0.60	0.72	1.69	2.02	1.28	0.34	-0.67	3.55	3.25	4.23	0.00	0.00	0.00	0.00	0.00
DAIRY	0.36	3.07	5.44	5.67	5.31	8.85	3.07	5.44	5.67	5.31	24.28	-3.13	18.46	18.49	18.55	13.14	-3.13	-7.47	-7.45	-7.40
FLOUR	0.47	2.08	5.42	7.33	2.57	72.25	2.08	5.42	7.33	2.57	22.22	-2.17	18.19	15.30	23.00	0.00	0.00	0.00	0.00	0.00
OOIL	158.84	0.27	0.31	0.82	-0.23	36.23	0.27	0.31	0.82	-0.23	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
OGR	5.13	0.73	1.60	1.66	1.58	10.56	0.73	1.60	1.66	1.58	56.14	1.20	9.45	10.53	8.83	131.61	1.20	-0.93	0.05	-1.50
CANNED	2.66	1.36	2.10	2.46	1.98	168.28	1.36	2.10	2.46	1.98	13.52	-0.05	25.54	25.30	25.86	3.40	-0.05	-3.65	-3.84	-3.41
SUGAR	1.89	2.25	4.42	6.34	4.93	3.35	2.25	4.42	6.34	4.93	69.87	-0.95	6.68	5.45	6.12	34.57	-0.95	-5.37	-6.46	-5.86
BEVER	9.95	1.51	4.81	5.00	4.70	34.40	1.51	4.81	5.00	4.70	33.21	-2.36	12.95	12.72	13.16	0.00	0.00	0.00	0.00	0.00
OAGRF	7.34	2.58	3.69	5.96	2.20	108.15	2.58	3.69	5.96	2.20	7.99	-3.73	16.76	12.75	19.52	45.50	-3.73	-5.54	-8.79	-3.31
MCV	39.19	9.10	7.88	7.86	7.86	110.66	9.10	7.88	7.86	7.86	144.79	30.28	31.25	30.64	30.84	62.34	-29.38	-28.85	-29.18	-29.07
IME	1490.05	4.46	4.25	4.21	4.21	265.89	4.46	4.25	4.21	4.21	4331.98	3.69	2.99	2.54	2.58	1529.09	-17.68	-18.23	-18.59	-18.56
CHEM	266.05	4.31	4.27	4.33	4.30	886.69	4.31	4.27	4.33	4.30	1187.35	12.96	12.06	12.12	12.17	463.88	-15.29	-15.96	-15.92	-15.88
TEXT	3712.72	2.20	2.27	2.31	2.27	290.90	2.20	2.27	2.31	2.27	2491.93	3.66	3.56	3.66	3.59	625.87	-3.12	-3.21	-3.12	-3.19
OMAN	148.95	6.35	5.87	5.95	5.84	145.51	6.35	5.87	5.95	5.84	795.95	20.00	19.69	19.86	19.58	199.91	-20.18	-20.38	-20.27	-20.46
MINING	32.53	0.88	0.94	0.97	0.98	61.78	0.88	0.94	0.97	0.98	34.93	12.41	11.92	11.91	11.82	68.12	-3.30	-3.72	-3.73	-3.81
WATERNA	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
WATERA	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
NMAN	711.23	3.75	3.42	3.44	3.44	216.25	3.75	3.42	3.44	3.44	459.48	-8.67	-10.34	-11.26	-10.94	443.50	-18.01	-19.52	-20.34	-20.05
SERV	3610.28	0.97	1.09	1.12	1.09	915.07	0.97	1.09	1.12	1.09	501.84	-1.40	-1.79	-1.73	-1.76	484.39	-1.40	-1.79	-1.73	-1.76

Note : values in the base year are in Million TD.

TABLE 9. POVERTY EFFECTS

	Incidence of Poverty P0					Poverty Gap P1				
	Initial	**Scen.1**	**Scen.2**	**Scen.3**	**Scen.4**	**Initial**	**Scen.1**	**Scen.2**	**Scen.3**	**Scen.4**
Rural households	2.05	-11.9	-11.9	-11.9	-8.5	0.78	-16.4	-9.5	-15.2	-10.5
Urban households	2.98	-2.01	-2.39	-3.12	2.9	0.96	-2.5	-3.21	-4.15	2.4

The different trade liberalization scenarios show that tariff dismantling for European industrial products and increased openness of agricultural markets would lead to a significant decrease of composite prices except in the olive oil and fruits sectors. Total production as well as domestic demand seems to decrease in the cereal and fruit sectors and to rise in the other sectors. The simulation results show also a significant increase of household consumption particularly in the rural areas.

Trade exchange appears to greatly improve as export supply to the different foreign partners as well as import demand from EU seem to increase globally. The reforms entail however a fall of the import demands from the other trading partners.

The effects of these reforms on poverty are very positive particularly in the rural areas. The results show an important decrease of the incidence of poverty as well as of the poverty gap for rural households. The decrease of the consumption prices and the resulting improvement in the living standard as well as the productivity gains lead to an increase in the labor demand in the agricultural sector and seem to favor the unskilled workers.

The impact of the trade reforms on the poverty levels in the urban area is less favorable. While we observe a fall in the head count and poverty gap indexes, the variation is less important than in the rural area. Trade liberalization appears to favor productivity in the agricultural sector as well as the demand of unskilled labor. This induced a greater improvement of the living conditions of agricultural farmers than of the poor urban households.

The simulation results of the last scenario show that an increase of international food prices would slowdown the beneficial effects of trade liberalization. Domestic demand, urban household consumption and imports of agricultural products appear to decrease. While the trade reforms continue to impact positively on poverty in the rural areas adverse effects are expected for urban households.

6. Concluding Remarks

Proponents of globalization identify strong benefits from trade liberalisation in terms of resource allocation, economic growth and poverty alleviation. Despite the controversy that surrounds the trade issues, there is widespread acceptance that relatively open policies contribute significantly to development.

The existing empirical literature has been relatively successful in examining the association between trade openness, growth and poverty; it has however much less to say about the link to agricultural productivity gains. For poverty reduction, however, even if the effects of trade on industry and economic growth are important, agricultural productivity would have the most direct effect.

The analysis of this paper has focused on the impact of trade liberalization on agricultural productivity and poverty in Tunisia. Agriculture is an important sector in the Tunisia economy as it represents an important source of income and output and employs a large segment of impoverished population.

Agriculture was subject to various protection mechanisms that have distorted market incentives and resulted in inefficient allocations of resources. As Tunisia proceeds with more plans for trade liberalization, attention has focused on the potential effects on agricultural productivity and poverty reduction towards evaluating the potential gains in the context of globalization.

To that end, our analysis examines the effects of trade openness on agricultural productivity, and asses how trade reforms and farming performance impinges on poverty using a general equilibrium model.

The distinguishing aspect of this study is the inclusion of econometric evidence of the trade productivity linkage into a general equilibrium model to estimate the poverty outcomes of agricultural liberalization in Tunisia. The econometric methodology follows the latent class stochastic frontier models to account for producers' heterogeneity.

The results show that trade openness exerts a significant ameliorating influence on the incidence of poverty in Tunisia. Opening up to foreign trade seems to facilitate catching up with the best practice technology, providing substantial support for the view that openness promotes productivity growth through technology transfers. Trade openness and agricultural productivity gains seem to have positive effects on the society as a whole but the rural poor would benefit more than proportionately.

The paper's results support the benefits of trade liberalization on agricultural growth and poverty reduction and provide direct testimony that Tunisia should be more actively pursuing efforts to increase trade linkages and integration.

It is necessary to emphasize, however, that the added benefits of trade liberalization are contingent on complementary efforts such as human capital development and institutional changes that would reinforce the positive effects of trade liberalization.

References

1. Battese, G. D.S.P. Rao, and C.J. O'Donnell (2004) "A metafrontier production function for estimation of technical efficiencies and technology gaps for firms operating under different technologies", Journal of Productivity Analysis 21, 91-103.
2. Barro, R. J., and Lee, J.W. (2000). International data on educational attainment: Updates and implications. NBER Working Paper 7911. Washington, DC: The World Bank.
3. Benhabib J. and Spiegel M. (2003) "Human Capital and Technology Diffusion", Handbook of Economic Growth.
4. Bibi, S. (2005). When is Economic Growth Pro-Poor? Evidence from Tunisia. Centre interuniversitaire sur le risque, les politiques économiques et l'emploi, CIRPÉE. Working Paper 05-22
5. Bibi S. and Chatti R. (2006) "Trade Liberalization and the Dynamics of Poverty in Tunisia: A Layered CGE Microsimulation Analysis" MPIA, Working paper 2006-07.
6. Bouët A., Decreux Y., Fontagné L., Jean S. and D. Laborde (2004) A consistent, ad-valorem equivalent measure of applied protection across the world: the MacMap-HS6 database" CEPII Working Paper.
7. Cameron, G., Proudman, J., and Redding, S. (2005). Technological Convergence, R&D, Trade and Productivity Growth. *European Economic Review* 49: 775 – 807.
8. Caudill S. (2003) "Estimating a Mixture of Stochastic Frontier Regression Models via the EM algorithm: A multiproduct Cost Function Application" Empirical Economics 28, p.581-598.
9. Chemengui M.A. and Thabet C. (2006) "Agricultural Trade Liberalization and Poverty in Tunisia: Micro-Simulation in a General Equilibrium Framework" MPIA Network Session Paper, 5th PEP Research Network General Meeting, June 2006, Addis Ababa Ethiopia.
10. Decaluwé B., Patry, A. Savard, L. and E. Thorbecke. (1999), Poverty Analysis within a General Equilibrium Framework. Cahier de recherche 99-09, CREFA, Université Laval, Quebec.
11. Diao, X, Rattso J, and Stokke, H.E. (2005) "International spillovers, productivity growth and openness in Thailand: an intertemporal general equilibrium analysis" Journal of Development Economics 76 (2005) 429– 450.
12. Greene, W. (2005) "Reconsidering heterogeneity in panel data estimators of the stochastic frontier model" *Journal of Econometrics* 126, p. 269–303.

13. Griffith, R., Redding, S., and Van Reenen, J. (2004). Mapping the Two Faces of R&D: Productivity Growth in a Panel of OECD Industries. *The Review of Economics and Statistics* 86(4): 883–895.
14. Kaufmann, D., Kraay, A. and Mastruzzi, M. (2007). Governance Matters VI: Governance Indicators for 1996-2006. World Bank Policy Research Working Paper 4280. Washington, DC : The World Bank.
15. Kumbhaker, S.C., and Lovell, K. C. A. (2000). Stochastic Frontier Analysis. Cambridge: Cambridge University Press.
16. Orea, L., and Kumbhakar, S.C. (2004). Efficiency Measurement Using a Latent Class Stochastic Frontier Model. *Empirical Economics* 29: 169-183.
17. Nelson R. and Phelps E. (1966) "Investment in Humans, Technology Diffusion and Economic Growth". Papers and Proceedings-American Economic Review 56, 69– 75.
18. Nissanke, M., and Thorbecke, E. (2006). Channels and Policy Debate in the Globalization–Inequality–Poverty Nexus. *World Development* 34(8): 1338–1360.
19. Pardey, P.G., Beintema, N.M., Dehmer, S., and Wood, S. (2006). Agricultural Research: A Growing Global Divide? IFPRI, ASTI, Washington, D.C., Food Policy Report.
20. Rao, P.D.S., Coelli, T.J., and Alauddin, M. (2004). Agricultural Productivity Growth, Employment and Poverty in Developing Countries, 1970-2000. School of Economics, University of Queensland, Brisbane, Australia, CEPA, Employment Strategy papers no 2004/9.
21. Ravallion, M., and Shaohua, C. (2007). China's (Uneven) Progress against Poverty. *Journal of Development Economics* 82 (1): 1-42.
22. Rattsø, J and Stokke H.E. (2005) "Ramsey model of barriers to growth and skill-biased income distribution in South Africa" Norwegian University of Science and Technology.
23. Sánchez Cantillo, M.C. (2004) "Rising Inequality and Falling Poverty in Costa Rica's Agriculture during Trade Reform: A Macro-micro General Equilibrium Analysis" PHD thesis, The Institute of Social Studies , the Hague, the Netherlands.
24. Self, S., and Grabowski, R. (2007). Economic Development and the Role of Agricultural Technology. *Agricultural Economics* 36: 395–4040
25. Stokke H. (2004) "Technology Adoption and Multiple Growth Paths: an Intertemporal General Equilibrium Analysis of the Catch-up Process in Thailand" Review of World Economics/Weltwirtschaftliches Archiv 140 (1), 80– 109.

26. Thirtle, C., Lin, L., and Piesse, J. (2003). The Impact of Research-Led Agricultural Productivity Growth on Poverty Reduction in Africa, Asia and Latin America. *World Development* 31(12): 1959-75.
27. Van Der Mensbrugghe D. (2005) "Prototype Model for a Single Country Real Computable General Equilibrium Model" Development Prospects Group, THE WORLD BANK.
28. Vollrath, D. (2007). Land Distribution and International Agricultural Productivity. *American Journal of Agricultural Economics 8*9: 202-216.
29. Winters L.A. (2004), 'Trade Liberalization and Economic Performance: An Overview', Economic Journal 114: F4-F21, February.
30. Winters, A. (2005) "The European agricultural trade policies and poverty", European Review of Agricultural Economics Vol 32 (3) (2005) p. 319–346.
31. Winters L. A., McCulloch N. and McKay A. (2004) "Trade Liberalization and Poverty: The Evidence so far." Journal of Economic Literature 42(1):72-115.

APPENDIX 1: SUMMARY STATISTICS AND SOME ESTIMATION RESULTS

A1. Variable definitions and sources of data

VARIABLES	DEFINITIONS	UNITS	SOURCES
Agricultural land	Total agricultural land	% of land area	WDI
Agricultural machinery	Total wheel and crawler tractors	Machinery/ 100 Ha of arable land	WDI
Average holdings	Average farm size for the commodities included in the analysis	Ha	FAO
Control of corruption	Control among public and private officials, extent of bribery etc.	Index value[a]	Kaufmann *et al*. (2007)
Equipment import	Agricultural machinery and equipment imports	% of agricultural value added	FAO
Fertilizers consumption	Total fertilizer consumption	100 grams/ Ha of arable land	WDI
Fertilizers	Fertilizers use by commodity	Thousand tons	FAO, FEMISE
Government effectiveness	Efficiency of country's bureaucracy, state's ability to create national infrastructure etc.	Index value[a]	Kaufmann *et al*. (2007)
Human capital	Average years of schooling in the population over age 25	Number of years	Barro and Lee (2000)
Labour	Labour use by commodity	Million of days worked	FAO, FEMISE
Land	Land use by commodity	Million Ha	FAO, FEMISE
Land fragmentation.	Part of holdings under 5ha	% of agricultural land	FAO
Land Gini	Inequality in land distribution measured by the Gini coefficient for land holdings	%	FAO
Land quality	Part of irrigated area	% of agricultural land	WDI
Machines	Wheel and crawler tractors use by commodity	Million hours	FAO, FEMISE
Output	Quantity of agricultural output	Million tons	FAO
Rain	Average precipitations (1961-1990)	km^3/year	WDI
R&D	Public and private agricultural R&D expenditures	Million 2000 international dollars	Pardey *et al*. (2006), ASTI
Total trade	Agricultural export and import	% of agric. value added	FAO, WDI
Trade Barrier	Average applied *ad-valorem* and *ad-valorem* equivalent agricultural protection	Tariff rate	CEPII, AMAD, MAcMaps
Water	Water use by commodity	Mm3	FAO, FEMISE

TABLE A2: LATENT CLASS MODEL PARAMETER ESTIMATES: COMMODITY GROUPS

	FRUITS	CITRUS	CEREALS	SHELL FRUITS	PULSES	VEGETABLES
			PRODUCTION FRONTIER			
Land	0.227	0.327	0.326	0.327	0.328	0.242
Water	0.349	0.413	0.182	0.286	0.216	0.559
Labor	0.135	0.223	0.108	0.185	0.195	0.269
Fertilizers	0.111	0.159	0.117	0.126	0.07	0.078
Machines	0.276	0.165	0.355	0.193	0.212	0.075
Time	0.013	0.014	0.007	0.009	0.05	0.0013
Intercept	0.72	0.44	0.115	1.08	0.83	1.04
			EFFICIENCY TERM			
Land GINI	0.17	0.14	0.21	0.65	0 .18	0.186
Land fragment.	0.03	0.128	0.157	0.058	0.011	0.04
Land quality	-0.04	-0.064	-0.056	-0.065	-0.002	-0.002
International trade	-0.263	-0.923	-0.718	-0.537	-0.141	-0.729
Human capital	-0.102	-0.439	-0.176	-0.283	-0.012	-0.88
R&D	-0.003	-0.0023	-0.002	-0.0015	0.004	-0.003

Gov. effectiveness	-0.0018	0.004	0.002	0.011	-0.0001	0.007
$\gamma = \sigma_u^2/\sigma^2$	0.796	0.988	0.722	0.966	0.838	0.916
				PROBABILITIES		
Total fertilizers	-0.12	0.22	0.391	-0.52	0.27	0.314
Total machinery	0.384	0.494	0.676	0.95	0.17	0.978
Total agricul. land	-0.53	-0.08	0.31	0.35	-0.11	0.45
Average farm size	0.38	1.43	-0.773	-0.38	0.254	-0.757
Rain	0.298	0.165	0.319	0.041	0.029	0.292
Intercept	-0.29	1.04	0.45	-0.28	0.69	-0.64
Number of Obs.	224	224	224	224	224	224

Notes: the estimated parameters correspond to the weighted sum for the different classes parameters (see Green, 2005 for details). A negative sign in the inefficiency model means that the associated variable has a positive effect on technical efficiency.

APPENDIX 2: THE GENERAL EQUILIBRIUM MODEL EQUATIONS

I- Production

- $CI_j = io_j XS_j$

- $VA_j = \nu_j XS_j$

- $VA_{aga} = A_{aga}^{VA} LDT_{aga}^{\beta_{aga}^{L}} LAT_{aga}^{\beta_{aga}^{D}} KD_{aga}^{\beta_{aga}^{K}}$

- $LDT_{aga} WT_{aga} = \beta_{aga}^{L} PVA_{aga} VA_{aga}$

- $LAT_{aga} rdt_{aga} = \beta_{aga}^{D} PVA_{aga} VA_{aga}$

- $KD_j rk_j = \beta_j^k PVA_j VA_j$

- $$LDT_{agr} = \left[\gamma_{'uwa',agr} A_{agr}^{L\; -\rho_{agr}^{L} - \frac{bias_{agr}}{2}} LD_{'uwa',agr}^{-\rho_{agr}^{L}} + \gamma_{'swa',agr} A_{agr}^{L\; -\rho_{agr}^{L} + \frac{bias_{agr}}{2}} LD_{'swa',agr}^{-\rho_{agr}^{L}} + \gamma_{'faw',agr} A_{agr}^{L\; -\rho_{agr}^{L}} LD_{'faw',agr}^{-\rho_{agr}^{L}} \right]^{\frac{-1}{\rho_{agr}^{L}}}$$

- $$LD_{'swa',agr} = \left[\frac{W_{'uwa'}}{W_{'swa'}} \frac{\gamma_{'swa'}}{\gamma_{'uwa'}} \left(A_{agr}^{L} \right)^{bias_{agr}} \right]^{\sigma_{agr}^{L}} LD_{'uwa',agr}$$

- $$LD_{'faw',agr} = \left[\frac{W_{'uwa'}}{W_{'faw'}} \frac{\gamma_{'faw'}}{\gamma_{'uwa'}} \left(A_{agr}^{L} \right)^{\frac{bias_{agr}}{2}} \right]^{\sigma_{agr}^{L}} LD_{'uwa',agr}$$

- $$LAT_{aga} = \left[\gamma_{aga}^{LD} A_{aga}^{D\; -\rho_{aga}^{LD} - \frac{bias_{aga}^{D}}{2}} LAN_{'adal',aga}^{-\rho_{aga}^{LD}} + \left(1-\gamma_{aga}^{LD}\right) A_{aga}^{D\; -\rho_{aga}^{LD} + \frac{bias_{aga}^{D}}{2}} WLAN_{aga}^{-\rho_{aga}^{LD}} \right]^{\frac{-1}{\rho_{aga}^{LD}}}$$

- $$WLAN_{aga} = \left[\frac{rdaga_{'adal'}}{rdw_{aga}} \frac{1-\gamma_{aga}^{LD}}{\gamma_{aga}^{LD}} \left(A_{aga}^{D} \right)^{bias_{aga}^{D}} \right]^{\sigma_{aga}^{LD}} LAN_{'adal',aga}$$

- $$WLAN_{aga} = A_{aga}^{DW} \left[\gamma_{aga}^{DW} LAN_{'aial',aga}^{-\rho_{aga}^{DW}} + \left(1-\gamma_{aga}^{DW}\right) DI_{'watera',aga}^{-\rho_{aga}^{DW}} \right]^{\frac{-1}{\rho_{aga}^{LW}}}$$

- $$LAN_{'aial',aga} = \left[\frac{PC_{'wateral'}}{rdaga_{'aial'}} \frac{\gamma_{aga}^{DW}}{1-\gamma_{aga}^{DW}} \right]^{\sigma_{aga}^{DW}} DI_{'watera',aga}$$

- $$LAT_{agp} = \left[\gamma_{agp}^{LD} A_{agp}^{D\; -\rho_{agp}^{LD} - \frac{bias_{agp}^{D}}{2}} LAN_{'pdal',agp}^{-\rho_{agp}^{LD}} + \left(1-\gamma_{agp}^{LD}\right) A_{agp}^{D\; -\rho_{agp}^{LD} + \frac{bias_{agp}^{D}}{2}} WLAN_{agp}^{-\rho_{agp}^{LD}} \right]^{\frac{-1}{\rho_{agp}^{LD}}}$$

- $$WLAN_{agp} = \left[\frac{rdagp_{'pdal',agp}}{rdw_{agp}} \frac{1-\gamma^{LD}_{agp}}{\gamma^{LD}_{agp}} \left(A^{D}_{agp}\right)^{bias^{D}_{agp}} \right]^{\sigma^{LD}_{agp}} LAN_{'pdal',agp}$$

- $$WLAN_{agp} = A^{DW}_{agp} \left[\gamma^{DW}_{agp} LAN_{'pial',agp}{}^{-\rho^{DW}_{agp}} + \left(1-\gamma^{DW}_{agp}\right) DI_{'watera',agp}{}^{-\rho^{DW}_{agp}} \right]^{\frac{-1}{\rho^{LW}_{agp}}}$$

- $$LAN_{'pial',agp} = \left[\frac{PC_{'wateral'}}{rdagp_{'pial',agp}} \frac{\gamma^{DW}_{agp}}{1-\gamma^{DW}_{agp}} \right]^{\sigma^{DW}_{agp}} DI_{'watera',agp}$$

- $$VA_{nag} = A^{VA}_{nag} LDT_{nag}{}^{\beta^{L}_{nag}} KD_{nag}{}^{\beta^{K}_{nag}}$$

- $$LDT_{nag} WT_{nag} = \beta^{L}_{nag} PVA_{nag} VA_{nag}$$

- $$LDT_{nag} = \left[\gamma_{'uwna',nag} A^{L}_{nag}{}^{-\rho^{L}_{nag} - \frac{bias_{nag}}{2}} LD_{'uwna',nag}{}^{-\rho^{L}_{nag}} + \gamma_{'swna',nag} A^{L}_{nag}{}^{-\rho^{L}_{nag} + \frac{bias_{nag}}{2}} LD_{'swna',nag}{}^{-\rho^{L}_{nag}} \right]^{\frac{-1}{\rho^{L}_{agr}}}$$

- $$LD_{'swna',nag} = \left[\frac{W_{'uwna'}}{W_{'swna'}} \frac{\gamma_{'swna'}}{\gamma_{'uwna'}} \left(A^{L}_{nag}\right)^{bias_{nag}} \right]^{\sigma^{L}_{nag}} LD_{'uwna',nag}$$

- $$DI_{i,j} = aij_{i,j} CI_{j}$$

II- Productivity

- $$A_{agr} = A^{VA}_{agr} \left(A^{L}_{agr}\right)^{\beta^{L}_{agr}} \left(A^{D}_{agr}\right)^{\beta^{D}_{agr}}$$

- $$A_{nag} = A^{VA}_{nag} \left(A^{L}_{nag}\right)^{\beta^{L}_{nagr}}$$

- $$\frac{A_j - A^0_j}{A^0_j} = \left[\alpha^{H} \frac{G}{GDP} \right]^{\alpha^{H1}} + b_j \left[\alpha^{H} \frac{G}{GDP} \right]^{\alpha^{H2}} \left[\frac{TRADE_j}{P^0_j XS_j} \right]^{\alpha^{OP}} \left[1 - \frac{A_j}{A^F} \right]$$

- $$\frac{A^{D}_{agr} - A^{D0}_{agr}}{A^{D0}_{agr}} = b^{D}_{agr} \left[\alpha^{H} \frac{G}{GDP} \right]^{\alpha^{DH2}} \left[\frac{TRADE_{agr}}{P^0_{agr} XS_{agr}} \right]^{\alpha^{DOP}} \left[1 - \frac{A_{agr}}{A^F} \right]$$

- $$BIAS_j = \alpha^{B}_{j} \left(\left[\frac{TRADE_j / XS_j}{TRADE^0_j / XS^0_j} \right]^2 - 1 \right)$$

- $$BIAS^{D}_{agr} = \alpha^{BD}_{agr} \left(\left[\frac{TRADE_{agr} / XS_{agr}}{TRADE^0_{agr} / XS^0_{agr}} \right]^2 - 1 \right)$$

III- Income and savings

- $$YH_h = \sum_l \lambda^L_{h,l}\left(W_l \sum_j LD_{l,j}\right) + \sum_{land}\lambda^D_{h,land}\left[\left(rdaga_{land}\sum_{aga} LAN_{land,aga}\right) + \left(\sum_{agp} rdagp_{land,agp} LAN_{land,agp}\right)\right]$$
$$+\lambda^K_h\left(\sum_j rk_j KD_j\right) + DIV_h + TRG^H_h + \sum_r eTRR^H_{h,r}$$

- $$YDH_h = YH_h - DTH_h - TRH^G_h$$
- $$SH_h = pms_h YDH_h$$
- $$CTH_h = YDH_h - SH_h - TRH^F_h - \sum_r TRH^R_{r,h}$$
- $$YF = \left(1 - \sum_h \lambda^K_h\right)\left(\sum_j rk_j KD_j\right) + \sum_h TRH^F_h + TRG^F + \sum_r eTRR^F_r$$
- $$DIV_h = \gamma^{DIV}_h\left(1 - \sum_h \lambda^K_h\right)\left(\sum_j rk_j KD_j\right)$$
- $$TRF^R_r = \gamma^{DIVR}_r\left(1 - \sum_h \lambda^K_h\right)\left(\sum_j rk_j KD_j\right)$$
- $$SF = YF - \sum_h DIV_h - \sum_r TRF^R_r - DTF - TRF^G$$
- $$YG = \sum_h \left(DTH_h + TRH^G_h\right) + DTF + TRF^G + \sum_r eTRR^G_r + TI + \sum_r TIM_r$$
- $$DTH_h = td^H_h YH_h$$
- $$TRH^G_h = tr^H_h YH_h$$
- $$DTF = td^F YF$$
- $$TRF^G = tr^F YF$$
- $$TI = \sum_j\left[tx_j PL_j D_j + tx_j \sum_r PWM_{j,r} e\,(1 + tm_{j,r}) IM_{j,r}\right]$$
- $$TIM = \sum_j \left[tm_{j,r} PWM_{j,r} e\, IM_{j,r}\right]$$
- $$SG = YG - G - \sum_h TRG^H_h - TRG^F - \sum_r TRG^R_r$$

IV- Demand

- $C_{j,h}PC_j = C_{j,h}^{\min}PC_j + \alpha_{j,h}^{C}\left(CTH_h - \sum_i C_{i,h}^{\min}PC_i\right)$

- $G = PC_{'serv'}CG_{'serv'}$

- $DIT_j = \sum_i DI_{j,i}$

- $PC_j\,INV_j = \gamma_j^{INV}\,IT$

V- International trade

- $XS_j = B_j^X\left[\gamma_j^X EXT_j^{\rho_j^X} + (1-\gamma_j^X) D_j^{\rho_j^X}\right]^{\frac{1}{\rho_j^X}}$

- $EXT_j = \left[\frac{1-\gamma_j^X}{\gamma_j^X}\frac{PET_j}{PL_j}\right]^{\sigma_j^X} D_j$

- $EXT_j = B_j^{XR}\left[\gamma_j^{XR} EX_{j,'EU'}^{\rho_j^{XR}} + (1-\gamma_j^{XR}) EX_{j,'ROW'}^{\rho_j^{Xr}}\right]^{\frac{1}{\rho_j^{XR}}}$

- $EX_{j,'EU'} = \left[\frac{1-\gamma_j^{XR}}{\gamma_j^{XR}}\frac{PE_{j,'EU'}}{PE_{j,'ROW'}}\right]^{\sigma_j^X} EX_{j,'ROW'}$

- $EXD_{j,r} = EXD_{j,r}^0\left[\frac{PWE_{j,r}}{PE_{j,r}^{FOB}}\right]^{\sigma_j^W}$

- $Q_j = B_j^Q\left[\gamma_j^Q IMT_j^{-\rho_j^Q} + (1-\gamma_j^Q) D_j^{-\rho_j^Q}\right]^{\frac{-1}{\rho_j^Q}}$

- $IMT_j = \left[\frac{\gamma_j^Q}{1-\gamma_j^Q}\frac{PD_j}{PMT_j}\right]^{\sigma_j^Q} D_j$

- $IMT_j = B_j^{MR}\left[\gamma_j^{MR} IM_{j,'EU'}^{-\rho_j^{MR}} + (1-\gamma_j^{MR}) IM_{j,'RDM'}^{-\rho_j^{MR}}\right]^{\frac{-1}{\rho_j^{MR}}}$

- $IM_{j,'EU'} = \left[\frac{\gamma_j^{MR}}{1-\gamma_j^{MR}}\frac{PM_{j,'RDM'}}{PM_{j,'EU'}}\right]^{\sigma_j^{MR}} IM_{j,'RDM'}$

- $TRADE_{j'} = EXT_j\,PET_j^0 + IMT_j\,PMT_j^0$

- $$CAB = \sum_r \left\{ e \sum_j PWM_{j,r} IM_{j,r} + \sum_h TRH_{r,h}^{R} + TRF_r^R + TRG_r^R - e \sum_j PE_{j,r}^{FOB} EX_{j,r} - e \sum_h TRR_{h,r}^{H} - e\, TRR_{h,r}^{F} - e\, TRR_r^G \right\}$$

VI - Prices

- $PC_j Q_j = PMT_j\, IMT_j + PD_j D_j$
- $PMT_j\, IMT_j = \sum_r PM_{j,r} IM_{j,r}$
- $PM_{j,r} = e\, PWM_{j,r} (1 + tm_{j,r})\, (1 + tx_j)$
- $PD_j = PL_j\, (1 + tx_j)$
- $P_j\, XS_j = PET_j\, EXT_j + PL_j D_j$
- $PET_j\, EXT_j = \sum_r PE_{j,r} EX_{j,r}$
- $PE_{j,r} = e\, PE_{j,r}^{FOB}$
- $P_j\, XS_j = PVA_j VA_j + \sum_i PC_i\, DI_{i,j}$
- $WT_j\, LDT_j = \sum_l W_j\, LD_{l,j}$
- $rdt_{aga} LAT_{aga} = rdw_{aga} WLAN_{aga} + rdaga_{'adal'} LAN_{'adal',aga}$
- $rdw_{aga} WLAN_{aga} = rdaga_{'aial'} LAN_{'aial',aga} + PC_{'watera'} DI_{'watera',aga}$
- $rdt_{agp} LAT_{agp} = rdw_{agp} WLAN_{agp} + rdagp_{'pdal',agp} LAN_{'pdal',aga}$
- $rdw_{agp} WLAN_{agp} = rdagp_{'pial',agp} LAN_{'pial',agp} + PC_{'watera'} DI_{'watera',agp}$

VII – Labour market

- $U_l\, LS_l = LS_l - \sum_j LD_{l,j}$
- $W_l \geq W_l^{MIN}$
- $\left(W_l - W_l^{MIN}\right) U_l = 0$

VIII – Equilibrium

- $Q_j = \sum_h C_{j,h} + CG_j + INV_j + DIT_j$
- $IT = \sum_h SH_h + SG + SF + CAB$
- $EXD_{j,r} = EX_{j,r}$
- $LAN^S_{land} = \sum_{agr} LAN_{land,agr}$
- $GDP = \sum_j \left[\sum_h PC_j C_{j,h} + PC_j CG_j + PC_j INV_j + \sum_r e\, PE^{FOB}_{j,r} EX_{j,r} - \sum_r e\, PWM_{j,r} IM_{j,r} \right]$

<u>I- SECTORS</u>

All industries:

$i, j \in J = \{TWHEAT, HWHEAT, BARLEY, OCER, LEGUM, OLIV, CITR, DAT, OFRUITS, VEG, LVST, INDCUL, OCROPS, FISH, MEAT, DAIRY, FLOUR, OOIL, OGR, CANNED, SUGAR, BEVER, OAGRI, MCV, IME, CHEM, TEXT, OMAN, MINING, WATERNA, WATERA, NMAN, SERV\}$

Agricultural industries:

$agr \in AGR \subset J = \{TWHEAT, HWHEAT, BARLEY, OCER, LEGUM, OLIV, CITR, DAT, OFRUITS, VEG, INDCUL, OCROPS\}$

Annual agricultural industries:

$aga \in AGA \subset AGR = \{TWHEAT, HWHEAT, BARLEY, OCER, LEGUM, VEG, INDCUL, OCROPS\}$

Perennial agricultural industries: $agp \in AGR \subset J = \{OLIV, CITR, DAT, OFRUITS\}$

Other industries:

$nag \in NAG = \{LVST, FISH, MEAT, DAIRY, FLOUR, OOIL, OGR, CANNED, SUGAR, BEVER, OAGRI, MCV, IME, CHEM, TEXT, OMAN, MINING, WATERNA, WATERA, NMAN, SERV\}$

Labor skills:

$l \in L = \{RAW, UWA, SWA, UWNA, SWNA\}$

Land types:

$land \in LAND = \{AIAL, ADAL, PIAL, PDAL\}$

Trading partner:

$r \in R = \{EU, ROW\}$

Households:

$h \in H = \{RUR, URB\}$

II- VARIABLES

A_j	: Total augmenting technical progress
A_j^L	: Labour augmenting technical progress
A_{agr}^D	: Land augmenting technical progress
$bias_j$	: Labour technological bias
$bias_{agr}^D$	: Land technological bias
$C_{j,h}$	: Households h consumption of commodity j
$C_{j,h}^{\min}$	: Households h minimum consumption of commodity j
CAB	: Current account balance
CG_j	: Public final consumption of commodity j
CI_j	: Aggregate intermediate consumption of sector *j*
CTH_h	: Household h consumption budget
D_j	: Commodity j produced locally
$DI_{i,j}$	: Intermediate consumption of commodity i by sector *j*
DIT_j	: Total intermediate demand for commodity j
DIV_h	: Dividend paid to household h
DTF	: Firms direct taxes
DTH_h	: Household h direct taxes
e	: Exchange rate
$EX_{j,r}$	: Export of commodity j to region r
$EXD_{j,r}$	: Export demand of commodity j to region r
EXT_j	: Total export of commodity j
G	: Public expenditure
GDP	: Gross domestic product
$IM_{j,r}$	: Imports of commodity j from region r

IMT_j : Total import of commodity j

INV_j : Investment in commodity j

IT : Total investment

KD_j : Capital demand

$LAN_{lamd,agr}$: Demand for land

LAN_l^S : Land supply

LAT_{agr} : Demand for aggregate land bundle

$LD_{l,j}$: Demand for labor

LDT_j : Demand for aggregate labor bundle

LS_l : Labor supply

P_j : Producer price of commodity j

PC_i : Composite price of commodity i

PD_j : Consumer price of commodity j produced locally

$PE_{j,r}$: Export price of commodity j to region r

$PE_{j,r}^{FOB}$: FOB export price of exports of commodity j to region r

PET_j : Aggregated price of exports of commodity j

PL_j : Producer price of commodity j produced locally

$PM_{j,r}$: Import price of commodity j from region r

PMT_j : Price of composite import of commodity j

PVA_j : Value added price

$PWM_{j,r}$: World price of commodity j imported from region r

$PWE_{j,r}$: World price of commodity j exported to region r

Q_j : Composite commodity j

rdt_{agr} : Composite price for land in sector agr

$rdaga_{land}$: Land price

$rdagp_{land,agp}$: Land price

rdw_{agr} : Composite price of irrigated land – water aggregate

rk_j : Capital price

SF : Firms savings

SG : Government savings

SH_h : Household h savings

TI : Total indirect taxes

TIM_r : Total tariff duties

$TRADE_j$: Trade of sector j

TRF^G : Transfers from firms to government

TRF_r^R : Transfers from firms to region r

TRG^F : Public transfers to firms

TRG_h^H : Public transfers to household h

TRG_r^R : Transfers from government to region r

TRH_h^F : Transfers from household h to firms

$TRH_{r,h}^R$: Transfers from household h to region r

TRR_r^F : Transfers from region r to firms

TRR_r^G : Transfers from region r to government

$TRR_{h,r}^H$: Transfers from region r to household h

U_l : Unemployment rate

VA_j : Value added of sector *j*

W_l : Wages

$WLAN_{agr}$: Demand for irrigated land – water aggregate

W_l^{MIN} : Minimum wage

WT_j : Wages

XS_j : Aggregate output of sector *j*

YDH_h : Household h disposable income

YF : Firms income

YG : Government income

YH_h : Household h income

III- PARAMETERS

A^F : Frontier TFP

A_j^{VA} : Scale parameter

$aij_{i,j}$: Technical coefficient

α_j^B : Bias parameter

α_j^{BD} : Bias parameter

$\alpha_{j,h}^C$: Marginal consumption of commodity j by household h

α^{DH} : Land productivity-Human capital elasticity

α^{DOP} : Land productivity-Openness parameter

α^H : TFP-Human capital parameter

α^{H1} : TFP-Human capital elasticity

α^{H2} : TFP-Human capital elasticity

α^{OP} : TFP-Openness parameter

b_j : TFP-Human capital parameter

b_j^D : Land productivity-Human capital parameter

B_j^{MR} : Scale parameter (CES between imports by region)

B_j^Q : Scale parameter (CES between IMT and D)

B_j^X : Scale parameter (CET between EXT and D)

B_j^{XR} : Scale parameter (CET between regions)

β_j^L : C-D Labor elasticity

β_{agr}^D : C-D Land elasticity

β_j^K : C-D Capital elasticity

$\gamma_{l,j}$: Repartition parameter

γ_h^{DIV} : Share of return to capital transferred to household h

γ_r^{DIVR} : Share of return to capital transferred to foreigners

γ_{agr}^{DW} : Repartition parameter (CES between irrigated land and water)

γ_j^{INV} : Share of commodity j in total investment

γ_{agr}^{LD} : Repartition parameter (CES between land)

γ_j^{MR} : Share parameter (CES between imports by region)

γ_j^{Q} : Share parameter (CES between IMT and D)

γ_j^{X} : Share parameter (CET between EXT and D)

γ_j^{XR} : Share parameter (CET between regions)

io_j : Technical coefficient

$\lambda_{h,l}^{L}$: Share of wages from labor l received by household h

$\lambda_{h,land}^{D}$: Share of return to land received by household h

λ_h^{K} : Share of return to capital received by household h

pms_h : Average propensity to save for household h

ρ_{agr}^{DW} : Elasticity parameter (CES between irrigated land and water)

ρ_j^{L} : Elasticity parameter (CES between labor types)

ρ_{agr}^{LD} : Elasticity parameter (CES between land)

ρ_j^{MR} : Elasticity parameter (CES between imports by region)

ρ_j^{Q} : Elasticity parameter (CES between IMT and D)

ρ_j^{X} : Elasticity parameter (CET between EXT and D)

ρ_j^{XR} : Elasticity parameter (CET between regions)

σ_{agr}^{DW} : Elasticity (CES between irrigated land and water)

σ_j^{L} : Elasticity (CES between labor types)

σ_{agr}^{LD} : Elasticity (CES between land)

σ_j^{MR} : Elasticity (CES between imports by region)

σ_j^{Q} : Elasticity (CES between IMT and D)

σ_j^{X} : Elasticity (CET between EXT and D)

σ_j^{XR} : Elasticity (CET between regions)

σ_j^{W} : Elasticity (World demand)

td^{F} : Direct tax rate on firms income

td_h^{H} : Direct tax rate on households h income

tm_j : Tariff rate on imports of commodity j

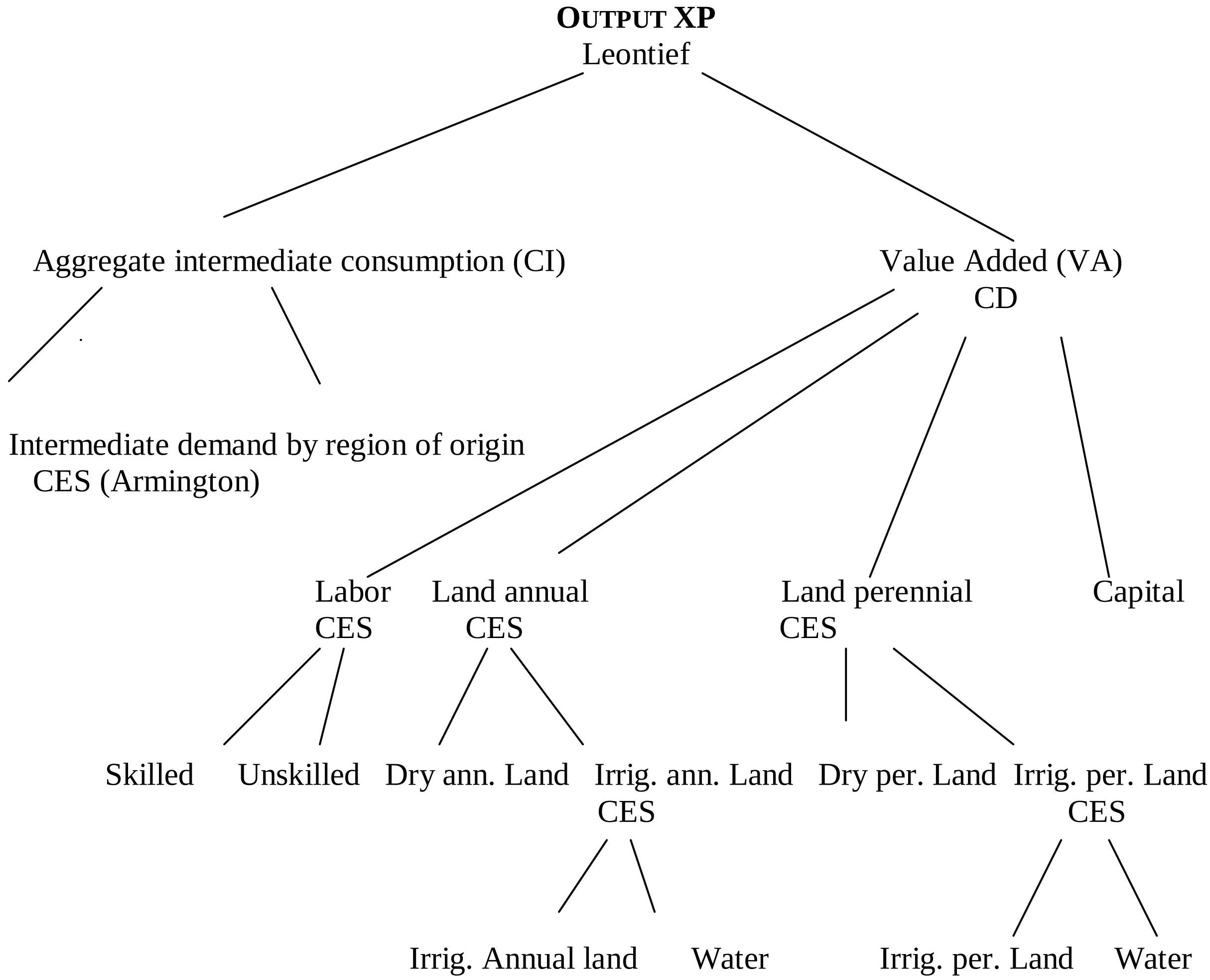
tr^{F} : Rate of transfers from firms to government

tr_h^{H} : Rate of transfers from households h to government

tx_j : Indirect tax rate on commodity j

v_j : Technical coefficient

NESTED STRUCTURE OF PRODUCTION



NESTED STRUCTURE OF CONSUMER DEMAN