ECONOMIC RESEARCH FORUM

منتدى البحوث الاقتصادية

2010

working paper series

DOES AGRICULTURAL TRADE LIBERALIZATION HELP THE POOR IN TUNISIA? A MICRO-MACRO VIEW IN A DYNAMIC GENERAL EQUILIBRIUM CONTEXT

Nadia Belhaj Hassine, Veronique Robichaud, and Bernard Decaluwé

Working Paper No. 556

DOES AGRICULTURAL TRADE LIBERALIZATION HELP THE POOR IN TUNISIA? A MICRO-MACRO VIEW IN A DYNAMIC GENERAL EQUILIBRIUM CONTEXT[1]

Nadia Belhaj Hassine, Veronique Robichaud, and Bernard Decaluwé

Working Paper 556

October 2010

This research has benefited from the financial contribution of ERF as part of the ERF-GDN Regional Research Competition. The content of this publication is the sole responsibility of the authors and can in no way be taken to reflect the views of ERF or GDN.

Send correspondence to:
Nadia Belhaj Hassine
Economic Research Forum, Cairo, Egypt
Email: nbelhaj@erf.org.eg

[1] The authors acknowledge with thanks financial support from the Economic Research Forum for the Arab Countries, Iran, and Turkey. The use of data, interpretations, and conclusions expressed in this paper are entirely those of the authors.

First published in 2010 by
The Economic Research Forum (ERF)
7 Boulos Hanna Street
Dokki, Cairo
Egypt
www.erf.org.eg

Abstract

This paper is an attempt to contribute to the research on poverty-alleviation potential of trade, by exploring the poverty effects of agricultural trade liberalization in Tunisia. Specifically, the study uses a small open economy computable general equilibrium (CGE) that includes technology transfer and endogenous productivity effects from trade openness in agriculture to investigate whether the trade reforms benefit the poor and whether agricultural productivity growth boosts the potential gains from trade. 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 presents some features of the Tunisian economy, in particular with regard to the agricultural sector and reviews the data used in the econometric and CGE models. Section 5 reports the empirical results and section 6 synthesizes the main findings and draws some conclusions.

ملخص

تقدم هذه الورقة دراسة يمكن اعتبارها محاولة للمساهمة في البحث الذي تم اجراؤه عن إمكانية مساهمة التجارة في تخفيف حدة الفقر وذلك عن طريق استكشاف مظاهر الفقر الناتجة عن تحرير التجارة الزراعية في بلد مثل تونس. وتستخدم الدراسة على وجه التحديد نموذج مصغر للتوازن العام المحسوب الذي يتم تطبيقه علي الدول التي تتبنى نظام الانفتاح الاقتصادي. ويتضمن تطبيق هذا النموذج تاثير نقل التكنولوجيا والنمو المصاحب للإنتاجية الناشئة عن تطبيق الانفتاح التجاري في مجال الزراعة وذلك لبحث ما إذا كان الفقراء يستفيدون من الإصلاحات التجارية ام لا أوعما إذا كان نمو الإنتاجية الزراعية يعزز المكاسب المحتملة من التجارة ام لا. وتنقسم هذه الدراسة الي عدة اقسام: القسم الثاني يحدد الخطوط العريضة لخطة بحث تجريبية عملية كما يقدم الإجراءات المتبعة لقياس إجمالي عامل الإنتاجية. القسم الثالث يشرح نموذج التوازن العام المحسوب ويوضح كيف ان الانتاجية والسياسة التجارية تربط بينهما علاقة ترابطية متداخلية. القسم الرابع يقدم بعض ملامح الاقتصاد التونسي وخاصة فيما يتعلق بالقطاع الزراعي ويستعرض البيانات المستخدمة في نماذج الاقتصاد القياسي والتوازن العام المحسوب. القسم الخامس يعرض النتائج العملية. اما القسم السادس فيؤلف بين النتائج الرئيسية ليخرج لنا اهم الاستنتاجات التي توصلت اليها الدراسة.

1. Introduction

The Uruguay Round commitments and the current Doha Round of agricultural trade talks have raised the interest in understanding how the trade reforms will impact the wellbeing of the poor.[2] While agriculture continues to be the major stumbling block in the ongoing trade negotiations, a progress was made towards reaching a consensus on a road map for agricultural liberalization (Anderson and Martin, 2006). Agriculture is of major importance for the poor who rely on this sector for their main source of income and sustenance. Thus expanding the agricultural market access opens up opportunities for developing the farming sector and offers scope for bettering the livelihoods of the poor, but it can also cause them many hardships (Hertel and Reimer, 2005; Bardhan, 2006; Hertel, 2006). The agricultural reforms have sparked a fervent debate about whether the removal of trade protection benefits the poor or not. While there is a great deal of empirical support for the poverty-alleviation potential of trade, the case has not yet been settled.

The extent of controversy surrounding this issue stems from the complexity of the different transmission mechanisms through which agricultural trade liberalization affects poverty. Several channels linking trade to poverty have been identified in the literature, and among the key ones are: changes in relative prices and hence consumption, factor markets and changes in labor income, technology transfer and productivity growth (Winters, 2004; Winters *et al*., 2004; Harrison and McMillan, 2007). These multifaceted linkages are interrelated and the net effects of agricultural openness on poverty can only be assessed on the basis of context-specific empirical research and depends highly on the assumptions underlying the analysis (Nissanke and Thorbecke, 2006).

An appraisal of likely impacts of agricultural trade reform on the poor is bound to be complex and has to be supported by modeling tools, either partial equilibrium models or computable

general equilibrium (CGE) models, that specify relevant interactions between the agricultural sectors and the rest of the economy (Van Tongeren *et al*. 2001). CGE models have long been recognized as well suited to predict the effects of trade policy changes, because they allow producing disaggregated results at the microeconomic level, within a consistent macroeconomic framework.

These models can provide useful insights on issues that matter for policy-making, care must however be taken as the results reached depend on the parameters and functions specified which can barely be tested one-by-one, let alone in combination (Winters *et al*., 2004). Likewise, these models can become quite complex and there is no framework that fully incorporates all the pathways through which trade reforms affect the poor. To keep the models tractable, most of the existing CGE applications have focused on the consumption side of the trade-poverty linkages and neglected the long-run productivity mechanisms.

Improved productivity has been identified as the key to sustained poverty reduction and abstracting from the productivity effects in the trade-poverty nexus could lead to mistaken results.[3] International trade is presumed to foster productivity growth through the transfer of technology from more advanced countries, which would confer strong pro-poor benefits on recipient developing economies (Winters, 2002; Cline, 2004; Bardhan, 2006, Belhaj Hasssine, 2008). The productivity enhancing effects of trade have been widely documented in both macro and case studies, mainly using econometric models. Few CGE analyses have

[2] See for example Litchfield *et al*. (2003), Hertel and Winters (2005), Koning and Pinstrup-Andersen (2007), McCalla and Nash (2007), and Porto (2007).

[3] See Winters *et al*. (2004); Self and Grabowski (2007); and Nissanke and Thorbecke, (2008) among others.

explored the effects of prospective trade liberalization on productivity and the extent to which productivity growth is a vehicle for poverty reduction.

A general equilibrium analysis of technical change in the Philippines by Coxhead and Warr (1995) revealed important earnings effects resulting from the increase of agricultural productivity. De Janvry and Sadoulet (2001) explored the implications of agricultural technology adoption on world poverty and found that price and income effects of agricultural productivity growth are important in reducing poverty. While these analyses underscored the critical role of farming productivity when examining the poverty impacts of external shocks, these are not trade liberalization studies.

Augier and Gasiorek (2003) have incorporated the productivity effects in a general equilibrium study of the welfare implications of trade liberalization between the South Mediterranean Countries and the European Union. The productivity measures are however estimated in an ad-hoc way.

Cline (2004) included econometrically estimated productivity gains from increased trade in a CGE analysis of the global poverty implications of trade liberalization. Anderson *et al*. (2005, 2006) also considered the productivity effects in the World Bank LINKAGE model. While reported in the same publications as CGE model results, the productivity effects, in Cline and Anderson *et al*. works, are off-line calculations based on the review of the available literature on productivity and trade. The off-line productivity calculations need a careful review of the findings of this literature which takes to follow a long and arduous path. Furthermore, the response of productivity to trade liberalization is a subject of a highly controversial debate among the economists. The estimated productivity gains from trade diverge as well broadly across studies and countries, which suggest some uncertainty about the magnitude of the productivity gains (Ackerman, 2005).

Rutherford *et al*. (2006) explore the potential for international trade and foreign direct investment in the services sector to bring new varieties and new technologies to Russia, thereby enhancing productivity and economic growth, and alleviating poverty. The authors show that productivity growth contributes significantly to generating widespread gains from trade reforms.

Measuring the impact of trade reform on poverty through channels such as the effect on productivity is a lively subject on which research is still proceeding and remains challenging (Hertel and Winters, 2006).

This paper is an attempt to contribute to this research by exploring the poverty effects of agricultural trade liberalization in Tunisia. Specifically, the study uses a small open economy CGE that includes technology transfer and endogenous productivity effects from trade openness in agriculture to investigate whether the trade reforms benefit the poor and whether agricultural productivity growth boosts the potential gains from trade.

Over the last decade, Tunisia has implemented sweeping economic and agricultural reforms and has taken steps towards greater integration in the global economy. The country is about to start implementing a new agreement on trade in agricultural products under the EU-Mediterranean partnership and the Doha round of the WTO agreement on agriculture.

Agriculture is an economically and socially important sector in Tunisia, although highly distorted by trade barriers and domestic support measures. The levels of protection are relatively high for the commodities deemed as sensitive and for which the impact of foreign competition can have serious economic and social consequences such as cereals, dairy and livestock products.

As Tunisia presses ahead with liberalization within the framework of the Barcelona-Agreement, speculations have risen regarding the impact of trade reforms in accelerating agricultural development via technology transfer and in alleviating poverty. In a country with limited natural resources, adoption of new technology can raise labor and land productivity, as well as enhance employment creation through increased yields and improve the welfare of smallholder growers and poor households via food prices (Graff *et al*., 2006).

Previous work on the Doha round and Euro-Mediterranean Partnership has examined the poverty issues of agricultural trade reforms in Egypt, Morocco, Syria and Tunisia.[4] These studies vary in their assumptions regarding the linkages between trade and poverty and nearly all have neglected the productivity growth channel. The simulation results, while divergent, indicate a small potential for poverty reduction from further trade liberalization.

The main features that distinguish this paper from earlier CGE analyses of trade liberalization and poverty is that international trade is allowed to endogenously enhance agricultural productivity through technology transfer. The study incorporates econometric evidence of these trade-productivity linkages into a sequential dynamic general equilibrium model to capture the additional poverty reduction that could be expected from the ongoing growth effects of agricultural trade reform. The CGE model we use takes also into account the complexity of the labor market and explores the interaction between labor productivity and the wage rate determination.

Our approach involves a two-step procedure. First, we sketch 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 international trade to productivity growth through the speed of technology transfer using the distance from the technological frontier to capture the potential for technology transfer. Second, we incorporate econometric evidence of the productivity effects into a CGE model to arrive at a comprehensive evaluation of alternative trade liberalization scenarios on commodity prices and factor prices, as a basis for then calculating the corresponding impact on households' income, poverty and inequality.

Two liberalization scenarios are considered by simulating their consequences with and without endogenous productivity change. The first is a complete removal of the agricultural trade barriers; and the second is full liberalization of agricultural and nonagricultural tariffs. Such radical reforms are definitely unrealistic, but the analysis provides a benchmark relative to which one can compare the potential gains from any partial liberalization to emerge from the trade negotiations.

This paper should not be considered as providing an accurate depiction of what will really happen to the poor in Tunisia if the reform of agricultural trade is to be achieved. The complexity of the relationships embedded in the trade-poverty nexus and the limited accessibility to the underlying data limit the ability of the model to exactly predict the true poverty outcomes. The framework presented here provides an illustration of how the productivity effects can be introduced and investigated in a CGE analysis and of what would be the orders of magnitude of the trade liberalization effects.

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

4 See among others, Löfgren, (1999) and IFPRI, (2007).

model and explains how the link between productivity and trade policy is incorporated. Section 4 presents some features of the Tunisian economy, in particular with regard to the agricultural sector and reviews the data used in the econometric and CGE models. Section 5 reports the empirical results and section 6 synthesizes the main findings and draws some conclusions.

2. Econometric Model

2.1 International trade and productivity dynamics

The relation between openness in trade and productivity growth has long been a topic of interest in the economic literature. Trade is presumed to enhance productivity through different channels such as export, import, FDI and capital inflows, and technology diffusion.

The role of international trade as a carrier of foreign technology has been emphasized in numerous recent studies (Das, 2002; Keller, 2004; Cameron *et al.,* 2005; Xu, 2005; Wang, 2007). The idea is that increasing trade between advanced and developing countries involves the transfer of technology and knowledge embodied in the traded goods.

Our focus in this section is on the importance of international trade in stimulating technology transfer and productivity growth in the agricultural sector. The methodology is based on the work of Griffith *et al.* (2004) and Cameron *et al. (*2005). Productivity growth, in an economy behind the technological frontier, is assumed to be driven by both domestic innovation and technology transfer from technology-leading countries. The gap between a country's technology level and the technology frontier determines the potential for technology frontier. Thus the further a country lies behind the best practice technology, the greater the potential for trade to increase productivity growth through technology transfer from more advanced economies.[5]

New technologies might not however automatically affect the host country's productivity. The adaptability and local usability of foreign technologies depend on the skill content of the recipient country's workforce. These technologies might prove ineffective in countries without sufficient educated labor force to absorb international knowledge. Many studies in the endogenous growth literature pointed to the importance of human capital in enhancing the country's innovative capacity as well as its ability to adopt foreign technology (Xu, 2000; Benhabib and Spiegel, 2002; Cameron *et al*., 2005). Thus, we examine the role played by human capital on stimulating innovation and on facilitating the adoption of new technologies.

We consider the following specification in which agricultural productivity growth depends on domestic innovation and technology transfer. The innovation part is related to the level of human capital, while the transfer part is captured via a term interacting international trade with human capital and the technology gap to the frontier. The trade interaction captures the effect of international openness on productivity growth through the speed of technology transfer, while the human capital interaction reflects a country's capacity to adopt advanced technology.

The growth rate of agricultural productivity in country *i* at time *t* is then given by:

$$\dot{A}_{it} = \alpha_i + \alpha_1 H_{it}^{\alpha_H} + \alpha_2 IT_{it}^{\alpha_{op}} H_{it}^{\alpha_H}\left(1 - GAP_{it}\right) + \upsilon_{it} \qquad (1)$$

[5] According to technology diffusion models technology diffuses at a rate that increases with the gap between the leader and follower. Hence countries lagging behind the technological frontier would experience faster productivity growth than the leading country and thereby would enjoy technological catch up (Benhabib and Spiegel, 2002; Cameron *et al*., 2005; Xu, 2005).

where A is agricultural total factor productivity (TFP); H is the human capital level measured by average years of schooling in the population over age 25; IT is an index of international trade captured by two alternative variables namely, total agricultural trade as a share of GDP and agricultural tariff barriers; and GAP is the technology gap measured by the distance from the technological frontier to capture the potential for technology transfer. $\alpha_1, \alpha_2, \alpha_{op}$ and α_H are parameters to be estimated. α_i is a country-specific constant and υ_{it} is an error term. The dot indicates the growth rate.

2.2 Productivity Measurement

In order to estimate equation (1), measures of agricultural TFP and of technology gap are required. The common approach to estimating agricultural efficiency and multifactor productivity is the stochastic frontier model. 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 as the sum of technology change, factor accumulation, and changes in efficiency. A major limitation of this method is that all producers are assumed to use a common production technology. However, farmers that operate in different countries under various environmental conditions and resources endowments might not share the same production technologies. Ignoring the technological differences in the stochastic frontier model may result in biased efficiency and productivity estimates as unmeasured technological 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 farmers (or countries) in the data into discrete groups. Individuals within a specific group are assumed to share the same production possibilities, but these are allowed to differ between groups. Heterogeneity across countries 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. There is a latent clustering of the countries in the sample into J classes, unobserved by the analyst. We assume that a country from class j is using a technology of the Cobb-Douglas form:

$$\ln(y_{it}) = \ln f(x_{it}, \beta_j) + v_{it|j} - u_{it|j} \tag{2}$$

subscript i indexes countries (i: 1…N), t (t: 1…T) indicates time and j (j: 1, …, J) represents the different groups. βj is the vector of parameters for group j, yit and xit are, respectively, the production level and the vector of inputs. $v_{it|j}$ is a two-sided random error term which is independently distributed of the non-negative inefficiency component $u_{it|j}$.[6]

In this model, the unconditional likelihood for country i is constructed as a weighted average of the conditional on class j likelihood functions:

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

[6] We adopt the scaled specification for the inefficiency component: $u_{it}|_j = exp(z_{it}'\delta_j)\omega_{it}|_j$. z_{it} is a vector of country's specific control variables associated with inefficiencies, δ_j is a vector of parameters to be estimated, and $\omega_{it}\ |_{\mathrm{j}}$ is a random variable following the half normal distribution.

where, LF_{ijt} is the conditional likelihood function for country i at time t, and $\prod_{t:1}^{T} LF_{ijt} = LF_{ij}$ representing the contribution of country i to the conditional likelihood. P_{ij} is the prior probability attached by the econometrician to membership in class j and which reflects his uncertainty about the true partitioning in the sample. These class probabilities can be parameterized as a multinomial logit form:

$$P_{ij} = \frac{\exp(\lambda_j ' q_i)}{\sum_j \exp(\lambda_j ' q_i)} \qquad \lambda_1 = 0 \qquad \sum_j P_{ij} = 1 \tag{4}$$

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

Maximum likelihood parameter estimates of the model can be obtained by using the Expectation Maximization (EM) algorithm (Caudill, 2003; Green, 2005). [7] Using the parameters estimates and Bayes' theorem, we compute the conditional posterior class probabilities from:

$$P_{j|\mathrm{i}} = \frac{LF_{ij} P_{ij}}{\sum_j LF_{ij} P_{ij}} \tag{5}$$

Each country is assigned to a specific group based on the highest posterior probability. Each country's efficiency estimate can be determined relative to the frontier of the group to which that country belongs. This approach ignores however the uncertainty about the true partitioning in the sample. This somewhat arbitrary selection of the reference frontier can be avoided by evaluating the weighted average efficiency score as follows:[8]

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

where, $TE_{it}(j) = exp(-u_{it}|_j)$ is the technical efficiency of country i using the technology of class j as the reference frontier.

The productivity change can be estimated using the tri-partite decomposition (Kumbhakar and Lovell, 2000):

$$\dot{\mathrm{A}} = TC + \dot{TE} + Scale \tag{7}$$

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, $\dot{TE} = \frac{-\partial u_{it}|_j}{\partial t}$ represents the change in the inefficiency component 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 ε_{kj}.[9]

[7] EM is an iterative approach where each iteration is made up of two steps: the Expectation (E) step which involves obtaining the expectation of the log likelihood conditioned over the unobserved data, and the Maximization (M) step which involves maximizing the resulting conditional log likelihood for the complete dataset (Green, 2001).

[8] See Orea and Kumbhakar (2004) and Green (2005).

[9] 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.

In addition to estimating agricultural technical efficiency and productivity for each country, this approach allows for measuring technology gap. Once the group specific frontiers are estimated, we use the outer envelope of these group technologies to define the best practice technology or metafrontier, $f(x_{it}, \beta^*) = \max_j f(x_{it}, \beta_j)$. The deviation of group frontiers from the metafrontier is viewed as technology gap, which can be measured by the ratio of the output for the frontier production function for group *j* relative to the potential output defined by the best practice technology, $GAP_{it} = \frac{f(x_{it}, \beta_j)}{f(x_{it}, \beta^*)}$.[10]

3. The General Equilibrium Model

We develop a computable sequential dynamic general equilibrium (CGE) model including endogenous productivity effects from trade and technology transfer in agriculture to capture the impact of agricultural trade liberalization on inequality and poverty in Tunisia. The framework is a small open economy model with constant returns to scale and perfectly competitive markets designed for trade policy analysis with a large disaggregation of the agricultural sector.

The model draws from Belhaj Hassine, Robichaud and Decaluwé (2010) and incorporates econometric evidence of the linkages between international trade, technology transfer and agricultural productivity growth.

The trade-induced productivity gains may be accompanied by skill-biased technical change, which may affect the gap between skilled and unskilled wages. To capture this effect, the model integrates also the skill-biased effects of technological change following in that the work of Rattsø and Stokke (2005).

3.1 The model structure

The modeling of the production structure follows a standard nested approach. Perfect complementarity is assumed between value added and the intermediate consumptions in each sector. As the focus of this paper is on the impact of agricultural trade liberalization, the value added in agriculture sectors is modeled differently. Value added is a Cobb-Douglas (CD) function of aggregated labor input, capital and, for the agriculture sectors, an aggregate land bundle. Each land aggregate is a CES function of land (rain-fed agriculture) and a land-water composite (irrigated agriculture). The land-water composite, in turn, is produced by a CES production function to incorporate the possibility of substitution between land and water. We distinguish four types of land according to the nature of the crop (annual or perennial) and whether the land is irrigated or not. For the perennial crops, land is fixed by sector but there can be a substitution between irrigated and rain-fed land. This imperfect substitution is depicted by a CES function. For the annual crops, we assume that land can be used to produce different agricultural products, and therefore, land is assumed to be mobile between the different annual crops.

On the labor side, we distinguish five workers categories, classified by the level of qualification, skilled and unskilled, and by the sectors in which they are used (agriculture and non-agriculture). Agricultural workers are assumed to be fully mobile across the agricultural sectors and the same is assumed for the non agricultural workers. The restrictions to mobility between agricultural and nonagricultural employment do not derive from constraints imposed in the model but are due to the absence of their use in the benchmark equilibrium. Imperfect substitution is assumed between skilled and unskilled workers and is modeled through a CES

---

[10] For details see, Battese *et al*. (2004) and Kumbhakar (2006).

function. A technological bias is introduced in the equations and is discussed below in section 3.3.

Output is differentiated between goods destined for the domestic and export markets. Exports are further disaggregated according to whether they are destined for the European Union (EU) or the rest of the world (ROW). This relationship is characterized by a two-level constant elasticity of transformation frontier. Composite output is an aggregate of domestic output and composite exports; composite exports are aggregates of exports for the EU and ROW markets.

In the demand side, the consumers' preferences across sectors are represented by the Linear Expenditure System (LES) function to account for the evolution of the demand structure with the changes in disposable 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, namely EU or the Rest of the World (ROW). Total demand is made up of final consumption, intermediate consumption and capital goods.

Government expenditure is exogenous and grows at the rate of growth of the population and investment demand adjusts to the supply of total savings (saving driven closure).[11] At each period, the stock of capital available in each sector depends on the depreciated stock inherited from the previous period plus the value of investment. Investment in each sector follows a Jung-Thorbecke (2001) specification. The model allows tariff rates, export and import prices to differ depending on the trading partner, EU or the ROW. The current account balance is fixed per capita and the nominal exchange rate is used as the numeraire in the model. The current account balances the value of exports at world price plus net transfers and factor payments to the value of imports at world price.

3.2 Trade openness and productivity gains

Our framework integrates endogenous productivity relationships to capture the poverty alleviation that might arise from trade induced agricultural productivity gains.[12]

The agricultural production function is defined as:

$$VA_{agr} = A_{agr}^{VA} \, L_{agr}^{\beta_{agr}^{L}} LD_{agr}^{\beta_{agr}^{D}} K_{agr}^{\beta_{agr}^{K}} \tag{8a}$$

where VA_{agr} is agricultural value added and A_{agr}^{VA} is a scale parameter, L_{agr} indicates labor, LD_{agr} land and K_{agr} capital. β_{agr}^{L}, β_{agr}^{D} and β_{agr}^{K} are the labor, land and capital elasticities respectively.[13]

Similar characterization of the value added is assumed for non agricultural sectors, although land does not appear in the equation.

$$VA_{nag} = A_{nag}^{VA} \; L_{nag}^{\beta_{nag}^{L}} K_{nag}^{\beta_{nag}^{K}} \tag{8b}$$

We express agricultural TFP as a function of labor augmenting technical progress, A^{L}, and land augmenting technical progress, A^{D}:[14]

---

[11] The choice of the closure is important in CGE modeling. However, as the purpose of this analysis is to compare the poverty implications of trade liberalization with and without endogenous productivity effects, the choice of the closure is not particularly significant. Various closures have been tested and did not affect the direction and the magnitude of the productivity effects.

[12] Our analysis focuses on the links among trade liberalization, agricultural productivity growth and poverty. While productivity in the other sectors is endogenous, the point to highlight here is the potential for trade to improve agricultural productivity, through bringing new technologies, and to reduce poverty.

[13] See Diao *et al*. (2005) for a similar specification.

$$A_{agr} = A_{agr}^{VA}\left(A_{agr}^{L}\right)^{\beta_{agr}^{L}}\left(A_{agr}^{D}\right)^{\beta_{agr}^{D}} \tag{9a}$$

In the case of non agriculture sectors, TFP is simply a function of the labor augmenting technical progress:

$$A_{nag} = A_{nag}^{VA}\left(A_{nag}^{L}\right)^{\beta_{nag}^{L}} \tag{9b}$$

In line with the productivity growth model sketched out in the previous section, the growth rate of TFP is related with the stock of human capital, the degree of trade openness and the technology GAP. This association is tested by estimating the model in equation (1) econometrically. A similar equation for TFP gain of the following form is incorporated in the CGE model:

$$\hat{A}_j = \alpha_1\left(\frac{G}{GDP}\right)^{\alpha_H} + \alpha_2\left(\frac{G}{GDP}\right)^{\alpha_H}\left(\frac{Trade_j}{XS_j}\right)^{\alpha_{op}}\left(1-\frac{A_j}{A^F}\right) \tag{10}$$

where $\hat{A}_j$ is the proportional change in sectoral domestic TFP, A^F is the level of productivity in the frontier country, G is public expenditure, $Trade_j$ is total trade of sector J, *GDP is* gross domestic product and XS_j is sectoral output. The ratio of public expenditure to GDP captures the share of public expenditures on education and is used to proxy the level of human capital.[15] The share of trade to output measures the degree of the sector openness. A_j/A^F is the technology gap and captures the potential for technology transfer. α_1, α_2, α_H, α_{op} and A^F are estimated econometrically from equation (1) in the previous section.

3.3 The labor market and technological bias

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:

$$L_{agr} = B_{agr}\left[\begin{array}{l}\gamma_{ul,agr}\cdot\left(A_{agr}^{L}\right)^{-\rho_{agr}-\frac{\eta_{agr}}{2}}\cdot UL_{agr}^{-\rho_{agr}} + \gamma_{sl,agr}\cdot\left(A_{agr}^{L}\right)^{-\rho_{agr}+\frac{\eta_{agr}}{2}}\cdot SL_{agr}^{-\rho_{agr}}\\ +(1-\gamma_{ul,agr}-\gamma_{sl,agr})\cdot\left(A_{agr}^{L}\right)^{-\rho_{agr}}\cdot FL_{agr}^{-\rho_{agr}}\end{array}\right]^{\frac{-1}{\rho_{agr}}} \tag{11a}$$

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

We assume that family workers (FL_{agr}) are not affected by this bias.

Similar modeling of the labor market is assumed for non-agricultural sectors, although there are no family workers in these sectors:

[14] TFP in the industrial and services sector is assumed to be equal to labor augmenting technical progress.

[15] Human capital was approximated in the econometric model by the average years of schooling, in the CGE application we approximate it by the ratio of public expenditures to GDP. Since the model does not include an education function, we assume that a relatively important part of public expenditures is devoted to education.

$$L_{nag} = B_{nag}\left[\gamma_{ul,nag}\cdot\left(A_{nag}^{L}\right)^{-\rho_{nag}-\frac{\eta_{nag}}{2}}\cdot UL_{nag}^{-\rho_{nag}} + \left(1-\gamma_{ul,nag}\right)\cdot\left(A_{nag}^{L}\right)^{-\rho_{nag}+\frac{\eta_{nag}}{2}}\cdot SL_{nag}^{-\rho_{nag}}\right]^{\frac{-1}{\rho_{nag}}} \quad (11b)$$

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

$$\eta_j = \alpha_j\left(\left(\frac{\hat{Trade}_j}{XS_j}\right)^2 - 1\right) \quad (12)$$

where α_j is a constant parameter.

Recalling the model structure, labor is assumed to be perfectly mobile within each sub-sector but there is no migration between agricultural and non-agricultural activities. Wage differentials by skill level are allowed to co-exist reflecting specific institutional features related to the domestic labor markets.

3.4 Income distribution and poverty

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

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

$$P = P(Y, L(p)) \quad (13)$$

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 and P_1 are respectively the headcount ratio and the poverty gap.

The CGE model complemented by a micro-simulation approach is the core methodology of the analysis of the poverty impacts of agricultural trade liberalization and productivity gains. The interaction between the gain in labor productivity and the behavior of the labor market (downward nominal wage rigidity) will determine the outcome in terms of fluctuation in employment, households' income and cost of the consumption basket of households. The vectors of commodity and factor prices obtained from the different simulation scenarios are then fed into a micro-simulation framework to analyze income distribution and poverty at the household level using the micro data from the Tunisia household survey.

Our approach uses 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 *h* can be written as:

$$Y_e\left(p_0, p, y^h\right) = \prod_i\left(\frac{p_{i,0}}{p_i}\right)^{\beta_{h,i}}\left(y^h - \sum_i p_i C_{i,h}^{\min}\right) + \sum_i p_{i,0} C_{i,h}^{\min} \quad (14)$$

where $p_{i,0}$ and p_i are the price of commodity *i* at the base year and the price obtained from the simulation respectively, y^h the income of household *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*.

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:

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

where n_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 capture the change in the nominal value of the poverty line following a change in relative consumption prices of goods and services. The poverty line is represented by the value of an exogenous basket of goods composed of basic food and non food consumption needs as follows:

$$z = \sum_f p_f C_f^{\mathrm{basic}} \qquad (16)$$

where C_f^{basic} and p_f are the quantities and consumption prices of the basic consumption needs by commodity.[16]

The standard Gini and Theil coefficients are used to measure inequality at the individual household level. They are respectively defined as follows:

$$GINI = \frac{N+1}{N-1} - \frac{2}{N(N-1)\mu}\sum_h \kappa_h Y_e^h \qquad (17)$$

$$THEIL = \sum_h \left(Y_e^h \big/ Y\right) \ln\left(\frac{Y_e^h}{Y \big/ N}\right) \qquad (18)$$

where μ is the mean of household income, κ is the rank of the household in the distribution of income and Y is tot income of households.

4. Data

This section describes some features of the Tunisian agriculture and outlines the data used in the empirical analysis.

4.1 Description of the Tunisian agriculture

Agriculture represents an important foundation in the Tunisian economy as a source of employment and income in the rural areas and of foreign exchange earnings, as well as the mean of ensuring food security. Agriculture accounts for about 11% of the GDP and 9% of the exports and employs 16% of the workforce. Cereal crop, livestock, tree crops (mainly olive trees and date palms) and vegetables are the principal activities in the sector.

Tunisia enjoys a good potential in agricultural trade due to its favorable climatic conditions, its closeness to the European markets and its competitive advantage in several commodities

[16] The level of basic consumption needs is bound to be lower than the minimum consumption level in the utility function and which corresponds to each household's own perception of the minimal commodity basket that it needs to satisfy.

.

such as dates and olive oil. However, Tunisian agriculture suffers from lack of land and water resources and from farm fragmentation.[17]

Agriculture is currently heavily protected as apparent in Table 1. 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 establishment of hydro-agricultural projects for mobilizing water, expanding the irrigated areas and promoting export crops. A marked progress has been registered in fruit and vegetable productions with the development of irrigation schemes. This progress has been achieved primarily by medium-sized and large farms producing for exportation, which aggravated the dualistic feature of the sector. 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 tariff and non-tariff barriers.

The protection policies created perverse incentives to agricultural mismanagement and enhanced the entrenchments of resources in inefficient uses, raising the complexity of removing the protection. Reducing the agricultural trade barriers in the framework of the Barcelona-Agreement offers interesting perspectives and ambitious challenges for the Tunisian farmers.

Opportunities could lie in the modernization of the traditional agriculture through the transfer of new technologies. Challenges stem from the natural resources constraints and the prevalence of small farmers with inadequate skills who may have difficulties to sustain the stiffer international competition.

4.2 Data description

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

4.2.1 The econometric analysis

Our empirical application is based on country-level panel data referring to nine Southern Mediterranean Countries (SMC) involved in partnership agreements with the EU (Algeria, Egypt, Israel, Jordan, Lebanon, Morocco, Syria, Tunisia and Turkey) and five EU Mediterranean countries (France, Greece, Italy, Portugal and Spain) during the period 1990–2005. These countries are the leading trading partners and competitors of Tunisia. Our dataset includes observations on agricultural production and input use, international trade, income distribution, and a number of other variables that are frequently associated with agricultural productivity and growth. These variables, whose definitions, sources and descriptive statistics are provided in Tables A1 and A2 in Appendix I, are used to estimate the stochastic production function in (2), the class probabilities in (4) and the productivity growth equation in (1).

The stochastic production frontier is estimated using data on production of 36 agricultural commodities belonging to six product categories (fruits, shell-fruits, citrus fruits, vegetables, cereals, and pulses) and on the corresponding use of five inputs (cropland, irrigation water,

[17] According to the 2004/05 General Agricultural Census, 47% of farms were holdings of less than 5 ha.

fertilizers, labor and machines).[18] The six product categories include the main produced and traded commodities in the Mediterranean region.

The inefficiency effect model and the productivity growth equation incorporate an array of control variables representing trade openness, human capital, land holdings, agricultural research effort, land quality and institutional quality.

Two different measures are used to proxy the degree of trade openness of each country: the ratio of agricultural exports plus imports to GDP 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 MacMap 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 is drawn from this database.[19]

Human capital is proxied by the average years of schooling in the population over age 25 and is included to capture the impact of labor quality and the ability to absorb advanced technology. Land holdings include land fragmentation, which is controlled for by the percent of holdings under five hectares; inequality in operational holdings, measured by the land Gini coefficient; and average holdings approximated by the average farm size. Agricultural research effort is measured by public and private R&D expenditures. Land quality is measured by the percent of land under irrigation.

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 to protect property rights and enforce contracts. Improved institutional quality is thought to enhance farming efficiency and productivity, as it may facilitate human capital accumulation, appropriate technology adoption and provision of rural infrastructure (Self and Grabowski, 2007; Vollrath, 2007).

As determinants of the latent class probabilities, we consider country averages of five separating variables: total agricultural machinery, total applied fertilizers, agricultural land, average holdings and rainfall levels. Machinery and fertilizers help to identify countries endowed with modern inputs. Average farm size captures the differences in the scale of agricultural holdings across countries and distinguishes countries with an important proportion of small farms (Vollrath, 2007). Agricultural land and rainfall levels capture the influence of resources endowments and climatic conditions on class membership.

4.2.2 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 commodities and is implemented using the Input-Output (IO) table of 2001, the national-

[18] We construct aggregate output and input indices for each product category using the Tornqvist and Eltetö-Köves-Szulc (EKS) indexes. See Eltetö and Köves (1964).

[19] Available at http://www.macmap.org.

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[20]. 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 2 displays the macro SAM for the year 2001.

The micro SAM distinguishes 33 production sectors, including 23 agricultural and food activities with 10 urban industries and services; five types of labor namely, family agricultural workers, skilled and unskilled agricultural workers and skilled and unskilled nonagricultural workers; four types of land namely, annual irrigated and non irrigated land and perennial irrigated and non irrigated land; capital; and natural resources. Institutions include rural and urban households, companies, government and foreign trading partners (EU and ROW). This SAM provides a consistent set of relationships showing intermediate, final demand, value added and foreign transactions. The sectors, factors and institutions of the model are described in Table A5 in Appendix I along with their label.

The modeling analysis starts with a static model calibrated on the initial SAM and extends to a recursive dynamic model. As our SAM contains data on only two representative household groups, rural and urban households, the poverty and distributional impact from any simulation in the model cannot be computed with enough precision. To overcome this shortcoming, the CGE model is complemented by a micro-simulation methodology using the traditional "top-down" approach. We measure the distributional and poverty effects of agricultural trade policy changes using the 2000 expenditures household survey for Tunisia. The survey includes a nationally representative sample of about 6,000 households and contains information on household's characteristics, household consumption expenditures on food and a comprehensive range of non-food items such as schooling, health, transportation and recreation. The sample is clustered and stratified by region and urban/rural areas.

As is common in most MENA countries, the survey does not include information on household's income which is therefore approximated by expenditures. The top-down microsimulation allows them to capture mainly the effects of consumption prices variations on individuals' expenditures (income), poverty and inequality.[21]

5. Main Estimation Results

The ambition of our empirical investigation is to incorporate econometric evidence of the trade-productivity linkages into the CGE model to examine the impact of agricultural trade liberalization on poverty and inequality taking account of the farming productivity gains channel and the relationship between labor productivity and rigidities in the labor market.

We start by estimating the econometric model in section 2, and then incorporate the parameter estimates in the CGE model to investigate the inequality and poverty outcomes under different agricultural trade liberalization scenarios.

5.1 The econometric estimations

This empirical application involves basically a three-step analysis. First, the latent class model of equation (2) is estimated using maximum likelihood via the EM algorithm[22]. Second, efficiency and productivity levels and growth are computed for each country. Third,

[20] Mainly « Les Enquêtes Agricoles de base », « Annuaire des statistiques agricoles » and « Enquête sur les structures des exploitations agricoles ». ("Agricultural Surveys", "Yearbook of Agricultural Statistics" and "Survey of farm structures")

[21] For more details about the drawbacks of the top-down microsimulation method see Bourguignon *et al.* (2008).

[22] The estimation procedure was programmed in Stata 9.2.

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.

In each country, we carried out estimations at different levels of aggregation, both for each agricultural commodity group and for the whole agricultural sector. The results of estimating the input elasticities of the production frontier are reported in Table A3 in the Appendix.[23]

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.

The determinants of agricultural production efficiency among the selected countries proved significant. International trade, educational attainment, land quality, agricultural research effort and institutional factors appear 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. The sign of the parameters estimates indicate whether the separating variable increases the probability of assigning a country into the corresponding class or not. For example, increasing total applied fertilizers increases the probability of a country to belong to class three.

The average efficiency scores and TFP changes, estimated using equations (6) and (7) respectively, are reported in Table A4 in the Appendix. 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. On average, over the period under consideration, EU countries exhibited better efficiency levels than SMC.

Variation of agricultural 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 (1) that links agricultural productivity growth to technology gap, international trade, and human capital using the nonlinear least squares approach.

The estimation of this model poses several challenges relating to unobserved heterogeneity, potential endogeneity, and measurement error. The computational difficulties of the nonlinear fixed effect models preclude the introduction of individual specific effects to control for the differences between the countries. We add a set of institutional factors, including investment in research and development, institutional quality and average agricultural holdings, to the

[23] In the interest of space limitation we describe the results using pooled data. Estimates for specific crops are available from the authors upon request.

baseline specification. This strategy enables us to control for heterogeneity in certain observed variables and to check the robustness of the results.

Another econometric concern is that measurement error and endogeneity of some explanatory variables, such as technology gap, could lead to bias in the estimated coefficients. One way of dealing with this problem is to regress the technology gap against the lagged gap and use the predicted value as an alternative to the technology gap in the model.

Table 3 reports the estimation results considering the two proxies of international trade, namely the ratio of agricultural exports plus imports to GDP (column 1), and agricultural trade barriers (column 2).

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. The interaction term highlights the role of international trade in promoting technology transfer and points 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.

The linear effect of human capital on TFP provides also some support to the role of educational attainment in enhancing domestic innovation in agriculture.

There are also interesting results regarding the effect of the control variables on agricultural productivity growth. The findings provide evidence on the positive contribution of agricultural research efforts and larger farm sizes to productivity improvement. Control of corruption, government effectiveness and political stability enter with positive and statistically significant coefficients, indicating a positive role of institutional quality in enhancing agricultural growth.

5.2 Simulation of trade policy reform

Using a time horizon of 10 years, a business-as-usual (BAU) scenario and two trade reform scenarios are developed in the CGE framework. The model is solved in recursive dynamic mode and the simulation results in regard to changes in consumption prices and income are linked to a micro-simulation model. This macro-micro modeling enables analysis of the medium term poverty and distributional impacts of trade liberalization and investigation of the additional poverty alleviation that could be expected from the trade induced agricultural productivity gains.

Two sets of scenarios are developed and under each scenario we abstract from the productivity gains and then take these gains into account. The first scenario considers the complete removal of agricultural tariffs and the second is a scenario of full trade liberalization in agricultural and non-agricultural sectors. In what follows, we report the results for these scenarios:

> Scenario 1: Cutting tariffs on agricultural products and abstracting from the productivity link.
> Scenario 2: Cutting tariffs on agricultural products and taking account of the productivity link.
> Scenario 3: This scenario extends Scenario 1 to all products.
> Scenario 4: This scenario extends Scenario 2 to all products.

The simulation analysis focuses only on selected key variables, the choice of which relies on the mechanisms through which agricultural trade liberalization affects economic performance, poverty and inequality. The simulation results are reported using the percentage deviation from the model's baseline, and in the interest of space limitation, most of the results refer to agriculture and agri-food.[24]

5.2.1 Impacts on production, imports and exports

We begin by comparing the global impact of the four simulation scenarios on imports reported in Table 5. As expected agricultural trade openness exerts a significant positive effect on agricultural imports. The complete removal of tariffs on agricultural commodities induces a substantial reduction in the domestic prices of these commodities which, in turn, yields a substitution mechanism in favor of imported goods as this group increases on average by 12.6 percent in the last period. Simultaneously and taking into account the degree of substitutability between imported and domestic agricultural products, the increased competitiveness of imported commodities exerts a downward pressure on domestic prices that leads to a reduction in agricultural production of about one percent. This domestic prices decrease induces a slight increase of agricultural exports of less than one percent.[25] With the domestic market becoming less attractive, farmers would choose to sell their products on the export market.

We now examine what would happen if the trade-productivity linkages are incorporated in the model. As reported in Scenario 2 of Table 5, using more efficient production techniques in the agricultural sector would in part counteract the trade's negative effects of falling domestic prices on farming production. This is evident from the drop in agricultural production of only 0.3 percent compared to a drop of 1.1 percent in Scenario 1. Consequently, agricultural imports would rise less (i.e. 11.6 percent instead of 12.6 percent) and exports would increase slightly more. We observe quite similar effects in the nonagricultural sectors. The findings reveal that with including the trade-productivity linkages the trade reforms will lead to a greater increase in exports and a lower increase in imports. However these effects are quite small.

Table 5 illustrates also the simulation results of full liberalization of agricultural and nonagricultural tariffs without and with endogenous productivity growth (scenarios 3 and 4, respectively). As shown in both scenarios, the elimination of all import tariffs induces a substantial increase in non-agricultural imports and exports of 9 and 11 percent respectively. The rise of imports can be traced to the fall in their domestic prices resulting from the tariffs removal and which induces a substitution in their favor. Thus, the increase in imports leads to a real devaluation and an increase in exports.

The findings suggest that despite the substantial boost of imports in all sectors, agricultural imports would increase the most (12 percent) as the initial tariff barriers are the highest in this sector. Agricultural exports would however show a small decline of about 2 percent.

On the production side, the full trade liberalization creates a substantial increase in real GDP of 2.9 percent (compared to 0.5 percent in scenario 1) and a significant rise in non-agricultural production of 3.9 percent (compared to a small drop in agricultural production). The elimination of tariff barriers in the non-agricultural sector appears to create an important reallocation of resources in favor of the manufacturing and service sectors.

When the productivity effects are incorporated, we observe a higher increase in GDP (3.8 percent as against 2.9 percent in Scenario 3) as well as an important increase in both agricultural and non agricultural production. The growth of real GDP leads to an expansion of households' income and consumption and involves an increase in total demand and thus in

---

[24] Results on more variables and with different scenarios can be obtained from the authors upon request.

[25] As is well known, the magnitude of this effect depends on the value of the elasticity of substitution in the CET function. However, the basic mechanism remains almost unchanged even if we take more extreme values of the substitution elasticity.

production. The increase of agricultural production partly offsets the decrease in agricultural exports (which declines by one percent against a decline of 2.6 percent when the productivity effects are not included).

Table 5 illustrates the productivity gains as well as the imports and exports variations induced by the elimination of tariff on agricultural commodities (Scenario 2) and on all products (Scenario 4). The findings show important productivity gains in all agricultural productions. The sectors “Leguminous”, “Other fruits” and “Industrial cultures” seem to enjoy the most important productivity gains. These sectors are highly protected and the production and trade in these commodities are quite limited. Thus, the elimination of tariff barriers on these commodities appears to induce a substantial increase in their foreign trade, enhancing the transfer of new technologies and contributing to achieve gains in productivity. Full trade liberalization appears to improve productivity in agri-food sectors and particularly in the dairy, beverage and flour sectors.

5.2.2 The labor market

The removal of trade barriers and the transfer of new technologies will induce changes in the labor demand and might affect the skill structure of the labor force. As sketched earlier, the labor force in the agricultural sector is assumed to be composed of three categories of workers namely, family labor and skilled and unskilled wage workers. Rural workers are mobile only between agricultural activities and there is no migration from rural to urban sectors. With the real depreciation of the exchange rate needed to keep the current account balance in equilibrium, we observe a reduction of domestic prices with respect to foreign prices. Consequently import demand will increase while domestic demand and production will decline thereby inducing a decrease in labor demand.

These negative consequences would be offset to some extent by the productivity enhancing effects of trade. Improved productivity results in an upward shift of the production function, causing output to rise. At the same time, the decline in domestic prices stimulates export demand, further boosting production and employment in some sectors. On the other hand the trade-induced transfer of technology is biased in favor of skilled labor. The productivity of skilled workers increases more relative to that of unskilled workers, thereby enhancing the demand for skilled labor particularly in the agri-food sector. If output expands strongly enough to cause an increase in overall employment, skilled labor increases more proportionally. This is supported by the simulation results of scenarios 2 and 4 reported in Table 6.

The evidence reveals a sharp decrease in unskilled workers in sectors enjoying large productivity gains, as we observe a reduction of about 61 percent, 71 percent and 49 percent of unskilled labor in the “Leguminous”, “Other fruits” and “Industrial culture” sectors, respectively. On the other hand skilled labor shows an important increase in the first two sectors suggesting a substitution effect between these labor types. The demand for skilled workers appears to significantly increase in the agri-food sector under the full liberalization scenario.

In summary, the complete removal of agricultural tariffs as well as the full liberalization of trade in all sectors results in a reduction of domestic prices, an increase in import demand and a decline in domestic demand for local production. Local producers respond to the price variations by reorienting their production toward the export market, the export expansion is nevertheless limited (and even negative in case of full liberalization) in the agricultural sector.

Taking into account the trade-induced productivity effects leads to more optimistic results. The trade reforms are shown to generate important productivity gains, particularly in agriculture, and to boost output and employment in some sectors. Improved productivity contributes to increasing economic growth. The findings suggest that skilled workers would likely benefit the most from the opening process. It is important however to stress the fact that the magnitude of the sectoral impacts are linked to the initial level of protection, the initial technological gap with respect to the best practice frontier and the magnitude of the technological bias affecting the labor productivity.

5.3 The poverty and inequality impact

To examine the poverty and inequality implications of the trade liberalization scenarios analyzed, the top-down microsimulation is employed. At the top, the CGE model is used to estimate changes in commodity prices and household consumption resulting from the trade reforms. These changes are then fed into the household expenditure survey for 2000 to evaluate changes in household expenditures (income) and to analyze the poverty and inequality impacts of the trade liberalization scenarios.

As described in the previous section, household poverty is measured using the well known FGT poverty indicators, that is the headcount index (or the "incidence of poverty"), which gives the proportion of the population with income below the poverty line; and the poverty gap index (or the "intensity of poverty"), which indicates how far below the poverty line the poor are. The poverty line is determined endogenously to capture the effects of trade on poverty through the cost of basic consumption. The basic commodities basket is constructed separately for the rural and urban areas following the methodology of the World Bank.[26] The selection of the basic food goods is determined on the basis of the average caloric requirements of the households around the official poverty line and the frequency of consumption by these households.[27] The poverty line is obtained by scaling up the food poverty line by Engel's coefficient to allow for essential non-food spending.[28]

The inequality is estimated using the Gini and Theil indexes. The poverty and inequality indicators are applied for the per capita household equivalent income.

The poverty and inequality impacts of the trade liberalization simulations are reported in Tables 6 and 7 respectively.

Table 6 presents evidence that trade liberalization contributes to poverty alleviation. All trade reform scenarios entail a decrease in rural and urban poverty and this reduction is more pronounced under the full removal of trade tariffs.

The observed changes in the poverty indicators derive from changes in the poverty line and changes in nominal expenditures (or income). The poverty line represents the cost of a basket of goods that fulfill the basic needs. The trade-induced decline in consumer prices affects the poverty line and if the change in the poverty line is not as great as the change in nominal consumption, then poverty decreases.

The headcount ratio and the poverty gap index show a decline in the extent and depth of poverty reflecting an improvement in the average consumption of those who remain poor. According to the results, trade liberalization would be more beneficial to rural households than to urban households, notably in terms of the poverty gaps. Besides, trade liberalization appears to benefit the poor more strongly when the productivity effects are taken into account. As can be seen from Table 7, the poverty incidence at the national level decreases

---

26 See "Republic of Tunisia, Poverty Alleviation, Preserving Progress while Preparing for the Future", Report n° 13993-TUN, World Bank 1995.

27 Estimated by the National Institute of Statistics (INS).

28 The values for the Engel coefficient are estimated by the World Bank to be around 1.5 and 1.38 for urban and rural areas respectively and the poverty lines are equivalent to 341 TD and 294 TD in 2000, respectively for the two areas.

from 4.6 percent to 3.3 percent for agricultural trade liberalization and to 1.5 percent for full trade liberalization, as opposed to a decline to 3.8 percent and 2.4 percent respectively, without the productivity impacts.

The results in Table 8 reveal a negligible effect of trade openness on income distribution. The Gini and Theil indexes appear to change very little under all the reform scenarios. Because of a lack of data on income sources and amounts at the individual level, the analysis fails to fully capture the distributional changes resulting from the effects of trade reform on the wage gap between skilled and unskilled labor. These results should be viewed as suggestive due to data limitations.

6. Conclusions

Assessing the poverty implications of trade liberalization has been the focus of considerable economic research. Despite the number of empirical studies on this issue, no broad conclusions can be drawn on the extent of poverty reduction due to trade openness. The economic linkages among trade and poverty are complex and designing a framework that accommodates all the underlying interactions is a challenging task.

General equilibrium models are currently the dominant methodology in the analysis of the poverty and distributional consequences of trade reform. Since these models can be quite complicated, most applications abstract from some mechanisms by which trade affects poverty, as for instance productivity growth.

Access to new technology and improved productivity has been identified among the most critical pathways through which trade openness may alleviate poverty. This paper provides an attempt to investigate the contribution of trade-productivity linkages to a general equilibrium analysis of poverty.

The study first estimates the impact of international trade on productivity growth. Econometric evidence of these trade-productivity linkages is then incorporated into a general equilibrium model to evaluate the poverty outcomes of agricultural liberalization in Tunisia.

The findings provide evidence that opening up to foreign trade promotes productivity growth through the transfer of technology from more advanced countries. The simulation results from the CGE model indicate that poverty would decrease by 15 and 43 percent under the agricultural and the full-liberalization scenarios, respectively. The reduction in poverty increases to 26 and 63 percent, for agricultural and full liberalization, respectively, when productivity impacts are considered. This result can be traced primarily to the fall in domestic prices resulting from the removal of import tariffs. The changes in poverty indexes derive from the change in household income and the change in consumer prices, which, in turn, affect the poverty line.

Trade liberalization and the transfer of technology appear to affect the labor demand and its skill structure. The reforms seem to enhance the demand of skilled workers in some sectors.

The distributional implications of trade openness seem negligible as shown by the little variation of the inequality indicators across the different simulation scenarios. However, these results should be interpreted with caution. Because of lack of data, the analysis is unable to capture the distributional changes resulting from the effects of trade reform on the wage gap between skilled and unskilled labor.

References

Ackerman, F. 2005. "The Shrinking Gains from Trade: A Critical Assessment of Doha Round Projections". GDAE Working Paper No. 05–01. USA: Tufts University.

Anderson, K. and W. Martin. 2006. "*Agricultural Trade Reform and the Doha Development Agenda"*. A co-publication of Palgrave Macmillan and the World Bank. The International Bank for Reconstruction and Development. Washington DC: The World Bank.

Anderson, K., Martin, W. and D. van der Mensbrugghe. 2005. "Distortions to World Trade: Impacts on Agricultural Markets And Farm Incomes". Policy Research Working Paper 3736. Washington DC: The World Bank.

Anderson, K., Martin, W. and D. van der Mensbrugghe. 2006. "Long-Run Global Impacts of Doha Reform on Poverty". In "*Poverty and the WTO: Impacts of the Doha Development Agenda"*, ed. T. Hertel and L. A. Winters. Basingstoke, U.K. Palgrave Macmillan. Washington, DC: The World Bank.

Augier, P. and M. Gasiorek. 2003. "The Welfare Implications of Trade Liberalization between the Southern Mediterranean and The EU". *Applied Economics* Vol. 35, pp. 1171–1190.

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* Vol. 21, pp. 91–103.

Bardhan, P. 2006. "Globalization And Rural Poverty". *World Development* Vol. 34, pp. 1393–1404.

Barro, R. J., and J.W. Lee. 2000. "International Data on Educational Attainment: Updates and Implications". NBER Working Paper 7911. Washington, DC: The World Bank.

Belhaj Hassine, N. 2008. "Trade, Human Capital and Technology Diffusion in the Mediterranean Agricultural Sector". *Economie Internationale* Vol. 113, pp. 115–142.

Belhaj Hassine, N., Robichaud, V. and B. Decaluwé. 2010. "Agricultural Trade Liberalization, Productivity Gain and Poverty Alleviation: A General Equilibrium Analysis". ERF Working Paper No. 519.

Benhabib, J. and M. Spiegel. 2002. "Human Capital and Technology Diffusion". Federal Reserve Bank of San Francisco Working Paper 03 – 02.

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". Working Paper 22. Centre d'Etudes Prospectives et d'Informations Internationales (CEPII). Paris: CEPII.

Bouët, A. 2006. **"**What Can the Poor Expect from Trade Liberalization?: Opening the "Black Box of Trade Modeling". International Food Policy Research Institute (IFPRI). MTID Discussion Paper No 93. Washington, DC: IFPRI.

Bourguignon, F., Bussolo, M. and L.A.P. da Silva. 2008. *The Impact of Macroeconomic Policies on Poverty and Income Distribution: Macro-Micro Evaluation Techniques and Tools*. The International Bank for Reconstruction and Development. Washington DC: The World Bank.

Cameron, G., Proudman, J. and S. Redding. 2005. "Technological Convergence, R&D, Trade and Productivity Growth". *European Economic Review* Vol. 49, pp. 775–807.

Caudill, S.B. 2003. "Estimating a Mixture of Stochastic Frontier Regression Models Via the EM Algorithm: A Multiproduct Cost Function Application". *Empirical Economics* Vol. 28, pp. 581–98.

Cline, W. 2004. "*Trade Policy and Global Poverty"*. Washington, D.C.: Institute for International Economics: Center for Global Development.

Coxhead, I. and P. Warr. 1995. "Does Technical Progress in Agriculture Alleviate Poverty? A Philippine Case Study". *Australian Journal of Agricultural Economics.* Vol. 39, N. 1, pp. 25-54.

Das, G.G. 2002. "Trade, Technology and Human Capital: Stylised Facts and Quantitative Evidence". *The World Economy* Vol. 25, pp. 257–81.

Decaluwé, B., Dumont, J.C. and L. Savard. 1999. "Measuring Poverty and Inequality in a Computable General Equilibrium Model". Cahiers de recherche du CREFA No. 9926. Quebec: Université Laval.

Decaluwé, B., Martens, A. and L. Savard. 2001. *La politique économique du développement et les modèles d'équilibre général calculable: Une introduction*. (*Economic policy development and models of general equilibrium: An Introduction*). Canada: Presses de l'Université de Montréal.

De Janvry, A. and E. Sadoulet. 2001. "World Poverty and the Role of Agricultural Technology: Direct and Indirect Effects". *Journal of Development Studies* Vol. 38, N. 4, pp. 1–26.

Diao, X, Rattso J, and H.E. Stokke. 2005. "International Spillovers, Productivity Growth and Openness in Thailand: An Intertemporal General Equilibrium Analysis". *Journal of Development Economics* Vol. 76, pp. 429– 450.

Eltetö, O. and Köves, P. 1964. "On A Problem of Index Number Computation Relating to International Comparisons". *Szatistikai Szemle*, Vol. 42, pp: 507-518.

Foster, J., Greer, J. and E. Thorbecke. 1984. "A Class of Decomposable Poverty Measures". *Econometrica* Vol. 52, pp. 761–66.

Graff, G., D. Roland-Holst, D. and D. Zilberman. 2006. "Biotechnology and Poverty Reduction in Low-Income Countries". *World Development* Vol. 34, N. 8, pp. 1430–1445.

Greene, W. 2001. "Fixed and Random Effects in Nonlinear Models". Working Paper 01-01. Department of Economics, Stern School of Business, New York University, *http://www.stern.nyu.edu/~wgreene/panel.pdf*.

Greene, W. 2005. "Reconsidering Heterogeneity in Panel Data Estimators of the Stochastic Frontier Model". *Journal of Econometrics* Vol. 126, pp. 269–303.

Griffith, R., Redding, S. and J. Van Reenen. 2004. "Mapping the Two Faces of R&D: Productivity Growth in a Panel of OECD Industries". *The Review of Economics and Statistics* Vol. 86, N. 4, pp. 883–895.

Harrison, A. and M. McMillan. 2007. "On the Links Between Globalization and Poverty". *The Journal of Economic Inequality* Vol. 5, pp. 123–134.

Hertel, W.T. 2006. "A Survey of Findings on the Poverty Impacts of Agricultural Trade Liberalization". *Journal of Agricultural and Development Economics* Vol. 3, N. 1, pp. 1–26.

Hertel, T. and J. Reimer. 2005. "Predicting the Poverty Impacts of Trade Reform". *Journal of International Trade & Economic Development* Vol. 14, N. 4, pp. 377–405.

Hertel, T. and L.A. Winters. 2005. "Estimating the Poverty Impacts of a Prospective Doha Development Agenda". *The World Economy* Vol. 28, N. 8, pp. 1057–1071.

Hertel, T. and L.A. Winters. 2006. *"Poverty & the WTO: Impacts of the Doha Development Agenda"*. A co-publication of Palgrave Macmillan and the World Bank. The International Bank for Reconstruction and Development. Washington DC: The World Bank.

IFPRI. 2007. "*Impact of Trade Liberalization on Agriculture in the Near East and North Africa*". Washington DC: International Food Policy Research Institute and International Fund for Agricultural Development.

Jung, H.S. and E. Thorbecke. 2001. "The Impact of Public Education Expenditure on Human Capital, Growth, and Poverty in Tanzania and Zambia: A General Equilibrium Approach". IMF Working Paper WP/01/106. International Monetary Fund.

Kaufmann, D., Kraay, A. and M. Mastruzzi. 2007. "Governance Matters VI: Governance Indicators for 1996–2006". World Bank Policy Research Working Paper 4280. Washington, DC: The World Bank.

Keller, W. 2004. "International Technology Diffusion". *The Journal of Economic Literature* Vol. 42, pp. 752–82.

Koning, N. and P. Pinstrup-Andersen. 2007. "Agricultural Trade Liberalization and the Least Developed Countries". *Wageningen UR Frontis Series* Vol. 19. Berlin: Springer Publishing.

Kumbhakar, S.C. and K. C. A. Lovell. 2000. "*Stochastic Frontier Analysis"*. Cambridge: Cambridge University Press.

Kumbhakar, S.C. 2006. "Productivity and Efficiency Measurement Using Parametric Econometric Methods". In "*Transparency, governance and markets"*, eds. Bagella, M., Becchetti L. and Hasan I., Amsterdam, Boston: Elsevier.

Litchfield, J., McCulloch, N. and L.A. Winters. 2003. "Agricultural Trade Liberalization and Poverty Dynamics in Three Developing Countries". *American Journal of Agricultural Economics* Vol. 85, pp. 1285–1291.

Löfgren, H. 1999. "Trade Reform and the Poor in Morocco: A Rural-Urban General Equilibrium Analysis of Reduced Protection". TMD Discussion Paper No. 38. Washington DC: International Food Policy Research Institute.

McCalla, A.F. and J. Nash. 2007. "*Reforming Agricultural Trade for Developing Countries"*. International Bank for Reconstruction and Development. Washington Dc: The World Bank.

Nissanke, M. and E. Thorbecke. 2006. "Channels and Policy Debate in the Globalization–Inequality–Poverty Nexus". *World Development* Vol. 34, pp. 1338–1360.

Orea, L. and S.C. Kumbhakar. 2004. "Efficiency Measurement Using a Latent Class Stochastic Frontier Model". *Empirical Economics* Vol. 29, pp. 169–183.

Pardey, P.G., Beintema, N.M., Dehmer, S. and S. Wood. 2006. "Agricultural Research: A Growing Global Divide?" Food Policy Report N. 17. International Food Policy Research Institute (IFPRI). Washington, DC: IFPRI.

Porto, G.G. 2007. "Globalisation and Poverty in Latin America: Some Channels and Some Evidence". *The World Economy* Vol. 30, N. 9, pp. 1430–1456.

Rattsø, J. and H. Stokke. 2005. "Ramsey Model of Barriers to Growth and Skill-Biased Income Distribution in South Africa". Trade and Industrial Policy Strategies (TIPS) Working Paper 4-2005. Pretoria, South Africa.

Rutherford, T., Tarr, D. and O. Shepotylo. 2006. "The Impact on Russia of WTO Accession and The DDA: The Importance of Liberalization of Barriers Against FDI in Services for Growth and Poverty Reduction". In "*Poverty and the WTO: Impacts of the Doha Development Agenda"*, ed. T. Hertel and L. A. Winters. Basingstoke, U.K. Palgrave Macmillan. Washington, DC: The World Bank.

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 Hague, Netherlands: The Institute of Social Studies.

Self, S. and R. Grabowski. 2007. "Economic Development and the Role of Agricultural Technology". *Agricultural Economics* Vol. 36, pp. 395–404.

Van Tongeren, F., van Meijl, H. and Y. Surry. 2001. "Global Models Applied to Agricultural and Trade Policies: A Review and Assessment". *Agricultural Economics* Vol. 26, pp. 149–172.

Vollrath, D. (2007). "Land Distribution and International Agricultural Productivity". *American Journal of Agricultural Economics,* Vol. 89, pp: 202-216.

Winters, L.A. 2002. "Trade Liberalization and Poverty: What are the Links?". *The World Economy* Vol. 25, pp. 1339–1367.

Winters L.A. 2004. “Trade Liberalization and Economic Performance: An Overview”. *Economic Journal* Vol. 114, pp. F4–F21.

Winters, A. 2005. “The European Agricultural Trade Policies and Poverty”. *European Review of Agricultural Economics* Vol. 32, N. 3, pp. 319–346.

Winters, L.A., McCulloch, N. and A. McKay. 2004. “Trade Liberalization and Poverty: The Evidence So Far”. *Journal of Economic Literature* Vol. 42, pp.72–115.

Wang, Y. 2007. “Trade, Human Capital, and Technology Spillovers: An Industry-level Analysis”. *Review of International Economics* Vol. 15, N. 2, pp. 269–283.

Xu, B. 2000. “Multinational Enterprises, Technology Diffusion, and Host Country Productivity Growth”. *Journal of Development Economics* Vol. 62, pp. 477–493.

Xu, B. and E. P. Chiang. 2005. “Trade, Patents and International Technology Diffusion”. *Journal of International Trade & Economic Development* Vol. 14, pp. 115–135.

Table 1: Trade Data and Applied Tariffs for the Main Agricultural Products

	Imports	Exports	Tariffs EU (%)	Tariffs Maghreb (%)	Tariffs Middle East (%)
Hard wheat	74.1	-	73	48.67	42.12
Soft wheat	206.4	-	17	48.67	42.12
Barley	124.8	5.1	73	48.67	42.12
Leguminous	9.64	0.62	100	67	58.6
Citrus	-	12.8	150	100	86.54
Dates	-	104.9	150	100	86.54
Other Fruits	7.5	6.5	100	65	77
Potatoes	0.4	1	150	100	86.54
Tomatoes	-	2.9	150	100	86.54
Bovine livestock	0.3	-	73	48.67	51
Ovine livestock	1.14	-	150	100	86.54
Fish, crustacean & mollusks	20.9	20.7	43	28.67	24.81
Eggs	5	0.1	150	100	86.54
Dairy products	35.13	7.5	92.5	78	72
Olive Oil	1.6	201.5	100	66.67	57.69
Other oils	156.5	16.5	15	10	8.65
Sugar	89.2	1.2	15	10	8.65

Source: INS and Macmap database.

Note: The exports and imports values reported in the table are for the year 2001.The amounts are in Million TD.

Table 2: The 2001 Macro SAM for Tunisia (Million 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	

Table 3: Impact of International Trade on Agricultural TFP Growth

	TRADE VOLUMES	TRADE BARRIERS
Human capital (α_1)	0.05**	0.04***
International trade*Human capital*(1-GAP) (α_2)	0.17*	-0.13***
α_{op}	0.34***	-0.14***
α_H	0.35***	-0.14**
R&D	0.024**	0.029**
Average holdings	0.0038*	0.0022*
Control of corruption	0.0003*	0.0002
Government effectiveness	0.0004*	0.0003*
Political stability	0.0003*	0.0002*
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.

Table 4: Macroeconomic Results (Last Period)

Variable	BAU[1]	Scenario 1 (%)	Scenario 2 (%)	Scenario 3 (%)	Scenario 4 (%)
Real GDP	32961	0.5	0.7	2.9	3.8
Agricultural Production	3454	-1.1	-0.3	-0.8	1.7
Non-agricultural Production	65466	0.7	0.9	3.9	4.7
Agricultural exports	202	0.3	0.4	-2.6	-1.0
Non-agricultural exports	17716	0.9	1.0	10.6	11.6
Agricultural imports	1114	12.6	11.6	11.9	12.2
Non-agricultural imports	21212	0.1	0.3	9.1	9.9

Notes: [1] in Million TD.

Table 5: Trade Induced TFP Gains and External Trade (Last Period)

	Scenario 2 (%)			Scenario 4 (%)		
	TFP Gain	Imports	Exports	TFP Gain	Imports	Exports
Agricultural	1.1	11.6	0.4	1.0	12.2	-1.0
Non-agricultural	-0.0	0.3	1.0	0.3	9.9	11.6
Soft wheat	1.3	10.4	na	1.2	9.5	na
Hard wheat	1.0	18.5	na	1.0	17.4	na
Barley	0.2	3.7	2.1	0.2	-0.6	1.8
Other cereals	0.3	4.8	2.3	0.5	9.1	2.6
Leguminous	3.2	65.1	43.3	3.4	72.5	45.9
Olives	0.0	na	-0.3	0.0	na	0.4
Citrus fruits	0.0	1.2	-0.3	-0.2	8.6	-2.1
Dates	0.0	1.1	-0.5	-0.2	9.5	-3.4
Other fruits	4.2	148.0	5.9	4.2	154.4	8.9
Vegetables	0.1	4.1	1.7	0.3	9.2	1.4
Livestock	0.0	-0.9	2.6	1.3	50.6	5.9
Industrial cultures	2.8	7.9	-5.2	2.9	10.9	-2.7
Other crops	1.0	22.1	0.1	0.8	18.4	8.6
Fish, crust. & moll.	0.0	2.0	-0.9	0.8	28.7	-8.7
Meat	0.0	-0.5	2.3	0.3	27.3	6.4
Dairy	-0.1	0.1	2.2	4.8	125.3	13.7
Flour	0.1	-6.4	12.5	2.3	127.4	21.7
Olive oil	0.0	na	-0.3	0.0	na	0.7
Other oils	0.0	2.5	0.5	1.3	18.6	8.2
Canned	0.0	0.2	1.5	1.5	149.3	0.4
Sugar	-0.5	-2.8	11.9	1.2	27.2	24.9
Beverage	-0.1	-0.9	2.7	3.1	103.3	11.1
Other agri-food	0.0	-5.0	9.0	2.3	95.8	21.7

Table 6: Labor Demand by Type (Last Period)

	Family Workers			Unskilled Workers			Skilled Workers		
	BAU	Sc. 2	Sc. 4	BAU	Sc. 2	Sc. 4	BAU	Sc. 2	Sc. 4
Soft wheat	19	-14.4	-8.8	3	-23.6	-13.8	2	-27.5	-30.0
Hard wheat	65	-3.5	1.0	10	-15.8	-7.9	5	-16.3	-19.6
Barley	16	-0.6	1.1	3	-2.8	3.5	1	-23.0	-28.3
Other cereals	39	-0.4	5.8	6	-3.3	5.1	3	-22.4	-22.7
Leguminous	15	-24.1	-17.1	3	-61.0	-57.0	1	12.0	15.8
Olives	115	2.0	8.0	15	2.2	12.5	9	-22.9	-24.8
Citrus fruits	30	2.6	12.3	6	2.9	18.2	3	-22.5	-22.7
Dates	74	2.2	9.9	14	2.4	15.0	7	-22.8	-23.8
Other fruits	217	-6.4	1.0	41	-71.3	-67.5	19	130.8	127.7
Vegetables	305	1.9	9.9	28	1.1	12.3	16	-22.3	-21.9
Livestock	236	4.2	16.3	33	4.2	15.7	22	-21.2	-15.2
Industrial cultures	6	-40.5	-35.7	1	-49.2	-43.1	0	-47.3	-47.3
Other crops	119	0.0	5.6	19	-2.1	7.7	12	-22.7	-24.9
Fish, crust. & moll.	-	-	-	50	2.1	11.4	3	2.3	24.4
Meat	-	-	-	34	2.7	18.6	12	2.8	19.5
Dairy	-	-	-	77	2.0	-10.3	27	2.0	50.4
Flour	-	-	-	193	6.0	10.5	67	6.1	22.6
Olive oil	-	-	-	16	0.9	12.5	5	0.9	12.3
Other oils	-	-	-	37	3.2	-0.7	13	3.3	6.0
Canned	-	-	-	32	2.5	-2.2	11	2.5	4.7
Sugar	-	-	-	41	8.5	8.2	15	8.3	11.7
Beverage	-	-	-	84	2.5	-2.5	29	2.5	28.5
Other agri-food	-	-	-	173	4.3	7.3	61	4.2	18.2

Note: values for the BAU are in million TD and values in the scenarios are in percentage.

Table 7: Poverty Effects

	Incidence of Poverty P0								
	Initial	Scen.1		Scen.2		Scen.3		Scen.4	
		First per.	Last Per.	First per.	Last Per.	First per.	Last Per.	First per.	Last Per.
Rural households	3.6	2.9	2.8	2.4	2.3	1.8	1.7	1.2	1.1
Urban households	5.9	4.3	4.2	3.9	3.7	2.8	2.6	1.9	1.7
Total	4.6	3.9	3.8	3.4	3.3	2.6	2.4	1.7	1.5

	Poverty Gap P1								
	Initial	Scen.1		Scen.2		Scen.3		Scen.4	
		First per.	Last Per.	First per.	Last Per.	First per.	Last Per.	First per.	Last Per.
Rural households	0.9	0.6	0.6	0.4	0.4	0.3	0.3	0.2	0.2
Urban households	1.6	0.9	0.9	0.7	0.7	0.5	0.4	0.3	0.3
Total	1.3	0.8	0.8	0.6	0.6	0.5	0.4	0.3	0.3

Table 8: Inequality Effects

	Gini					Theil				
	Initial	Scen.1	Scen.2	Scen.3	Scen.4	Initial	Scen.1	Scen.2	Scen.3	Scen.4
Rural households	0.35	0.34	0.34	0.33	0.34	0.22	0.20	0.20	0.19	0.19
Urban households	0.37	0.36	0.36	0.35	0.35	0.25	0.23	0.23	0.22	0.22
Total	0.40	0.38	0.38	0.37	0.38	0.29	0.26	0.26	0.25	0.25

Appendix I: Data Summary

Table 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[b]
Control of corruption	Control among public and private officials. extent of bribery etc.	Index value[a]	Kaufmann et al. (2007)
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)
Labor	Labor 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
Political stability	The unlikelihood of armed conflict. ethnic tensions. terrorist threats etc.	Index value[a]	Kaufmann et al. (2007)
Rain	Average precipitations (1961-1990)	km3/year	WDI
R&D	Public and private agricultural R&D expenditures	Million 2000 international dollars	Pardey et al. (2006). ASTI
Water	Water use by commodity	Mm3	FAO. FEMISE

a: The governance scores lie between -2.5 and 2.5. with higher scores corresponding to better quality of governance.
b: http://faostat.fao.org.

Table A2: Descriptive Statistics

	Mean	St. dev.	Min	Max
Agricultural land	44.7	22	2.7	75.1
Agricultural machinery	5.23	4.7	0.45	21.1
Average holdings	3.06	3.48	0.25	20.22
Control of corruption	0.365	0.729	-0.88	1.69
Fertilizers consumption	1541.7	1131	50.5	4593.9
Fertilizers	4.2	9.75	0.0009	62.12
Government effectiveness	0.434	0.816	-1.28	1.95
Human capital	6.11	1.78	3.01	9.4
Labor	28.1	49.94	0.05	289.7
Land	0.859	1.99	0.0004	13.58
Land fragmentation	71.3	18.3	15	98.2
Land Gini	67.33	9.2	54	86
Land quality	27	22.7	6	100
Machines	31.86	69.54	0.016	434.53
Output	3.95	8.28	0.0016	58.82
Political stability	-0.226	0.908	-2.492	1.28
Rain	157	157.9	7	478
R&D	316.3	723.2	8.7	3100
Water	1615.9	5317.3	0.45	46146

Note: summary statistics are computed over the period. countries. and commodities included in the sample.

Table A3: Latent Class Model Parameter Estimates

	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***
Labor	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**
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.

Table A4: Efficiency Scores and TFP Index Growth

	Fruits		Citrus		Shell		Vegetables		Cereals		Pulses		Pool	
	TE[a]	GTFP[b]	TE	GTFP	TE	GTFP	TE	GTFP	TE	GTFP	TE	GTFP	TE	GTFP
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 (%).

Table A5: Classification of the Accounts in the Micro SAM

SECTORS . FACTORS AND INSTITUTIONS	LABELS
Activities and commodities	
Soft wheat	SWHEAT
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

Appendix II: The General Equilibrium Model Equations

I. Production

$$CI_{j,t} = io_j XS_{j,t}$$

$$VA_{j,t} = v_j XS_{j,t}$$

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

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

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

$$KD_{j,t} rk_{j,t} = \beta_{j}^{k} PVA_{j,t} VA_{j,t}$$

$$LDT_{agr,t} = \left[\gamma_{'uwa',agr} {A_{agr,t}^{L}}^{-\rho_{agr}^{L} - \frac{bias_{agr,t}}{2}} LD_{'uwa',agr,t}^{-\rho_{agr}^{L}} + \gamma_{'swa',agr} {A_{agr,t}^{L}}^{-\rho_{agr}^{L} + \frac{bias_{agr,t}}{2}} LD_{'swa',agr,t}^{-\rho_{agr}^{L}} \right.$$

$$\left. + \gamma_{'faw',agr} {A_{agr,t}^{L}}^{-\rho_{agr}^{L}} LD_{'faw',agr,t}^{-\rho_{agr}^{L}} \right]^{\frac{-1}{\rho_{agr}^{L}}}$$

$$LD_{'swa',agr,t} = \left[\frac{W_{'uwa',t}}{W_{'swa',t}} \frac{\gamma_{'swa'}}{\gamma_{'uwa'}} \left(A_{agr,t}^{L} \right)^{bias_{agr,t}} \right]^{\sigma_{agr}^{L}} LD_{'uwa',agr,t}$$

$$LD_{'faw',agr,t} = \left[\frac{W_{'uwa',t}}{W_{'faw',t}} \frac{\gamma_{'faw'}}{\gamma_{'uwa'}} \left(A_{agr,t}^{L} \right)^{\frac{bias_{agr,t}}{2}} \right]^{\sigma_{agr}^{L}} LD_{'uwa',agr,t}$$

$$LAT_{aga,t} = \left[\gamma_{aga}^{LD} {A_{aga,t}^{D}}^{-\rho_{aga}^{LD} - \frac{bias_{aga,t}^{D}}{2}} LAN_{'adal',aga,t}^{-\rho_{aga}^{LD}} + \left(1 - \gamma_{aga}^{LD}\right) {A_{aga,t}^{D}}^{-\rho_{aga}^{LD} + \frac{bias_{agamt}^{D}}{2}} WLAN_{aga,t}^{-\rho_{aga}^{LD}} \right]^{\frac{-1}{\rho_{aga}^{LD}}}$$

$$WLAN_{aga,t} = \left[\frac{rdaga_{'adal',t}}{rdw_{aga,t}} \frac{1 - \gamma_{aga}^{LD}}{\gamma_{aga}^{LD}} \left(A_{aga,t}^{D} \right)^{bias_{aga,t}^{D}} \right]^{\sigma_{aga}^{LD}} LAN_{'adal',aga,t}$$

$$WLAN_{aga,t} = A_{aga,t}^{DW} \left[\gamma_{aga}^{DW} LAN_{'aial',aga,t}^{-\rho_{aga}^{DW}} + \left(1 - \gamma_{aga}^{DW}\right) DI_{'watera',aga,t}^{-\rho_{aga}^{DW}} \right]^{\frac{-1}{\rho_{aga}^{LW}}}$$

$$LAN_{'aial',aga,t} = \left[\frac{PC_{'wateral',t}}{rdaga_{'aial',t}} \frac{\gamma_{aga}^{DW}}{1 - \gamma_{aga}^{DW}} \right]^{\sigma_{aga}^{DW}} DI_{'watera',aga,t}$$

$$LAT_{agp,t} = \left[\gamma_{agp}^{LD} {A_{agp,t}^{D}}^{-\rho_{agp}^{LD} - \frac{bias_{agp,t}^{D}}{2}} LAN_{'pdal',agp,t}^{-\rho_{agp}^{LD}} + \left(1 - \gamma_{agp}^{LD}\right) {A_{agp,t}^{D}}^{-\rho_{agp}^{LD} + \frac{bias_{agp,t}^{D}}{2}} WLAN_{agp,t}^{-\rho_{agp}^{LD}} \right]^{\frac{-1}{\rho_{agp}^{LD}}}$$

$$WLAN_{agp,t} = \left[\frac{rdagp_{'pdal',agp,t}}{rdw_{agp,t}} \frac{1 - \gamma_{agp}^{LD}}{\gamma_{agp}^{LD}} \left(A_{agp,t}^{D} \right)^{bias_{agp,t}^{D}} \right]^{\sigma_{agp}^{LD}} LAN_{'pdal',agp,t}$$

$$WLAN_{agp,t} = A_{agp,t}^{DW} \left[\gamma_{agp}^{DW} LAN_{'pial',agp,t}^{-\rho_{agp}^{DW}} + \left(1 - \gamma_{agp}^{DW}\right) DI_{'watera',agp,t}^{-\rho_{agp}^{DW}} \right]^{\frac{-1}{\rho_{agp}^{LW}}}$$

$$LAN_{'pial',agp,t} = \left[\frac{PC_{'wateral',t}}{rdagp_{'pial',agp,t}} \frac{\gamma_{agp}^{DW}}{1-\gamma_{agp}^{DW}} \right]^{\sigma_{agp}^{DW}} DI_{'watera',agp,t}$$

$$VA_{nag,t} = A_{nag}^{VA} LDT_{nag,t}{}^{\beta_{nag}^{L}} KD_{nag,t}{}^{\beta_{nag}^{K}}$$

$$LDT_{nag,t} WT_{nag,t} = \beta_{nag}^{L} PVA_{nag,t} VA_{nag,t}$$

$$LDT_{nag,t} = \left[\gamma_{'uwna',nag} A_{nag,t}^{L}{}^{-\rho_{nag}^{L} - \frac{bias_{nag,t}}{2}} LD_{'uwna',nag,t}{}^{-\rho_{nag}^{L}} + \gamma_{'swna',nag} A_{nag,t}^{L}{}^{-\rho_{nag}^{L} + \frac{bias_{nag,t}}{2}} LD_{'swna',nag,t}{}^{-\rho_{nag}^{L}} \right]^{\frac{-1}{\rho_{agr}^{L}}}$$

$$LD_{'swna',nag,t} = \left[\frac{W_{'uwna',t}}{W_{'swna',t}} \frac{\gamma_{'swna'}}{\gamma_{'uwna'}} \left(A_{nag,t}^{L} \right)^{bias_{nag,t}} \right]^{\sigma_{nag}^{L}} LD_{'uwna',nag,t}$$

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

II. Productivity

$$A_{agr,t} = A_{agr}^{VA} \left(A_{agr,t}^{L} \right)^{\beta_{agr}^{L}} \left(A_{agr,t}^{D} \right)^{\beta_{agr}^{D}}$$

$$A_{nag,t} = A_{nag}^{VA} \left(A_{nag,t}^{L} \right)^{\beta_{nagr}^{L}}$$

$$\frac{A_{j,t} - A_{j}^{0}}{A_{j}^{0}} = \left[\alpha^{H} \frac{G_t}{GDP_t} \right]^{\alpha^{H1}} + b_j \left[\alpha^{H} \frac{G_t}{GDP_t} \right]^{\alpha^{H1}} \left[\frac{TRADE_{j,t}}{P_j^0 XS_{j,t}} \right]^{\alpha^{OP}} \left[1 - \frac{A_{j,t}}{A^F} \right]$$

$$\frac{A_{agr,t}^{D} - A_{agr}^{D0}}{A_{agr}^{D0}} = b_{agr}^{D} \left[\alpha^{H} \frac{G_t}{GDP_t} \right]^{\alpha^{DH2}} \left[\frac{TRADE_{agr,t}}{P_{agr}^{0} XS_{agr,t}} \right]^{\alpha^{DOP}} \left[1 - \frac{A_{agr,t}}{A^F} \right]$$

$$BIAS_{j,t} = \alpha_j^B \left(\left[\frac{TRADE_{j,t} / XS_{j,t}}{TRADE_j^0 / XS_j^0} \right]^2 - 1 \right)$$

$$BIAS_{agr,t}^{D} = \alpha_{agr}^{BD} \left(\left[\frac{TRADE_{agr,t} / XS_{agr,t}}{TRADE_{agr}^{0} / XS_{agr}^{0}} \right]^2 - 1 \right)$$

III. Income and Savings

$$YH_{h,t} = \sum_{l} \lambda_{h,l}^{L} \left(W_{l,t} \sum_{j} LD_{l,j,t} \right) + \sum_{land} \lambda_{h,land}^{D} \left[\left(rdaga_{land,t} \sum_{aga} LAN_{land,aga,t} \right) + \left(\sum_{agp} rdagp_{land,agp,t} LAN_{land,agp,t} \right) \right]$$
$$+ \lambda_h^K \left(\sum_j rk_{j,t} KD_{j,t} \right) + DIV_{h,t} + PIXCON_t TRG_{h,t}^{H} + \sum_r e_t TRR_{h,r,t}^{H}$$

$$YDH_{h,t} = YH_{h,t} - DTH_{h,t} - TRH_{h,t}^{G}$$

$$SH_{h,t} = pms_h YDH_{h,t}$$

$$CTH_{h,t} = YDH_{h,t} - SH_{h,t} - TRH_{h,t}^{F} - \sum_{r} TRH_{r,h,t}^{R}$$

$$YF_{t} = \left(1 - \sum_{h} \lambda_{h}^{K}\right)\left(\sum_{j} rk_{j,t} KD_{j,t}\right) + \sum_{h} TRH_{h,t}^{F} + PIXCON_{t} TRG_{t}^{F} + \sum_{r} e_{t} TRR_{r,t}^{F}$$

$$DIV_{h,t} = \gamma_{h}^{DIV}\left(1 - \sum_{h} \lambda_{h}^{K}\right)\left(\sum_{j} rk_{j,t} KD_{j,t}\right)$$

$$TRF_{r,t}^{R} = \gamma_{r}^{DIVR}\left(1 - \sum_{h} \lambda_{h}^{K}\right)\left(\sum_{j} rk_{j,t} KD_{j,t}\right)$$

$$SF_{t} = YF_{t} - \sum_{h} DIV_{h,t} - \sum_{r} TRF_{r,t}^{R} - DTF_{t} - TRF_{t}^{G}$$

$$YG_{t} = \sum_{h}\left(DTH_{h,t} + TRH_{h,t}^{G}\right) + DTF_{t} + TRF_{t}^{G} + \sum_{r} e_{t} TRR_{r,t}^{G} + TI_{t} + \sum_{r} TIM_{r,t}$$

$$DTH_{h,t} = td_{h}^{H} YH_{h,t}$$

$$TRH_{h}^{G} = tr_{h}^{H} YH_{h}$$

$$DTF_{t} = td^{F} YF_{t}$$

$$TRF_{t}^{G} = tr^{F} YF_{t}$$

$$TI_{t} = \sum_{j}\left[tx_{j,t} PL_{j,t} D_{j,t} + tx_{j} \sum_{r} PWM_{j,r,t} e_{t}\ (1 + tm_{j,r}) IM_{j,r,t}\right]$$

$$TIM_{t} = \sum_{j}\left[tm_{j,r} PWM_{j,r,t} e_{t}\ IM_{j,r,t}\right]$$

$$SG_{t} = YG_{t} - G_{t} - PIXCON_{t} \sum_{h} TRG_{h,t}^{H} - PIXCON_{t} TRG_{t}^{F} - PIXCON_{t} \sum_{r} TRG_{r,t}^{R}$$

IV. Demand

$$C_{j,h,t} PC_{j,t} = C_{j,h,t}^{\min} PC_{j,t} + \alpha_{j,h}^{C}\left(CTH_{h,t} - \sum_{i} C_{i,h,t}^{\min} PC_{i,t}\right)$$

$$G_{t} = PC_{'serv',t} CG_{'serv',t}$$

$$DIT_{j,t} = \sum_{i} DI_{j,i,t}$$

$$PC_{j,t} INV_{j,t} = \gamma_{j,t}^{INV} IT_{t}$$

V. International Trade

$$XS_{j,t} = B_{j}^{X}\left[\gamma_{j}^{X} EXT_{j,t}^{\rho_{j}^{X}} + \left(1 - \gamma_{j}^{X}\right) D_{j,t}^{\rho_{j}^{X}}\right]^{\frac{1}{\rho_{j}^{X}}}$$

$$EXT_{j,t} = \left[\frac{1-\gamma_j^X}{\gamma_j^X} \frac{PET_{j,t}}{PL_{j,t}} \right]^{\sigma_j^X} D_{j,t}$$

$$EXT_{j,t} = B_j^{XR} \left[\gamma_j^{XR} EX_{j,'EU',t}^{\rho_j^{XR}} + \left(1-\gamma_j^{XR}\right) EX_{j,'ROW',t}^{\rho_j^{Xr}} \right]^{\frac{1}{\rho_j^{XR}}}$$

$$EX_{j,'EU',t} = \left[\frac{1-\gamma_j^{XR}}{\gamma_j^{XR}} \frac{PE_{j,'EU',t}}{PE_{j,'ROW',t}} \right]^{\sigma_j^X} EX_{j,'ROW',t}$$

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

$$Q_{j,t} = B_j^Q \left[\gamma_j^Q IMT_{j,t}^{-\rho_j^Q} + \left(1-\gamma_j^Q\right) D_{j,t}^{-\rho_j^Q} \right]^{\frac{-1}{\rho_j^Q}}$$

$$IMT_{j,t} = \left[\frac{\gamma_j^Q}{1-\gamma_j^Q} \frac{PD_{j,t}}{PMT_{j,t}} \right]^{\sigma_j^Q} D_{j,t}$$

$$IMT_{j,t} = B_j^{MR} \left[\gamma_j^{MR} IM_{j,'EU',t}^{-\rho_j^{MR}} + \left(1-\gamma_j^{MR}\right) IM_{j,'RDM',t}^{-\rho_j^{MR}} \right]^{\frac{-1}{\rho_j^{MR}}}$$

$$IM_{j,'EU',t} = \left[\frac{\gamma_j^{MR}}{1-\gamma_j^{MR}} \frac{PM_{j,'RDM',t}}{PM_{j,'EU',t}} \right]^{\sigma_j^{MR}} IM_{j,'RDM',t}$$

$$TRADE_{j,t} = EXT_{j,t} PET_j^0 + IMT_{j,t} PMT_j^0$$

$$CAB_t = \sum_r \left\{ e_t \sum_j PWM_{j,r,t} IM_{j,r,t} + \sum_h TRH_{r,h,t}^R + TRF_{r,t}^R + PIXCON_t TRG_{rt}^R \right.$$
$$\left. - e_t \sum_j PE_{j,r,t}^{FOB} EX_{j,r,t} - e_t \sum_h TRR_{h,r,t}^H - e_t\ TRR_{h,r,t}^F - e_t\ TRR_{r,t}^G \right\}$$

VI. Prices

$$PC_{j,t} Q_{j,t} = PMT_{j,t} IMT_{j,t} + PD_{j,t} D_{j,t}$$

$$PMT_{j,t} IMT_{j,t} = \sum_r PM_{j,r,t} IM_{j,r,t}$$

$$PM_{j,r,t} = e_t\ PWM_{j,r,t} (1+tm_{j,r})\,(1+tx_j)$$

$$PD_{j,t} = PL_{j,t}\ (1+tx_j)$$

$$P_{j,t} XS_{j,t} = PET_{j,t} EXT_{j,t} + PL_{j,t} D_{j,t}$$

$$PET_{j,t} EXT_{j,t} = \sum_r PE_{j,r,t} EX_{j,r,t}$$

$$PE_{j,r,t} = e_t\ PE_{j,r,t}^{FOB}$$

$$P_{j,t}XS_{j,t} = PVA_{j,t}VA_{j,t} + \sum_i PC_{i,t}DI_{i,j,t}$$

$$WT_{j,t}LDT_{j,t} = \sum_l W_{j,t}LD_{l,j,t}$$

$$rdt_{aga,t}LAT_{aga,t} = rdw_{aga,t}WLAN_{aga,t} + rdaga_{'adal',t}LAN_{'adal',aga,t}$$

$$rdw_{aga,t}WLAN_{aga,t} = rdaga_{'aial',t}LAN_{'aial',aga,t} + PC_{'watera',t}DI_{'watera',aga,t}$$

$$rdt_{agp,t}LAT_{agp,t} = rdw_{agp,t}WLAN_{agp,t} + rdagp_{'pdal',agp,t}LAN_{'pdal',aga,t}$$

$$rdw_{agp,t}WLAN_{agp,t} = rdagp_{'pial',agp,t}LAN_{'pial',agp,t} + PC_{'watera',t}DI_{'watera',agp,t}$$

$$PIXCON_t = \frac{\sum_i PC_{i,t} \sum_h C^O_{i,h}}{\sum_i PC^O_i \sum_h C^O_{i,h}}$$

VII. Labor Market

$$U_{l,t}LS_{l,t} = LS_{l,t} - \sum_j LD_{l,j,t}$$

$$\frac{W_{l,t}}{PIXCON_t} \geq \frac{W_l^{MIN}}{PIXCON^O}$$

$$\left(\frac{W_{l,t}}{PIXCON_t} - \frac{W_l^{MIN}}{PIXCON^O}\right)U_{l,t} = 0$$

VIII. Equilibrium

$$Q_{j,t} = \sum_h C_{j,h,t} + CG_{j,t} + INV_{j,t} + DIT_{j,t}$$

$$IT_t = \sum_h SH_{h,t} + SG_t + SF_t + CAB_t$$

$$EXD_{j,r,t} = EX_{j,r,t}$$

$$LAN^S_{land,t} = \sum_{agr} LAN_{land,agr,t}$$

$$GDP_t = \sum_j \left[\sum_h PC_{j,t}C_{j,h,t} + PC_{j,t}CG_{j,t} + PC_{j,t}INV_{j,t} + \sum_r e_t\ PE^{FOB}_{j,r,t}EX_{j,r,t} - \sum_r e_t\ PWM_{j,r,t}IM_{j,r,t}\right]$$

IX. Dynamics

$$KD_{j,t+1} = KD_{j,t}\left(1-\delta_j\right) + IND_{j,t}$$

$$\frac{IND_{j,t}}{KD_{j,t}} = \phi_j\left[\frac{RK_{j,t}}{UC_{j,t}}\right]^{\sigma_t^{INV}}$$

$$IT_t = \sum_j PK_t IND_{j,t}$$

$$PK_t = \frac{1}{A^K}\prod_i \left[\frac{PC_{i,t}}{\gamma_i^{INV}}\right]^{\gamma_i^{INV}}$$

$$UC_{j,t} = PK_t\left(\delta_j + ir_t\right)$$

$$LS_{l,t+1} = LS_{l,t}\left(1+n_t\right)$$

$$TRG_{h,t+1}^H = TRG_{h,t}^H\left(1+n_t\right)$$

$$TRG_{t+1}^F = TRG_t^F\left(1+n_t\right)$$

$$TRG_{r,t+1}^R = TRG_{r,t}^R\left(1+n_t\right)$$

$$TRR_{h,r,t+1}^H = TRR_{h,,rt}^H\left(1+n_t\right)$$

$$TRR_{r,t+1}^F = TRR_{r,t}^F\left(1+n_t\right)$$

$$TRR_{r,t+1}^G = TRR_{r,t}^G\left(1+n_t\right)$$

$$TRH_{h,t+1}^F = TRH_{h,t}^F\left(1+n_t\right)$$

$$TRH_{h,r,t+1}^R = TRH_{h,r,t}^R\left(1+n_t\right)$$

$$C_{h,t+1}^{\min} = C_{h,t}^{\min}\left(1+n_t\right)$$

$$CG_{j,t+1} = CG_{j,t}\left(1+n_t\right)$$

$$CAB_{t+1} = CAB_t\left(1+n_t\right)$$

I. Sectors

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:

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

Land Types:

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

Trading Partner:

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

Households:

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

II. Variables

$A_{j,t}$	: Total augmenting technical progress
$A^{L}_{j,t}$	: Labor augmenting technical progress
$A^{D}_{agr,t}$	: Land augmenting technical progress
$bias_{j,t}$	: Labor technological bias
$bias^{D}_{agr,t}$	: Land technological bias
$C_{j,h,t}$	: Households h consumption of commodity j
$C^{\min}_{j,h,t}$	: Households h minimum consumption of commodity j
CAB_{t}	: Current account balance
$CG_{j,t}$	: Public final consumption of commodity j
$CI_{j,t}$	: Aggregate intermediate consumption of sector *j*
$CTH_{h,t}$	: Household h consumption budget
$D_{j,t}$	: Commodity j produced locally
$DI_{i,j,t}$	: Intermediate consumption of commodity i by sector *j*
$DIT_{j,t}$	: Total intermediate demand for commodity j
$DIV_{h,t}$	: Dividend paid to household h

DTF_t : Firms direct taxes

$DTH_{h,t}$: Household h direct taxes

e_t : Exchange rate

$EX_{j,r,t}$: Export of commodity j to region r

$EXD_{j,r,t}$: Export demand of commodity j to region r

$EXT_{j,t}$: Total export of commodity j

G_t : Public expenditure

GDP_t : Gross domestic product

$IM_{j,r,t}$: Imports of commodity j from region r

$IMT_{j,t}$: Total import of commodity j

$IND_{j,t}$: Investment in sector j

$INV_{j,t}$: Investment in commodity j

ir_t : Interest rate

IT_t : Total investment

$KD_{j,t}$: Capital demand

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

$LAN^S_{l,t}$: Land supply

$LAT_{agr,t}$: Demand for aggregate land bundle

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

LDT_{jt} : Demand for aggregate labor bundle

$LS_{l,t}$: Labor supply

$P_{j,t}$: Producer price of commodity j

$PC_{i,t}$: Composite price of commodity i

$PD_{j,t}$: Consumer price of commodity j produced locally

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

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

$PET_{j,t}$: Aggregated price of exports of commodity j

$PIXCON_t$: Consumer price index

PK_t : Price of new capital

$PL_{j,t}$: Producer price of commodity j produced locally

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

$PMT_{j,t}$: Price of composite import of commodity j

$PVA_{j,t}$: Value added price

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

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

$Q_{j,t}$: Composite commodity j

$rdt_{agr,t}$: Composite price for land in sector agr

$rdaga_{land,t}$: Land price

$rdagp_{land,agp,t}$: Land price

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

$rk_{j,t}$: Capital price

SF_t : Firms savings

SG_t : Government savings

$SH_{h,t}$: Household h savings

TI_t : Total indirect taxes

$TIM_{r,t}$: Total tariff duties

$TRADE_{j,t}$: Trade of sector j

TRF_t^G : Transfers from firms to government

$TRF_{r,t}^R$: Transfers from firms to region r

TRG_t^F : Public transfers to firms

$TRG_{h,t}^H$: Public transfers to household h

$TRG_{r,t}^R$: Transfers from government to region r

$TRH_{h,t}^F$: Transfers from household h to firms

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

$TRR^F_{r,t}$: Transfers from region r to firms

$TRR^G_{r,t}$: Transfers from region r to government

$TRR^H_{h,r,t}$: Transfers from region r to household h

$U_{l,t}$: Unemployment rate

$UC_{j,t}$: User cost of capital

$VA_{j,t}$: Value added of sector *j*

$W_{l,t}$: Wages

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

W_l^{MIN} : Minimum wage

$WT_{j,t}$: Wages

$XS_{j,t}$: Aggregate output of sector *j*

$YDH_{h,t}$: Household h disposable income

YF_t : Firms income

YG_t : Government income

$YH_{h,t}$: Household h income

III. Parameters

A^F : Frontier TFP

A^K : Scale parameter

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^{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

δ_j : Depreciation rate

$\gamma_{l,j}$: 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

n_t : Population growth rate

pms_h : Average propensity to save for household h

φ_j : Scale parameter (investment function)

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^{INV} : Elasticity (investment function)

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

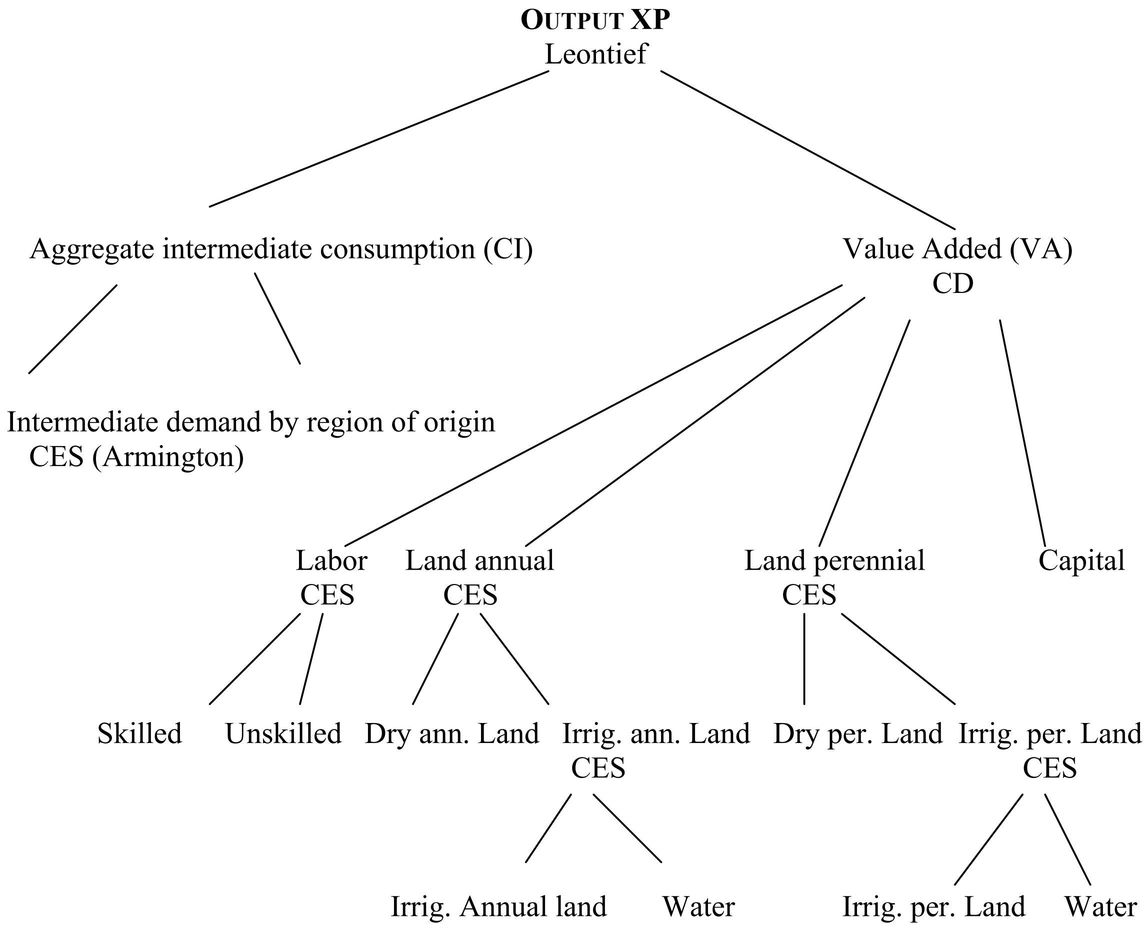
tr^{F} : Rate of transfers from firms to government

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 Demand