An Assessment of the Distributional Impact of Agricultural Trade Policies in the Triad

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This paper estimates the distributional impact of agricultural trade policies in the Triad using the new concept of effective protection developed by Anderson (1998). The level of protection received by an industry is measured by the uniform tariff, which is equivalent in terms of sector specific rents to the actual differentiated tariff structure.

In order to evaluate the cost of agricultural trade policies we construct an original computable general equilibrium framework, which incorporates three sources of price distortions: *ad-valorem* tariffs (which include ad-valorem equivalents of specific tariffs and tariff quotas), export and production subsidies or taxes. Our estimations allow us to evaluate international differences in levels of trade liberalization in agricultural sectors and to bring out some properties of the effective protection rates developed by Anderson.

On the first point, we show that the cost of agricultural trade policies in the Triad is far from being trivial. This cost, measured in terms of the sacrifice bear by the community to protect sectoral rents is particularly high in Japan and in the European Union in the cereal sector. On the second point, we stress the discrepancy between the new concept of effective protection and the usual one defined as the percentage change in value added per unit induced by the tariff structure.

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1. Introduction

The Uruguay Round Agreement on Agriculture (URRA) was a big step forward to bring agricultural trade into the overall framework of rules and disciplines of the GATT. However, agriculture still has a specific status in trade relations as it is characterized by numerous exceptions and as trade negotiations in this field are particularly difficult to implement. Indeed, the WTO member governments failed to meet the 31 March 2003 deadline for agreeing agriculture negotiating modalities. This failure reflects the skepticism of some governments and their farm constituents about the benefits expected from further agricultural trade liberalization. Trade negotiations could be facilitated if all WTO members were aware of the height of protection received by agricultural sectors and especially of the distortion created by trade and domestic support policies in the agricultural field. The measure of the level and the cost of agricultural trade policies poses a problem since numerous tools (tariffs, tariff rate quotas but also domestic support measures, sanitary and phyto-sanitanary norms…), are used to protect agricultural producers. Difficulties arise thus to evaluate an average level of sectoral protection as it implies to find an optimal measure of the intensity of each barrier to trade and an adequate procedure of aggregation. Even when concentrating on tariff barriers, the assessment of the level of protection received by an industry is a complicated task since the protection of a sector not only depends on its nominal rate of protection but also of the level of protection of the goods incorporated in the production process.

The search for an adequate indicator of the level of protection received by an industry leads thus to put forward effective protection rates (ERPs) developed by Corden (1966). Indeed, whereas the nominal rate only measures the extent of domestic price increase consecutive to the tariff set up, the effective rate measures the extent of the value added increase by taking into account tariffs on imported intermediate goods and the share of the value added of the industry in the value of final good.

As stressed by Kim Anderson (2002), four stylized facts emerge from numerous empirical studies using ERPs:

i. The level of ERPs largely exceeds the level of nominal rates;
ii. The ERP of numerous industries is negative whereas the nominal rate of these industries is high;
iii. The international differences between nominal and effective rates are not constant;
iv. The ranking of industries according to their nominal or effective rate is all the more likely to differ that the degree of disaggregation is weak.

These stylized facts suggest that the ERPs are most adequate measures than nominal rates to compare the levels of trade protection among countries and sectors. However, since Corden's work, the theoretical foundations of this measure have been seriously questioned. Indeed, this concept is a pertinent one if it makes it possible to measure resource allocation effects. However, Ethier (1977) showed that it was in general impossible to link the sectoral effective rates of protection to the changes in sectoral output. The attraction of effective protection concept tends thus to vanish.

In order to rehabilitate effective protection, Anderson (1998) proposes to redefine the concept from distributional concerns. More precisely, the ERPs do not allow anymore to assess the impact of trade protection on the level of sectoral output but to assess the effect of protection on sectoral rents. The effective rate of protection of a sector is hence defined as the uniform tariff (applied to all distorted goods), which is equivalent to the existing tariff structure in terms of sectoral specific factor return. The effective protection received by an industry reflects thus the sacrifices of general welfare to preserve the rents of the producers of this industry. As noted by Anderson (1998), this definition is particularly useful to measure the height of sectoral protection in testing political economy models.

The advantages of this “new” definition of effective protection go even far beyond. Indeed, this approach has the advantage of basing the measure of effective protection on theoretical foundations[1]. At the same time, it makes it possible to aggregate different instruments of trade policy in a coherent manner: output subsidies, production taxation, quotas… But, above all, this measure is really a matter of evaluating the degree of distortion due to protectionism whereas standard ERPs seek only to assess the level of trade protection.

In this paper, we adopt the approach developed by Anderson (1998) to assess the distributional impact of agricultural trade policies in the Triad. For this purpose, we construct an original computable general equilibrium (CGE) model that views the trade relations of a country with the rest of the world. Three sources of price distortions are taken into account: *ad-valorem* tariffs (which include *ad-valorem* equivalents of specific tariffs and tariff quotas), export and production subsidies or taxes. Data are taken from GTAP5 database and we distinguish 13 agricultural sectors out of 22 total sectors. We develop four variations of the model. Concerning the nature of competition: either the economy is placed within a competitive framework, or some sectors are characterized by monopolistic competition. Regarding the market power, either all countries are supposed to be small ones, or they are able to influence world prices in some sectors.

Our results show that the cost of agricultural trade policies (especially in cereal sector) remains high in Japan and in the European Union. We show however that the sacrifice bear by the community to guarantee the payment received by specific factor owners in an industry is not always correlated to the nominal rate of protection or to Corden’s definition of effective protection. Most important, the sign of protection according to the two definitions of effective protection is reversed for two American and European sectors and for three Japanese sectors.

The following section gives the basic general equilibrium model and the assumptions relative to the nature of competition and to the world market power. Section 3 presents the methodology adopted to estimate the effective rates of protection and the empirical results r the countries of the Triad. Section 4 concludes.

2. The Basic General Equilibrium Trade Model

2.1. Overview of the Model

The model we developed[2] considers the trade relations of a country with the rest of the world (it is defined as a single trade country model). Whether it does not allow for preferential trade regimes, it incorporates however the main sources of price distortions: ad-valorem tariffs (which include ad-valorem equivalents of specific, mixed and composed tariffs and of tariff quotas), export and production subsidies.

We do not attempt to assess the impact of costly rent-seeking activities associated with lobbying for getting or preserving barriers to trade. So, the government’s role is confined to collection and distribution of trade-related revenues. Thus, instead of modeling it explicitly, we rather assume a representative agent who earns domestic income and whose consumption is both private and public.

We develop four variations of the model. The first source of variation relates to the nature of competition. Either we assume that all sectors are perfectly competitive with an Armington assumption, or some sectors are characterized by monopolistic competition with an Armington-Dixit-Stiglitz assumption. The second source of variation relates to the existence of market power. Either all countries are supposed to be small ones, or they are able to influence world prices (export and/or import world prices) in some sectors. The sectors where countries have a monopoly

[1] The effective protection index for a sector is obtained from the distance function applied in the space of distorted prices which can be defined as the uniform price deflator which maintains profits in the sector studied.

[2] This model has been previously used to estimate trade restrictivenes indexes developed by Anderson and Neary (1996, 1999) in a sample of countries (see Bouët *et al*., 2001).

(respectively monopsony) power are the ones with a ratio domestic imports/world imports (respectively domestic exports/ world exports) grater than 20%. The large country assumption is thus considered for European Union and for the United States.

The model distinguishes 13 agricultural sectors out of 22 total sectors and is initialized on GTAP5 data.

We start by briefly describe the structure of the model under the perfect competition assumption and without market power and then focus on the assumptions of monopolistic competition and of market power. The complete set of equations and the definitions of endogenous variables, exogenous variables and of parameters are given in appendix.

2.2. The Competitive Model

2.2.1. The Demand Side

Assuming a representative agent who earns domestic income, his global consumption could be distributed among private and public consumption; however, in concern of simplicity, we do not operate this distinction.

Domestic income corresponds to total value added evaluated at net prices plus aggregate taxes minus aggregate subsidies. Savings are a fixed share of domestic income. Below this first-tier Cobb-Douglas function, the consumer's decision problem can be decomposed into "three-stage budgeting"[3].

In the first stage (or top level), the consumer maximizes a CES function of a composite agricultural good and of all final non-agricultural commodities (both imported and domestic) given income and composite prices. This specification allows for more substituability between two agricultural goods or two industrial goods than between the set of all agricultural goods and an industrial good.

In the second stage, the consumer maximizes a CES subutility function of all composite agricultural commodities subject to the expenditure allocated to total agricultural consumption from the first stage maximization.

In the last stage, the consumer maximizes each of the subutility functions subject to the expenditure allocated to consumption of the *i*th agricultural (non-agricultural) commodity from the second-stage (first-stage) maximization. This Armington assumption gives rise to both import and export flows in each sector. We assume that, because of their perishable nature, domestic and imported agricultural goods are less substitutable than industrial goods.

Total demand is made up of final consumption, intermediate consumption and capital goods. An Armington assumption is already set for intermediate and capital goods.

2.2.2. The Supply Side

Production makes use of capital and labor (perfectly mobile across sectors) and, for some agricultural sectors, of a specific factor (land and/or natural resources). Factor endowments are assumed to be fully employed.

Sectoral production is characterized by two-level nesting[4]. At the first level is a Leontieff input-output production function of which arguments are value added and total intermediate consumption. At the second level, each of the Leontieff function arguments is defined.

For sectors, which only use generic factors, value added is a CES function of capital and labor. For sectors using a specific factor, value added is a CES function of this specific factor and of a generic factor of production (which is a composite of labor and capital). This specification allows for different degrees of substitution between the three factors of production. We thus assume that the

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[3] The nesting for consumer demand is presented in appendix (the last stage of this nesting does not apply to the competitive model).

[4] This nesting is presented in appendix. Here again, the last stage does not apply to the competitive model.

elasticity of substitution between labor and capital is higher in industrial and service sectors than in agricultural industries.

Composite intermediate inputs are a fixed share of total intermediate consumption. Each sector uses intermediate inputs, which come from domestic and foreign sources. Intermediate inputs demand in a given sector are a composite of domestic and imported intermediate goods and is given by a CES function.

A CET function of the output reflects, in each sector, the substitution possibilities in sales between the domestic and the export markets. As the elasticity of transformation increases, goods for sales on the domestic and export markets become homogenous. On the domestic market, firms fix the price at the marginal cost whereas, on the export market, they sale at the world price increased eventually by an export subsidy.

2.2.3. Investment and Market Clearing

Sectoral investment is a fixed share of aggregate investment. To carry out this investment, firms can buy domestic or imported capital goods according to a CES function.

Equilibrium prevails on the market of goods and on the market of factors of production. The model includes an accounting balance constraint, which states that domestic income is allocated among consumption, investment and trade imbalance.

2.3. Introduction of Monopolistic Competition

A variant of the model is constructed by considering imperfectly competitive sectors: processed agricultural sectors and industrial ones except textiles, wearing apparel and wood and paper industries.

In each imperfectly competitive sector i, N_i firms offer their own and unique variety of the same good and horizontal differentiation of products exhibit a love for variety. We thus add a stage in the nesting of consumer demand (*cf* appendix). Following the Armington nesting between domestic and imported goods, consumption of domestic goods in these sectors is a CES function of domestic varieties.

The total cost function of imperfectly competitive firms breaks down into a fixed cost and a variable cost. Fixed costs are expressed as a fixed quantity of output whereas variable costs incorporate primary factors (labor and capital) and intermediate inputs and are proportional to the firms' output. The marginal cost is assumed to be constant and the average cost equals the sum of marginal cost and unitary fixed cost.

Following de Melo and Tarr (1992), imperfectly competitive firms are assumed to exert their market power only on the domestic market. On the foreign market, on which they naturally have less market power, they are price-takers whereas, on the domestic market, they apply to the price of a variety a mark-up that depends on the price elasticity of demand as perceived by the firms.

Under the assumption of a negligible Ford effect[5] and of the chamberlinian hypothesis of "big groups", cross price elasticity of demand addressed to a firm is nil. Thus, the mark-up is function of the elasticity of substitution between varieties which corresponds to the opposite of the price elasticity of demand addressed to a variety (there is always a high number of varieties in each sector) and thus to the opposite of price elasticity of demand as perceived by a firm. In the short-run, the number of firms is held constant and profits can vary but in the long run, free entry and exit is assumed so that the number of firms fits in order to get the zero profit condition.

[5] Firms rule out the possibility that their production decision may affect the global level of demand through a revenue effect.

2.4. Introduction of World Market Power

A variant of the model is constructed by introducing a large country assumption. When domestic imports (respectively domestic exports) account at less for 20% of world imports (respectively world exports), the import or export world price is influenced by domestic imports or exports.

2.5.Data and Calibration

The model is based on GTAP5 for production, employment trade and protection data. Elasticities of substitution are set after a survey of literature and are subject to sensitivity analysis. The value of elasticities and the results of the sensitivity analysis are presented in appendix. For the elasticity of substitution between mobile factors of production as for Armington elasticities, agricultural sectors are differentiated from non-agricultural sectors. We adopt the same values for all three countries of the Triad.

For imperfectly competitive sectors, we set the elasticity of substitution between varieties and the number of firms in order to calibrate the mark-up. We thus assume that there are initially a high number of firms by sector (50) in order to calibrate output per firm; the elasticity of substitution between domestic varieties then equals the opposite of the price elasticity of demand. The fixed cost is calibrated by assuming that initially the long-run equilibrium with zero-profits prevails.

3. Estimation of Agricultural Effective Protection in the Triad

Our assessment of agricultural trade protection in the Triad is based on the calculation of effective protection rates (ERPs) according to Corden's definition and Anderson's one.

3.1. Methodology

Estimates of effective protection following the methodology developed by Anderson (1998) first imply to determine the income obtained by each specific factor owners in the initial general equilibrium given the original system of trade policies. All these protectionist tools are then removed in order to estimate the uniform tariff –applied to the prices of all goods subject to any distortion – that gives the same real income that the one that prevails in the initial general equilibrium.

The basic general equilibrium is thus modified on three points.

i. Each sector specific factor return becomes successively an exogenous variable.
ii. The same custom duty (which can be negative) applies to all goods; it corresponds to the ERP of the sector for which the real income of specific factor owners is fixed.
iii. Initial barriers to trade (tariffs, export and output subsidies) are removed.

3.2. The Initial Protectionist Structure

Data relative to the commercial policy of the countries of the Triad are given by GTAP5 database[6] and adapted to the sectoral aggregation adopted in the CGE model[7]. Three types of barriers to trade are integrated: tariffs, export subsidies and output subsidies.

3.2.1. Average Import Tariffs

GTAP5 database gives sectoral average tariffs weighed by imports and that incorporate *ad-valorem* equivalents of specific, mixed or composed tariffs and of tariff quotas. These average tariffs are computed from applied rates in 1997 for manufactured goods and from bounded rates for

[6] See Dimaranan and McDougall (2002) for a detailed presentation of protection data in GTAP5.
[7] The correspondence between the two classifications is presented in appendix.

agricultural products. Trade of major free trade areas and preferential agreements are not taken into account.

These data show that Japan essentially protect cereals, processed sugar and dairy products whereas European trade protection is concentrated in unrefined sugar and in rice (both paddy and processed rice) and American trade protection is the highest for refined sugar and dairy products. One can also notice that food products are the most highly protected among manufacturing sectors.

3.2.2. Export Subsidies

GTAP5 data are based on information from country submissions to the WTO on export subsidy expenditures in 1998 and incorporate tax equivalents for Agreement on Textile and Clothing (ATV) quotas.

The European Union stands out by the dominating share it occupies in exports subsidies noticed by all WTO members. Whereas agricultural exports are weakly taxed in Japan, the United States only subsidy dairy products and the level of European exports subsidies is particularly high for meat products, dairy products and refined sugar.

3.2.3. Output Subsidies

Domestic support in agriculture is calculated from the Producer Support Estimates (PSE) of the OCDE. Excluding market price support, all the PSE components are sorted out into four domestic support categories: output subsidies, intermediate input subsidies, land-based payments and capital-based payments.

Output subsidies only account for a small share of total payments in the PSE data. They stay rather significant for the wheat in the United States and raw milk in Japan.

3.3. Agricultural Effective Protection in the Triad: an Analysis in terms of Specific Factors Returns

The study of ERPs according to Anderson's definition is carried out by putting the premium on three elements: the influence of the theoretical framework adopted, the differences between sectors and countries and the comparison with the traditional ERPs.

3.3.1. Levels of ERP and Theoretical Framework

For all three countries studied, one may notice that the introduction of imperfect introduction and/or the introduction of the large country assumption almost hardly alter the levels of ERPs.

The variation of ERPs when the perfect competition assumption is removed is thus generally lower than 5% in absolute value and reaches at the most 27.1% in the cattle sector in the United States. The near invariance of the results to the nature of competition can be explained by the fact that agricultural sectors with specific factor (those for which the ERP is estimated) are always supposed to be perfectly competitive. Regarding the introduction of a world market power, only the paddy rice sector in the United States is significantly modified with an absolute variation about 40%.

One can also notice that the alteration of the initial theoretical framework tends generally to decrease the levels of ERPs of agricultural products. Only meat products in the United States and the other primary products in the United States and the European Union see their effective protection increase following the introduction of monopolistic competition and/or of the large country assumption.

3.3.2. Sectoral and International Comparison of ERP

Following Anderson's definition, the ERP of a sector corresponds to the uniform tariff that gives to the owners of the factor specific to this sector the same remuneration as the one obtained in the existing protectionist structure. The effective protection received by an industry can be thus interpreted as the sacrifice bear by the whole community to preserve producers' rents of this sector.

According to this conception, in each of the countries of the Triad, the protection of paddy rice is the most costly. The ERP of this sector reaches peaks in Japan (around 400%), stays very high in the European Union (more than 60%) and is far from being negligible in the United States (about 30% under the small country assumption). The level of effective protection is also consequent for unrefined sugar in the European Union (with an ERP about 25%) and in the sectors of cattle and raw vegetable products in the United States (with an ERP nearby respectively 30% and 20%) whereas, in Japan, excepting the sectors of raw animal products and of the other primary products for which the ERP is negative, the burden supported by the community to protect agriculture is always very high.

The international comparison of ERPs stresses thus the very huge effective protection in Japan (particularly of cereals and raw vegetable products); a phenomenon that was already shown through the study of nominal rates. If the assessment of the American situation is limited insofar as it was possible to estimate ERPs in only five sectors, the cost of agricultural protection seems nonetheless less important in the United States than in the European Union. One can however notice the high cost of the protection of American cattle breeders (the ERP of this sector is higher than 30%) who seem yet weakly protected as regards to the nominal rate (0.8%).

3.3.3. Comparison of "Old" and "New" ERP

In a rather surprising way, old and new ERP are highly correlated. For the whole results, taking for each country the most elaborated version of the model (with monopolistic competition and eventually with a world market power), the correlation coefficient is of 95%. If, in partial equilibrium (for a given price of primary factors), the two versions of ERPs coincide; in general equilibrium, it is very difficult to give an explanation for such a correlation. Indeed, the computation of ERP according to Corden's definition do not allow to take into account the impact of price variation on the price of production factors. The level of traditional ERPs has thus *a priori* nothing to do with the level of Anderson's ERP that are precisely based on the variation of sectoral rents induced by the protectionist structure. A more detailed analysis allows besides to bring to the fore huge differences between the two measures of effective protection.

On can first notice that for the sectors RAWMILK and PRIMPRODS in the European Union, CATT and RAWANI in the United States and for the sectors RAWSUG, CATT and RAWANI in Japan, the ERP changes sign according to the definition adopted. Thus, in the European Union, whereas the nominal tariff of raw milk is nil and according to Corden's definition this sector receives negative effective protection, the new ERP is abut 9%. This gap can be explained by the fact that this sector benefits from output subsidies, which are incorporated in the computation of Anderson's ERP. Conversely, in Japan, whereas raw animal products receive positive effective protection of 7.5% according to Corden's definition, the estimation of the ERP following Anderson leads to a largely negative effective protection (-20%). Such a divergence can also be explained by the non-negligible level of output and export taxes. However, the gap between the level of the old and the new ERPs mainly results from the fact that these two rates refer to totally different concepts. Corden's measure try to assess the level of protection induces by the tariff structure whereas Anderson's measure tries to assess the cost, in terms of income distribution, of the whole protectionist structure.

Thus, even when the sign of the ERP does not vary, a large difference of level between the two versions of ERPs is often seen. The most striking example is given by the sector of sugar cane and sugar beet in the European Union. With a nominal tariff that exceeds 100% and an effective protection according to Corden's definition even higher (201.6%), this sector appears to be highly protected. However, the new indicator shows that the distortion supported by the whole economy is not so important as the "new" TPE is lower than 28%.

3.3.4. Sensitivity Analysis

The sensitivity analysis is based on varying the base case elasticity parameter by 50% upward and downward. This analysis is not made for each sector but for each type of elasticity. The results are presented in appendix and show that the elasticity values weakly alter our study of effective protection. Indeed, there are no sign changes and, for each country, the variation of ERPs is lower than 10% in absolute value for more than 70% of the estimates. However, one must notice that there are numerous examples of non-monotonic relationships. Since existence and uniqueness were not practical problems, this non-monotonicity cannot nonetheless reflect multiple equilibria.

4. Conclusion

In this paper, using an original CGE model, we apply the methodology of Anderson (1998b) to assess the effective protection of agricultural sectors in the Triad. The ERP of a sector is thus defined as the uniform tariff, which has the same impact on the profit of the sector as the actual protectionist structure. This approach allowed us to aggregate in a coherent manner three types of barriers to trade (tariffs, output and export subsidies/taxes) to evaluate the distributional impact of trade policies.

The integration of different assumptions (relative to the nature of competition and to the existence of a world market power) and the sensitivity analysis tend to show that the "new" ERPs are relatively robust indicators. Our estimates show that the cost of agricultural trade policies (especially in cereals and raw vegetable products sectors) is particularly high in Japan, a country where tariff escalation and tariff peaks are the highest. We show however that the sacrifice bear by the community to guarantee the payment received by specific factor owners in an industry is not always correlated to the nominal rate of protection or to Corden's definition of effective protection. Moreover, as specific market access conditions and domestic support (other than output subsidies) in agriculture are not integrated in the CGE model, our results must be taken with precaution.

The discrepancy between the new and the old concept of effective protection could lead us to reject this last measure. However, the two indicators are rather complementary. On the eve of trade negotiations gathering developed and developing countries, Corden's measure seems to be more adequate because it allows to assess tariff escalation and thus to take into account the difficulties meet by developing countries to develop their manufacturing industries. Conversely Anderson's measure seems to be the most pertinent to evaluate sectoral rents and thus to direct domestic policies aiming at rationalizing the support to domestic industries.

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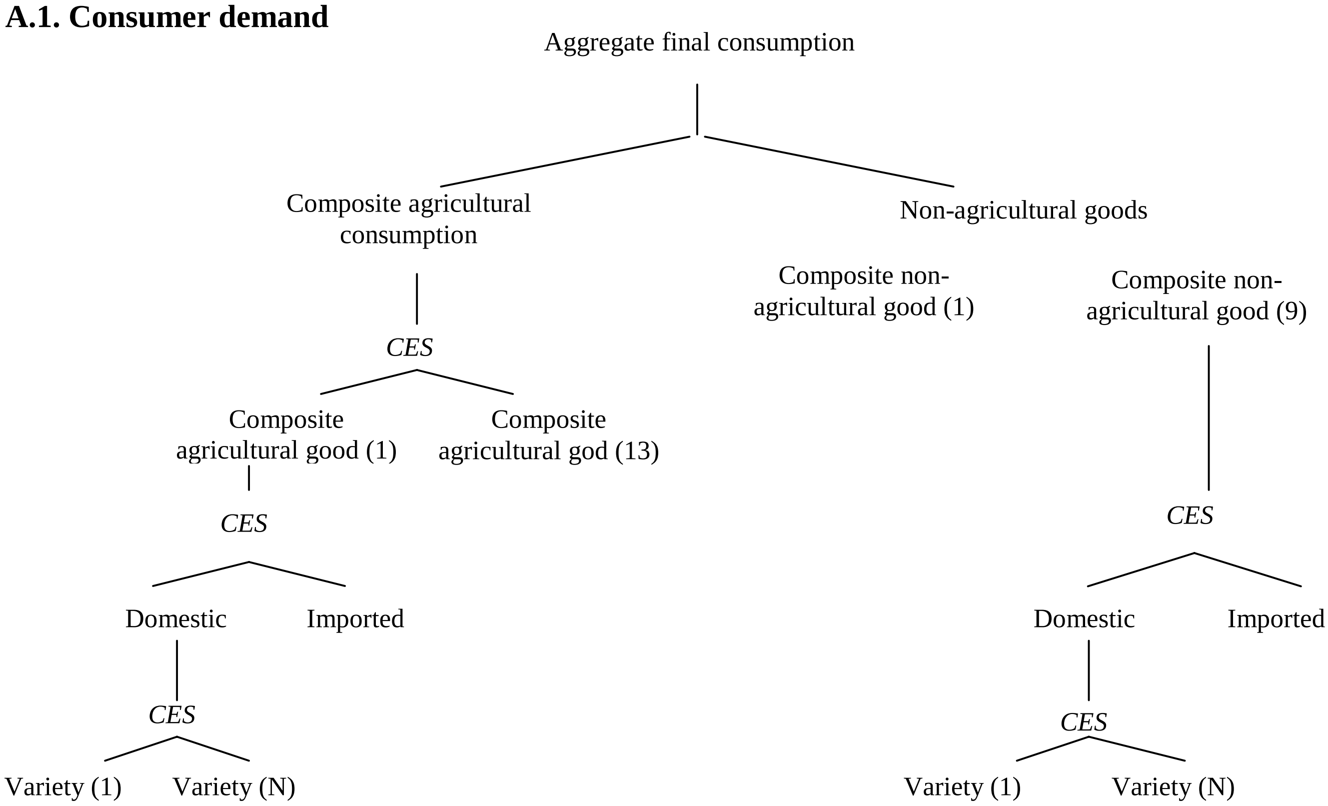
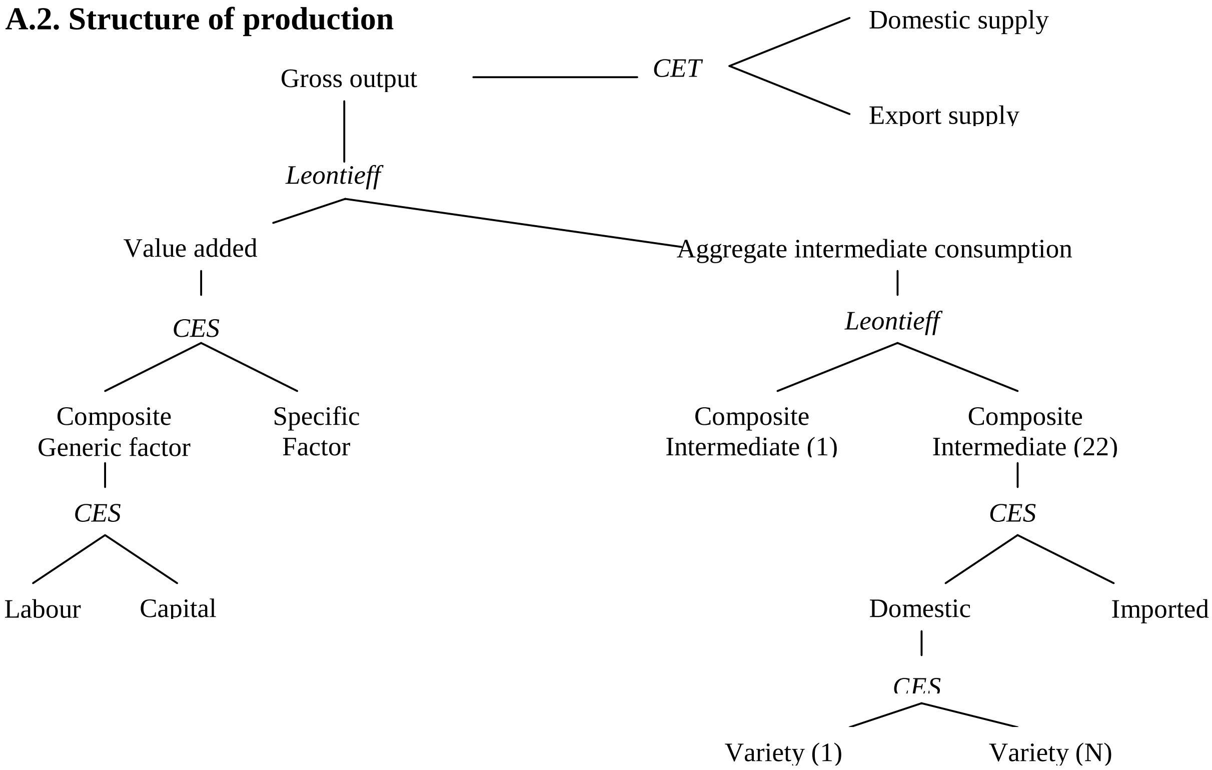
Appendix

A. Model structure

A.1. Consumer demand



A.2. Structure of production



B. Equations of the Basic Trade Model

B.1. Notation

Variable subscripts indicate sectors. If double subscripts are employed, the first one denotes the sector of origin and the second one, the sector of destination. Uppercase letters are reserved for endogenous variables, unless they have a bar, in which case they are exogenous parameters and are denoted by Greek or lowercase Latin letters.

There are $i, j = 1,...,14$ sectors.

$iag\ (inag)$ refers to the set of agricultural (non-agricultural) sectors;

$isf\ (insf)$ refers to the set of sectors with (without) specific factor;

$ipc\ (inpc)$ refers to the set perfectly (monopolistic) competitive sectors;

$ied\ (ined)$ refers to the set of sectors with (without)

$ims\ (inms)$ refers to the set of sectors with (without)

B.2. Model Equations

- Output

$$XD_i = XDF_i \cdot N_i \qquad i \in incp \tag{1}$$

$$XD_i = Min\left(\frac{VA_i}{v_i};\frac{CI_i}{io_i}\right) \tag{2}$$

- Value added

$$VA_i = av_i \cdot \left[\beta_i \cdot \overline{FS}_i^{-\rho v_i} + (1-\beta_i)\cdot FM_i^{-\rho v_i}\right]^{-1/\rho v_i} \qquad i \in isf \tag{3}$$

$$\frac{FM_i}{\overline{FS}_i} = \left[\left(\frac{1-\beta_i}{\beta_i}\right)\cdot\left(\frac{WS_i}{WM_i}\right)\right]^{\sigma v_i} \qquad i \in isf \tag{4}$$

$$VA_i = FM_i \qquad i \in insf \tag{5}$$

- Factors of production

$$FM_i = af_i \cdot \left[\alpha_i \cdot L_i^{-\rho f_i} + (1-\alpha_i)\cdot K_i^{-\rho f_i}\right]^{-1/\rho f_i} \tag{6}$$

$$\frac{K_i}{L_i} = \left[\left(\frac{1-\alpha_i}{\alpha_i}\right)\cdot\left(\frac{W}{R}\right)\right]^{\sigma f_i} \tag{7}$$

- Output allocation

$$XD_i = at_i \cdot \left[\delta_i \cdot XXD_i^{\rho t_i} + (1-\delta_i)\cdot E_i^{\rho t_i}\right]^{1/\rho t_i} \tag{8}$$

$$\frac{E_i}{XXD_i} = \left[\left(\frac{1-\delta_i}{\delta_i}\right)\cdot\left(\frac{PD_i}{PE_i}\right)\right]^{-\sigma t_i} \tag{9}$$

- Costs of monopolistic competitive firms

$$CTF_i = \left(\frac{PP_i}{PP0_i}\right) \cdot CTF0_i \qquad i \in inpc \qquad (10)$$

$$CTV_i = \nu_i \cdot XDF_i \cdot WM_i + \sum_j \left(aij_{ji} \cdot io_i \cdot XDF_i \cdot PCI_{ji}\right) - sx_i \cdot XDF_i \qquad i \in inpc \qquad (11)$$

$$CMA_i = \frac{CTV_i}{XDF_i} \qquad i \in inpc \qquad (12)$$

$$CFU_i = \frac{CTF_i}{XDF_i} \qquad i \in inpc \qquad (13)$$

$$CMO_i = CMA_i + CFU_i \qquad i \in inpc \qquad (14)$$

- Price setting

$$PP_i \cdot XD_i = PVA_i \cdot VA_i + \sum_j \left(PCI_{ji} \cdot CIJ_{ji}\right) - sx_i \cdot XD_i \qquad i \in ipc \qquad (15)$$

$$PP_i = CMO_i \qquad i \in inpc \qquad (16)$$

$$PDV_i = CMA_i \cdot \frac{\sigma s_i}{(\sigma s_i - 1)} \qquad i \in inpc \qquad (17)$$

- Output and value added prices

$$PVA_i = av_i^{-1} \cdot \left[\beta^{\sigma v_i} \cdot WS_i^{1-\sigma v_i} + (1-\beta_i)^{\sigma v_i} \cdot WM_i^{1-\sigma v_i}\right]^{1/(1-\sigma v_i)} \qquad i \in isf \qquad (18)$$

$$PVA_i = WM_i \qquad i \in insf \qquad (19)$$

$$WM_i = af_i^{-1} \cdot \left[\alpha^{\sigma f_i} \cdot W^{1-\sigma f_i} + (1-\alpha_i)^{\sigma f_i} \cdot R^{1-\sigma f_i}\right]^{1/(1-\sigma f_i)} \qquad (20)$$

$$PP_i = at_i^{-1} \cdot \left[\delta_i^{-\sigma t_i} \cdot PD_i^{1+\sigma t_i} + (1-\delta_i)^{-\sigma t_i} \cdot PE_i^{1+\sigma t_i}\right]^{1/(1+\sigma t_i)} \qquad i \in ipc \qquad (21)$$

$$PP_i \cdot XD_i = PD_i \cdot XXD_i + PE_i \cdot E_i + N_i \cdot CTF_i \qquad i \in inpc \qquad (22)$$

- Prices of traded goods

$$PM_i = PWM_i \cdot (1 + tm_i) \cdot \overline{ER} \qquad (23)$$

$$PE_i = PWE_i \cdot (1 + se_i) \cdot \overline{ER} \qquad (24)$$

- Import supply and export demand

$$PWM_i = \overline{PWM}_i \qquad i \in inms \qquad (25)$$

$$PWM_i = constm_i \cdot M_i^{1/\varphi m_i} \qquad i \in ims \qquad (26)$$

$$PWE_i = \overline{PWE}_i \qquad i \in ined \qquad (27)$$

$$PWE_i = conste_i \cdot E_i^{-1/\varphi e_i} \qquad i \in ied \tag{28}$$

- Taxes and subsidies

$$TARIFF = \sum_i \left(tm_i \cdot PWM_i \cdot M_i \right) \tag{29}$$

$$SUBE = \sum_i \left(se_i \cdot PWE_i \cdot E_i \right) \tag{30}$$

$$SUBO = \sum_i \left(sx_i \cdot XD_i \right) \tag{31}$$

- Income

$$INCOME = \sum_i \left(PVA_i \cdot VA_i \right) + TARIFF - SUBE - SUBO \tag{32}$$

$$YFS_i = PVA_i \cdot VA_i - W \cdot L_i - R \cdot K_i \qquad i \in ifs \tag{33}$$

$$SAVINGS = mps \cdot INCOME \tag{34}$$

- Capital goods demand

$$PCK_i \cdot K_i = kish_i \cdot INVEST \tag{35}$$

$$IT_i = ak_i \cdot \left[\kappa_i \cdot ID_i^{-\rho k_i} + (1-\kappa_i) \cdot IM_i^{-\rho k_i} \right]^{-1/\rho k_i} \tag{36}$$

$$\frac{IM_i}{ID_i} = \left[\left(\frac{1-\kappa_i}{\kappa_i} \right) \cdot \left(\frac{PD_i}{PM_i} \right) \right]^{\sigma k_i} \tag{37}$$

$$IDV_i = bv_i^{-1} \cdot ID_i \cdot N_i^{\sigma s_i / (\sigma s_i - 1)} \qquad i \in inpc \tag{38}$$

- Intermédiaire goods demand

$$CIJ_{ij} = aij_{ij} \cdot CI_i \tag{39}$$

$$CIJ_{ij} = az_{ij} \cdot \left[\gamma_{ij} \cdot ZD_{ij}^{-\rho z_{ij}} + (1-\gamma_{ij}) \cdot ZM_{ij}^{-\rho z_{ij}} \right]^{-1/\rho z_{ij}} \tag{40}$$

$$\frac{ZM_{ij}}{ZD_{ij}} = \left[\left(\frac{1-\gamma_{ij}}{\gamma_{ij}} \right) \cdot \left(\frac{PD_i}{PM_i} \right) \right]^{\sigma z_{ij}} \tag{41}$$

$$ZDV_i = bv_i^{-1} \cdot ZD_{ij} \cdot N_i^{\sigma s_i / (\sigma s_i - 1)} \qquad i \in inpc \tag{42}$$

- Consumer goods demand

$$DT_i = ad_i \cdot \left[\lambda_i \cdot DD_i^{-\rho d_i} + (1-\lambda_i) \cdot DM_i^{-\rho d_i} \right]^{-1/\rho d_i} \tag{43}$$

$$\frac{DM_i}{DD_i} = \left[\left(\frac{1-\lambda_i}{\lambda_i} \right) \cdot \left(\frac{PD_i}{PM_i} \right) \right]^{\sigma d_i} \tag{44}$$

$$DDV_i = bv_i^{-1} \cdot DD_i \cdot N_i^{\sigma s_i / (\sigma s_i - 1)} \qquad i \in inpc \qquad (45)$$

$$CPAG = ag\left[\sum_{i \in iag}\left(\theta_i \cdot DT_i^{-\rho g}\right)\right]^{-1/\rho g} \qquad (46)$$

$$\frac{DT_j}{DT_i} = \left[\left(\frac{\theta_j}{\theta_i}\right) \cdot \left(\frac{PCF_i}{PCF_j}\right)\right]^{\sigma g} \qquad i, j \in iag \qquad (47)$$

$$U = ac \cdot \left[\Omega \cdot CPAG^{-\rho c} + \sum_{i \in inag}\left(\omega_i \cdot DT_i^{-\rho c}\right)\right]^{-1/\rho c} \qquad (48)$$

$$\frac{DT_i}{CPAG} = \left[\left(\frac{\omega_i}{\Omega}\right) \cdot \left(\frac{PINDEXAG}{PCF_i}\right)\right]^{\sigma c} \qquad i \in inag \qquad (49)$$

- Average purchase prices

$$PD_i = bv_i^{-1} \cdot PDV_i \cdot N_i^{1/(1-\sigma s_i)} \qquad i \in incp \qquad (50)$$

$$PCK_i = ak_i^{-1} \cdot \left[\kappa^{\sigma k_i} \cdot PD_i^{1-\sigma k_i} + (1-\kappa_i)^{\sigma k_i} \cdot PM_i^{1-\sigma k_i}\right]^{1/(1-\sigma k_i)} \qquad (51)$$

$$PCI_{ij} = az_i^{-1} \cdot \left[\gamma_{ij}^{\sigma z_{ij}} \cdot PD_i^{1-\sigma z_{ij}} + (1-\gamma_{ij})^{\sigma z_{ij}} \cdot PM_i^{1-\sigma z_{ij}}\right]^{1/(1-\sigma z_{ij})} \qquad (52)$$

$$PCF_i = ad_i^{-1} \cdot \left[\lambda^{\sigma d_i} \cdot PD_i^{1-\sigma d_i} + (1-\lambda_i)^{\sigma d_i} \cdot PM_i^{1-\sigma d_i}\right]^{1/(1-\sigma d_i)} \qquad (53)$$

$$PINDEXAG = ag^{-1} \cdot \left[\sum_{i \in iag} \theta_i^{\sigma g} \cdot PCF_i^{1-\sigma g}\right]^{1/(1-\sigma g)} \qquad (54)$$

$$PINDEX = ac^{-1} \cdot \left[\Omega^{\sigma c} \cdot PINDEXAG^{1-\sigma c} + \sum_{i \in inag} \omega_i^{\sigma c} \cdot PCF_i^{1-\sigma c}\right]^{1/(1-\sigma c)} \qquad (55)$$

- Equilibrium

$$\sum_i L_i = \overline{L} \qquad (56)$$

$$\sum_i K_i = \overline{K} \qquad (57)$$

$$M_i = \sum_j ZM_{ij} + IM_i + DM_i \qquad (58)$$

$$XXD_i = \sum_j ZD_{ij} + ID_i + DD_i \qquad (59)$$

$$\sum_i PCF_i \cdot DT_i = (1 - mps) \cdot INCOME \qquad (60)$$

$$SAVINGS - INVEST = \sum_i PWE_i \cdot E_i - \sum_i PWM_i \cdot M_i \qquad (61)$$