



*A Graphical Exposition  
of the GTAP Model*

by **Martina BROCKMEIER**

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GTAP stands for the Global Trade Analysis Project which is administered by the Center for Global Trade Analysis, Purdue University, West Lafayette, IN 47907-1145 USA. For more information about GTAP, please refer to our Worldwide Web site at <http://www.agecon.purdue.edu/gtap/>, or send a request to [conner@agecon.purdue.edu](mailto:conner@agecon.purdue.edu).

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## *Abstract*

This paper offers a graphical exposition of the GTAP model of global trade. Particular emphasis is placed on the accounting, or equilibrium, relationships in the model. It begins with a treatment of the a one region version of GTAP, thereafter adding a rest of world region to highlight the treatment of trade flows in the model. The implementation of policy instruments in GTAP is also explored, using simple supply-demand graphics. The material provided in this paper was first developed as an introduction to GTAP for participants taking the annual short course. Based on its success in that venue, this paper has been placed on the “highly recommended” reading list for individuals seeking an introduction and overview of the GTAP framework. It was modified in March of 2001 to reflect the changes in version 6.0 of the GTAP model.

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# *A Graphical Exposition of the GTAP Model*

## *1. Introduction*

Over the last several decades Applied General Equilibrium (AGE) models has become an important tool for analyzing economic issues. This development is explained by the capability of AGE models to provide an elaborate and realistic representation of the economy including the linkages between all agents, sectors and other economies. While this complete coverage permits a unique insight into the effects of changes in the economic environment throughout the whole economy, single country, and especially global AGE models very often include an enormous number of variables, parameters and equations.

GTAP (Global Trade Analysis Project) is a multi-regional AGE model which captures world economic activity in 57 different industries of 66 regions (Version 5 of the data base). However, the theory behind the GTAP model is similar to that of other standard, multi-regional AGE models. The underlying equation system of GTAP accordingly includes two different kinds of equations. One part covers the accounting relationships which ensure that receipts and expenditures of every agent in the economy are balanced. The other part of the equation system consists of behavioral equations which based upon microeconomic theory. These equations specify the behavior of optimizing agents in the economy, such as demand functions.

Given the large number of components necessary to build GTAP, it is not easy to get a general idea of the theory behind the model. For this reason, the following documentation gives an overview of the model structure by focusing on the accounting relationships. It provides a useful companion to chapter 2 of the GTAP book (HERTEL, 1997) in which the theory behind the model and especially the derivation of the behavioral equations are covered in more detail.

This paper is organized as follows. The first section presents the accounting relationships in a closed economy version of the GTAP model without government intervention. There, the generation and distribution of income as well as domestic demand and supply are discussed. In the following section, taxes and subsidies are introduced into this closed economy. The implementation of policy instruments changes most parts of the model structure. Therefore, the accounting relationships in the one region model are considered once again. Additionally, the computation of tax revenues and subsidy expenditures are discussed in detail. In the third section, the closed economy is then extended to a multi-region version of GTAP which includes a trading sector. Finally, an assessment of the accounting relationships in an open economy and the computation of subsidies and taxes implemented in the trading sector completes this graphical exposition of the GTAP model.

## 2. *One Region Closed Economy Without Government Interventions*

The following graphical illustration will explain the basic concept of GTAP by focusing on the accounting relationships. Different economic activities are introduced step by step into these figures. In so doing, one agent after the other is added to the graph, and thereby the GTAP model is developed piece by piece.

The starting point in this exposition is a regional household associated with each country or composite region of GTAP (figure 1). This regional household collects all income that is generated in the closed economy. According to a Cobb Douglas, *per capita* utility function, regional income is exhausted over the three forms of final demand: *PRIVate household EXPenditures (PRIVEXP)*, *GOVERNment EXPenditures (GOVEXP)* and *savings (SAVE)*. This approach represents the standard closure of GTAP in which each component of final demand maintains roughly a constant share of total regional income.<sup>1</sup> Thus, an increase in regional income causes a (roughly) equiproportional change in private expenditures, government expenditures and savings.<sup>2</sup>

In a second step, the producers are added to the graph (figure 2)<sup>3</sup>. The firms and the regional household together with its three components of final demand now build a closed economy. This makes it possible to take a closer look at the accounting identities specified in the GTAP model. Starting with the regional household, the top half of the graph shows that the available regional income consists of the *Value of Output at Agent's prices (VOA)* paid by producers for the use of *endowment commodities* to the regional household.<sup>4</sup> In order to give a clearer presentation, the figures only display the value flows in the economy. However, there are corresponding flows or ownerships of an asset which cross markets in the opposite direction. In the case described above, the value flow *VOA* also has a corresponding flow of endowment commodities, going from the

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1. The reason expenditure shares are not constant, as might be expected in a Cobb-Douglas demand system, is that the private expenditure function is non-homothetic and therefore the “price” of private consumption depends on the amount “purchased.” Accommodating this endogeneity in the regional households’ optimization problem results in a new set of demand equations in which the shares are non-constant. See McDougall, 2001, for a complete exposition of the new final demand system in the version 6.0 GTAP model.

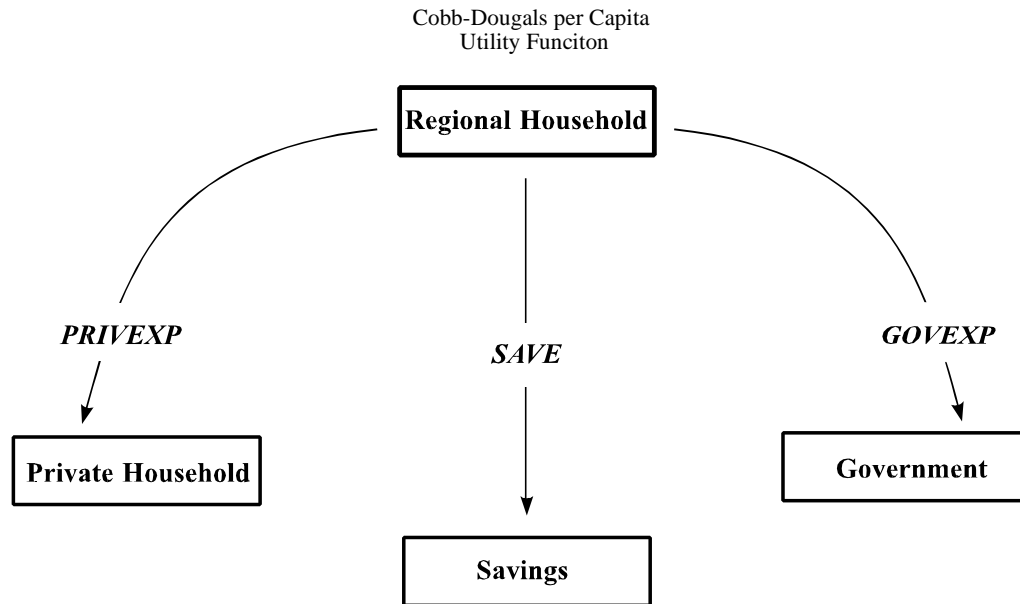
2. The new theory of regional household demand developed by McDougall (2001) permits the user to fix any one of these components of final demand by shifting preferences. Thus, for example, the level of government activities could be fixed, and the associated preference parameter permitted to vary. In this way the regional household is assured of remaining on its budget constraint, and welfare analysis may still be conducted – albeit with allowance for the impact of changing preferences. See McDougall (2001) for details.

3. Every value flow which is initiated by introducing a new agent into the graph is in bold. This procedure is also given in each of the following graphs.

4. In this specification *VOA* is the value added actually received by the private household in return for the use of its endowments. Endowment commodities are non-tradeable goods which include agricultural land, labor and capital.

Figure 1 Regional Household and Components of Final Demand

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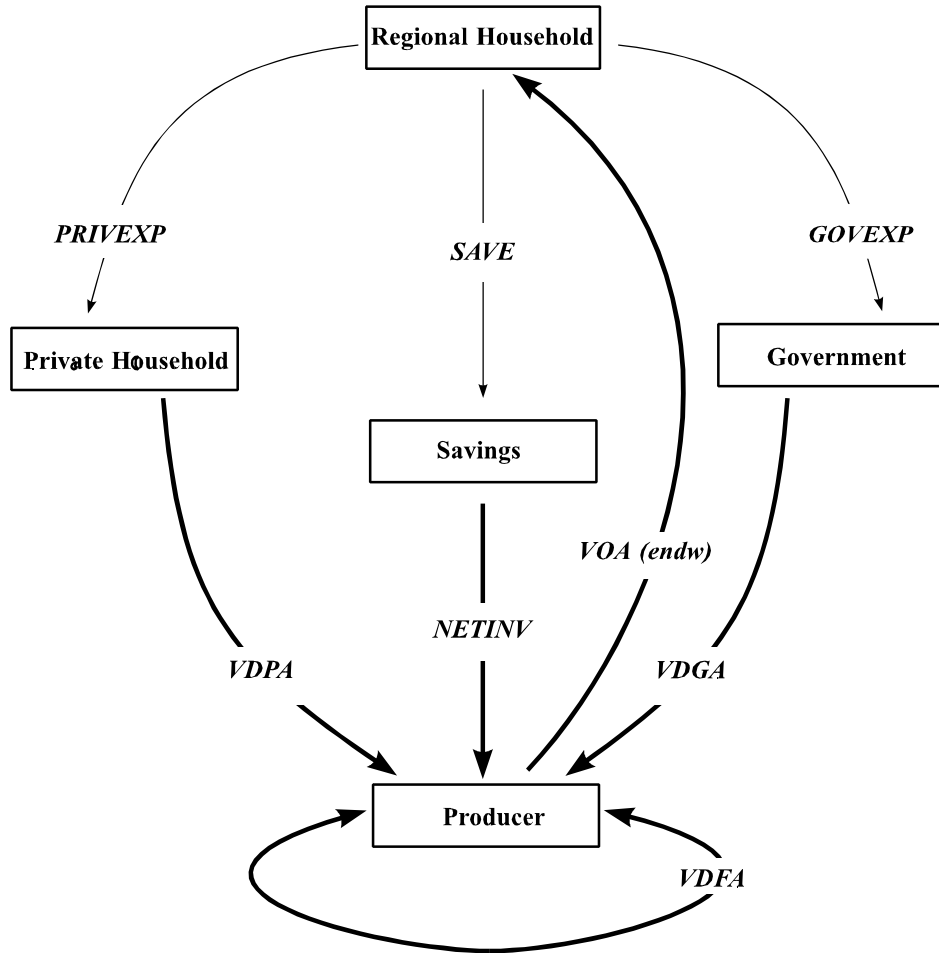
regional household back to the producers. This flow, as well as the other goods and service flows are not included in the graphs.

Figure 2 clearly indicates that available regional income is collected by the regional household and entirely exhausted over private household expenditures, government expenditures and savings. Modeling the components of final demand via this regional household has the advantage that no agent can spend more income than she receives. Besides, this concept of regional income is well-suited to computing equivalent variation as a measure of regional welfare which arises due to different policy scenarios.

Having established the distribution of regional income, we are now in a position to consider the economic activities of other agents in the closed economy. First, figure 2 shows the accounting relationship for government expenditures, private consumption and savings. Government purchases are denoted as *Value of Domestic Government purchases, evaluated at Agents' prices (VDGA)*. In order to model the behavior of government spending, a Cobb Douglas sub-utility function is employed in GTAP. In this case the Cobb Douglas expenditure shares are constant across all commodities.

Figure 2 One Region Closed Economy without Government Intervention

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The second component of final demand is private consumption (*Value of Domestic Private household purchases, evaluated at Agents' prices, VDPA*). The constrained optimizing behavior of private consumption is represented in GTAP by the CDE (Constant Difference of Elasticity) implicit expenditure function. The CDE function is less general than the fully flexible functional forms on the one hand, but more flexible than the commonly used CES/LES functions on the other hand. It is easily calibrated using data on income and own price elasticities of demand (for more detail see HERTEL, et.al., 1991).

Considering the third component of final demand, figure 2 shows that savings are completely exhausted on investment (*NETINV*). In GTAP the demand for investment is savings-driven. Given the static nature of the GTAP model, current investment is assumed not to be installed during the considered period, and therefore does not affect the productive capability of the industries in the model. However, the demand for investment goods will affect the economic activity in the region through its effects on the pattern of production. The mix of capital goods used for investment is treated in a manner analogous to the modeling of intermediate demand which is discussed below.

Looking at the production side of the closed economy, figure 2 also shows the accounting relationships of firms in GTAP. The producers receive payments for selling consumption goods to the private households (*VDPA*) and the government (*VDGA*), intermediate inputs to other producers (*Value of Domestic Firm Purchases, evaluated at Agents' prices, VDFA*) and investment goods to the savings sector (*NETINV*). Under the zero profit assumption employed in GTAP, these revenues must be precisely exhausted on expenditures for intermediate inputs (*VDFA*) and primary factors of production (*VOA*).<sup>5</sup>

The nested production technology in GTAP exhibits constant returns to scale and every sector produces a single output. Furthermore, it is assumed the technology is weakly separable between primary factors of production and intermediate inputs. Profit maximizing firms therefore choose their optimal mix of primary factors independently of the prices of intermediate inputs. Utilizing this type of separability also means that the elasticity of substitution between any individual primary factor and different intermediate inputs is equal. This technology is further simplified by employing the Constant Elasticity of Substitution (CES) functional form in the aggregation of primary factors, as well as in the combination of value-added and intermediate inputs in order to produce output. This reduces the total number of substitution parameters in the production function to two per sector.

Among the primary factors, the GTAP model additionally distinguishes between endowment commodities which are perfectly mobile and those which are sluggish to adjust. In the former case, the factor earns the same market return regardless of where it is employed. In the case of sluggish endowment commodities, returns in equilibrium may differ across sectors.

The complete accounting relationships in this one region closed economy model form a simultaneous equation system in which one identity is redundant and can be dropped. In GTAP the savings-

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5. Since firms get revenue for selling their goods to other producers on the one hand and buy intermediate inputs on the other hand, these values flow in both directions.



investment identity is not imposed. A separate computation of savings and investment therefore offers a consistency check on the accounting relationships and verifies that Walras' Law is satisfied. Since the model can only be solved for N-1 prices, the one price is set exogenously, and all other prices are evaluated relative to this numeraire.<sup>6</sup>

### ***3. One Region Closed Economy With Policy Interventions***

In addition to the demand and supply activities, every economy also includes government interventions. Figure 3 presents the additional value flows which arise due to policy interventions. In order to simplify matters, the new value flows are all denoted as *TAXES*. Notice also that these transactions are transfers (either voluntary or involuntary) which are not accompanied by flows of goods or services crossing the market in the opposite direction.

In figure 3, *TAXES* flow from the private household, firms and government to the regional household. Since these value flows include both taxes and subsidies, they denote net tax revenues. Due to the introduction of government intervention, most of the accounting relationships in the closed economy must change. Private households and the government now not only spend their available income on consumption goods, but also pay *TAXES* to the regional household. In the case of the government, *TAXES* consist of consumption taxes on commodities which are produced in the closed economy. In contrast to that, *TAXES* paid by the private household cover consumption taxes and income tax net of subsidies. The accounting relationships of these two agents therefore include *TAXES* as additional expenditures. This is captured by the distinction between market prices and agent's (tax inclusive) prices.

Because producers are also the object of taxation, their accounting relationships change as well. Beside buying intermediate inputs and primary factors, firms now also have to pay *TAXES* to the regional household. These value flows represent taxes on intermediate inputs and production taxes net of subsidies.<sup>7</sup>

Finally figure 3 shows that all *TAXES* levied in the economy always accrue to the regional household. As a result, the regional income consists of *VOA* paid for the use of *endowment commodities* and the sum over all taxes net of subsidies.

In GTAP, tax revenues and subsidy expenditures are computed by comparing the value of a given transaction, evaluated at agents' and market prices. If there is a discrepancy between two of these

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6. In the original GTAP model, the price of savings was chosen as the numeraire. In the version 6.0 model the price of savings varies by region. Here the global average return to primary factors is typically used as the numeraire.

7. If subsidies to the private households (firms) are higher than taxes, the value flow presents additional income (revenue).



values, then the difference must be equal to the tax or subsidy in question. Thus, the approach used here neither keeps track of any individual tax and subsidy, nor of the different possible uses of these tax revenues (i.e. increased government purchases, reduced public sector deficit). Taxes and subsidies drive a wedge between the market price and the agents' price. In GTAP this linkage is taken into account by multiplying the market price of the particular commodity by the power of the associated ad valorem tax or subsidy, whereby the agents' price of the commodity is obtained. According to the demand and supply elasticities in the individual market, the market price as well as the agents' price in the new equilibrium will be changed. Whether the resulting agents' price will be higher or lower than the associated market price depends on which agent pays the tax. In the case of a tax (subsidy) on the demand side, the agents' price is higher (lower) than the market price. If the tax (subsidy) is imposed on supplier of the particular commodity, the agents' price is lower (higher) than the market price.

Figures 4 and 5 show these relations in more detail. Here it is assumed that every other tax or subsidy is equal to zero, except the particular intervention which is considered in the different parts of these figures. Turning attention first to the tax on private household's purchases, figure 4.1 shows that in the initial equilibrium, the power of the ad valorem tax ( $TPD$ ) is equal to one and the market price ( $PM^0$ ) therefore equals the agents' price ( $PPD^0$ ). After imposing a tax on the private household's purchases of commodity I, the market price ( $PM^1$ ) is reduced, whereas the agents' price ( $PPD^1$ ) is increased.

The power of the ad valorem tax in this case is given by the ratio of the *Value of Domestic Private household's purchases evaluated at Agents' price* ( $VDPA$ ) to the *Value of Domestic Private household's purchases evaluated at Market price* ( $VDPM$ ):

$$TPD = VDPA/VDPM$$

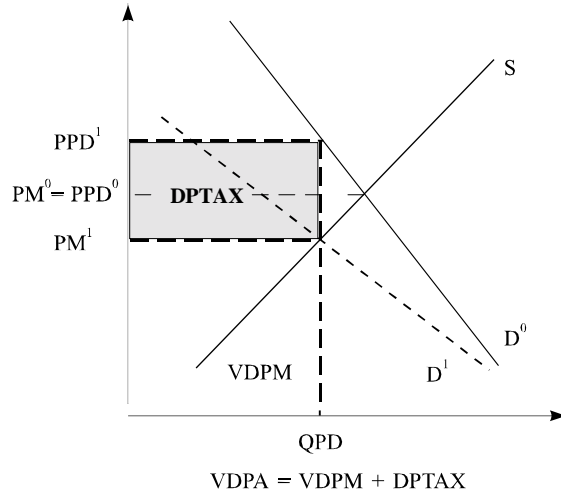
Since  $TPD$  is greater than one, the agents' price must be higher than the market price according to the price linkage relationship  $PM^1/TPD = PPD^1$ . In a second step the tax revenues ( $DTAX$ ) can be computed by:  $DPTAX = VDPA - VDPM$ . These taxes are paid by the private household or the consumption side and are included in the *TAXES* flowing to the regional household or the income side in figure 3. Furthermore,  $VDPM$  indicates the revenues which are received by the producers for selling their commodities.

Figure 4.2 represents the adjustments which have taken place after a subsidy on the private household's purchases of commodity  $i$  is implemented. In this instance,  $VDPM$  is greater than  $VDPA$ , so that the power of the ad valorem tax,  $TPM$ , is smaller than one and the agents' price ( $PPD^1$ ) is lower than the market price ( $PM^1$ ). Accordingly,  $DPTAX$  is negative and withdrawn from the regional income. Thus, the *TAXES* flowing from the private household to the regional household represent net tax revenues.

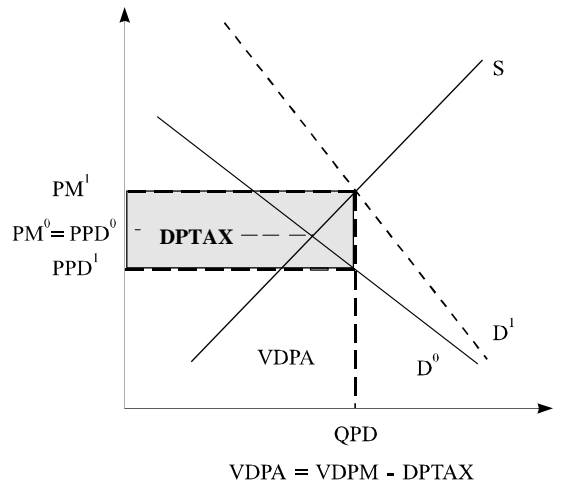
Figure 5 shows an intervention on the supply side. Here, a tax on output is considered first (figure 5.1). In the initial equilibrium, the power of the ad valorem tax,  $TO$ , equals one so that the agents' price ( $PS^0$ ) and the market price ( $PM^0$ ) coincide. The introduction of a producer tax drives a wedge

Figure 4 Taxes and Subsidies on Demand in a Closed Economy

**4.1 Tax on Private Household's Purchases**



**4.2 Subsidy on Private Household's Purchases**

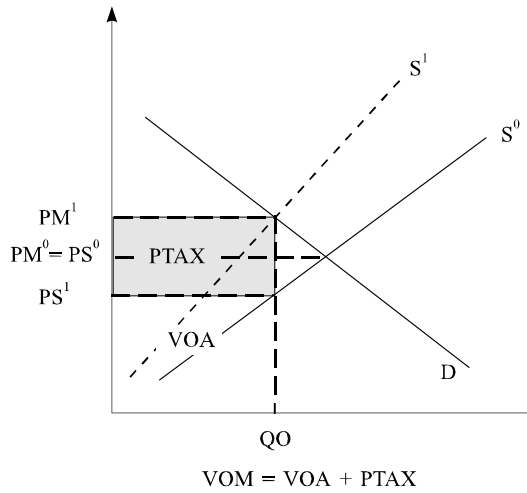



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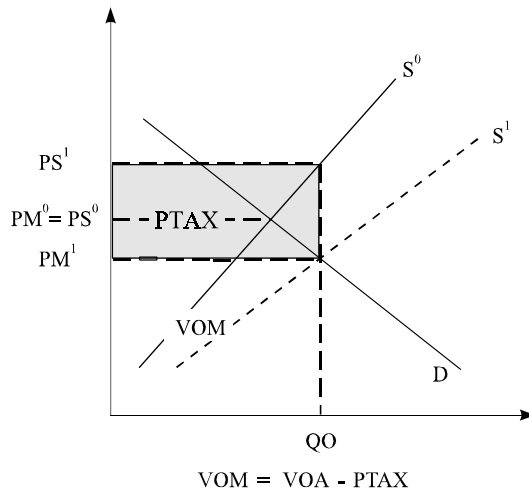
PM	Market price of commodity i
PPD	Private household's price of commodity i
QPD	Private household demand for commodity i
VDPA/VDPM	Value of private household's purchases of commodity i valued at agents'/market price
DPTAX	Tax/subsidy on commodity i purchased by private households
$D^{0,1}$	Pretax/taxed demand of commodity i
S	Supply of commodity i,

Figure 5: Taxes and Subsidies on Supply in a Closed Economy

**5.1 Tax on Output**



**5.2 Subsidy on Output**




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PM	Market price of commodity i
PS	Supply price of commodity i
QO	Supply quantity of commodity i
VOA/VOM	Value of output at agents'/market price
PTAX	Tax/subsidy on production of commodity i
D	Demand of commodity i
S <sup>01</sup>	Pretax/taxed supply of commodity i

between these two prices. In contrast to taxation of the demand side, the agents' price ( $PS^I$ ) is now lower than the market price ( $PM^I$ ). Therefore, the power of the ad valorem tax, calculated as the ratio of the *Value of Output at Agents' price (VOA)* to the *Value of Output evaluated at Market price (VOM)*, is smaller than one. Producer tax revenue,  $PTAX$ , is given by the difference between  $VOM$  and  $VOA$ :

$$PTAX = VOM - VOA$$

Because all taxes levied in the closed economy accrue to the regional household, these tax revenues are included in the  $TAXES$  flowing from the producers to the regional household in figure 3.

Finally, figure 5.2 shows the price adjustments which occur after an implementation of a subsidy on sales of commodity  $i$ . Here, the agents' price ( $PS^I$ ) lies above the market price ( $PM^I$ ). Correspondingly,  $VOA$  is greater than  $VOM$ , and  $PTAX$  represents an expenditure which is withdrawn from regional income.

## 4. *Multi-Region Open Economy*

Given knowledge of the theory behind the one region version of the GTAP model, we are now in a position to integrate a trading sector into the model. How could this be done graphically? Actually, there are two opportunities. One possibility would be to take all single countries and regions included in GTAP, put them together in one graph and connect them to each other by drawing all of the existing trade flows. Since the version 5.0 GTAP data base covers 66 regions, this would certainly be too much for one graph! The other alternative is to combine all regions in the model except one in a sector called Rest of the World. The one single region is then used to show the changes in the model structure which has to be done in order to model an open economy. Since these changes occur in every region of the multi region model, a complete overview is given by this approach.

In figure 6, a sector called Rest of the World and the value flows initiated by this new agent are added to the graph. Therefore, the graph represents a multi-region open economy in which the accounting relationships of all agents have changed once again.<sup>8</sup> Considering the production side of the open economy, figure 6 indicates that firms on one side get additional revenues for selling commodities to the Rest of the World. These exports are denoted by  $VXMD$ . On the other side, the producers now spend their revenues not only on primary factors and domestically produced intermediate inputs, but also on imported intermediate inputs,  $VIFA$ . Furthermore, the firms have to pay an additional consumption tax on imported inputs to the regional household. Since this tax

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8. GTAP actually includes a transportation sector which accounts for the difference between *FOB* and *CIF* values for a particular commodity shipped along a particular route. This transportation sector is neglected in figure 6 in order to provide a simpler presentation.

expenditure is included in the *TAXES* flowing from the producer to regional household, the graph does not show any change in this respect.

The GTAP model employs the so-called Armington assumption in the trading sector which provides the possibility to distinguish imports by their origin and explains intra-industry trade of similar products. Thus, imported commodities are assumed to be separable from domestically produced goods and combined in an additional nest in the production tree. The elasticity of substitution in this input nest is equal across all uses. Under these circumstances, the firms decide first on the sourcing of their imports and based on the resulting composite import price, they then determine the optimal mix of imported and domestic goods. In contrast to the closed economy, the multi-region model therefore includes separate conditional demand equations for domestic and imported intermediate inputs.

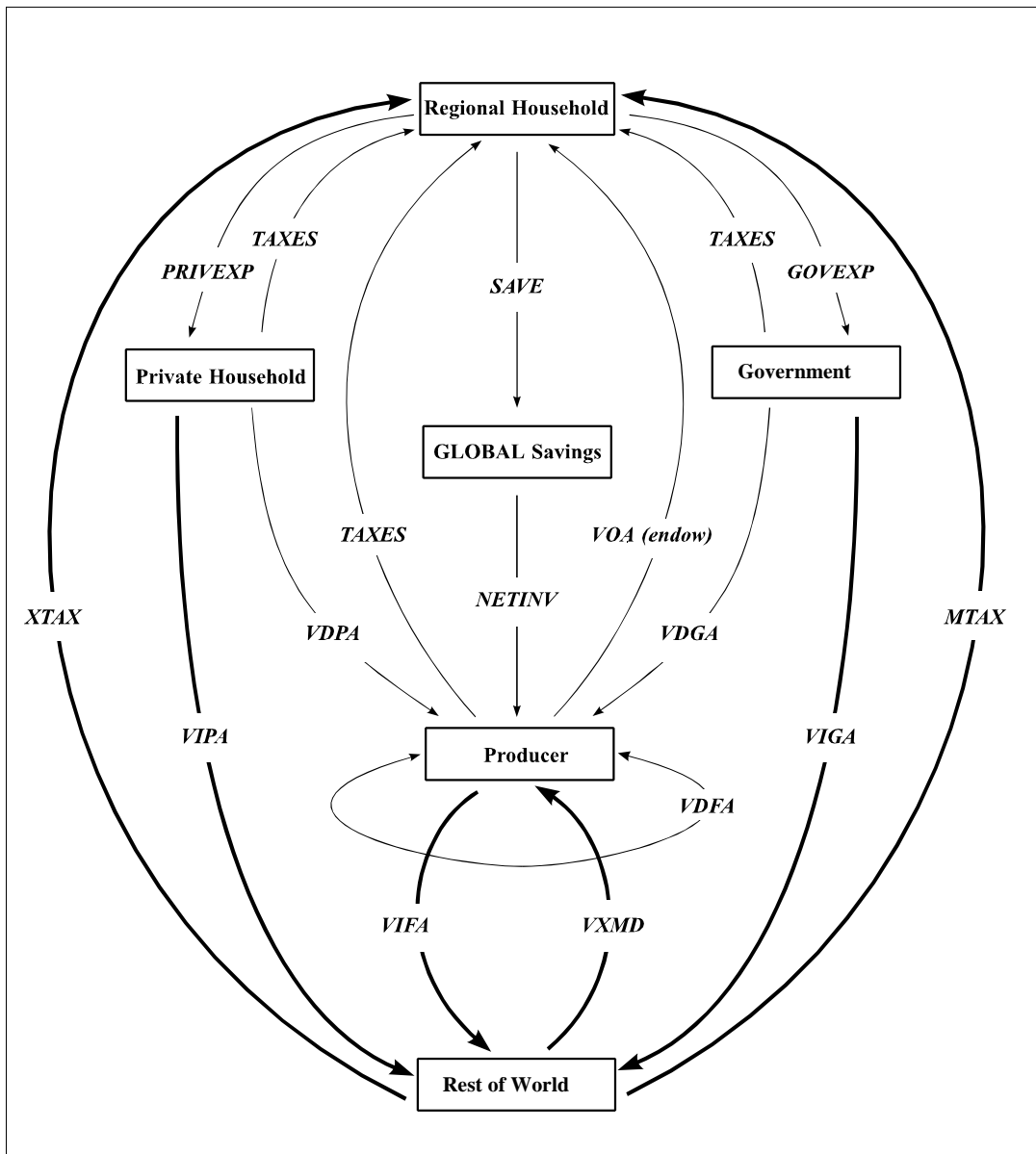
Figure 6 also shows the accounting relationships of the component of final demand in an open economy. Here, the government and private households not only spend their income on domestically produced but also on imported commodities which are denoted as *VIPA* and *VIGA*, respectively. Furthermore, both agents have to pay additional commodity taxes on imports to the regional household, so that the accounting relationships of these two agents now also include consumption taxes and expenditure for imported commodities. Analogous to the firms behavior described above, the multi region GTAP model includes conditional demand equations for imported commodities reported for government and private consumption. Imported commodities and domestically produced commodities are combined in a composite nest for both private and government expenditures, respectively. The elasticity of substitution between imported and domestically produced goods in this composite nest of the utility tree is assumed to be equal across uses. Firms and households import demand equations therefore differ only in their import shares.

The accounting relationship of the third component of final demand, savings, has also changed. Since these variations cannot easily be represented in the figure, the savings in figure 6 are denoted simply as *GLOBAL Savings*. In the multi region version of the GTAP model, savings and investment are computed on a global basis, so that all savers in the model face a common price for this savings commodity. This means that if all other markets in the multi regional model are in equilibrium, all firms earn zero profits, and all households are on their budget constraint, then global investment must equal global savings and Walras' Law will be satisfied.

Finally, we have to check the accounting relationships for the rest of the world. According to the graph, the rest of the world gets payments for selling their goods for private consumption, government, and firms. These revenues will be spent on commodities exported from the single region to the rest of the world, denoted as *VXMD*, and on import taxes, *MTAX*, and export taxes, *XTAX* paid to the regional household.

Trade generated tax revenues and subsidy expenditures are computed in a manner analogous to the ones which are being raised by policy instruments used in the domestic market. The only difference is that now the tax or subsidy rates are defined as the ratio of market prices to world prices. If there is an import tax (subsidy), the market price is higher (lower) than the world price, so that the power

Figure 6 Multi Region Open Economy





of the ad valorem tax is greater (smaller) than one. In the case of an export tax (subsidy), the market price lies below (above) the world price and the power of the ad valorem tax is smaller (greater) than one.

Once again, these relations may be examined graphically. Figure 7 first shows interventions on exports of commodity  $i$  from region  $r$  to region  $s$ . This export supply represents the sales to region  $s$ , net of export supplies to all other regions included in GTAP. The initial pretaxed equilibrium in figure 7.1 is given by the intersection of export supply and import demand. Since the power of the ad valorem export tax is equal to zero, domestic (PM) and *job* (PFOB) price of commodity  $i$  in region  $s$  of origin  $r$  coincide. After implementation of an export tax the domestic price of commodity  $i$  in region  $s$  decreased, whereas the FOB price increased. The power of the export tax can be calculated as the ratio of the *Value of eXports of commodity  $i$  from region  $r$  to region  $s$ , valued at the exporter's domestic market, by destination price* ( $VXMD(i,r,s)$ ) to the *Value of eXports of commodity  $i$  from region  $r$  to region  $s$ , valued at the world prices, by destination* ( $VXWD(i,r,s)$ ):

$$TXS(i,r,s) = VXMD(i,r,s)/VXWD(i,r,s)$$

$TXS$  is smaller than one in the presence of an export tax. Thus, the domestic price of commodity  $i$  in region  $s$  is reduced according to the price linkage relationship  $PM = PFOB / TXS$ , and the export tax revenues ( $XTAX$ ) are given by the difference between  $VXWD$  and  $VXMD$ .

It is also possible to trace back these export tax revenues in figure 6. In so doing, it is assumed that the one single region shown in figure 6 represents region  $r$ , whereas region  $s$  is covered by the Rest of the World account. Under these circumstances, the export tax described above is paid by the purchaser of commodity  $i$  in region  $s$  to the regional household in region  $r$ . The export tax revenues are therefore included in the  $TAXES$  flowing from the rest of the world to the regional household in figure 6.

Figure 7.2 presents the situation where a subsidy is imposed on the exports of commodity  $i$  from region  $r$  to region  $s$ . As a result of this intervention,  $VXMD$  is now higher than <sup>9</sup> the *job* value. In addition, the export subsidy, calculated as  $VXWD - VXMD$ , represents an expenditure paid by the regional household in region  $r$  to the sellers of commodity  $i$  in region  $r$ . Hence, it is covered by the  $TAXES$  flowing from the regional household to the producers in figure 6.

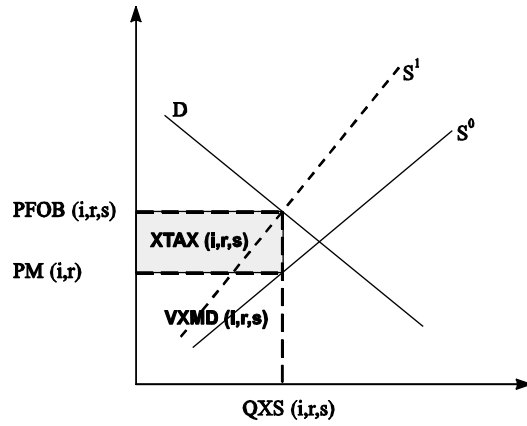
Figure 8.1 portrays the case of a tax on imports of commodity  $i$  from country  $s$  into country  $r$ . The introduction of an import tax drives a wedge between the domestic price and the *cif* price. Therefore, the power of the ad valorem import tax,  $TMS$ , calculated as the ratio of the *Value of Imports of commodity  $i$  from region  $s$  to region  $r$ , at Market prices, by Source* ( $VIMS(i,s,r)$ ) to the *Value of Imports of commodity  $i$  from region  $s$  to region  $r$ , World prices, by Sourceprice* ( $VIWS(i,s,r)$ ) is greater than one.

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9. Since the  $TAXES$  always represents net tax revenues, the tax flows from the regional household to all other agents in the economy also include subsidy expenditures in the opposite direction which are not explicitly shown in figure 6.

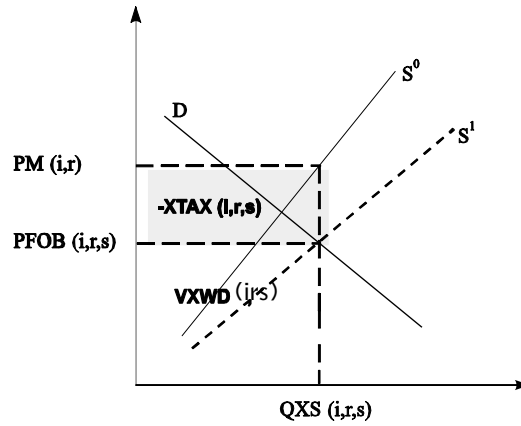
Figure 7 Export Subsidy or Tax in Region s on Purchases from Region r

### 7.1 Export Tax



$$VXWD(i,r,s) = VXMD(i,r,s) + XTAX(i,r,s)$$

### 7.2 Export Subsidy



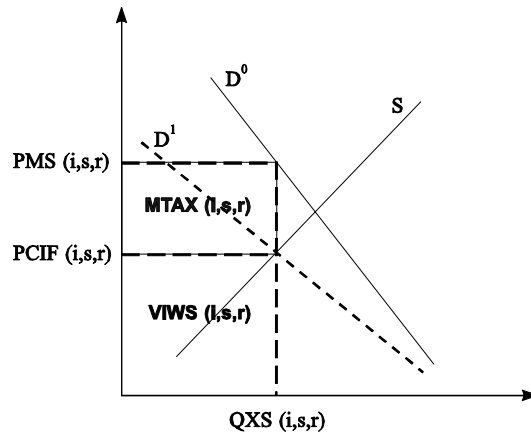
$$VXWD(i,r,s) = VXMD(i,r,s) + XTAX(i,r,s)$$

- PM Domestic price of commodity I in region s from origin r  
 PFOB FOB price of commodity I supplied from region r to region s  
 QXS Export of commodity I from region r to region s  
 VXMD Exports of commodity I from region r to region s, valued at exporter's domestic price  
 VXWD Exports of commodity I from region r to region s, valued at FOB price  
 XTAX Tax revenues/Subsidy expenditures  
 D Demand for imports of commodity I supplied from region r by region s  
 S<sup>0,1</sup> Pretax/taxed net supply of commodity I from region r in region s, where:  

$$S(i,r) = QO(i,r) - \sum_{k \neq s} QXS(i,r,s) - VST(i,r)$$

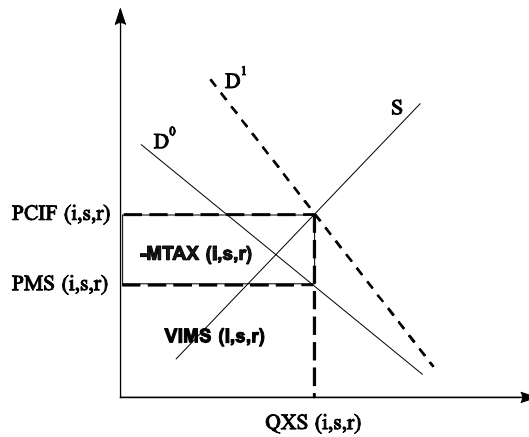
Figure 8: Import Subsidy or Tax in Region s on Purchases from Region r

### 8.1 Import Tax



$$VIMS(i,s,r) = VIWS(i,s,r) + MTAX(i,s,r)$$

### 8.2 Import Subsidy



$$VIMS(i,s,r) = VIWS(i,s,r) + MTAX(i,s,r)$$

- PMS Importer's domestic price of commodity i supplied from region s to region r  
 PCIF CIF price of commodity i supplied from region s to region r  
 QXS Exports of commodity i from region s to region r  
 VIMS Imports of commodity i from region s to region r, valued at importer's domestic price  
 VIWS Imports of commodity i from region s to region r, valued at CIF price  
 MTAX Tax revenues/Subsidy expenditures  
 $D^{0,1}$  Pretax/taxed demand for differentiated imports of commodity i from region s in region r  
 S Net supply of commodity I from region s in region r, where:

$$S(i,r) = QO(i,r) - \sum_{k \neq s} QXS(i,r,s) - VST(i,r)$$

Given the price linkage relationship  $PMS = PCIF / TMS$ , the import tax revenues can be computed as follows:

$$MTAX(i,s,r) = VIMS(i,s,r) - VIWS(i,s,r)$$

These import taxes are paid by the purchaser of commodity  $i$  (private household, government and firms) in region  $r$ . Since tax revenues always accrue to the regional household these import taxes are included in the *TAXES* flowing from the private household, the government and the producers to the regional household in region  $r$  (figure 6).

Finally, figure 8.2 demonstrates the situation which results in the presence of an import subsidy. Here, the *cif* price of commodity  $i$  supplied from region  $s$  to region  $r$  exceeds the importer's domestic price. Accordingly, the power of the ad valorem import tax is smaller than one, and *MTAX* calculated as the difference between *VIMS* and *VIWS* is an expenditure that is withdrawn from the regional household. In figure 6, import subsidy expenditures are embodied in the *TAXES* flowing from the regional household to all purchases of imported commodity  $i$ . Since this value flow is the last one to be considered, it also completes the overview of the basic structure of GTAP. Readers wishing to continue their introduction to the GTAP model are referred to chapter 2 of the GTAP book (HERTEL, ed.)

## *References*

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