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GTAP Technical Paper No. 6

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Abstract

This technical paper documents one approach to incorporating monopolistic competition into the GTAP model. In this framework, consumer preferences are heterogeneous, leading to an apparent "love of variety" in the aggregate utility function for each region. The more heterogeneous are preferences, the smaller the elasticity of substitution in the aggregate utility function, and the greater the value placed on the addition of new varieties. The same is true for firms, which experience lower unit costs for differentiated, intermediate inputs, as the number of varieties on offer increases. In order to meet the diverse needs of consumers, and firms, producers differentiate their products through research and development (R&D) as well as advertising activities. These costs are assumed to be invariant to the total volume of sales for a given variety of product. With production occurring at constant returns to scale, this gives rise to declining average total costs. A zero profits equilibrium in this model is characterized by firms marking up their price over marginal costs by an amount sufficient to cover the fixed costs associated with establishing a new variety in the marketplace. Since the optimal markup is itself determined by the elasticity of substitution among varieties, this establishes a direct relationship between fixed costs and the degree of preference heterogeneity.

The main differences between the monopolistically competitive sectors and the traditional GTAP sectors may be summarized as follows:

—   Two new variables are introduced. n, the number of firms, and qof, output per firm.
—   Minimum expenditure and unit costs are declining in n.
—   Average total costs are declining in output per firm.

— Unlike the nested Armington specification, foreign and domestic firms compete directly in the representative consumer's utility function.

We illustrate this framework with a 2 commodity/3 region example in which we eliminate US antidumping duties on the import of Japanese manufactured goods. This example demonstrates the role of changing varieties in determining aggregate utility. It also highlights the importance of the monopolistically competitive cost structure in determining the equilibrium change in output per firm. A comparison with the standard, perfectly competitive GTAP model is also provided.

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Introducing Monopolistic Competition into the GTAP Model

1. Introduction

1.1 Background

Applied general equilibrium (AGE) models are ever more widely used in economic policy analyses. Major clients of these modeling efforts are policy makers dealing with issues of multilateral liberalization of international trade, regional integration of economies and the consequent implications for energy and environmental standards. Examples include the recently concluded Uruguay Round of GATT negotiations and the North American Free Trade (NAFTA) agreement. Simulations using AGE models have provided a vital input into these negotiations. However, the suppliers of this critical input are not homogeneous. Applied economists have used different model structures with very different underlying assumptions, different data sets, and various base years.

By way of example, of the five quantitative assessments of the Uruguay Round Agreement represented in the World Bank's recent conference on this topic (MARTIN and WINTERS), three different data bases were used. Analyses using the OECD's RUNS model (Goldin and VAN DER MENSBRUGGHE), and the University of Michigan model (BROWN *et al.*), both use their own data bases, while the other three studies (FRANCOIS *et al.* 1995, HARRISON *et al.*, and HERTEL *et al.*) all use the Global Trade Analysis Project (GTAP) data base. Given the tremendous effort involved in developing and maintaining a global data base, it appears likely that most such studies will gradually converge on a common data base, thereby eliminating this source of difference (the OECD has already begun to use the GTAP data base). However, there remains tremendous scope for differences in the treatment of economic behavior in these AGE models. The three GTAP-based studies cited above consider a variety of different assumptions regarding the treatment of investment as well as the nature of firm behavior. It is important that users of the GTAP data base have access to these alternative closures and behavioral assumptions, so that they can choose which is most appropriate for the problem which they seek to address. This is one of the primary goals of the GTAP technical paper series. FRANCOIs *et al.* (1996) have provided a GTAP technical on the macro closure (investment) issue. The purpose of this technical paper is to introduce GTAP users to a framework which permits them to treat selected sectors in the model as monopolistically competitive.

The standard implementation of the GTAP model assumes perfect competition in all industries. Hertel and Tsigas clearly recognize the need for a GTAP model with imperfect competition and endogenous product differentiation:

> "In sum, while we are not particularly happy with the Armington specification, it does permit us to explain cross-hauling of similar products and to track bilateral trade flows. We believe that, in many sectors, an imperfect competition/endogenous product differentiation approach would be preferable. ... Clearly this is an important area for future work."

1.2 *Motivation*

A casual look at a modern market economy is sufficient to conclude that consumption and production are complex phenomena for the decision-makers involved. On any given visit to the supermarket, the typical consumer[1] wanting to buy, say a video camera, is confronted with a myriad of products to choose from. Note that the decision to buy *a* camera has already been made[2], which is reflected from the kind of retail store or department within a super market the consumer has chosen. However, the actual type of camera chosen depends on the consumer's preferences.

With millions of consumers, it is natural to expect preferences to be rather diverse. Firms respond to this diversity by producing differentiated products of the same good. When viewed as an aggregate grouping, this is often termed a *love of variety*, even though each individual only purchases a single type of camera. Firms in the camera industry thus have an incentive to incur fixed costs related to R & D and marketing, in order to establish their product as differentiated -- in the eyes of the consumer. The existence of this fixed cost makes the market for this product imperfectly competitive on two counts: firms cannot adopt marginal cost pricing, and they do not produce a homogeneous good; both deviations from the perfectly competitive behavior. Assuming that production occurs at constant returns to scale, then firms experience *increasing returns to scale* in sales.

One of the important properties of this type of a market is that the share of total costs devoted to R & D and marketing activities will be directly related to the degree of preference heterogeneity. The more diverse are individual consumers, the greater the demand for variety, and the greater the scope

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1 The typical consumer differs from the idiosyncratic consumer, in that the former is likely to make different choices at different times, while the latter is loyal to the product they consume.

2 We distinguish between levels of decision-making and the implications for industry competition. The decision whether or not to buy a camera is made at a previous stage or higher level of decision-making. At this higher level, the group of firms in the camera industry compete with firms from a different industry, which is *inter-industry competition*. Once the decision to buy a camera has been made, the competition is among the firms within the camera industry, which is *intra-industry competition*.

for marking up the price of the differentiated product. It is this markup over marginal cost which allows firms to recoup the fixed costs associated with their marketing and R & D activities. Of course, in the extreme case where preferences are completely homogeneous, there is no reason to differentiate your product and the model collapses to one of homogeneous products/perfect competition.

While this theory is largely developed in the context of consumer preferences, the subsequent "love of variety" is also observed among firms, leading Ethier to apply the same approach to intermediate inputs. Since a large share of international trade is in intermediate goods, this extension is potentially very important. Therefore, we treat ALL sales (both intermediate and final) in a symmetric manner with respect to product differentiation.

Having settled on this general approach to monopolistic competition, the questions that naturally follow are then - *which* are the industries (sectors) that are more appropriately modeled by a differentiated products approach? and *when* is it appropriate to do so? Clearly, the answers to these are context-specific and we only make an attempt at them.

The answer to the 'which' question follows. Since preferences are unobservable, a more practical approach would be to go by the characteristics of the industries being modeled. This requires *both* a good knowledge of the industry and the availability of good data to support quantification. We propose to focus on industries where significant attempts at product differentiation are evidenced in high advertising and/or R & D expenditures. This suggests including industries producing processed foods, beverages, textiles, wearing apparel, automobiles, electricals, electronics, and other durables but not including primary industries producing chiefly homogenous intermediate inputs such as primary agriculture, natural resources, mining, and primary metals.

The answer to the 'when' question depends on the objective of the user. If the exercise is to address issues such as efficiency gains, inter- and intra-industry trade patterns, impacts of economic integration on the integrating countries, then a monopolistically competitive approach is superior, if only because it offers the user a wider spectrum of possibilities. Also it captures two important issues: the effects of variety on consumer utility and on potential scale economics. In a policy scenario, these have an important bearing on welfare and resource allocation matters. It is thus critical to embed this diversity in consumer preferences and examine its implications for trade policy effects.

This paper is laid out in the following manner. The next section explains the theoretical foundations for monopolistic competition. Section 3 reviews some of the existing applied trade models with imperfect competition and shows the link with our modeling efforts here. The structure of the

Monopolistically Competitive GTAP model, GTAPMC, is laid out in section 4. (The GEMPACK[3] code for the model implementation, GTAPMC.TAB, is presented in the Appendix.) Section 5 outlines the data requirements for introducing monopolistic competition into the GTAP model. Section 6 contains a simple example designed to illustrate a policy application using the monopolistically competitive GTAP model. This is followed by our summary and conclusions.

2. *Theoretical Foundations for Monopolistic Competition*

The theoretical literature on imperfect competition is characterized by a myriad of models, ranging from monopoly, to oligopoly, to monopolistic competition. Recent advances in industrial organization theory have proliferated the number of oligopoly models. Theoretically elegant and mathematically complex, these models are difficult to operationalize and are largely unsuitable for economy-wide AGE models, as they require information on the nature of strategic interaction between firms in the imperfectly competitive industry which is simply not available at the level of aggregation in most AGE models.

Chamberlin's monopolistic competition has been widely used in AGE models. What makes this market structure appealing, is the large group assumption which permits us to abstract from inter-firm rivalry. The variant of the Chamberlinian model which we use was first formulated by Spence, and Dixit and Stiglitz. They use a *representative consumer* as a simplifying construct whose utility embodies the preferences of the aggregate population of consumers. The utility of the representative consumer is defined over all existing (and potential) products. The representative consumer purchases some of *every* product available and is therefore at an interior solution. In these theoretical studies, preferences of the representative consumer are *symmetric,* that is no product can be ranked over another product, based on price. This form of product differentiation is known as the *non-address* approach since there is no notion of the most preferred or less preferred product.

There are two important criticisms of this approach to modeling heterogeneous preferences. First of all, individual consumers tend to buy only one, or at most a few, of the differentiated products offered. In the camera example alluded to earlier, an individual consumer buys only one camera and is at a corner solution for all of the other camera products available. Is the representative consumer a valid aggregate description of the underlying population of heterogeneous consumers characterized by discrete choices made by the individual? How are we to interpret this "love of variety"? What

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3. GEMPACK is the software suite used to implement the GTAP modeling framework. The equations in the model are written in algebraic form and read in the form of a TABLO code file as input to the program.

preference characteristics determine the all-important elasticity of substitution among varieties? In order to answer these questions, we draw on theoretical work by Anderson, de Palma, and Thisse.

Anderson *et al.* begin with a specific utility function for individual consumers in the economy. This utility function includes a quadratic penalty term for departures from the consumer's ideal variety. The authors then make the assumption that preferences in the population at large can be represented with the multinomial logit distribution function. In this case, the standard deviation associated with consumers' ideal variety is given by the parameter μ When μ is large, then preferences are diverse, when it is small, then preferences are homogeneous. Anderson *et al.* also permit the consumer to vary the quantity of their ideal variety purchased. In particular, they adopt a specification of the utility function which implies a unitary elasticity of demand for the chosen variety. With these assumptions, Anderson *et al.* are able to derive the consequences for aggregate, sectoral behavior of the sort we are attempting to model here. Interestingly, they obtain the result that the aggregate demand relationship implied by this specification is of the Constant Elasticity of Substitution (CES) form, with the elasticity of substitution between different varieties equal to the inverse of μ. This provides us with a valuable interpretation of the CES demand function: the elasticity of substitution should be large in those cases where preferences are homogeneous, and small in those cases where preferences for the products in question are heterogeneous.

The second problem with the Spence-Dixit-Stiglitz approach to modeling preferences has to do with the symmetry assumption. In practice, market shares of firms supplying differentiated products vary in ways which this simple, aggregate representation of preferences cannot explain. From the point of view of international trade, the most striking illustration of this point is the predominance of domestic firms in consumer's consumption bundles. For example, in the GTAP framework, even after complete elimination of border distortions, domestic sales are still predominant in almost all regions (HERTEL and MCCORRISTON).

Venables has explored the theoretical implications of this preference for domestic varieties in a model of monopolistic competition. He shows that this asymmetry translates into additional welfare losses when protection for differentiated products is cut and some domestic firms/varieties exit from the industry. Thus, in order to make an accurate assessment of the welfare effects of trade policy, it is important to take account of asymmetries in preferences. (There is also a practical motivation for introducing these preference biases, since it is impossible to calibrate the model to observed data in their absence!)

3. *Applied GE Models with Imperfect Competition*

In the last ten years, many AGE models have introduced imperfect competition, economies of scale, and product differentiation. Harris is credited as being the pioneer in this effort. He implemented versions of imperfectly competitive models with and without product differentiation for Canada, a *small open economy*. Norman argues that the presence of imperfect competition has significant implications for inter-industry trade patterns and welfare effects of trade liberalization. He goes on to show that the Armington product differentiation, used to explain intra-industry trade in perfectly competitive AGE models, does a bad job in explaining the inter-industry trade patterns and welfare effects of trade policy in the presence of imperfect competition.

Abayasiri-Silva and Horridge have adopted a Harris-type implementation for Australia, assuming monopolistic competition for all sectors. However both models have assumed *competitive foreign product differentiation* for the behavior of the imperfectly competitive sectors in the residual rest of world, though recognizing the need for modeling foreign importers. Moreover, the former study treats *all* sectors as monopolistically competitive for purposes of comparing different assumptions on technology and pricing on model results. Harris treated 20 of the 29 industries as imperfectly competitive.

A number of recent studies of the Uruguay Round have employed model variants with imperfect competition. The main purpose of these studies was to compare the welfare gains using the model with increasing returns to scale (IRTS) with the constant returns to scale model. Harrison *et al.* reported *relatively small increases in global welfare* of only 3% due to incorporating scale economies internal to the firm. In order to make a pure comparison between the two model variants, they retain the Armington nesting structure, but introduce an additional level of nesting for all regions at the bottom level in the IRTS model. Thus, there are no benefits due to additional varieties.

The values of the cost disadvantage ratio (CDR), otherwise known as markups, are important for the results generated by Harrison, *et al*. Of the 13 industries that are modeled with firm level economies out of a total of 22, the CDR ranges from a low of 3% for minerals and energy sectors to a high of 13% for processed rice. The small increases in welfare are attributed to these two factors - relatively low CDRs and maintaining a strict IRTS regime in the imperfect competition model. (It is not clear how they have chosen to treat the composition of fixed costs, since in a pure IRTS model with a standard markup pricing equation, this might have a key role to play.)

Harrison *et al*. choose their treatment of monopolistic competition in order to facilitate easy comparison with existing, perfect competition, Armington-based analyses of the Uruguay Round. This is useful in terms of understanding what these studies might be missing, but it may not be the best way to construct a model based on the theory of monopolistic competition. We observe this tension between maintaining consistency with earlier studies, and implementing a new theory, in a number

of other studies.[4] In the approach outlined below, we have opted for a sharper break with the Armington-based models, such as GTAP.

FRANCOIS *et al.*(1995) provide a critical review of a number of alternative approaches to modeling the impact of the Uruguay Round, analyzing the effects of theoretical and data structure on model outcomes. Thirteen of the nineteen sectors are modeled as monopolistically competitive, with CDRs ranging from a low of 8% in the mining industry to a high of 15% in the processed food, chemicals, transport equipment and machinery industries. In their assessment of the Round, FRANCOIS *et al.* use two variants of monopolistic competition - the non-nested (global) monopolistic competition, where firms from different regions compete directly and the nested (regional or national) monopolistic competition where firms in each region compete with those in other regions according to an Armington specification. The non-nested specification yields greater welfare effects than the nested version.

Hertel and Lanclos emphasize the importance of changes in the cost structure of monopolistically competitive firms (see also LANCLOS and HERTEL). They point out that when tariffs are cut on intermediate inputs, there is a tendency for average variable costs to fall, relative to scale-constant, average total costs. When production is subject to constant returns to scale, average variable costs equal marginal costs. With a constant markup, the change in marginal cost dictates price. Yet for zero profits to apply, price must also equal average total cost. Therefore, in order to simultaneously satisfy the markup pricing and zero profit conditions, output per firm must increase, thereby permitting average variable costs and average total costs to move in concert. In their analysis of trade liberalization, they find that these cost-driven changes in output per firm account for the majority of the welfare gains attributable to the monopolistic competition formulation.

Modeling the production structure of the imperfectly competitive industries is a rich area offering a number of modeling choices in terms of the following issues: Are all or only a few sectors monopolistically competitive? Is the sector characterized by only scale economies or both scale economies and love of variety? What is the structure of nesting in the monopolistically competitive sectors? Is the product differentiation firm-based or firm-based and national? What is the nature of the markup pricing equations? What is the composition of the fixed costs? And finally, are both inputs and outputs differentiated?

Further progress in the application of this theory will hinge on finding appropriate answers to each of the questions for the particular industry under consideration.

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4. We find it useful to model a plausible monopolistically competitive model and then proceed to make a perfectly competitive variant of this to allow for a straight forward comparison between the two. We do this by eliminating the variety effect on utility/cost functions as well as the scale effect. The former is achieved by rewriting the derived demand equations to resemble the perfectly competitive model and the latter by fixing the output per firm.

4. *Structure of the Monopolistically Competitive GTAP Model, GTAPMC*

This section provides a detailed description of the monopolistically competitive structure underlying the model. We refer to version 2.2a of the GTAP model (GTAP94.TAB) as the standard model, which is characterized by perfectly competitive industries. We build on the standard model and therefore assume a fair amount of familiarity with its structure on part of the user. This allows us to focus on features that have been added and on those that have been modified. The changes to notation, to accommodate the new data and model features, have been kept to a minimum.

Adopting the Chamberlinian theory of monopolistic competition introduces two new concepts to the model - economies of scale and differentiated products. Modeling these involve substantive modifications to the behavioral assumptions made for all agents in the economy - firms in the different industries, private household, and government.

4.1 Demand Structure

We retain the Cobb-Douglas functional form for the regional household's utility function and the government's utility function as well as the Constant Difference Elasticity of substitution (CDE) utility structure of the private household. The sub-utility function for composite commodities is the most appropriate level in the utility tree to incorporate the differentiated products.

Before we describe the specification of the agent-specific demand functions, some discussion on the treatment of "foreign" versus "domestic" commodities is warranted. In the *standard model*, homogeneous commodities are produced by perfectly competitive industries in each region. Due to the Armington assumption, an *ad hoc* product differentiation scheme is made possible based on the geographical origin of the homogeneous commodity (national product differentiation).

The same physical commodity produced in different regions are imperfect substitutes in the demand for a composite imported commodity. The quantity index resulting from the consumption/usage of imports from different sources is termed the composite import. In turn, the composite import, devoid of its geographical origins, imperfectly substitutes for the domestically produced commodity. Thus, sourced imports do not directly compete with the domestic commodity. Also, imports are not sourced directly to the agents. The composite import commodity, formed at the border, is demanded by all the agents in the economy.

When firms within the same region produce differentiated products, the geographic origin of a product becomes an issue of lesser importance. In fact, the characteristics of the product that

differentiate it from another product produced in the *same* region is what is striking. Consumers are often unaware of where a product originates, though they are aware of the 'brand name'. In many instances, even if the educated consumer cares about the geographic origin of the commodity they are buying, there is no distinct national identity for a vast number of cases. Individual components are often sourced from many different countries, and the site of assembly for a given product may change from one year to the next.

Consider the case of a personal computer - with the mouse made in Malaysia, the keyboard assembled in Mexico using USA-made components, the monitor made in Taiwan, and the Intel chip itself made in the USA. One is hard put to identify the national origin of such a good! Rather, a consumer finds herself choosing between a Compaq, a Dell, or a Packard Bell personal computer. This is also the case with textiles and clothing, software products, processed foods, pharmaceuticals, and the list goes on. Therefore, in our opinion, it makes little sense to leave the import-domestic distinction for monopolistically competitive industries producing differentiated products. We thus let imported varieties compete directly with domestic varieties in a non-nested fashion.

This has many implications. *First*, we cannot afford to lose the geographic origin of the imported product at the border because this corresponds to a particular set of firms in the exporting region. If thenumber of firms in this region increases, sot too will the varietal index associated with that flow. We must retain the origin of the foreign product until we source it to the agent. We must *source imports to agents* just as we source domestic products to the various agents in the economy. This involves a fundamental change in data structure. We explain in the data requirements section the procedure used to obtain this new structure from the standard GTAP data base.

One important aspect of this new structure is reflected in the price linkages. The modified price linkages, due to the sourcing of imports by agents, are defined for *all* tradeable commodities and shown in figure 1. The price linkages relating to the endowment commodities remain the same as in the standard model. Note that the price definitions do not discriminate between domestic prices or import prices. For example, *PPS(i,r,s)*, the private household price for the sourced commodity, in GTAPMC, replaces *PPD(i,r)* - private household price for domestics and *PPM(i,r)* - private household price for composite imports, in the standard model. The market price of commodity i in region r, *PM(i,r)*, would thus equal *PPS(i,r,s)*, for $r = s$, when r is a single country region, and tax on private household demand is zero.[5] Similarly, *PGS(i,r,s)* and *PFS(i,r,j,s)* replace *PGD(i,r)* and *PGM(i,r)* and *PFD(i,j,r)* and *PFM(i,j,s)* respectively. It is useful to introduce the modified price-quantity-value notation here. Figure 2 tracks the disposition of sales, indicating the associated price concepts and the corresponding value flows.

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5. This equality between *PM(i,r)* and *PPS(i,r,s)* may not hold for intra-regional sales when r is a composite region. The data requirements section contains more discussion on this.

The *second*, and more serious implication, is a very practical one in terms of modeling. Sourcing of imports has introduced *an extra dimension* into the demands of all agents, as evidenced from the price concepts discussed above. The extra dimensionality causes a dramatic increase in model size[6] - the number of variables to be solved for and the number of equations to determine them - as the number of regions increases.

We first explain the modifications made to the private household utility/expenditure structure. We will then briefly explain changes made to the specification of government demand and intermediate input demands by industries.

4.1.1 Private Household Utility

In the representative consumer approach, an aggregate utility function is used to represent the consumption of all varieties[7]. To capture the effect of variety on utility, the average consumer's utility is defined over the quantities of the different varieties consumed *and* the total number of varieties consumed. The sub-utility function in the levels[8] is thus given by,

$$Y_{i,s} = \text{sum}\{r, N_{i,r} * Q_{i,r,s}^{(\sigma(i)-1)/\sigma(i)}\}^{\sigma(i)/(\sigma(i-1))} \tag{1}$$

where, $Y_{i,s}$ is the sub-utility derived by the representative consumer in region *s* from the consumption of commodity *i*, $Q_{i,r,s}$ is the quantity consumed by the representative consumer in region *s* of *a representative product* of commodity *i* produced in region *r*, $N_{i,r}$ is the number of varieties of *i* produced in *r*, and $\sigma(i) > 1$ is the positive, constant elasticity of substitution between the differentiated products of *i*. To relate to the bilateral trade data among regions, we assume that all firms in any given region, *r*,

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6. The data requirements section gives some hints on how model size may be reduced before attempting to solve it.

7. Varieties and products are used interchangeably.

8. For purposes of clarity, we derive new or modified equations using generic notation in the 'Demand' sub- section. The generic notation is applicable to all agents. We begin the derivation from the levels form. In the final step of the derivation, we translate the generic notation to agent-specific, GTAP notation and write it in linearized form as found in the implementation of the TAB file.

Figure 1. Price Linkages, i ∈ TRAD_COMM, r,s ∈ REG

```
                       PS(i,r)                          : Producer Price
                         |
                         |
                         |
                         |      TO(i,r)                  : Output Tax
                         |
                         |
                         |
                       PM(i,r)                          : Market Price
                         |
                         |
                         |
                         |      TXS(i,r,s)               : Export Tax
                         |
                         |
                         |
                       PFOB(i,r,s)                      : World Price of Exports
                         |
                         |
                         |
                         |      PT                       : Transport Margin
                         |
                         |
                         |
                       PCIF(i,r,s)                      : World Price of Imports
                         |
                         |
                         |
                         |      TMS(i,r,s)               : Import Tax
                         |
                         |
                         |
                       PMS(i,r,s)                       : Market Price of Imports
                        / |   \
                       /  |    \
                      /   |     \
  TGS(i,r,s)         /    |      \   TPS(i,r,s)
                    /     |       \
  Tax on           /      |        \        Tax on Private
  Govt Demand     /       |         \       Household Demand
                 /        |          \
                /         |           \
               /          |            \
              /           |             \
          PGS(i,r,s)      |          PPS(i,r,s)
                          |
     Government Price     |          Private Household Price
                          |
                          |    TFS(i,r,j,s)
                          |
                          |    Tax on Firms' Demand
                          |
                          |
                       PFS(i,r,j,s)


                       Firms' Price
```

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Figure 2.   Disposition of Sales, i ∈ TRAD_COMM, r, s ∈ REG

```
              Quantity              *      Price              =      Value
             ~~~~~~~~                      ~~~~~                      ~~~~~
         QO(i,r)               *     PM(i,r)              =      VOM(i,r)
        /|\
       / | \
      /  |  \
         |
         |
         |
         QS(i,r,s)             *     PM(i,r)              =      VSMD(i,r,s)
         |
         |
         |
         |                           [TXS(i,r,s)]
         |
         |
         |
         QS(i,r,s)             *     PFOB(i,r,s)          =      VSWD(i,r,s)
         |
         |
         |
         |                           [PT]
         |
         |
         |
         QS(i,r,s)             *     PCIF(i,r,s)          =      VDWS(i,r,s)
         |
         |
         |
         |                           [TMS(i,r,s)]
         |
         |
         |
         QS(i,r,s)             *     PMS(i,r,s)           =      VDMS(i,r,s)
        /    |    \
       /     |     \
      /      |      \
     /       |       \
    /        |        \
 QGS(i,r,s)  |     QPS(i,r,s)
             |
 *           |     *
             |
 PPS(i,r,s)  |     PGS(i,r,s)
             |
 =           |     =
             |
 VPAS(i,r,s) |     VGAS(i,r,s)
             |
             |
         QFS(i,r,j,s)
         *
         PFS(i,r,j,s)
         =
         VFAS(i,r,j,s)
```

12
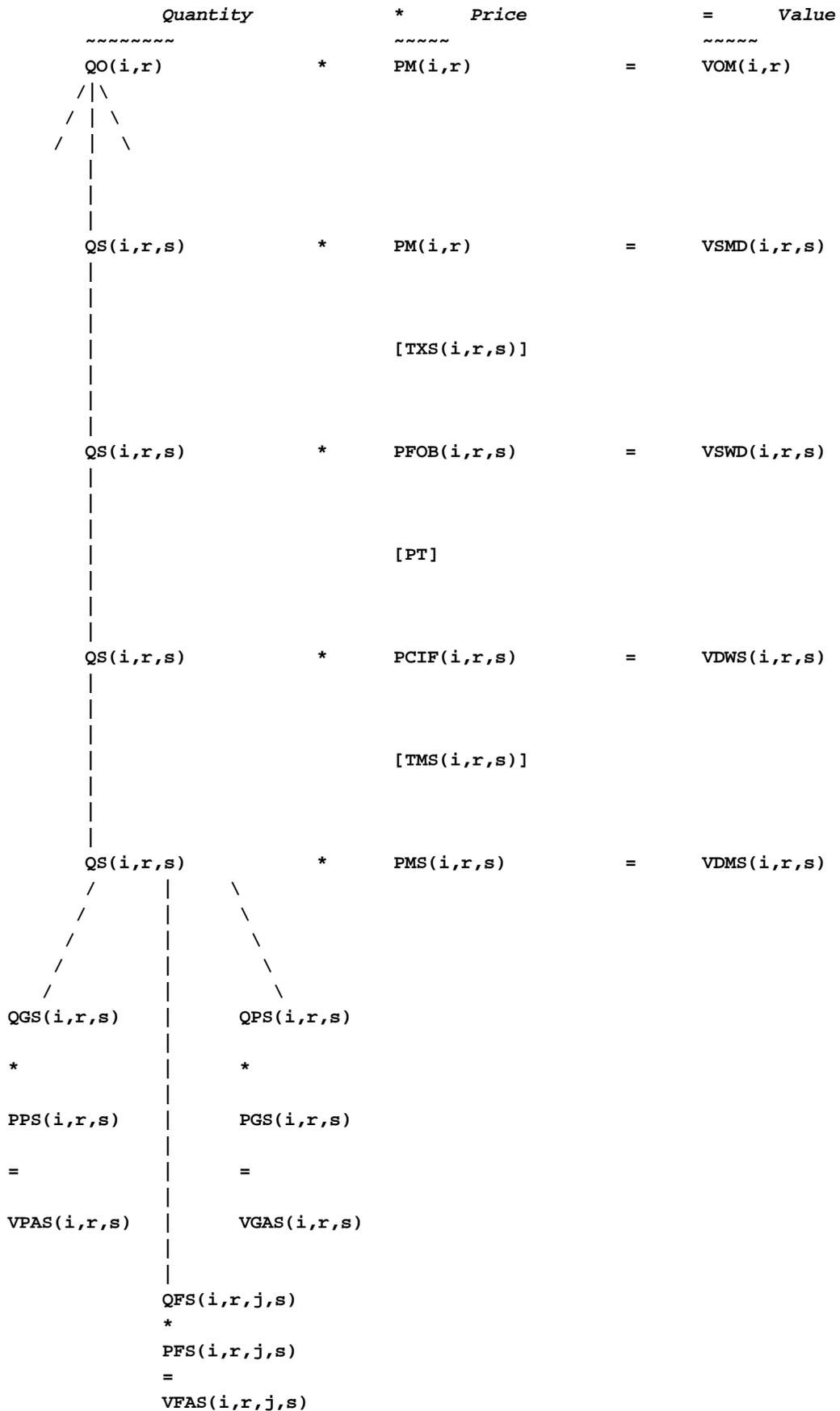
charge the same price, and furthermore, *that firms are active in any region s, where sales from r appear.*

Maximizing the sub-utility subject to the budget constraint yields the *derived demand for a product of i* from source *r*,

$$Q_{i,r,s} = Y_{i,s} / [\ P_{i,r,s} / Z_{i,s}\ ]^{\sigma(i)} \tag{2}$$

where, $Z_{i,s}$, the expenditure spent on all varieties of commodity *i* in *s*, is given by

$$Z_{i,s} = \text{sum}\{r,\ N_{i,r} * P_{i,r,s}^{(1-\sigma(i))}\}^{(1/1-\sigma(i))} \tag{3}$$

and $P_{i,r,s}$ is the unit price of *a product* of *i* in *s* sourced from *r*.

Equation (2) must be modified so as to define the aggregate derived demand for differentiated products originating from source *r*. Lacking information on the number, size, composition, and sales data of firms in the monopolistically competitive industry, we are forced to impose symmetry here. Total derived demand for all products of *i* sourced from *r* is thus given by

$$Q_{i,r,s} * N_{i,r} = N_{i,r} * Y_{i,s} / [\ P_{i,r,s} / Z_{i,s}\ ]^{\sigma(i)} \tag{4}$$

Totally differentiating the aggregate derived demand function given in (4) we have,[9]

$$q_{i,r,s} + n_{i,r} = n_{i,r} + y_{i,s} - \sigma(i) * [\ p_{i,r,s} - z_{i,s}\ ] \tag{4'}$$

(4') is the linearized representation of the aggregate derived demand equation in generic notation. To derive the linearized representation of the price index equation, we begin by totally differentiating (3),

$$z_{i,s} = \text{sum}\{r,\ \theta_{i,r,s} * p_{i,r,s}\} - [1 / [\sigma(i) - 1]] * \text{sum}\{r,\ \theta_{i,r,s} * n_{i,r}\} \tag{3'}$$

where $\theta_{i,r,s}$, the expenditure share of all varieties of commodity *i* originating from source *r* in total expenditure on all varieties from all sources, in region *s*, is given by

$$\theta_{i,r,s} = N_{i,r} * [P_{i,r,s} / Z_{i,s}\ ]^{(1-\sigma(i))} \tag{5}$$

The expenditure shares, $\theta_{i,r,s}$, can be expressed in an alternative manner that is more transparent. Rewriting (2),

$$Q_{i,r,s} / Y_{i,s} = [\ P_{i,r,s} / Z_{i,s}\ ]^{-\sigma(i)}$$

Multiplying both sides by the ratio of $P_{i,r,s}$ to $Z_{i,s}$,

$$[\ Q_{i,r,s} / Y_{i,s}\ ]*[\ P_{i,r,s} / Z_{i,s}\ ] = [\ P_{i,r,s} / Z_{i,s}\ ]^{-\sigma(i)} * [\ P_{i,r,s} / Z_{i,s}\ ]$$

---

9. Lower case letters denote percentage changes in the corresponding upper case variables. Thus, $x = [\ dX/X\ ]*100$ gives the percentage change in *X*.

Rearranging terms,

$$[Q_{i,r,s} * P_{i,r,s}] / [Y_{i,s} * Z_{i,s}] = [P_{i,r,s} / Z_{i,s}]^{(1-\sigma(i))}$$

Multiplying both sides by $N_{i,r}$,

$$N_{i,r} * [Q_{i,r,s} * P_{i,r,s}] / [Y_{i,s} * Z_{i,s}] = N_{i,r} * [P_{i,r,s} / Z_{i,s}]^{(1-\sigma(i))}$$

$$\theta_{i,r,s} = [N_{i,r} * Q_{i,r,s} * P_{i,r,s}] / [Y_{i,s} * Z_{i,s}] \tag{6}$$

We can thus express $\theta_{i,r,s}$ in terms of the data base, where the numerator is the expenditure on *all* varieties of *i* originating from source *r*, and the denominator is the aggregate expenditure on *i* in region *s* (total expenditure on all varieties of *i* originating from all sources consumed/used). The actual computation of $\theta_{i,r,s}$ for the different agents is as follows (see also figure 2):

Private Household:

```
PTHETA(i,r,s)          = VPAS(i,r,s)/sum{t,REG, VPAS(i,t,s)}
```

Government:
```
GTHETA(i,r,s)          = VGAS(i,r,s)/sum{t,REG, VGAS(i,t,s)}
```
Firms in industry j:

```
FTHETA(i,r,j,s)        = VFAS(i,r,j,s)/sum{t,REG, VFAS(i,t,j,s)}
```

VPAS(i,r,s) is the **V**alue of **P**rivate household expenditure in region *s*, at **A**gents' prices by **S**ource. Note that *VPAS(i,r,s)* gives the total expenditure on all products of *i* originating from *r*, but no breakdown per product per region is available. From (1), it can be seen that the effect of additional variety on utility is positive. As the number of varieties of a differentiated commodity increases, the sub-utility derived from their consumption increases, even if the quantity consumed remains the same. Also from (3), we see that additional variety has a negative effect on unit expenditure. At constant prices, an increase in the number of varieties lowers the amount of expenditure necessary to attain a unit of utility.

The linearized forms of the derived demand and price index equations now have to be related to the agent-specific equations in GTAPMC.TAB. The private household's demand for differentiated products of commodity *i* are given by a set of three linearized equations.

Private Household's Demand for Differentiated Products
The derived demand by the private household in region *s* for the differentiated products of commodity *i* sourced from *r*, *qdfps(i,r,s),* is determined by

```
EQUATION PHLDSRCDF

! Private HousehoLD demand for SouRCed DiFferentiated commodity !
(all,i,MCOMP_COMM)(all,r,REG)(all,s,REG)
```

```
qdfps(i,r,s) = qp(i,s) + n(i,r) - SIGMA(i) * [pps(i,r,s) - pp(i,s)] ;
```

Equation PHLDSRCDF relates to (4') above. *qdfps(i,r,s)* thus depends on the sub-utility derived by the private household in *s* from the consumption of differentiated products, *qp(i,s)*, number of products of *i* produced in *r*, *n(i,r)*, private household's price of the sourced differentiated product of *i* produced in *r*, *pps(i,r,s)*, and the unit expenditure of the private household in region *s* on commodity *i*, *pp(i,s)*.

Private Household's Composite Price Index for Differentiated Product

The composite price index for differentiated products facing the private household in region *s*, *pp(i,s)*, is computed by

```
EQUATION PHLDDFCOMPR

! Private HousehoLD PRice for DiFferentiated COMposite commodity.  !
(all,i,MCOMP_COMM)(all,s,REG)
pp(i,s) = sum{r,REG, PTHETA(i,r,s) * pps(i,r,s)} - {1/[SIGMA(i) - 1]} * vp(i,s)
```

Equation PHLDDFCOMPR relates to (3') above. *pp(i,s)* thus depends on the price to the private household in *s* for differentiated product *i* sourced from *r*, *pps(i,r,s)*, the number of varieties of *i* produced in *r*, *n(i,r)*, and the budget share of differentiated products from source *r* in the total expenditure on commodity *i*, *PTHETA(i,r,s)*.

Private Household Varietal Index for Differentiated Products

The private household's index measuring the availability of varieties of commodity *i*, *vp(i,s)*, is given by

```
EQUATION PHLDVARIN

! Private HousehoLD VARiety INdex.  !
(all,i,MCOMP_COMM)(all,s,REG)
vp(i,s) = sum{r,REG, PTHETA(i,r,s) * n(i,r)} ;
```

Equation PHLDVARIN shows that the varietal index rises with an increase in the number of varieties produced in a region or with an increase in the budget share of a region.

The utility structure for the consumption of differentiated products by the private household is shown in panel A of figure 3. The sub-utility derived from the consumption of commodity *i* by the private household in region *s*, *QP(i,s)*, is a function of the quantities demanded by the private household of differentiated products of *i* sourced from region *r*, *QDFPS(i,r,s)*, the number of differentiated products of *i* produced in *r*, *N(i,r)*, and the elasticity of substitution between differentiated products of *i*, *SIGMA(i)*. This substitution parameter is also the perceived demand elasticity of the firm producing the differentiated product. More about this parameter in the section on production structure.

Private Household's Derived Demand Undifferentiated Commodity

The derived demand by the private household in region *s* for the undifferentiated commodity *i* sourced from *r*, *qhmps(i,r,s),* is given by

```
EQUATION PHLDSRCPC
! Private HousehoLD demand for SouRCed Perfectly Competitive commodity !
(all,i,PCOMP_COMM)(all,r,REG)(all,s,REG)
  qhmps(i,r,s) = DELTA(r,s) * {qp(i,s) + ESUBD(i) * [pp(i,s) - pps(i,s,s)]}
               + [1 - DELTA(r,s)] * {qpm(i,s) + ESUBM(i)
               * [ppm(i,s) - pps(i,r,s)]} ;
```

Figure 3.A   Utility Structure, i ∈ MCOMP_COMM, r, s ∈ REG

```
                           QP(i,s)
                           / | \
                          /  |  \----------> SIGMA(i)
                         /   |   \
                        /    |    \
                       /     |     \
                      /      |      \
                     /       |       \
                    /        |        \
                   /         |         \
                  /          |          \
                 /           |           \
       QDFPS(i,r₁,s) QDFPS(i,s,s)   QDFPS(i,rₜ,s)    Demand for i sourced
            |             |             |              from r by private
            |             |             |              household in s
            |             |             |
            |             |             |
            |             |             |
            |             |             |
         N(i,r₁)        N(i,s)        N(i,rₜ)        Number of varietites
                                                     of i produced in r
```
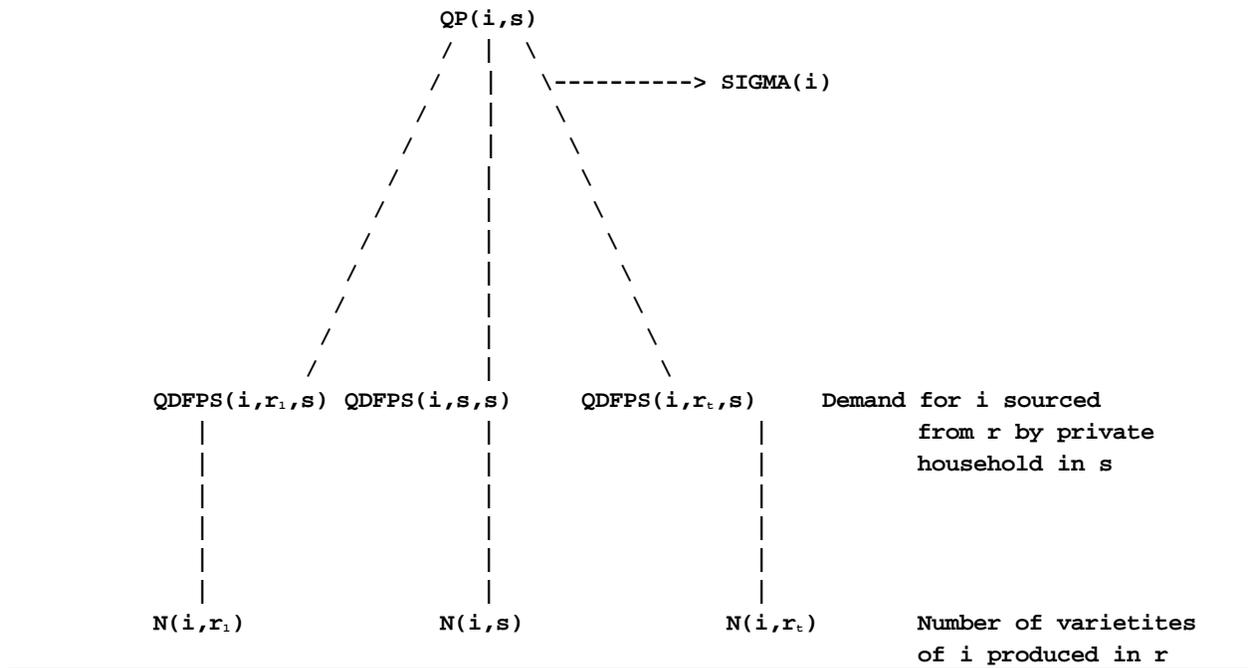
Figure 3.B   Utility Structure, i ∈ PCOMP_COMM, r, s ∈ REG

```
                              QP(i,s)
                              /    \
                             /      \--------> ESUBD(i)
                            /         \
                           /           \
                          /             \
                         /               \
                        /                 \
                       /                   \
                      /                     \
                     /                       \
                 QPM(i,s)                   QHMPS(i,s,s)    Demand for domestically
                 / | \                                     produced i by private
                /  |  \------> ESUBM(i)                     household in s
               /   |   \
              /    |    \
             /     |     \
            /      |      \
           /       |       \
          /        |        \
         /         |         \
    QHMPS(i,r₁,s)  QHMPS(i,r₂,s)  QHMPS(i,rₜ,s)     Demand for i sourced from r
                                                    by private household in s,
                                                    r ≠ s
```
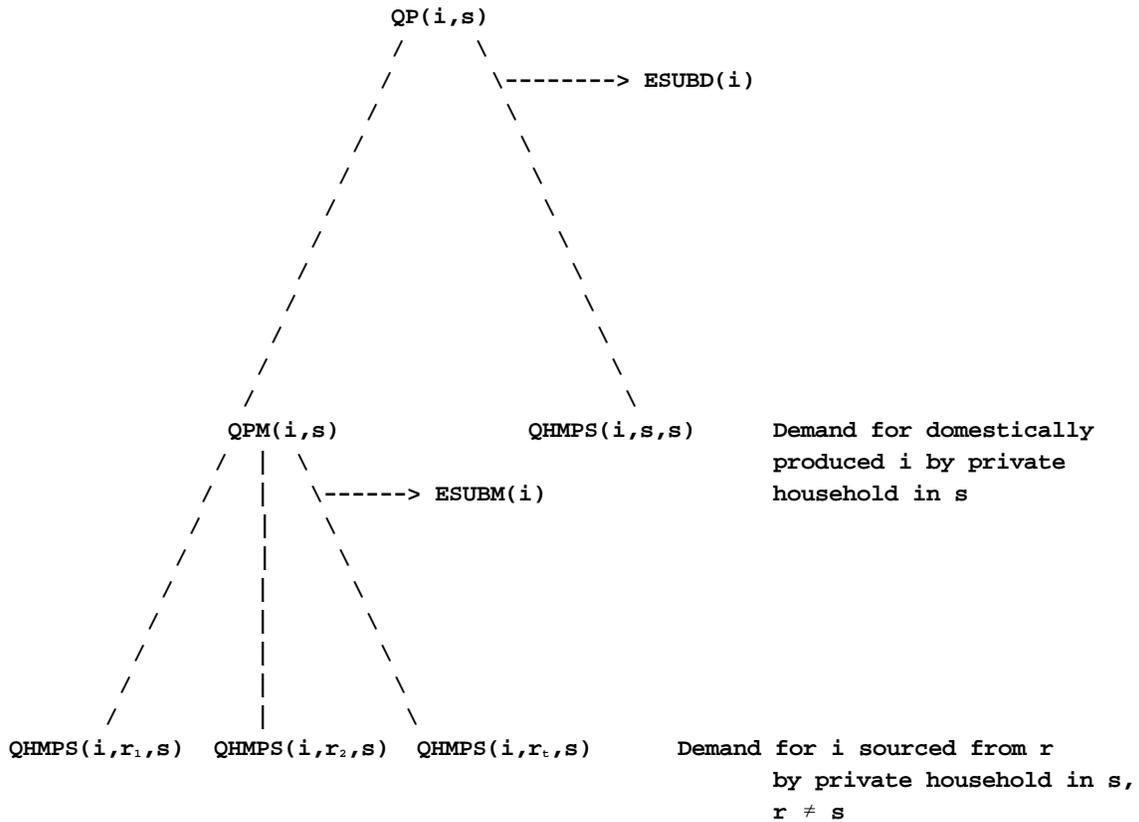
Equation PHLDSRCPC combines two different equations - IMPORTDEMAND(i,r,s) and PHHLDDOM(i,s) - in the standard model due to the sourcing of imports by agents and the consequent change in notation. This is made possible using the Kronecker delta, *DELTA(r,s) = 1* for *r = s*, and 0 otherwise, to specify *qhmps(i,r,s)*. The first term in this equation computes the derived demand for the commodity sourced from within the same region (which includes domestically produced commodity and intra-regional imports)[10], and the second term computes the derived demand for sourced imports of commodity *i*.

Panel B of figure 3 shows the utility structure for the consumption of undifferentiated products by the private household. The sub-utility structure retains the Armington nesting and the import-domestic distinction is also maintained. Note that the sourced imports are assembled into a composite import by each agent in the economy, here the private household.

---

10. The treatment of intra-regional imports and domestic sales is discussed in the data requirements section.

4.1.2 Government Utility

The derivation of government consumption equations is analogous to that for the private household. New equations - GOVSRCDF, GOVDFCOMPR, and GOVVARIN - are introduced to represent the demand for differentiated products analogous to the private household.

4.1.3 Intermediate Input Demands

Industry derived demand equations for intermediate inputs are four dimensional. The extra dimension for this agent indexes the industry making the input purchases. Firms also have heterogeneous needs. Production costs are lowered if the number of input varieties increases, at constant input prices. Considering the huge volume of trade in intermediate inputs, this approach is potentially important. Firms are thus treated symmetrically and the derivation of industry demand equations for intermediate inputs - INDSRCDF, INDDFCOMPR, and INDVARIN - is analogous to the derivation of the demand equations for the private household. The demand for sourced differentiated products of intermediate inputs in the production structure is shown in panel A of figure 4. Panel B in the same figure shows the demand for undifferentiated sourced intermediate inputs in the production structure. Note that it is the nature of the intermediate input that determines the specification of the derived demand equations regardless of the industry or agent demanding it.

4.2 Production Structure

The production structure characterizing the firms in the monopolistically competitive industry is discussed below. We assume that the modeler can specify *a priori* which industries are perfectly competitive and which are monopolistically competitive. The monopolistically competitive industry is characterized by scale economies internal to the firm and firms producing differentiated products. Products are said to be *differentiated* when they are imperfect substitutes in demand, although produced by firms within the same industry. A point to note here is that if an industry *j* is monopolistically competitive in a region *r*, then so it is in all other regions modeled. Again, due to the lack of data on firms' sales, we are forced to assume that firms producing differentiated products in any region are symmetric. This allows us to use industry level data, cost shares, quantities etc. to describe the behavior of the representative firm. The representative firm is thus a scaled down version of the industry as a whole. The firm specific concepts include output per firm and fixed costs. For convenience, we will use the notation used in the model in deriving the markup, cost, and firm output equations.

4.2.1 Firms and Varieties

A firm producing in the monopolistically competitive industry incurs fixed costs to produce a differentiated product. It is appealing to treat the fixed component of costs as arising due to research and development expenditures incurred by the firm to produce a new product as well as marketing and advertisement costs incurred on artificially differentiating an otherwise homogeneous product. There is a one-to-one mapping between varieties and firms. Due to this simplifying assumption, the

number of varieties produced is equal to the number of firms in the industry. This falls out of our assumptions that (a) each firm produces only one product (the complexity of the model and calibration procedures is vastly increased if we have firms producing multiple varieties necessitating a different pricing rule for each variety) (SMITH and VENABLES), and (b) any given product is produced by no more than one firm (a firm about to enter the industry would always do better by producing a new product rather than duplicating an existing one). The key thing to note here is that firms producing differentiated products are trying to capture a "niche" in the product space.

4.2.2 Fixed Costs, Markups and Output per Firm

Firms seeking to enter the monopolistically competitive industry require a set of fixed inputs comprising marketing and R&D outlays. In addition, variable inputs are reqiored to produce the differentiated product. Variable inputs are combined according to a constant returns to scale technology. Average variable cost, AVC, is thus equal to the *constant* marginal costof production, MC. Economies of scale (increasing returns to scale) in sales result due to the fixed component of total costs which is itself unaffected by production level. With free entry, unit output price, P, is equal to the total unit cost of production or the average total cost, ATC.

$$P = ATC = AVC + AFC \tag{7}$$

Markup Pricing

From (2), the own price elasticity of demand for a firm producing differentiated products is $-\sigma(j)$ which is the negative of the elasticity of substitution between differentiated products of commodity *j*. Due to the Chamberlinian large group assumption, the cross price elasticity of demand is zero. $-\sigma(j)$ is thus the perceived demand elasticity faced by a firm in the monopolistically competitive industry *j*.

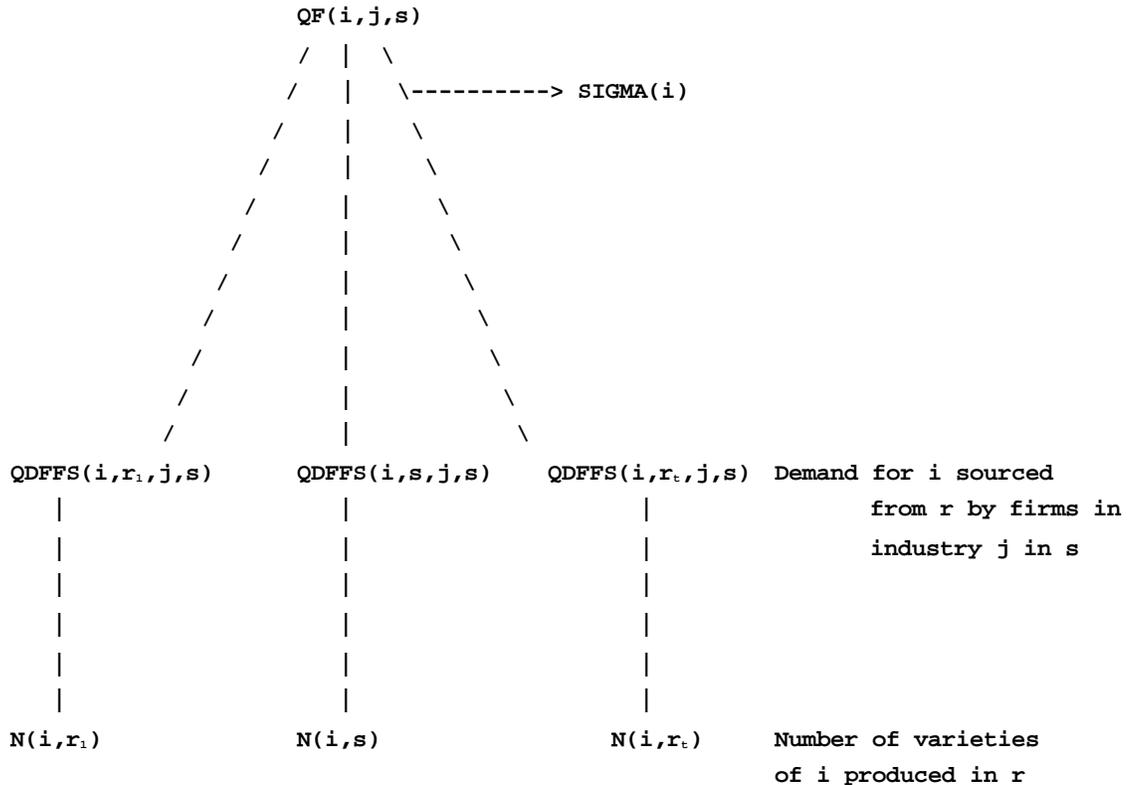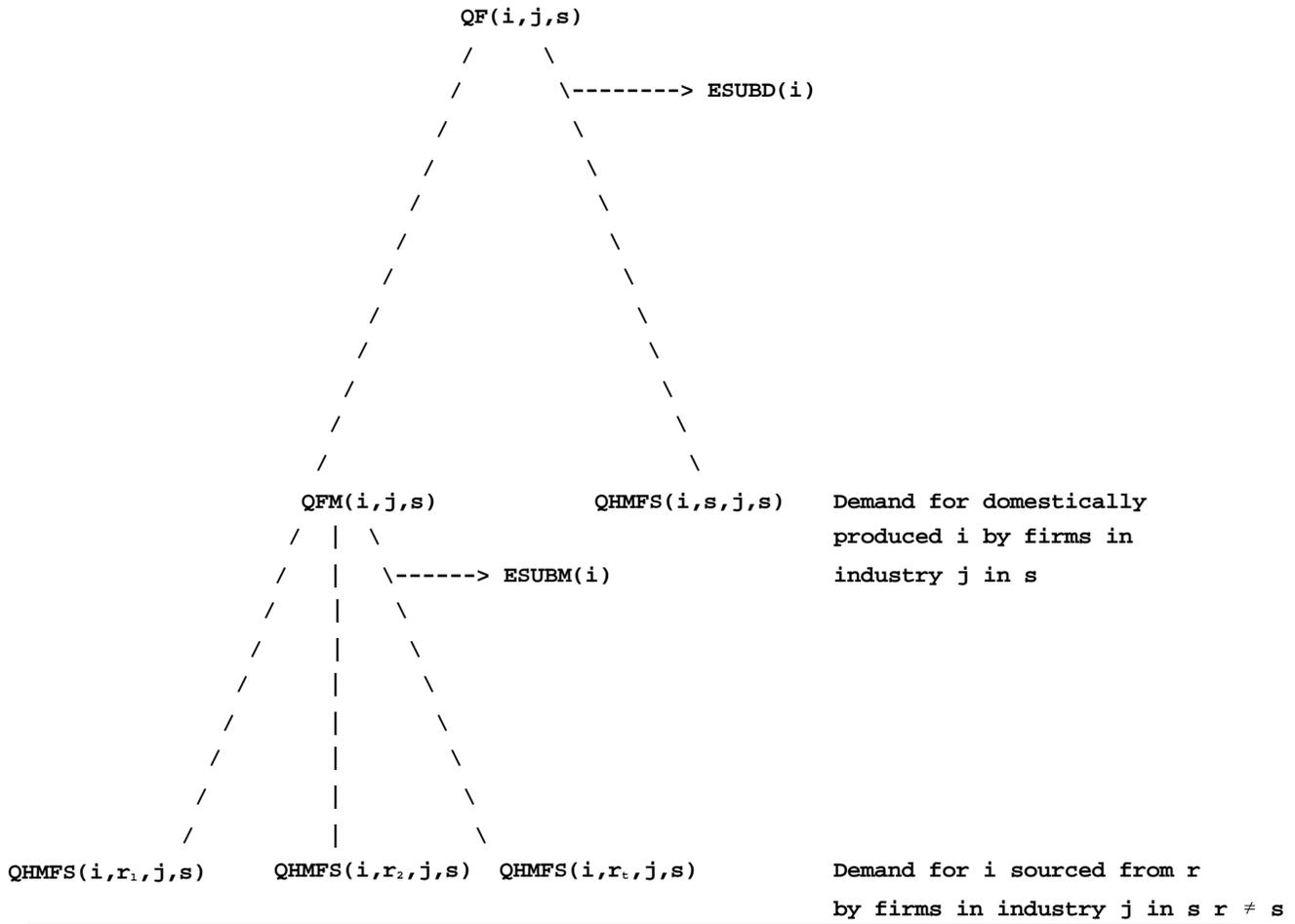Figure 4.A   Intermediate Input Nest, $j \in$ PROD_COMM, $i \in$ MCOMP_COMM, r, s $\in$ REG

```
                              QF(i,j,s)
                           /         \
                         /            \--------> ESUBD(i)
                       /                \
                     /                    \
                   /                        \
                 /                            \
               /                                \
             /                                    \
           /                                        \
         /                                            \
       /                                                \
     QFM(i,j,s)                    QHMFS(i,s,j,s)    Demand for domestically
      /  |  \                                        produced i by firms in
    /    |    \------> ESUBM(i)                       industry j in s
   /     |      \
  /      |       \
 /       |        \
/        |          \
/        |            \
/        |              \
/        |                \
QHMFS(i,r₁,j,s)   QHMFS(i,r₂,j,s)  QHMFS(i,rₜ,j,s)    Demand for i sourced from r
                                                       by firms in industry j in s r ≠ s
```

A profit maximizing firm equalizes marginal revenue, MR, with marginal cost. The following equation gives the marginal revenue on the left hand side, where *PS(j,s)* gives the output price of a firm producing in the monopolistically competitive industry *j* in region *s*.

$$PS(j,s) * [1 - [1 / \sigma(j)]] = MC\ (j,s) = AVC(j,s) \tag{8}$$

$$MARKUP(j,s) = PS(j,s) / AVC(j,s) = [\sigma(j)/[\sigma(j) - 1]] > 1,\ \text{for } \sigma(j) > 1 \tag{9}$$

The monopolistically competitive firm thus marks up its output price above average variable cost, by the amount of the markup, *MARKUP(j,s)*. The markup decreases with the elasticity of substitution, σ(j). Note that the *markup is a constant* due to the assumption of a constant elasticity of substitution between varieties in consumption/usage, in the Dixit-Stiglitz tradition. Totally differentiating (9) yields,

$$markup(j,s) = ps(j,s) - avc(j,s) = 0 \tag{9'}$$

According to (9'), *PS(j,s)* rises proportionately with *AVC(j,s)*. The markup equation determines the output level of the firm, *QOF(j,s)*, which, when multiplied by W(j,s), yields industry output, *QO(j,s)*. *QOF(j,s)* is therefore, the complementary variable for the markup pricing equation. In order to be

able to fix the firm's output level, we introduce a slack variable, *mkupslack(j,s)*, which absorbs the difference between price and variable costs. The associated MKUPRICE equation is:

```
EQUATION MKUPRICE
! Markup pricing (with constant markup). !
(all,j,MCOMP_COMM)(all,s,REG)
  ps(j,s) = avc(j,s) + mkupslack(j,s) ;
```

Average Variable Cost, and Scale Constant Average Total Cost

Owing to entry/exit, industry total revenue equals total costsin this model. Total costs are composed of intermediate and primary input costs. Value added output, *VA(j,s)*, is equal to the sum of primary input costs (see also figure 5).

$$VOA(j,s) \qquad = sum\{i,TRAD\_COMM, VFA(i,j,s)\} \qquad\qquad (10)$$

$$\qquad\qquad\qquad + sum\{i,ENDW\_COMM, VFA(i,j,s)\}$$

$$VOA(j,s) \qquad = sum\{i,TRAD\_COMM, VFA(i,j,s)\} + VA(j,s) \qquad (11)$$

We make an important assumption that all fixed costs are made up of primary factor costs and that variable costs are composed of both primary factor and intermediate input costs. The fixed overhead associated with producing new products such as the salaries of engineers engaged in R & D activities and of marketing staff involved in advertising and the capital required to build the R & D labs are thus primary factor costs.[11] Furthermore, we assume that fixed and variable value-added components have

---

1111. Brown studied the effects on firm output of tariffs in a monopolistically competitive industry, using different assumptions on factor intensity in this industry. She discusses the importance of this effect on average total costs.

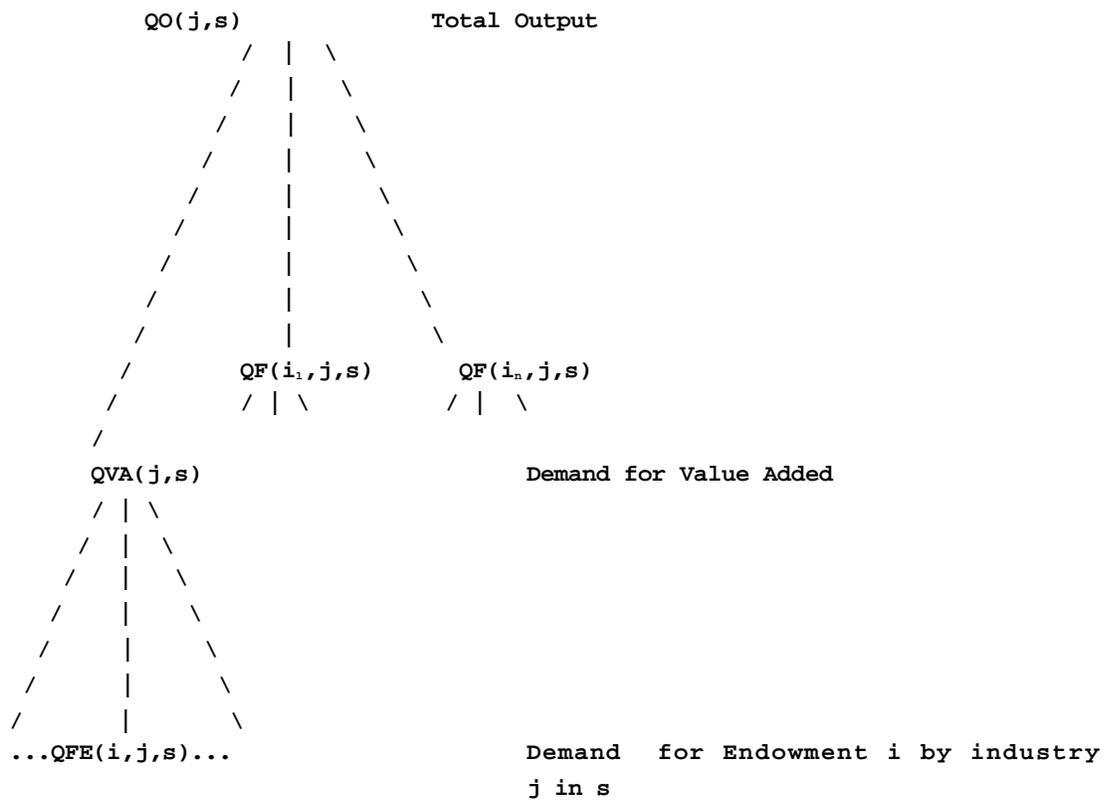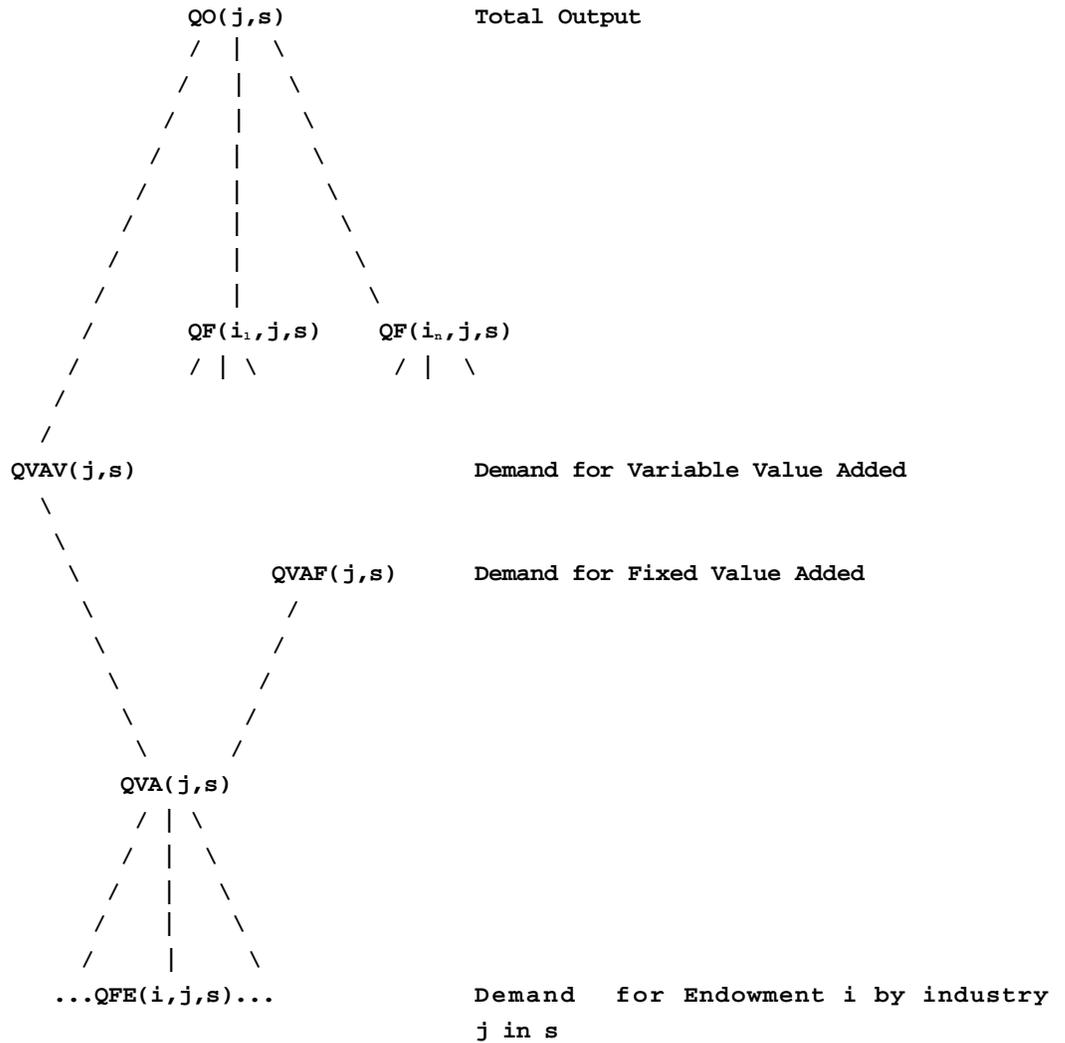Figure 5.A   Total Output and Value-Added Nests, j ∈ PCGDS_COMM, s ∈ REG

```
                    QO(j,s)              Total Output
                    /  |  \
                   /   |   \
                  /    |    \
                 /     |     \
                /      |      \
               /       |       \
              /        |        \
             /         |         \
            /          |          \
           /        QF(i₁,j,s)        QF(iₙ,j,s)
          /          / | \          / | \
         /
       QVA(j,s)                        Demand for Value Added
       / | \
      /  |  \
     /   |   \
    /    |    \
   /     |     \
  /      |      \
 /       |       \
...QFE(i,j,s)...                        Demand  for Endowment i by industry
                                        j in s
```

Figure 5.B   Total Output and Value-Added Nests, $j \in$ MCOMP_COMM, $s \in$ REG

```
                    QO(j,s)                Total Output
                   / | \
                  /  |  \
                 /   |   \
                /    |    \
               /     |     \
              /      |      \
             /       |       \
            /        |        \
           /     QF(i₁,j,s)    QF(iₙ,j,s)
          /        / | \          / | \
         /
        /
   QVAV(j,s)                    Demand for Variable Value Added
      \
       \
        \                QVAF(j,s)    Demand for Fixed Value Added
         \              /
          \            /
           \          /
            \        /
             \      /
          QVA(j,s)
           / | \
          /  |  \
         /   |   \
        /    |    \
       /     |     \
   ...QFE(i,j,s)...             Demand   for Endowment i by industry
                               j in s
```

the same primary factor intensities. These two assumptions are open to criticism. Our contention is that the composition of fixed costs must be dictated by a knowledge of the industries in question where data is available. Varying capital-labor intensities across the fixed and variable cost components requires more industry-specific data to do the actual split. In other cases, it should be the discretion of the modeler to adopt some sensible *ad hoc* rule that is transparent and lends itself to easy analysis and simple interpretation.

Total value added costs are therefore split into two components - variable value added, *VAV(j,s)*, and fixed value added, *VAF(j,s)*. (See also figure 5.).

$$VOA(j,s) \qquad = \text{sum}\{i, \text{TRAD\_COMM}, VFA(i,j,s)\} + VAV(j,s) + VAF(j,s) \qquad (12)$$

Variable costs, *VC(j,s)* and fixed costs, *FC(j,s)* are thus equal to

$$VC(j,s) \quad = sum\{i,TRAD\_COMM, VFA(i,j,s)\} + VAV(j,s) \quad (13)$$

$$= sum\{i,TRAD\_COMM, PF(i,j,s)*QF(i,j,s)\} + PVA(j,s)*QVAV(j,s)$$

$$FC(j,s) = VAF(j,s) = PVA(j,s)*QVAF(j,s) \quad (14)$$

AVC(j,s) is determined by equation AVERAGEVC. This is derived by total differentiation of (13) and using the envelope theorem (when all quantity changes are zero in the neighborhood of an optimum).

$$VC(j,s)*avc(j,s) = sum\{i,TRAD\_COMM, VFA(i,j,s)*pf(i,j,s)\} + VAV(j,s)*pva(j,s) \quad (13')$$

```
EQUATION AVERAGEVC

! AVERAGE Variable Cost !
(all,j,MCOMP_COMM)(all,s,REG)
VC(j,s)  *  avc(j,s)  =  sum(i,TRAD_COMM,  VFA(i,j,s)  *  pf(i,j,s)) +
VAV(j,s) * pva(j,s)
```

Fixed costs are invariant to firm output level and variable costs rise linearly with output, at constant input prices. In other words, average variable cost is invariant to output level but average fixed cost varies with output and with fixed input prices. From (13') we see that average variable cost is just a function of the variable input prices. However, changes in a firm's average total cost (which is output price as well, under zero profits) can arise from two sources: a.) change in firm's output, *qof(j,s)*, given constant prices of all inputs, and b.) change in one or more of the input prices, at constant firm output level.

We calculate the change in average total cost that is attributable only to changes in all input prices as the *scale constant average total cost*, *scatc(j,s)*, by holding the level of output per firm (scale) constant. To derive scale constant average total costs, we begin from the total cost equation in (11). Totally differentiating it and using the envelope theorem,

$$VOA(j,s)*scatc(j,s) \quad = sum\{i,TRAD\_COMM, VFA(i,j,s)*pf(i,j,s)\}$$
$$+ VA(j,s)*pva(j,s) \quad (11')$$

The variable *scatc(j,s)* is determined by equation SCLCONATC.

```
EQUATION SCLCONATC
! Average Total Cost at CONstant SCale. !
(all,j,MCOMP_COMM)(all,s,REG)
  VOA(j,s)  *  scatc(j,s)  =  sum(i,TRAD_COMM,  VFA(i,j,s)  *  pf(i,j,s))
                        + VA(j,s) * pva(j,s) ;
```

4.2.3 Industry Profits and Number of Firms

Perhaps the most distinguishing feature of the monopolistically competitive model is the *endogeneity* of the number of firms owing to the possibility of entry and exit of firms into/from the industry, in order to satisfy the zero profit condition. We follow the more common approach first taken by Harris in allowing the number of firms to be near continuous[12].

Zero Profits

The change in output price must equal the change in average total cost to earn zero profits in equilibrium. The change in average total cost now includes changes in *all* arguments. To derive the zero profit equation we start from equation (11).

$$VOA(j,s) = sum\{i,TRAD\_COMM, VFA(i,j,s)\} + VA(j,s)$$

$$PS(j,s)*QO(j,s) = sum\{i,TRAD\_COMM, PF(i,j,s)*QF(i,j,s)\} + PVA(j,s)*QVA(j,s)$$

Totally differentiating this (using the envelope theorem result) we have,

$$VOA(j,s)*ps(j,s) = sum\{i,TRAD\_COMM, VFA(i,j,s)*pf(i,j,s)\}$$
$$+ VA(j,s)*pva(j,s) - VAF(j,s)*qof(j,s)$$

Substituting (11') on the right hand side, we have,

$$VOA(j,s)*ps(j,s) = VOA(j,s)*scatc(j,s) - VAF(j,s)*qof(j,s)$$

A slack variable, *zpislack(j,s)* is introduced in this equation to let firms earn positive profits in the short run[13]. Under certain closure assumptions we fix the number of firms in an industry by allowing *zpislack(j,s)* to be non-zero. This allows existing firms to earn positive profits when output expansion occurs.

```
EQUATION MZEROPROFITS

!ZERO  pure  PROFITS  condition  for  firms  in  the  Monopolistically
competitive industry!
(all,j,MCOMP_COMM)(all,s,REG)
  VOA(j,s) * ps(j,s) = VOA(j,s) * scatc(j,s) - VAF(j,s) * qof(j,s)
+ zpislack(j,s);
```

Note that both equations SCLCONATC and MZEROPROFITS are derived from the same total cost equation given in (11). There lies a critical difference between the two. In getting to SCLCONATC,

---

12[12]. Mercenier and Schmitt reported extreme complexity in the computation of an integer number of firms in equilibrium.

13[13]. The medium and long run cases are characterized by entry/exit and firms make zero profits. However, the long run is not very meaningful in a comparative static model in the absence of factor accumulation.

we allow only the prices of all inputs to vary, holding the scale of the firm's operation constant, whereas in getting to MZEROPROFITS, we allow *all* arguments to vary.

The presence of fixed costs creates a wedge between price and marginal costs, which is equal to the markup. However, the subtle point to note is that price and average total cost will not move in tandem since average variable cost and average total cost are separated by a wedge that decreases (increases) with increase (decrease) in output per firm.

4.2.4 Industry Output

Industry output in sector *j* of region *s*, *QO(j,s)*, is the product of a number of symmetric firms, *N(j,s)*, and the output of the representative firm in the industry, *QOF(j,s)*.

QO(j,s) = N(j,s) * QOF(j,s)

Totally differentiating this we have,

qo(j,s) = n(j,s) + qof(j,s)

Industry output is computed by equation INDOUTPUT.

```
EQUATION INDOUTPUT

! INDustry OUTPUT in the monopolistically competitive industry !
(all,j,MCOMP_COMM)(all,s,REG)
  qo(j,s) = qof(j,s) + n(j,s) ;
```

If industry output were to increase purely due to an increase in firm output level with no change in the number of firms, we have a decline in average total cost of production. On the other hand, if industry output does not change but there is exit of firms from the industry, output per firm rises and we have a *rationalization* of the industry due to the decline in the fixed costs and the average cost of production.

4.2.5 Industry Derived Demands

The industry exhibits derived demands for both primary factors and intermediate inputs. The derived demand for intermediate inputs has already been covered in the sub-section on 'Intermediate Input Demands'. The derived demand equations for primary factors in the output of composite value-added, ENDWDEMAND(j,s) are left unmodified. However, unlike the perfectly competitive industry, the monopolistically competitive firms now have derived demands for both fixed and variable inputs.

Fixed, Variable, and Total Value Added
The demand for fixed value-added is directly proportional to the number of firms. The more differentiated an industry is, the more resources are devoted to fixed costs. The existence of fixed costs in the monopolistically competitive industry is viewed as the "economic cost" of differentiating

products. The economic benefit stems from the demand side due to a negative effect on the unit expenditure/cost function, as discussed in the sub-section on 'Demand Structure'. This is key to industry rationalization effects that will be explained in the results section.

EQUATION VAFDEMAND

```
!   Monopolistically   competitive   industry   DEMAND   for   Fixed
Value-Added!
(all,j,MCOMP_COMM)(all,s,REG)
  qvaf(j,s) = n(j,s) ;
```

The derived demand for the variable value-added (and intermediate) inputs is directly proportional to the industry output since we retain the Leontief production structure for the total output nest.

EQUATION VAVDEMAND

```
!   monopolistically   competitive   industry   DEMAND   for   Variable
Value-Added. !
(all,j,MCOMP_COMM)(all,s,REG)
  qvav(j,s) = qo(j,s) ;
```

The demand for total value-added in the industry producing differentiated products is a sum of the fixed and variable components.

EQUATION VATOT

```
!   monopolistically   competitive   industry   demand   for   total
Value-Added !
(all,j,MCOMP_COMM)(all,s,REG)
    qva(j,s)  =  [VAV(j,s)/VA(j,s)]  *  qvav(j,s)  +  [VAF(j,s)/VA(j,s)]
* qvaf(j,s) ;
```

5.   *Data Requirements*

To implement the monopolistically competitive GTAP model, we have to work with a data base whose structure is fundamentally different than the standard GTAP data base. This requires that the new GTAP data base - the sets (GTAPSETS), the data (GTAPDATA), and the parameters (GTAPPARM) files - be compatible with the monopolistically competitive model, GTAPMC, outlined in the previous section. We explain in this section the procedures used in transforming the standard GTAP data base. The associated files, in electronic form, are in the ZIP file associated with the paper (MCOMP.ZIP)

5.1   *Transformation of the Sets File*

Three new sets have to be added to the standard GTAPSETS file. We implement this by modifying the standard sets file, using the GEMPACK program MODHAR[14]. The new sets are:

MCOMP_COMM	**M**onopolistically **comp**etitive **comm**odities
PCOMP_COMM	**P**erfectly **comp**etitive **comm**odities
PCGDS_COMM	**P**erfectly competitive and **c**apital **goo**ds **comm**odities

All the elements of the set of tradable commodities, TRAD_COMM, in the standard sets file are classified as either monopolistically competitive or perfectly competitive, such that MCOMP_COMM and PCOMP_COMM are *mutually exclusive sets.* All the perfectly competitive commodities and capital goods (investment), CGDS_COMM, are classified as PCGDS_COMM. It follows that,

MCOMP_COMM $\cup$ PCOMP_COMM	= TRAD_COMM, and
PCOMP_COMM $\cup$ CGDS_COMM	= PCGDS_COMM

5.2   *Transformation of the Parameters File*

In the parameters file, ESUBD(i) and ESUBM(i) should now index only the set PCOMP_COMM. The array elements corresponding to the elements that are not in PCOMP_COMM should be deleted. Care should be exercised to preserve the ordering of the elements in each array. The ordering should match the order in which the elements are defined. We introduce SIGMA(i), indexed over MCOMP_COMM, as a new array in this file. The modified parameters file is best created by hand editing the standard parameters file.

5.3   *Transformation of the Data File*

The data program, DATMCV3.TAB, transforms the standard GTAP data base to a monopolistically competitive GTAP data base. The three main steps in this process are - sourcing of imports valued at market prices by agents, deriving the value of these flows at agents' prices, and deriving trade data. The data program copies the following data (stored under headers with the same name in the data file) from the input data set to the output data set without any changes - *EVOA*, *EVFA*, *VFM*, *VST*, *SAVE*, *VDEP*, *VKB*, *VAD*, *VTA*, *VMFA*, *VPU*, *VVER*, *VXT*, and *URVT*.

1414. An alternative to MODHAR would be to directly define the new sets in the model file. This requires hard coding the elements of these new sets in the TAB file. We prefer the MODHAR approach to keep track of changes independent of the model file.

5.3.1 Sourcing of Imports Valued at Importer's Market Prices by Agents, VPMS(i,r,s), VGMS(i,r,s), and VFMS(i,r,j,s)

The consumption of aggregate imports of *i* by the private household in *s* is given by *VIPM(i,s)* in the standard data base. We define the market share of source *r* in the total imports of *i* by region *s*, *MSHRS(i,r,s)*, and use it to source out the aggregate imports consumed by the agent. This yields the consumption of imports of *i* from source *r* by the private household in region *s*, *VPMS(i,r,s)*, valued at market prices.

When the source region, *r*, is the same as the destination region, *s*, we have the case of intra-regional imports, usually associated with a margin. But *MSHRS(i,r,s)* could be zero if *r* is a single-country GTAP region. When sourcing out to the same region, we must include domestic sales that are already sourced. Thus *VPMS(i,s,s)* includes *VDPM(i,s)*. Therefore, when *r = s*, domestic sales and intra- regional imports get blended. This procedure is extended to industry and government demands to yield *VFMS(i,r,j,s)* and *VGMS(i,r,s)*.

As a result of this transformation, agents' domestic and import demands are replaced by sourced demands, all valued at market prices. Thus, *VPMS(i,r,s)* replaces *VDPM(i,s)* and *VIPM(i,s)*, *VGMS(i,r,s)* replaces *VDGM(i,s)* and *VIGM(i,s)*, and *VFMS(i,r,j,s)* replaces *VDFM(i,j,s)* and *VIFM(i,j,s)*.

5.3.2 Deriving the Value of the Sourced Demands at Agents' Prices, VPAS(i,r,s), VGAS(i,r,s), and VFAS(i,r,j,s)

We define the power of the average (ad valorem) tax on total demand by an agent as the ratio of total demand valued at agents' prices to the total demand valued at market prices. Thus, the power of the average tax on the demand for *i* by the private household in *s*, *TP(i,s)*, is the ratio of the sum of *VIPA(i,s)* and *VDPA(i,s)* to the sum of *VIPM(i,s)* and *VDPM(i,s)*. This average tax, *TP(i,s)*, multiplied by the sourced demand at market prices, *VPMS(i,r,s)*, yields the value of the sourced demand at agents' prices, *VPAS(i,r,s)*. This procedure is extended to government and industry demands to yield *VGAS(i,r,s)* and *VFAS(i,r,j,s)*.

Consequently, agents' domestic and import demands are replaced by sourced demands, all valued at agents' prices. Thus, *VPAS(i,r,s)* replaces *VDPA(i,s)* and *VIPA(i,s)*, *VGAS(i,r,s)* replaces *VDGA(i,s)* and *VIGA(i,s)*, and *VFAS(i,r,j,s)* replaces *VDFA(i,j,s)* and *VIFA(i,j,s)*.

5.3.3 Deriving Trade Data

Basically, the bilateral trade matrices (fob and cif) do not undergo much transformation. "Exports" and "imports" are renamed as "sales" and "demands" respectively and the notation is changed to reflect this. Therefore, *VXMD(i,r,s)*, *VXWD(i,r,s)*, *VIWS(i,r,s)*, and *VIMS(i,r,s)* are renamed as *VSMD(i,r,s)*, *VSWD(i,r,s)*, *VDWS(i,r,s)*, and *VDMS(i,r,s)* respectively. For *r = s*, we need to take

account of domestic sales as well, to ensure market equilibrium. The sum of domestic sales to all agents of commodity *i* in region *s*, *VDM(i,s)*, evaluated at market prices, is therefore added to *VSMD(i,s,s)* and is carried forward through the system. This procedure is justified on the grounds that there are hardly any consumption/usage taxes on domestic demands. Where domestic sales are very large relative to intra regional trade, we note that this will dilute the distortion, if any, on intra regional trade. The protection data (export or import tax revenues/subsidy costs) by instrument do not undergo any change either.

5.4   Checks on the Transformed Data Base

DATMCV3 performs two checks on the new data set it creates - non-negativity of variable value added costs and balancing conditions.

Non negativity of Variable Value Added Costs
Fixed costs are made up of primary factor costs as alluded to earlier in the discussion on production structure. Value added costs, *VA(j,s)*, are split into variable, *VAV(j,s)*, and fixed value added, *VAF(j,s)* [see (12) above]. Fixed costs are thus equal to *VAF(j,s)* [see (14) above]. The perceived demand elasticity determines the share of fixed costs in total costs, in the Dixit-Stiglitz tradition. From (8) it follows that fixed costs are comprised of $[1 / \sigma(j)]$ portion of total costs.

```
  (all,i,TRAD_COMM)(all,r,REG)
```

```
VAF(i,r) = VOA(i,r) * {1 - [1 / MARKUP(i,r)]}  ;
```
Once fixed costs are calibrated in this manner, variable value added is a residual in total value added.

```
  (all,i,TRAD_COMM)(all,r,REG)
```

```
VAV(i,r) = VA(i,r) - VAF(i,r)  ;
  (all,i,TRAD_COMM)(all,r,REG)
CHK_VAVPOS(i,r) = IF{ [VA(i,r) - VAF(i,r)] > 0, 1 }  ;
```

The coefficient CHK_VAVPOS(i,r) checks that fixed value added does not exceed total value added costs, for a given SIGMA(i). This is a check to warn of those industries that might be characterized by an extremely low expenditure on value-added relative to total output. If this coefficient returns a "0" (which is its default) for a given SIGMA(i), then it is problematic to classify that industry *i* in region *r*, as monopolistically competitive. Either it must be reclassified, or the value of SIGMA(i) must be increased. The data program thus serves as a useful precursor to the model.

Check Balancing Conditions of the New Data Set

We also check the balancing conditions on the newly created data set after it gets written. These include the standard accounting relationships that are checked for the standard data base in the program GTAPCHK.TAB.

5.5   *Implementation of the GTAPMC Model*

Due to the increased size of the model, it becomes necessary to perform a condensation of the model before implementing it. This procedure effectively reduces the model size and reduces the computation time. The condensation operation must be modified depending on the closure chosen by the user.

6.   *Policy Application*

The objective of this policy application using the monopolistically competitive formulation outlined above is to show the effects of introducing economies of scale and product differentiation into the GTAP model. We explain the strategic aggregation used, the experimental design adopted, and the results of the simulations conducted.

6.1   *Strategic Aggregation*

We illustrate the monopolistically competitive GTAP model with a simple, unilateral trade policy liberalization experiment. For this purpose, we have aggregated the version 3 GTAP global data base into 2 tradable commodities and 3 regions (2x3). We have kept the size of the model small to aid in exposition of the results.

The three regions are Japan (JPN), United States (USA), and the Rest of World (ROW). The two tradable commodities are manufacturing (MNFG) and non-manufacturing (nonMNFG). This aggregation is referred to as "3P-MC", where 3P denotes version 3 prerelease and MC denotes monopolistic competition. This aggregated 2x3 data set is then transformed into a form that is compatible with the monopolistically competitive model using the data transformation program, DATMCV3.TAB, discussed in the previous section and outlined in Appendix B. The sets file is also modified to include the new sets. We treat manufacturing as the monopolistically competitive sector and non-manufacturing as the perfectly competitive sector. Thus, MNFG $\in$ MCOMP_COMM and nonMNFG $\in$ PCOMP_COMM.

6.2   *Experimental Design*

We carry out a trade policy liberalization experiment whereby the USA region eliminates the antidumping duty on its manufacturing imports from JPN, leaving the tariffs in place. This policy change is implemented as a shock to the variable denoting the (percentage change in the) power of the overall import tariff on U.S. imports of Japanese manufacturing products, *tms*(MNFG,JPN,USA). The initial wedge between the border price of imports, *PCIF*(MNFG,JPN,USA) and the import market price, *PMS*(MNFG,JPN,USA) is such that *TMS*(MNFG,JPN,USA) = 1.2189. This comprises a 17.8% antidumping duty and a 4.09% tariff. Therefore, elimination of the antidumping duties amount to a shock of *tms*(MNFG,JPN,USA) = [-0.178/1.2189] * 100 % = -14.6%. This same shock is used in all experiments.

In the base experiment we adopt the standard closure. In the remaining three experiments we adopt different closures. In the second experiment, we drop the markup pricing equation and fix the output per firm, *qof*(MNFG,r). This is designed to isolate the industry rationalization effects occurring due to output expansion, also termed the *scale effect*. In the third experiment we drop the zero profit condition and fix the number of varieties, *n*(MNFG,r). This isolates the industry rationalization effects occurring due to exit of firms. This is known as the *variety effect*. The final experiment is designed to mimic a perfectly competitive model and hence uses a slightly different model file. It eliminates both the variety and scale effects by fixing *qof* and eliminating *n*. However, the industry still makes zero profits. This is made possible by restoring the perfectly competitive structure to the derived demand and price index equations.

6.3   *Results*

The results of the four experiments are presented in table 1. The direct effect of the policy change is seen as a 12.58% reduction in the USA market price of manufacturing products sourced from Japan, *pms*(MNFG,JPN,USA). This reduction is *smaller* than the reduction in the power of the import tariff because of a 2.37% rise in the *cif* price of imports. The market price of Japanese manufacturing products sold in ROW rise by 2.34%. The benefits from a decline in the price of global shipping services by 0.87% accrue to the US and ROW and not to Japan which experiences the full impact of the rise in the price of manufacturing products, *pm*(MNFG,JPN) by 2.53%. The change in the market price in the region of origin mirrors the change in the supply price, which will be explained via changes in the industry cost structure.

In order to meet the increased demand for Japanese manufactures, industry output of manufacturing products, *qo*(MNFG,JPN) increases by 0.53%. Of course, this displaces demand for US and ROW products in the US market, leading to a 0.39% decline in total US output and a 0.07% decline in the

ROW region. The increased output in Japan is sold to the US, with the quantity of bilateral sales increasing by 89.07%. This dramatic increase causes the price of Japanese manufactures to rise, as seen above. This permits some of the increase in net supply to the US to be met by diverting sales from the domestic and ROW markets, where the quantity of Japanese manufactures sold actually declines. Interestingly enough, despite decreased overall output, the US actually *increases its sales to Japan* and ROW by 32.02% and 9.53% respectively. This is due to the cost reduction experienced by US exporters relying on imported Japanese intermediate inputs. As expected, however, US firms sell less domestically, and this effect dominates, leading to an overall decline in output. In sum, the removal of US antidumping duties on Japanese imports does a great deal to stimulate intra-industry trade. Aggregate exports from Japan rising by qxw(MNFG,JPN) = 13.18%, and US exports of manufactures increasing by 11.69%. Overall, the volume of global trade rises by 4.5%, with a 5.9% increase in manufactures and a 2% increase in world non-manufactures trade.

Up to this point, we have only discussed industry-wide variables. These are common across all sectors, whether or not they are monopolistically competitive. However, the key feature of the monopolistically competitive sectors is that they also incorporate information about changes in the number of varieties on offer, as well as changes in output per firm. Together, these explain the change in industry output. However, there is no reason why all three of these variables must move in the same direction. Indeed, we find this not to be the case in the present example. Our strategy for analysis will be as follows. We first explain the change in output per firm, as dictated by the changes in cost structure flowing from the removal of antidumping duties. We then observe the change in number of varieties/firms as the difference between the change in industry output and the change in output per firm. If output per firm rises by more than total output, then some firms must exit the industry in order to satisfy the equilibrium conditions.

In the standard closure, *mkupslack(j,s)* is exogenous, so that firms in the industry mark up marginal cost by to determine their optimal price. Hence, price and average variable cost move by the same proportion.

ps(j,s)   = avc(j,s)

Also, we have from the zero profits equation,

ps(j,s)   = scatc(j,s) - [VAF(j,s) / VOA(j,s)] * qof(j,s)

Thus, we can solve for *qof(j,s)* as,

qof(j,s) = [VAF(j,s) / VOA(j,s)]$^{-1}$ * {scatc(j,s) - avc(j,s)}

Thus, per firm output changes as scale constant average total cost and average variable cost change at differing rates. An increase in the price of a primary factor or an intermediate input increases both *scatc(.)* and *avc(.)*, but *not* at the same rate.

In the case of Japan, removal of the antidumping duties faced by its products causes a general appreciation in the relative price of its non-tradeable, primary factors. This has the effect of bringing

the economy back into external balance, following the increase in demand for its exports. It does so by raising the cost of Japanese products. Of course, the extent to which various cost indices go up will depend on their primary factor intensity. Since fixed costs are assumed to be entirely made up of primary factors, and since firms have the option of importing intermediate inputs. average total costs tend to rise more than average variable costs. Specifically, in the case of Japanese manufactures, the variable *scatc(.)* rises faster than *avc(.)* because price index of value-added increases by 3.19% but that of intermediates by less than 2.5%. *Value-added matters more for scatc than avc.* Thus, avc rises by 2.53% and scatc rises more, by 2.66%. As a consequence, *qof(.)* must increase. As it happens, the increase of *qof* = 0.74% exceeds the increase in total Japanese manufacturing output, so firms exit the industry, and *n* = -0.22%.

In the case of ROW, *qof(.)* Falls for the opposite reason of that in Japan. For this region, there is a decline in demand for the manufacturing exports, as they are displaced by Japan in the US market. For this reason, primary factor prices must fall, relative to imported inputs. This causes *scatc* to fall more rapidly than *avc* so that *qof* also falls, in this case by -0.023%. This reinforces a decline in the number of firms, so that overall output falls by -0.07%.

In the US, the forces operating on *qof(.)* are more complex. The decline in demand for US products lowers the relative price of US primary factors, relative to tradeables *in general*. However, US manufacturers also import a significant share of their inputs from Japan. The cost of these inputs falls when antidumping duties are removed. As we can see from the results, this latter effect is strong enough to outweigh the real exchange rate effect and *avc* falls more than does *scatc* and *qof* rises. This is a somewhat striking effect, in light of the overall contraction in output in this sector. Therefore the number of firms must fall more than does aggregate output.

In order to understand the welfare effects of this experiment, it is useful to begin with the change in real GDP, *qgdp*. With fixed endowments, the only way to produce a greater volume of goods and services is to allocate existing resources more efficiently. This could involve moving factors from relatively lightly to heavily taxed sectors, or it could involve increasing output per firm in industries with scale economies. The latter effect is dominant in this experiment, with *qgdp* increasing in USA and JPN, and decreasing in ROW. Another determinant of welfare is what happens to the variety of goods available for consumption. Since the number of firms falls in all regions, this is clearly negative. Finally, it is useful to consider the impact which removal of antidumping duties has on the regional terms of trade. Here, there is a significant shift in favor of Japan, with the TOT declining for USA and ROW. The combination of these three factors gives rise to a decline in utility in USA and ROW, with utility increasing substantially in Japan (EV = $41,585mill.).

Finally, it is useful to consider the impact of fixing output per firm and varieties. These results are also reported in table 1. It is clear that the largest impact is generated by the change in output per firm. When this component is fixed (and the markup equation eliminated), we break the link between cost structure and optimal scale. Consequently, aggregate output in Japanese manufacturing rises by much less, and the welfare gain is moderated.

Table 1. Percentage Changes in Key Endogenous Variables

	Base Case			Scale Effect[a]			Variety Effect[b]			Scale and Variet Effect[c]		
	JPN	USA	ROW	JPN	USA	ROW	JPN	USA	ROW	JPN	USA	ROW
Industry Output												
Manufacturing, qo(MNFG,s)	0.53	-0.39	-0.07	0.32	-0.41	-0.06	0.46	-0.49	-0.10	0.34	-0.44	-0.07
Non-Manufacturing, qo(MNFG,s)	-0.06	0.12	0.02	-0.12	0.11	0.02	-0.09	0.08	0.01	-0.12	0.12	0.02
Investment Goods, qo(CGDS,s)	0.23	0.11	0.17	0.21	0.11	0.16	0.22	0.11	0.17	0.21	0.11	0.16
Output per Firm, qof(MNFG,s)	0.74	0.10	-0.02	0	0	0	0.46	-0.49	-0.10	0	0	0
Number of Varieties, n(MNFG,s)	-0.22	-0.49	-0.05	0.32	-0.41	-0.06	0	0	0	0.34	-0.44	-0.07
Output Price of Manufacturing, ps(MNFG,s)	2.53	-2.45	-0.83	2.66	-2.44	-0.84	2.54	-2.39	-0.85	2.62	-2.37	-0.83
Average Variable Cost, avc(MNFG,s)	2.53	-2.45	-0.83	2.54	-2.45	-0.84	2.54	-2.39	-0.85	2.50	-2.40	-0.83
Scale Constant Average Total Cost, scatc(MNFG,s)	2.66	-2.44	-0.83	2.66	-2.44	-0.84	2.67	-2.36	-0.85	2.62	-2.37	-0.83
Real GDP, qgdp(s)	0.26	0.15	-0.03	0.23	0.15	-0.3	0.25	0.14	-0.03	0.19	0.18	-0.02
Terms of Trade, tot(s)	3.07	-2.41	-0.50	3.12	-2.42	-0.52	3.07	-2.33	-0.54	3.07	-2.35	-0.54
Utility, u(s)	1.32	-0.26	-0.12	1.30	-0.26	-0.12	1.31	-0.26	-0.13	1.24	-0.21	-0.11
Equivalent Variation, EV(s) in $ billion	41.59	-13.84	-14.61	-41.06	-13.93	-14.64	41.36	-13.76	-15.22	39.13	-11.26	-13.63

[a] Output per firm, $qof(j,r)$, exogenous

[b] Number of firms, $n(j,r)$, exogenous

[c] Output per firm exogenous and effect of variety on utility/cost functions eliminated

Appendix: GTAPMC.TAB

```
!----------------------------------------------------------------------          !
!                       Global Trade Analysis Project                            !
!                       The GTAP Modeling Framework                              !
!                            GTAPMC Version 1                                     !
!                               June 1996                                         !
!----------------------------------------------------------------------          !



!----------------------------------------------------------------------          !
!                         History of this file                                    !
!----------------------------------------------------------------------          !


! Version 1    June 1996      Used in Advanced Course in Global Trade Analysis
                              June 1996


   GTAPMC   is   the   Monopolistically   Competitive   GTAP   model   that   incorporates
   monopolistic   competition  --  product   differentiation   and   economies   of   scale  --   into
   user-specified   sectors.   This   allows   the   modeler   to   analyze   the   effects   of   product
   variety   on   utility/cost   structure   and   the   consequent   implications   for   welfare   and
   resource   allocation   issues.   This   is   an   extension   to   the   standard   GTAP
   model(GTAP94.TAB, Version 2.2a, August 1995). !


!----------------------------------------------------------------------          !
!                         Model Documentation                                     !
!----------------------------------------------------------------------          !


!
```

Extended Model:

1. Swaminathan, P.V. and T.W. Hertel "Introducing Monopolistic Competition   into the
    GTAP Model," GTAP Technical Paper No. 6, Center for Global Trade Analysis, Purdue
    University, West Lafayette, IN 47907, USA.

Standard Model:

2. Hertel, T.W. and M.E. Tsigas "Structure of the Standard GTAP Model",   Chapter 2 in
    T.W. Hertel (editor) Global Trade Analysis: Modeling and   Applications, Cambridge
    University Press, 1996.

!

```
!-----------------------------------------------------------------------                          !
!                                              Notes                                              !
!-----------------------------------------------------------------------                          !
```

!

```
* Data Transformation Program: DATMCV3.TAB
  ~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
```

   DATMCV3 is the data program associated with GTAPMC.TAB. It reads in any   standard
   version 3 GTAP data base that is compatible with the standard model, GTAP94.TAB, and
   writes a monopolistically competitive data base compatible with this model,
   GTAPMC.TAB. DATMCV3 makes certain assumptions in order to transform the standard
   data base. It also checks the accounting identities on the transformed data base.

```
*   the standard sets and parameters file also need to be modified
    [See documentation #1 for this]
```

```
* Data Check Program: CHK_MC.TAB
  ~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
```

   GTAPMC.TAB displays all the coefficients, shares, and checks on the accounting
   identities. CHK_MC.TAB is the data check program analogous to GTAPCHK.TAB for the
   standard model. GTAPMC.TAB contains essentially the same code as found in
   CHK_MC.TAB.

```
* Set Maximum Size: 10x10
  ~~~~~~~~~~~~~~~~~~~~~~~~
```

   The set sizes are set for a 10x10 aggregation (maximum of 10 tradable   commodities
   and 10 regions) in this file. The set sizes for the new sets,   MCOMP_COMM and
   PCOMP_COMM, are 2 and 8 respectively. The set sizes have to be edited when the size
   of the aggregation changes.

!

```
!-----------------------------------------------------------------------                          !
!                                              Files                                              !
!-----------------------------------------------------------------------                          !
```

```
file !
*****!
```

```
GTAPSETS # set specification # ;
```

```
GTAPDATA # base data # ;
(text) GTAPPARM # behavioral parameters # ;


!------------------------------------------------------------------------!          !
!                                          Sets                          !          !
!------------------------------------------------------------------------!          !


set !
****!


REG # regions in the model # maximum size 10
  read elements from file GTAPSETS header "H1"
  ;
TRAD_COMM # traded commodities # maximum size 10
  read elements from file GTAPSETS header "H2"
  ;
NSAV_COMM # non-savings commodities # maximum size 14
  read elements from file GTAPSETS header "H3"
  ;
DEMD_COMM # demanded commodities # maximum size 13
  read elements from file GTAPSETS header "H4"
  ;
PROD_COMM # produced commodities # maximum size 11
  read elements from file GTAPSETS header "H5"
  ;
ENDW_COMM # endowment commodities # maximum size 3
  read elements from file GTAPSETS header "H6"
  ;
ENDWS_COMM # sluggish endowment commodities # maximum size 3
  read elements from file GTAPSETS header "H7"
  ;
ENDWM_COMM # mobile endowment commodities # maximum size 3
  read elements from file GTAPSETS header "H8"
  ;
CGDS_COMM # capital goods commodities # maximum size 1
  read elements from file GTAPSETS header "H9"
  ;
MCOMP_COMM # monopolistically competitive commodities # maximum size 2
  read elements from file GTAPSETS header "H10"
  ;
PCOMP_COMM # perfectly competitive commodities # maximum size 8
  read elements from file GTAPSETS header "H11"
  ;
PCGDS_COMM # perfectly competitive and cgds commodities # maximum size 9
  read elements from file GTAPSETS header "H12"
  ;
```

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```
ENDWC_COMM # capital endowment commodity #
  (capital)
  ;
```

```
subset !
*******!


PROD_COMM  is subset of NSAV_COMM ;
DEMD_COMM  is subset of NSAV_COMM ;
TRAD_COMM  is subset of DEMD_COMM ;
TRAD_COMM  is subset of PROD_COMM ;
CGDS_COMM  is subset of PROD_COMM ;
PCGDS_COMM is subset of PROD_COMM ;
PCOMP_COMM is subset of TRAD_COMM ;
MCOMP_COMM is subset of TRAD_COMM ;
ENDW_COMM  is subset of DEMD_COMM ;
ENDWS_COMM is subset of ENDW_COMM ;
ENDWM_COMM is subset of ENDW_COMM ;
ENDWC_COMM is subset of NSAV_COMM ;
```

```
!---------------------------------------------------------------------                    !
!                                Variables                                                 !
!---------------------------------------------------------------------                    !
```

! Variables are divided into six groups -- quantities, prices, technical change,
  policies (tax/subsdiy "wedges"), income and utility, and finally slack variables.
  In GEMPACK, variables refer to those items which will be changing endogenously with
  each solution. They are assigned lower case labels to denote the fact that they are
  percentage changes. (This is purely for convenience, since GEMPACK is not case
  sensitive.) !

```
variable !
*********!

! 1. Quantity Variables
  -------------------- !

  (all,i,NSAV_COMM)(all,r,REG)
qo(i,r) # Quantity of industry Output of commodity i in region r #
  ;
  (all,i,TRAD_COMM)(all,r,REG)(all,s,REG)
qs(i,r,s) # Quantity of Sales of commodity i from source r to destination s #
```

```
   ;
   (all,i,TRAD_COMM)(all,r,REG)
qst(i,r) # Quantity of Sales of i from r to international Transport sector #
   ;
   (all,i,ENDWS_COMM)(all,j,PROD_COMM)(all,r,REG)
qoes(i,j,r) # Quantity of Sluggish Endowment i supplied to sector j in r #
   ;
   (all,i,ENDW_COMM)(all,j,PROD_COMM)(all,r,REG)
qfe(i,j,r) # Quantity of Endowment i demanded by Firms in sector j in r #
   ;
   (all,j,PROD_COMM)(all,r,REG)
qva(j,r) # Quantity of Value-Added demanded in industry j of region r #
   ;
   (all,i,TRAD_COMM)(all,j,PROD_COMM)(all,r,REG)
qf(i,j,r) # Quantity of composite commodity i demanded by Firms in j in r #
   ;
   (all,i,PCOMP_COMM)(all,r,REG)(all,j,PROD_COMM)(all,s,REG)
qhmfs(i,r,j,s) # Quantity of Sourced HoMogeneous i dem by Firms in j in s #
   ;
   (all,i,MCOMP_COMM)(all,r,REG)(all,j,PROD_COMM)(all,s,REG)
qdffs(i,r,j,s) # Quantity of Sourced DiFferentiated input i dem by Firms in j # ;
   (all,i,PCOMP_COMM)(all,j,PROD_COMM)(all,s,REG)
qfm(i,j,s) # Quantity of composite iMports of i demanded by Firms in j in s #
   ;
   (all,i,MCOMP_COMM)(all,r,REG)
qvaf(i,r) # Quantity of Fixed Value-Added demanded by firms in i in r #
   ;
   (all,i,MCOMP_COMM)(all,r,REG)
qvav(i,r) # Quantity of Variable Value-Added demanded by firms in i in r #
   ;
   (all,i,MCOMP_COMM)(all,j,PROD_COMM)(all,r,REG)
vf(i,j,r) # number of Varieties of i available to Firms in j in r #
   ;
   (all,i,MCOMP_COMM)(all,r,REG)
qof(i,r) # Quantity of Output per Firm in industry i of region r #
   ;
   (all,i,MCOMP_COMM)(all,r,REG)
n(i,r) # Number of firms active in industry i of region r #
   ;
   (all,i,TRAD_COMM)(all,r,REG)
qp(i,r) # Quantity of composite commodity i demanded by Private hhld in r #
   ;
   (all,i,PCOMP_COMM)(all,r,REG)(all,s,REG)
qhmps(i,r,s) # Quantity of Sourced HoMogeneous comm i dem by Pvt hhld in s #
   ;
   (all,i,MCOMP_COMM)(all,r,REG)(all,s,REG)
```

```
qdfps(i,r,s) # Quantity of Sourced DiFferentiated comm i dem by Pvt hhld in s # ;
  (all,i,PCOMP_COMM)(all,s,REG)
qpm(i,s) # Quantity of composite iMports of i demanded by Private hhld in s #
  ;
  (all,i,MCOMP_COMM)(all,r,REG)
vp(i,r) # number of Varieties of i available to Private household in r #
  ;
  (all,i,TRAD_COMM)(all,r,REG)
qg(i,r) # Quantity of composite commodity i demanded by Government in r #
  ;
  (all,i,PCOMP_COMM)(all,r,REG)(all,s,REG)
qhmgs(i,r,s) # Quantity of Sourced HoMogeneous comm i dem by Government in s #
  ;
  (all,i,MCOMP_COMM)(all,r,REG)(all,s,REG)
qdfgs(i,r,s) # Quantity of Sourced DiFferentiated comm i dem by Govt in s #
  ;
  (all,i,PCOMP_COMM)(all,s,REG)
qgm(i,s) # Quantity of composite iMports of i demanded by Government in s #
  ;
  (all,i,MCOMP_COMM)(all,r,REG)
vg(i,r) # number of Varieties of i available to Government in region r #
  ;
  (all,r,REG)
qcgds(r) # Quantity of output of investment sector, CGDS in region r #
  ;
  (all,r,REG)
qsave(r) # Quantity of net SAVings demanded in region r #
  ;
  (all,r,REG)
ksvces(r) # quantity of capital services available in region r #
  ;
  (all,r,REG)
kb(r) # Beginning-of-period capital stock in region r #
  ;
  (all,r,REG)
ke(r) # End-of-period capital stock in region r #
  ;
globalcgds # GLOBal supply of capital goods for NET investment #
  ;
qt # Quantity of Transportation (global shipping) services provided #
  ;
  (all,r,REG)
pop(r) # POPulation in region r #
  ;
walras_dem # demand in the omitted market - global demand for savings #
  ;
```

walras_sup # supply in the omitted market - global supply of cgds composite #
  ;
  (all,r,REG)
qgdp(r) # GDP Quantity index in region r #
  ;
  (all,i,TRAD_COMM)(all,r,REG)
qxw(i,r) # Quantity of aggregate eXports of i from r at World (fob) prices #
  ;
  (all,i,TRAD_COMM)(all,s,REG)
qiw(i,s) # Quantity of aggregate Imports of i by s at World (cif) prices #
  ;
  (all,r,REG)
qxwreg(r) # Quantity of aggregate eXports by REGion r at World (fob) prices #
  ;
  (all,r,REG)
qiwreg(r) # Quantity of aggregate Imports by REGion r at World (cif) prices #
  ;
  (all,i,TRAD_COMM)
qxwcom(i) # Quantity of aggregate eXports of COMmodity i at World (cif) prices #
  ;
  (all,i,TRAD_COMM)
qiwcom(i) # Quantity of aggregate Imports of COMmodity i at World (cif) prices # ;
qxwwld # Quantity index of WorLD eXports at World (fob) prices #
  ;
  (all,i,TRAD_COMM)
qow(i) # Quantity index of World Output of commodity i #
  ;

! 2. Price Variables
  ----------------- !

  (all,i,NSAV_COMM)(all,r,REG)
ps(i,r) # Supply Price of commodity i in region r #
  ;
  (all,i,ENDWS_COMM)(all,j,PROD_COMM)(all,r,REG)
pmes(i,j,r) # Market Price of Sluggish Endowment i used by industry j in r #
  ;
  (all,i,TRAD_COMM)(all,j,PROD_COMM)(all,r,REG)
pf(i,j,r) # demand Price of commodity i for Firms in industry j in r #
  ;
  (all,i,ENDW_COMM)(all,j,PROD_COMM)(all,r,REG)
pfe(i,j,r) # demand Price of Endowment i for Firms in industry j in r #
  ;
  (all,j,PROD_COMM)(all,r,REG)
pva(j,r) # Price of Value-Added in industry j in region r #
  ;

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```
  (all,i,TRAD_COMM)(all,r,REG)(all,j,PROD_COMM)(all,s,REG)
pfs(i,r,j,s) # demand Price of i by Source for Firms in industry j in s #
  ;
  (all,i,PCOMP_COMM)(all,j,PROD_COMM)(all,s,REG)
pfm(i,j,s) # demand Price of composite iMports of i for Firms in j in s #
  ;
  (all,i,MCOMP_COMM)(all,r,REG)
avc(i,r) # Average Variable Cost of production in industry i in region r #
  ;
  (all,i,MCOMP_COMM)(all,r,REG)
scatc(i,r) # Average Total Cost at Constant Scale in industry i in region r #
  ;
  (all,i,TRAD_COMM)(all,r,REG)
pp(i,r) # demand Price of composite commodity i for Private household in r #
  ;
  (all,i,PCOMP_COMM)(all,s,REG)
ppm(i,s) # demand Price of composite iMports of i for Private household in s #
  ;
  (all,i,TRAD_COMM)(all,r,REG)(all,s,REG)
pps(i,r,s) # demand Price of i by source for Private household in region s #
  ;
  (all,r,REG)
ppriv(r) # Price index for PRIVate household expenditures in region r #
  ;
  (all,i,TRAD_COMM)(all,r,REG)
pg(i,r) # demand Price of composite commodity i for Government in region r #
  ;
  (all,i,PCOMP_COMM)(all,s,REG)
pgm(i,s) # demand Price of composite iMports of i for Government in s #
  ;
  (all,i,TRAD_COMM)(all,r,REG)(all,s,REG)
pgs(i,r,s) # demand Price of i by Source for Government in region s #
  ;
  (all,r,REG)
pgov(r) # Price index for GOVernment expenditures in region r #
  ;
  (all,i,NSAV_COMM)(all,r,REG)
pm(i,r) # Market Price of commodity i in region r #
  ;
  (all,i,TRAD_COMM)(all,r,REG)(all,s,REG)
pms(i,r,s) # Market Price of composite iMports of i by Source in region s #
  ;
  (all,i,TRAD_COMM)(all,r,REG)(all,s,REG)
pfob(i,r,s) # FOB world Price of commodity i supplied from r to s #
  ! i.e., prior to incorporation of transportation margin !
  ;
```

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```
   (all,i,TRAD_COMM)(all,r,REG)(all,s,REG)
pcif(i,r,s) # CIF world Price of commodity i supplied from r to s #
   ! i.e., subsequent to incorporation of transportation margin !
   ;
pt # Price of Transportation (global shipping) services provided #
   ;
   (all,r,REG)
rental(r) # RENTAL rate on capital stock in region r = ps("capital",r) #
   ;
   (all,r,REG)
rorc(r) # Current net Rate Of Return on capital stock in region r #
   ;
   (all,r,REG)
rore(r) # Expected net Rate Of Return on capital stock in region r #
   ;
rorg # Global net Rate Of Return on capital stock #
   ;
psave # Price of capital goods supplied to SAVErs #
   ;
   (all,r,REG)
pcgds(r) # Price of investment goods in region r = ps("cgds",r) #
   ;
   (all,r,REG)
psw(r) # Price index of tradables Sold by region r at World (fob) prices #
   ! Note: this includes sales of net investment in r !
   ;
   (all,r,REG)
pdw(r) # Price index of tradables Demanded by region r at World (cif) prices #
! Note: this includes purchases of net savings in region r !
   ;
   (all,r,REG)
tot(r) # Terms Of Trade for region r: tot(r) = psw(r) - pdw(r) #
   ;
   (all,r,REG)
pgdp(r) # GDP Price index in region r #
   ;
   (all,i,TRAD_COMM)(all,r,REG)
pxw(i,r) # Price index for aggregate eXports of i from r at World (fob) prices # ;
   (all,i,TRAD_COMM)(all,r,REG)
piw(i,r) # Price index for aggregate Imports i by r at World (cif) prices #
   ;
   (all,r,REG)
pxwreg(r) # Price index of aggregate eXports by REGion r at World (fob) prices # ;
   (all,r,REG)
piwreg(r) # Price index of aggregate Imports by REGion r at World (cif) prices # ;
   (all,i,TRAD_COMM)
```

```
pxwcom(i) # Price index of agg eXports of COMmodity i at World (fob) prices #
  ;
  (all,i,TRAD_COMM)
piwcom(i) # Price index of agg Imports of COMmodity i at World (cif) prices #
  ;
pxwwld # Price index of WorLD eXports at World (fob) prices #
  ;
  (all,i,TRAD_COMM)
pw(i) # Price index for total supply of commodity i at World (fob) prices #
  ;


! 3. Technical Change Variables
  --------------------------- !


! Specification: If, for example, technical progress is Hicks-neutral across
  all inputs at the rate of 1 percent, then ao(j,r) = 1. !


  (all,j,PROD_COMM)(all,r,REG)
ao(j,r) # Output Augmenting technical change in sector j of region r #
  ;
  (all,i,ENDW_COMM)(all,j,PROD_COMM)(all,r,REG)
afe(i,j,r) # Endowment i Augmenting technical change for Firms in j of r #
  ;
  (all,i,TRAD_COMM)(all,j,PROD_COMM)(all,r,REG)
af(i,j,r) # composite input i Augmenting tech change for Firms in j of r #
  ;
  (all,i,PROD_COMM)(all,r,REG)
ava(i,r) # Value Added Augmenting technical change in sector i of region r #
  ;
  (all,i,TRAD_COMM)(all,r,REG)(all,s,REG)
atr(i,r,s) # Augmenting tech change in TRansport of i from region r to s #
  ;
  (all,i,MCOMP_COMM)(all,r,REG)
avav(i,r) # Variable Value Added Augmenting technical change in sector i of r # ;


! 4. Policy Variables
  ------------------ !


  (all,i,NSAV_COMM)(all,r,REG)
to(i,r) # power of the Tax on Output of commodity i in region r #
  ;
  (all,i,ENDW_COMM)(all,j,PROD_COMM)(all,r,REG)
tf(i,j,r) # power of the Tax on endowment i demanded by Firms in j in r #
  ;
  (all,i,TRAD_COMM)(all,r,REG)(all,j,PROD_COMM)(all,s,REG)
tfs(i,r,j,s) # power of the Tax on Sourced i demanded by Firms in j in s #
```

```
   ;
  (all,i,TRAD_COMM)(all,r,REG)(all,s,REG)
tps(i,r,s) # power of the Tax on Sourced i demanded by Private hhld in s #
   ;
  (all,i,TRAD_COMM)(all,r,REG)(all,s,REG)
tgs(i,r,s) # power of the Tax on sourced i demanded by Government in region s # ;
  (all,i,TRAD_COMM)(all,r,REG)(all,s,REG)
tms(i,r,s) # power of the Tax on Sourced iMports of i in region s #
   ;
  (all,i,TRAD_COMM)(all,r,REG)(all,s,REG)
txs(i,r,s) # power of the Tax on eXports of i by region r #
   ;
  (all,i,TRAD_COMM)(all,s,REG)
tm(i,s) # power of the source-generic Tax on iMports of i in region s #
   ;
  (all,i,TRAD_COMM)(all,r,REG)
tx(i,r) # power of the destination generic Tax on eXports of i by region r #
   ;


! 5. Value, Income and Utility Variables
  ------------------------------------- !

  (all,i,TRAD_COMM)(all,s,REG)
vxwfob(i,s) # Value of eXports of i by region s at World (FOB) prices #
   ;
  (all,i,TRAD_COMM)(all,s,REG)
viwcif(i,s) # Value of Imports of i by region s at World (CIF) prices #
   ;
  (all,r,REG)
vxwreg(r) # Value of aggregate eXports by REGion r at World (fob) prices #
   ;
  (all,r,REG)
viwreg(r) # Value of aggregate Imports by REGion r at World (cif) prices #
   ;
  (all,i,TRAD_COMM)
vxwcom(i) # Value of aggregate eXports of COMmodity i at World (fob) prices #
   ;
  (all,i,TRAD_COMM)
viwcom(i) # Value of aggregate Imports of COMmodity i at World (cif) prices #
   ;
vxwwld # Value of WorLD eXports at World (fob) prices #
   ;
  (all,i,TRAD_COMM)
valuew(i) # VALUE of World supply of commodity i #
   ;
  (all,r,REG)
```

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vgdp(r) # Value of GDP in region r #
  ;
  (all,r,REG)
y(r) # regional household income in region r #
  ;
  (all,r,REG)
yp(r) # Private household expenditure in region r #
  ;
  (all,r,REG)
up(r) # per capita Utility from Private expenditure in region r #
  ;
  (all,r,REG)
ug(r) # aggregate Utility from Government expenditure in region r #
  ;
  (all,r,REG)
u(r) # per capita Utility from regional household expenditure in region r #
  ;
  (CHANGE)(all,r,REG)
EV(r) # Equivalent Variation, in constant $ US million #
  ! Hicksian equivalent variation.
    Positive figure indicates welfare improvement !
  ;
  (CHANGE)
WEV # Equivalent Variation for the World, in constant $ US million #
  ;
  (CHANGE)(all,r,REG)
DTBAL(r) # change in Trade BALance X - M, in constant $ US million #
  ! Positive figure indicates increase in exports exceeds imports. !
  ;
  (CHANGE)(all,i,TRAD_COMM)(all,r,REG)
DTBALi(i,r) # change in Trade BALance by commodity and region, $ US million #
  ! Positive figure indicates increase in exports exceeds imports. !
  ;

! 6. Slack Variables
  ------------------ !

  (all,j,PCGDS_COMM)(all,r,REG)
zppslack(j,r) # slack variable in the zero profit equation of PCGDS_COMM #
    ! This is exogenous, unless the user wishes to fix industry output in the perfectly
    competitive industry. !
  ;
  (all,j,MCOMP_COMM)(all,r,REG)
zpislack(j,r) # slack variable in the zero profit equation of MCOMP_COMM #
    ! This is exogenous, unless the user wishes to fix the number of firms in the
    monopolistically competitive industry. !

```
   ;
   (all,j,MCOMP_COMM)(all,r,REG)
mkupslack(j,r) # slack variable in the optimal markup equation #
      ! This is exogenous, unless the user wishes to fix the output per firm in   the
      monopolistically competitive industry. !
   ;
   (all,r,REG)
incomeslack(r) # slack variable in the expression for regional income #
   ! This is exogenous, unless the user wishes to fix regional income. !
   ;
   (all,i,ENDW_COMM)(all,r,REG)
endwslack(i,r) # slack variable in the endowment market clearing condition #
      ! This  is  exogenous,  unless  the  user  wishes  to  fix  the  returns  for  the  primary
      factors. !
   ;
   (all,r,REG)
cgdslack(r) # slack variable for qcgds(r) #
      ! This  is  exogenous,  unless  the  user  wishes  to  specify  the  level  of  new  capital
      goods in a region. !
   ;
   (all,r,REG)
saveslack(r) # slack variable in regional demand for savings #
      ! This  is  exogenous,  unless  the  user  wishes  to  fix  the  level  of  savings  in  a  region.
      !
   ;
   (all,r,REG)
govslack(r) # slack variable to permit fixing of real govt purchases #
      ! This  is  exogenous,  unless  the  user  wishes  to  fix  the  level  of  government
      purchases. !
   ;
   (all,i,TRAD_COMM)(all,r,REG)
tradslack(i,r) # slack variable in the tradables market clearing condition #
! This is exogenous, unless the user wishes to fix the price of tradables. !
   ;
walraslack # slack variable in the omitted market #
      ! This  is  endogenous  under  normal,  GE  closure.  If  the  GE  links  are  broken,  then  this
      must  be  swapped  with  the  numeraire,  thereby  forcing  global  savings  to  explicitly
      equal global investment. !
   ;


!-------------------------------------------------------------------------------                              !
!                                      Data Base                                                              !
!-------------------------------------------------------------------------------                              !

!  The base data are divided into two sections:  base revenues and expenditures   and
      technology  and  preference  parameters.  Since  these  are  invariant  for  each  solution
```

of the model, they are termed coefficients. Coefficients are assigned upper case to
distinguish them from variables. (Again, this is purely cosmetic, as GEMPACK is not
case sensitive.) !

coefficient !
************!

! 1. Base Revenues and Expenditures
   -------------------------------- !

   (all,i,ENDW_COMM)(all,r,REG)
EVOA(i,r) # Value of Endowment Output, at Agents' prices #
   ;
   (all,i,ENDW_COMM)(all,j,PROD_COMM)(all,r,REG)
EVFA(i,j,r) # Value of Firms' purchases of Endowment, at Agents' prices #
   ;
   (all,i,TRAD_COMM)(all,r,REG)(all,j,PROD_COMM)(all,s,REG)
VFAS(i,r,j,s) # Value of Firms' purchases by Source, at Agents' prices #
   ;
   (all,i,TRAD_COMM)(all,r,REG)(all,s,REG)
VPAS(i,r,s) # Value of Private hh expenditure by Source, at Agents' prices #
   ;
   (all,i,TRAD_COMM)(all,r,REG)(all,s,REG)
VGAS(i,r,s) # Value of Government expenditure by Source, at Agents' prices #
   ;
   (all,i,ENDW_COMM)(all,j,PROD_COMM)(all,r,REG)
VFM(i,j,r) # Value of Firms' purchases, at Market prices #
   ;
   (all,i,TRAD_COMM)(all,r,REG)(all,j,PROD_COMM)(all,s,REG)
VFMS(i,r,j,s) # Value of Firms' purchases by Source, at Market prices #
   ;
   (all,i,TRAD_COMM)(all,r,REG)(all,s,REG)
VPMS(i,r,s) # Value of Private hh expenditure by Source, at Market prices #
   ;
   (all,i,TRAD_COMM)(all,r,REG)(all,s,REG)
VGMS(i,r,s) # Value of Government expenditure by Source, at Market prices #
   ;
   (all,i,TRAD_COMM)(all,r,REG)(all,s,REG)
VSMD(i,r,s) # Value of Sales by Destination, at Market prices #
   ;
   (all,i,TRAD_COMM)(all,r,REG)(all,s,REG)
VDMS(i,r,s) # Value of Demands by Source, at Market prices #
   ;
   (all,i,TRAD_COMM)(all,r,REG)(all,s,REG)
VSWD(i,r,s) # Value of Sales by Destination, at World (fob) prices #

```
  ;
  (all,i,TRAD_COMM)(all,r,REG)(all,s,REG)
VDWS(i,r,s) # Value of Demands by Source, at World (cif) prices #
  ;
  (all,i,TRAD_COMM)(all,r,REG)
VST(i,r) # Value of Sales to Transport sector at market prices #
  ;
  (all,r,REG)
SAVE(r) # SAVings #
  ;
  (all,r,REG)
VKB(r) # Value of Beginning-of-period capital stock #
  ;
  (all,r,REG)
VDEP(r) # Value of DEPreciation #
  ;


! 2. Technology and Preference Parameters
  -------------------------------------- !


  (all,i,TRAD_COMM)(all,r,REG)
SUBPAR(i,r) # substitution parameter in the CDE min expenditure function #
  ;
  (all,i,TRAD_COMM)(all,r,REG)
INCPAR(i,r) # expansion parameter in the CDE min expenditure function #
  ;
  (all,i,PCOMP_COMM)
ESUBD(i) # elasticity of substitution between domestic and imported goods #
  ;
  (all,i,PCOMP_COMM)
ESUBM(i) # elasticity of substitution among imports from different sources #
  ;
  (all,j,PROD_COMM)
ESUBVA(j) # elasticity of substitution in the production of value-added #
  ;
  (all,i,ENDWS_COMM)
ETRAE(i) # elasticity of transformation for sluggish primary factors #
  ! It is non-positive by definition. !
  ;
  (all,r,REG)
RORFLEX(r) # flexibility of expected net rate of return on capital stock #
    ! If a region's capital stock increases by 1%, then it is expected that the   net
    rate of return on capital will decline by RORFLEX % !
  ;
RORDELTA # a binary coefficient to determine the allocation investment funds #
```

```
   ! When RORDELTA = 1, investment funds are allocated across regions to equate the
     change in the expected rates of return (i.e., rore(r)). When RORDELTA = 0,
     investment funds are allocated across regions to maintain the existing composition
     of capital stocks !
   ;
   (all,i,MCOMP_COMM)
SIGMA(i) # elasticity of substitution among differentiated products #
   ;


! regional utility and population ratios for calculating EV !

coefficient (all,r,REG)
URATIO(r) # ratio of the per capita utility to its presimulation value #
   ;
formula (initial)(all,r,REG)
URATIO(r) = 1
   ;


coefficient (all,r,REG)
POPRATIO(r) # ratio of population in region r to its presimulation value #
   ;
formula (initial)(all,r,REG)
POPRATIO(r) = 1
   ;


!----------------------------------------------------------------------            !
!                                  Updates                                         !
!----------------------------------------------------------------------            !

!   The updating command indicates how the new level of the coefficient will be computed
     based on the previous solution. Note that the notation used in the update commands
     is a shorthand for total differentials of these coefficient values. Thus, w * v
     indicates that we want to take the total differential of W * V, plug in the
     calculated values of w and v, and add this to the base level in order to obtain a
     revised value for this product. Finally, the technology & preference parameters do
     not change at all and so require no update statement. !

update !
*******!

   (all,i,ENDW_COMM)(all,r,REG)
EVOA(i,r) = ps(i,r) * qo(i,r)
   ;
   (all,i,ENDW_COMM)(all,j,PROD_COMM)(all,r,REG)
EVFA(i,j,r) = pfe(i,j,r) * qfe(i,j,r)
   ;
```

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```
  (all,i,PCOMP_COMM)(all,r,REG)(all,j,PROD_COMM)(all,s,REG)
VFAS(i,r,j,s) = pfs(i,r,j,s) * qhmfs(i,r,j,s)
  ;
  (all,i,MCOMP_COMM)(all,r,REG)(all,j,PROD_COMM)(all,s,REG)
VFAS(i,r,j,s) = pfs(i,r,j,s) * qdffs(i,r,j,s)
  ;
  (all,i,PCOMP_COMM)(all,r,REG)(all,s,REG)
VPAS(i,r,s)= pps(i,r,s) * qhmps(i,r,s)
  ;
  (all,i,MCOMP_COMM)(all,r,REG)(all,s,REG)
VPAS(i,r,s)= pps(i,r,s) * qdfps(i,r,s)
  ;
  (all,i,PCOMP_COMM)(all,r,REG)(all,s,REG)
VGAS(i,r,s)= pgs(i,r,s) * qhmgs(i,r,s)
  ;
  (all,i,MCOMP_COMM)(all,r,REG)(all,s,REG)
VGAS(i,r,s)= pgs(i,r,s) * qdfgs(i,r,s)
  ;
  (all,i,ENDWM_COMM)(all,j,PROD_COMM)(all,r,REG)
VFM(i,j,r) = pm(i,r) * qfe(i,j,r)
  ;
  (all,i,ENDWS_COMM)(all,j,PROD_COMM)(all,r,REG)
VFM(i,j,r) = pmes(i,j,r) * qfe(i,j,r)
  ;
  (all,i,PCOMP_COMM)(all,r,REG)(all,j,PROD_COMM)(all,s,REG)
VFMS(i,r,j,s) = pms(i,r,s) * qhmfs(i,r,j,s)
  ;
  (all,i,MCOMP_COMM)(all,r,REG)(all,j,PROD_COMM)(all,s,REG)
VFMS(i,r,j,s) = pms(i,r,s) * qdffs(i,r,j,s)
  ;
  (all,i,PCOMP_COMM)(all,r,REG)(all,s,REG)
VPMS(i,r,s)= pms(i,r,s) * qhmps(i,r,s)
  ;
  (all,i,MCOMP_COMM)(all,r,REG)(all,s,REG)
VPMS(i,r,s)= pms(i,r,s) * qdfps(i,r,s)
  ;
  (all,i,PCOMP_COMM)(all,r,REG)(all,s,REG)
VGMS(i,r,s)= pms(i,r,s) * qhmgs(i,r,s)
  ;
  (all,i,MCOMP_COMM)(all,r,REG)(all,s,REG)
VGMS(i,r,s)= pms(i,r,s) * qdfgs(i,r,s)
  ;
  (all,i,TRAD_COMM)(all,r,REG)(all,s,REG)
VSMD(i,r,s) = pm(i,r) * qs(i,r,s)
  ;
  (all,i,TRAD_COMM)(all,r,REG)(all,s,REG)
```

```
VDMS(i,r,s) = pms(i,r,s) * qs(i,r,s)
  ;
  (all,i,TRAD_COMM)(all,r,REG)(all,s,REG)
VSWD(i,r,s) = pfob(i,r,s) * qs(i,r,s)
  ;
  (all,i,TRAD_COMM)(all,r,REG)(all,s,REG)
VDWS(i,r,s) = pcif(i,r,s) * qs(i,r,s)
  ;
  (all,i,TRAD_COMM)(all,r,REG)
VST(i,r) = pm(i,r) * qst(i,r)
  ;
  (all,r,REG)
SAVE(r) = psave * qsave(r)
  ;
  (all,r,REG)
VKB(r) = kb(r) * pcgds(r)
  ;
  (all,r,REG)
VDEP(r) = kb(r) * pcgds(r)
  ;
  (all,r,REG)
URATIO(r) = u(r)
  ;
  (all,r,REG)
POPRATIO(r) = pop(r)
  ;


!-------------------------------------------------------------------------------                !
!                                         Read Base Data                                         !
!-------------------------------------------------------------------------------                !

read !
*****!

EVOA from file GTAPDATA header "EVOA" ;
EVFA from file GTAPDATA header "EVFA" ;
VFAS from file GTAPDATA header "VFAS" ;
VPAS from file GTAPDATA header "VPAS" ;
VGAS from file GTAPDATA header "VGAS" ;
VFM  from file GTAPDATA header "VFM" ;
VFMS from file GTAPDATA header "VFMS" ;
VPMS from file GTAPDATA header "VPMS" ;
VGMS from file GTAPDATA header "VGMS" ;
VSMD from file GTAPDATA header "VSMD" ;
VDMS from file GTAPDATA header "VDMS" ;
VSWD from file GTAPDATA header "VSWD" ;
```

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```
VDWS from file GTAPDATA header "VDWS" ;
VST  from file GTAPDATA header "VST" ;
SAVE from file GTAPDATA header "SAVE" ;
VKB  from file GTAPDATA header "VKB" ;
VDEP from file GTAPDATA header "VDEP" ;
SUBPAR  from file GTAPPARM ;
INCPAR  from file GTAPPARM ;
ESUBD   from file GTAPPARM ;
ESUBM   from file GTAPPARM ;
ESUBVA  from file GTAPPARM ;
ETRAE   from file GTAPPARM ;
RORFLEX from file GTAPPARM ;
RORDELTA from file GTAPPARM ;
SIGMA    from file GTAPPARM ;


!----------------------------------------------------------------------------                 !
!                              Derivatives of the Base Data                                    !
!----------------------------------------------------------------------------                 !


ZERODIVIDE (ZERO_BY_ZERO) DEFAULT 0 ;


coefficient (all,r,REG)(all,s,REG)
DELTA(r,s) # Kronecker delta, equals 1 for r = s, 0 otherwise #
! Kronecker delta designed to isolate domestic transactions on the part of all agents
  in region s !
  ;
formula (all,r,REG)(all,s,REG)
DELTA(r,s) = 0
  ;
  (all,s,REG)
DELTA(s,s) = 1
  ;


! Industry Costs and Revenues
  -------------------------- !


coefficient (all,i,DEMD_COMM)(all,j,PROD_COMM)(all,r,REG)
VFA(i,j,r) # Value of Firms' expenditure at Agents' prices #
  ;
formula (all,i,ENDW_COMM)(all,j,PROD_COMM)(all,r,REG)
VFA(i,j,r) = EVFA(i,j,r)
  ;
formula (all,i,TRAD_COMM)(all,j,PROD_COMM)(all,s,REG)
VFA(i,j,s) = sum{t,REG, VFAS(i,t,j,s)}
  ;
```

```
coefficient (all,i,NSAV_COMM)(all,r,REG)
VOA(i,r) # Value of Output at Agents' prices #
  ;
formula (all,i,ENDW_COMM)(all,r,REG)
VOA(i,r) = EVOA(i,r)
  ;
formula (all,i,PROD_COMM)(all,r,REG)
VOA(i,r) = sum{j,DEMD_COMM, VFA(j,i,r)}
  ;


coefficient (all,i,NSAV_COMM)(all,r,REG)
VOM(i,r) # Value of Output at Market prices #
  ;
formula (all,i,ENDW_COMM)(all,r,REG)
VOM(i,r) = sum{j,PROD_COMM, VFM(i,j,r)}
  ;
formula (all,i,TRAD_COMM)(all,r,REG)
VOM(i,r) = sum{s,REG, VSMD(i,r,s)} + VST(i,r)
  ;
formula (all,h,CGDS_COMM)(all,r,REG)
VOM(h,r) = VOA(h,r)
  ;


! Fixed and Variable Costs in the Monopolistically Competitive Industry
  ---------------------------------------------------------------- !

! Define markup (the perceived demand elasticity of the firm), MARKUP(i,r) as a
  function of the elasticity of substitution, SIGMA(i). Note that the markup for an
  industry will be identical for all firms located in various regions. !

coefficient (all,i,MCOMP_COMM)(all,r,REG)
MARKUP(i,r) # optimal MARKUP of firms in the initial equilibrium #
  ;
formula (all,i,MCOMP_COMM)(all,r,REG)
MARKUP(i,r) = SIGMA(i) / [SIGMA(i) - 1]
  ;


coefficient (all,j,PROD_COMM)(all,r,REG)
VA(j,r) # total Value Added demanded #
  ;
formula (all,j,PROD_COMM)(all,r,REG)
VA(j,r) = sum{k,ENDW_COMM, VFA(k,j,r)}
  ;
```

! Define fixed value-added as a fraction of total costs or revenues. This follows from the Dixit-Stiglitz and Spence formalization of the Chamberlinian theory of monopolistic competition. !

coefficient (all,i,MCOMP_COMM)(all,r,REG)
VAF(i,r) # Fixed Value Added demanded by the monop comp industry #
  ;
formula (all,i,MCOMP_COMM)(all,r,REG)
VAF(i,r) = VOA(i,r) * {1 - [1 / MARKUP(i,r)]}
  ;

coefficient (all,i,MCOMP_COMM)(all,r,REG)
VAV(i,r) # Variable Value Added demanded by the monop comp industry #
  ;
formula (all,i,MCOMP_COMM)(all,r,REG)
VAV(i,r) = VA(i,r) - VAF(i,r)
  ;

coefficient (all,i,MCOMP_COMM)(all,r,REG)
VC(i,r) # Variable Cost in the production of the monop comp commodity #
  ;
formula (all,i,MCOMP_COMM)(all,r,REG)
VC(i,r) = VOA(i,r) - VAF(i,r)
  ;

! Private Consumption and Government Expenditures, Savings and GDP
  --- !

coefficient (all,i,TRAD_COMM)(all,r,REG)
VPA(i,r) # Value of Private household expenditure at Agents' prices #
  ;
formula (all,i,TRAD_COMM)(all,s,REG)
VPA(i,s) = sum{t,REG, VPAS(i,t,s)}
  ;

coefficient (all,r,REG)
PRIVEXP(r) # PRIVate consumption EXPenditure in region r #
  ;
formula (all,r,REG)
PRIVEXP(r) = sum{i,TRAD_COMM, VPA(i,r)}
  ;

coefficient (all,i,TRAD_COMM)(all,r,REG)
VGA(i,r) # Value of Government expenditure at Agents' prices #
  ;
formula (all,i,TRAD_COMM)(all,s,REG)

```
VGA(i,s) = sum{t,REG, VGAS(i,t,s)}
   ;


coefficient (all,r,REG)
GOVEXP(r) # GOVernment EXPenditure in region r #
   ;
formula (all,r,REG)
GOVEXP(r) = sum{i,TRAD_COMM, VGA(i,r)}
   ;


coefficient (all,r,REG)
INCOME(r) # regional expenditure in region r, which equals net INCOME #
   ;
formula (all,r,REG)
INCOME(r) = sum{i,TRAD_COMM, VPA(i,r) + VGA(i,r)} + SAVE(r)
   ;


coefficient (PARAMETER)(all,r,REG)
INC(r) # initial equilibrium regional expenditure data #
!  INC is set equal to INCOME and does not change during a simulation. This is used in
   calculating EV. !
   ;
formula (INITIAL)(all,r,REG)
INC(r) = INCOME(r)
   ;


coefficient (all,r,REG)
GDP(r) # Gross Domestic Product in region r #
   ! Trade is valued at fob and cif prices. !
   ;
formula (all,s,REG)
GDP(s) = sum{i,TRAD_COMM, VPA(i,s) }
       + sum{i,TRAD_COMM, VGA(i,s) }
       + sum{k,CGDS_COMM, VOA(k,s) }
       + sum{i,TRAD_COMM, sum{r,REG, VSWD(i,s,r)} + VST(i,s)}
       - sum{i,TRAD_COMM, sum{r,REG, VDWS(i,r,s)}}
   ;


! Gross and Net Regional Investment and Global Investment
   ------------------------------------------------------- !


coefficient (all,r,REG)
REGINV(r) # REGional gross INVestment in region r #
   ! This equals the value of output of the investment sector, "cgds" !
   ;
formula (all,r,REG)
```

```
REGINV(r) = sum{k,CGDS_COMM, VOA(k,r)}
  ;


coefficient (all,r,REG)
NETINV(r) # regional NET INVestment in region r #
  ;
formula (all,r,REG)
NETINV(r) = sum{k,CGDS_COMM, VOA(k,r)} - VDEP(r)
  ;


coefficient
GLOBINV # GLOBal net INVestment expenditures #
  ! Alternatively, GLOBINV may be computed as a sum of SAVE(r) !
  ;
formula
GLOBINV = sum{r,REG, NETINV(r)}
  ;


! Global Transportation Margins
  --------------------------- !

coefficient (all,i,TRAD_COMM)(all,r,REG)(all,s,REG)
VTWR(i,r,s) # Value of Transportation services associated by Route #
  ;
formula (all,i,TRAD_COMM)(all,r,REG)(all,s,REG)
VTWR(i,r,s) = VDWS(i,r,s) - VSWD(i,r,s)
  ;


coefficient
VT # Value of total international Transportation services #
  ;
formula
VT = sum{i,TRAD_COMM, sum{r,REG, sum{s,REG, VTWR(i,r,s)}}}
  ;


! Regional Trade Aggregates and Global Trade
  ---------------------------------------- !

! VXW(i,r) includes only extra-regional exports or sales outside the region !

coefficient (all,i,TRAD_COMM)(all,r,REG)
VXW(i,r) # Value of eXports at World (fob) prices, by commodity and region #
  ;
formula (all,i,TRAD_COMM)(all,r,REG)
VXW(i,r) = sum{s,REG, [1 - DELTA(r,s)] * VSWD(i,r,s)} + VST(i,r)
  ;
```

```
coefficient (all,r,REG)
VXWREGION(r) # Value of eXports at World (fob) prices, by REGION #
  ;
formula (all,r,REG)
VXWREGION(r) = sum{i,TRAD_COMM, VXW(i,r)}
  ;


coefficient (all,i,TRAD_COMM)
VXWCOMMOD(i) # Value of eXports at World (fob) prices, by COMMODity #
  ;
formula (all,i,TRAD_COMM)
VXWCOMMOD(i) = sum{r,REG, VXW(i,r)}
  ;


! VIW(i,r) includes only extra-regional imports or purchases outside the region !

coefficient (all,i,TRAD_COMM)(all,s,REG)
VIW(i,s) # Value of Imports at World (cif) prices, by commodity and region #
  ;
formula (all,i,TRAD_COMM)(all,s,REG)
VIW(i,s) = sum{r,REG, [1 - DELTA(r,s)] * VDWS(i,r,s)}
  ;


coefficient (all,r,REG)
VIWREGION(r) # Value of Imports at World (cif) prices, by REGION #
  ;
formula (all,r,REG)
VIWREGION(r) = sum{i,TRAD_COMM, VIW(i,r)}
  ;


coefficient (all,i,TRAD_COMM)
VIWCOMMOD(i) # Value of Imports at World (cif) prices, by COMMODity #
  ;
formula (all,i,TRAD_COMM)
VIWCOMMOD(i) = sum{r,REG, VIW(i,r)}
  ;


coefficient
VXWLD # Value of WorLD commodity eXports at world (fob) prices #
  ;
formula
VXWLD = sum{r,REG, VXWREGION(r)}
  ;


! NOTE    The   difference   between   VWLDSALES(r)   and   VXWREGION(r)   is   that   the   former
   includes NETINV(r) !
```

```
coefficient (all,r,REG)
VWLDSALES(r) # Value of SALES to the WorLD market by region r #
  ;
formula (all,r,REG)
VWLDSALES(r) = sum{i,TRAD_COMM, sum{s,REG, [1 - DELTA(r,s)]
           * VSWD(i,r,s)} + VST(i,r)} + NETINV(r)
  ;


coefficient (all,s,REG)
VWLDDEMAND(s) # Value of DEMANDs from the WorLD market by region r #
  ;
formula (all,s,REG)
VWLDDEMAND(s) = sum{i,TRAD_COMM, sum{r,REG, [1 - DELTA(r,s)]
            * VDWS(i,r,s)} } + SAVE(s)
  ;


! Aggregate Output
  ---------------- !

coefficient (all,i,TRAD_COMM)(all,r,REG)
VOW(i,r) # Value of Output at World (fob) prices by region r #
  ! This includes transportation services supplied by the region !
  ;
formula (all,i,TRAD_COMM)(all,r,REG)
VOW(i,r) = sum{s,REG, VSWD(i,r,s)} + VST(i,r)
  ;


coefficient (all,i,TRAD_COMM)
VWOW(i) # Value of World Output at World (fob) prices by commodity #
  ;
formula (all,i,TRAD_COMM)
VWOW(i) = sum{r,REG, VOW(i,r)}
  ;


! Private Consumption and Usage Shares
  ----------------------------------- !

coefficient (all,i,TRAD_COMM)(all,r,REG)
CONSHR(i,r) # SHaRe in private household CONsumption #
  ;
formula (all,i,TRAD_COMM)(all,r,REG)
CONSHR(i,r) = VPA(i,r) / sum{m, TRAD_COMM, VPA(m,r)}
  ;
```

```
!    Share  of  composite  imports  in  total  expenditure/purchases,  by  agent,  is    relevant
     only  for  the  perfectly  competitive  commodities  (PCOMP_COMM),   though  defined  over
     all tradables !

coefficient (all,i,TRAD_COMM)(all,j,PROD_COMM)(all,s,REG)
FMSHR(i,j,s) # SHaRe of composite iMports in total purchases by Firms #
  ;
formula (all,i,TRAD_COMM)(all,j,PROD_COMM)(all,s,REG)
FMSHR(i,j,s) = sum{r,REG, [1 - DELTA(r,s)] * VFAS(i,r,j,s)} / VFA(i,j,s)
  ;


coefficient (all,i,TRAD_COMM)(all,s,REG)
PMSHR(i,s) # SHaRe of composite iMports in Private household expenditure #
  ;
formula (all,i,TRAD_COMM)(all,s,REG)
PMSHR(i,s) = sum{r,REG, [1 - DELTA(r,s)] * VPAS(i,r,s)} / VPA(i,s)
  ;


coefficient (all,i,TRAD_COMM)(all,s,REG)
GMSHR(i,s) # SHaRe of composite iMports in Government expenditure #
  ;
formula (all,i,TRAD_COMM)(all,s,REG)
GMSHR(i,s) = sum{r,REG, [1 - DELTA(r,s)] * VGAS(i,r,s)} / VGA(i,s)
  ;


! Share  of  imports  by  source  in  composite  imports,  by  agent,  is  relevant  only  for  the
    perfectly   competitive   commodities   (PCOMP_COMM),   though   defined   over   all   tradables
    !

coefficient (all,i,TRAD_COMM)(all,r,REG)(all,j,PROD_COMM)(all,s,REG)
FMSHRS(i,r,j,s) # SHaRe of imports by Source in composite iMports of Firms #
  ;
formula (all,i,TRAD_COMM)(all,r,REG)(all,j,PROD_COMM)(all,s,REG)
FMSHRS(i,r,j,s) = [1 - DELTA(r,s)] * VFAS(i,r,j,s)
                / sum{t,REG, [1 - DELTA(t,s)] * VFAS(i,t,j,s)}
  ;


coefficient (all,i,TRAD_COMM)(all,r,REG)(all,s,REG)
PMSHRS(i,r,s) # SHaRe of imports by Source in Private hhld composite iMports #
  ;
formula (all,i,TRAD_COMM)(all,r,REG)(all,s,REG)
PMSHRS(i,r,s) = [1 - DELTA(r,s)] * VPAS(i,r,s)
              / sum{t,REG, [1 - DELTA(t,s)] * VPAS(i,t,s)}
  ;


coefficient (all,i,TRAD_COMM)(all,r,REG)(all,s,REG)
```

```
GMSHRS(i,r,s) # SHaRe of imports by Source in composite iMports by Govt #
  ;
formula (all,i,TRAD_COMM)(all,r,REG)(all,s,REG)
GMSHRS(i,r,s) = [1 - DELTA(r,s)] * VGAS(i,r,s)
            / sum{t,REG, [1 - DELTA(t,s)] * VGAS(i,t,s)}
  ;


! Share  of  demand  by  source  in  total  expenditure/purchases,  by  agent,  defined  only
  over the monopolistically competitive commodities (MCOMP_COMM) !

coefficient (all,i,MCOMP_COMM)(all,r,REG)(all,j,PROD_COMM)(all,s,REG)
FTHETA(i,r,j,s) # share of demand by source in Firms' total purchases #
  ;
formula (all,i,MCOMP_COMM)(all,r,REG)(all,j,PROD_COMM)(all,s,REG)
FTHETA(i,r,j,s) = VFAS(i,r,j,s) / sum{k,REG, VFAS(i,k,j,s)}
  ;


coefficient (all,i,MCOMP_COMM)(all,r,REG)(all,s,REG)
PTHETA(i,r,s) # share of demand by source in Private hhld expenditure #
  ;
formula (all,i,MCOMP_COMM)(all,r,REG)(all,s,REG)
PTHETA(i,r,s) = VPAS(i,r,s) / sum{k,REG, VPAS(i,k,s)}
  ;


coefficient (all,i,MCOMP_COMM)(all,r,REG)(all,s,REG)
GTHETA(i,r,s) # share of demand by source in Government expenditure #
  ;
formula (all,i,MCOMP_COMM)(all,r,REG)(all,s,REG)
GTHETA(i,r,s) = VGAS(i,r,s) / sum{k,REG, VGAS(i,k,s)}
  ;


! Cost and Revenue Shares
  ---------------------- !

coefficient (all,i,ENDW_COMM)(all,j,PROD_COMM)(all,r,REG)
SVA(i,j,r) # Share of endowment in total Value-Added #
  ;
formula (all,i,ENDW_COMM)(all,j,PROD_COMM)(all,r,REG)
SVA(i,j,r) = VFA(i,j,r)/sum{k,ENDW_COMM, VFA(k,j,r)}
  ;


coefficient (all,i,ENDW_COMM)(all,j,PROD_COMM)(all,r,REG)
SENT(i,j,r) # Share of ENdowment in Total costs #
  ;
formula (all,i,ENDW_COMM)(all,j,PROD_COMM)(all,r,REG)
SENT(i,j,r) = VFA(i,j,r)/sum{k,DEMD_COMM, VFA(k,j,r)}
```

```
  ;

coefficient (all,i,TRAD_COMM)(all,j,PROD_COMM)(all,r,REG)
SINT(i,j,r) # Share of INtermediate input in Total costs #
  ;
formula (all,i,TRAD_COMM)(all,j,PROD_COMM)(all,r,REG)
SINT(i,j,r) = VFA(i,j,r)/sum{k,DEMD_COMM, VFA(k,j,r)}
  ;


coefficient (all,i,ENDW_COMM)(all,j,PROD_COMM)(all,r,REG)
REVSHR(i,j,r) # SHaRe of a sector in total REVenue to an endowment #
  ;
formula (all,i,ENDW_COMM)(all,j,PROD_COMM)(all,r,REG)
REVSHR(i,j,r) = VFM(i,j,r)/sum{k,PROD_COMM, VFM(i,k,r)}
  ;


! Other Shares
  ------------ !

coefficient (all,i,TRAD_COMM)(all,r,REG)(all,s,REG)
FOBSHR(i,r,s) # SHaRe of FOB price in total import (cif) price #
  ;
formula (all,i,TRAD_COMM)(all,r,REG)(all,s,REG)
FOBSHR(i,r,s) = VSWD(i,r,s)/VDWS(i,r,s)
  ;


coefficient (all,i,TRAD_COMM)(all,r,REG)(all,s,REG)
TRNSHR(i,r,s) # SHaRe of TRaNsport margin in total import (cif) price #
  ;
formula (all,i,TRAD_COMM)(all,r,REG)(all,s,REG)
TRNSHR(i,r,s) = VTWR(i,r,s)/VDWS(i,r,s)
  ;


coefficient (all,r,REG)
INVKERATIO(r) # RATIO of gross INVestment to End-of-period capital stock #
  ;
formula (all,r,REG)
INVKERATIO(r) = REGINV(r) / [VKB(r) + NETINV(r)]
  ;


coefficient (all,r,REG)
GRNETRATIO(r) # RATIO of GRoss to NET rate of return on capital #
  ! VOA("capital",r) is GROSS returns to capital !
  ;
formula (all,r,REG)
GRNETRATIO(r) = sum{h, ENDWC_COMM, VOA(h,r)}
```

```
                    / [ sum{h, ENDWC_COMM, VOA(h,r)} - VDEP(r) ]
   ;




   display voa ;          display vom ;
   display va ;           display vaf ;             display vav ;        display vc ;
   display vpa ;          display vga ;             display income ;     display gdp ;
   display privexp ;      display govexp ;
   display reginv ;       display netinv ;          display globinv ;
   display vxw ;          display vxwregion ;       display vxwcommod ;
   display viw ;          display viwregion ;       display viwcommod ;
   display vwldsales ;                              display vwlddemand ;
   display vow ;          display vwow ;            display vxwld ;
   display conshr ;
   display fmshr ;        display gmshr ;           display pmshr ;
   display fmshrs ;       display gmshrs ;          display pmshrs ;
   display ftheta ;       display gtheta ;          display ptheta ;
   display sva ;          display sent ;            display sint ;     display revshr ;



! Allen partial elasticities of substitution, price and income elasticities
  ----------------------------------------------------------------------- !

coefficient (all,i,TRAD_COMM)(all,r,REG)
ALPHA(i,r) # 1 minus the substitution parameter in the CDE min expend fn #
   ;
formula (all,i,TRAD_COMM)(all,r,REG)
ALPHA(i,r) = [1 - SUBPAR(i,r)]
   ;


coefficient (all,i,TRAD_COMM)(all,k,TRAD_COMM)(all,r,REG)
APE(i,k,r) # Allen Partial Elasticity of substitution for composite goods #
   ;
formula (all,i,TRAD_COMM)(all,k,TRAD_COMM)(all,r,REG)
APE(i,k,r) = ALPHA(i,r) + ALPHA(k,r)
           - sum{m,TRAD_COMM, CONSHR(m,r) * ALPHA(m,r)}
   ;
formula (all,i,TRAD_COMM)(all,r,REG)
APE(i,i,r) = 2.0 * ALPHA(i,r)
           - sum{m,TRAD_COMM, CONSHR(m,r) * ALPHA(m,r)}
           - ALPHA(i,r) / CONSHR(i,r)
   ;


coefficient (all,i,TRAD_COMM)(all,r,REG)
COMPDEM(i,r) # own-price COMPensated elasticity of private hhld DEMand #
   ;
```

```
formula (all,i,TRAD_COMM)(all,r,REG)
COMPDEM(i,r) = APE(i,i,r) * CONSHR(i,r)
  ;


coefficient (all,i,TRAD_COMM)(all,r,REG)
EY(i,r) # income Elasticity of private household demand for composite good #
  ;
formula (all,i,TRAD_COMM)(all,r,REG)
EY(i,r) = [1.0/[sum{m,TRAD_COMM, CONSHR(m,r) * INCPAR(m,r)}]]
        * [INCPAR(i,r) * [1.0 - ALPHA(i,r)]
        + sum{m,TRAD_COMM, CONSHR(m,r) * INCPAR(m,r) * ALPHA(m,r)}]
        + [ALPHA(i,r) - sum{m,TRAD_COMM, CONSHR(m,r) * ALPHA(m,r)}]
  ;
coefficient (all,i,TRAD_COMM)(all,k,TRAD_COMM)(all,r,REG)
EP(i,k,r) # uncompensated cross-price elasticity of private hhld demand #
  ;
formula (all,i,TRAD_COMM)(all,k,TRAD_COMM)(all,r,REG)
EP(i,k,r) = 0
  ;
formula (all,i,TRAD_COMM)(all,k,TRAD_COMM)(all,r,REG)
EP(i,k,r) = [APE(i,k,r) - EY(i,r)] * CONSHR(k,r)
  ;


display compdem ;  display ey ;


ZERODIVIDE (ZERO_BY_ZERO) OFF ;


! Dummy Coefficients
  ------------------ !


! They eliminate spurious percentage changes in initially zero variables. !


coefficient (all,i,ENDW_COMM)(all,j,PROD_COMM)(all,r,REG)
D_EVFA(i,j,r) # 0, 1 variable for identifying zero expenditures in EVFA #
  ;
formula (all,i,ENDW_COMM)(all,j,PROD_COMM)(all,r,REG)
D_EVFA(i,j,r) = 0
  ;
formula (all,i,ENDW_COMM)(all,j,PROD_COMM)(all,r,REG: EVFA(i,j,r) > 0 )
D_EVFA(i,j,r) = 1
  ;


coefficient (all,i,TRAD_COMM)(all,j,PROD_COMM)(all,r,REG)
D_VFA(i,j,r) # 0, 1 variable for identifying zero expenditures in VFA #
  ;
formula (all,i,TRAD_COMM)(all,j,PROD_COMM)(all,r,REG)
```

65

```
D_VFA(i,j,r) = 0
   ;
formula (all,i,TRAD_COMM)(all,j,PROD_COMM)(all,r,REG: VFA(i,j,r) > 0 )
D_VFA(i,j,r) = 1
   ;


coefficient (all,i,TRAD_COMM)(all,r,REG)
D_VST(i,r) # 0, 1 variable to identify zero expenditures in VST #
   ;
formula (all,i,TRAD_COMM)(all,r,REG)
D_VST(i,r) = 0
   ;
formula (all,i,TRAD_COMM)(all,r,REG: VST(i,r)>0)
D_VST(i,r) = 1
   ;


coefficient (all,i,TRAD_COMM)(all,r,REG)(all,s,REG)
D_VPMS(i,r,s) # 0, 1 variable for identifying zero expenditures in VPMS #
   ;
formula (all,i,TRAD_COMM)(all,r,REG)(all,s,REG)
D_VPMS(i,r,s) = 0
   ;
formula (all,i,TRAD_COMM)(all,r,REG)(all,s,REG: VPMS(i,r,s) > 0 )
D_VPMS(i,r,s) = 1
   ;


coefficient (all,i,TRAD_COMM)(all,r,REG)(all,s,REG)
D_VGMS(i,r,s) # 0, 1 variable for identifying zero expenditures in VGMS #
   ;
formula (all,i,TRAD_COMM)(all,r,REG)(all,s,REG)
D_VGMS(i,r,s) = 0
   ;
formula (all,i,TRAD_COMM)(all,r,REG)(all,s,REG: VGMS(i,r,s) > 0 )
D_VGMS(i,r,s) = 1
   ;


coefficient (all,i,TRAD_COMM)(all,r,REG)(all,j,PROD_COMM)(all,s,REG)
D_VFMS(i,r,j,s) # 0, 1 variable for identifying zero expenditures in VFMS #
   ;
formula (all,i,TRAD_COMM)(all,r,REG)(all,j,PROD_COMM)(all,s,REG)
D_VFMS(i,r,j,s) = 0
   ;
formula
(all,i,TRAD_COMM)(all,r,REG)(all,j,PROD_COMM)(all,s,REG: VFMS(i,r,j,s) > 0 )
D_VFMS(i,r,j,s) = 1
   ;
```

```
!------------------------------------------------------------------------------                       !
!                                     Checking the Base Data                                           !
!------------------------------------------------------------------------------                       !

coefficient (all,i,TRAD_COMM)(all,r,REG)
CHKMKTCLTRD(i,r) # CHecK MarKeT CLearing condition for TRaDables #
  ;
formula (all,i,TRAD_COMM)(all,r,REG)
CHKMKTCLTRD(i,r) = VOM(i,r) - [sum{s,REG, VSMD(i,r,s)} + VST(i,r)]
  ;


coefficient (all,i,TRAD_COMM)(all,r,REG)(all,s,REG)
CHKMKTCLSL(i,r,s) # CHecK MarKeT CLearing condition in SaLes by destination #
  ;
formula (all,i,TRAD_COMM)(all,r,REG)(all,s,REG)
CHKMKTCLSL(i,r,s) = VDMS(i,r,s) - [VPMS(i,r,s) + VGMS(i,r,s)
                 + sum{j,PROD_COMM, VFMS(i,r,j,s) }]
  ;


coefficient (all,i,ENDW_COMM)(all,r,REG)
CHKMKTCLENDW(i,r) # CHecK MarKeT CLearing condition for ENDoWment #
  ;
formula (all,i,ENDW_COMM)(all,r,REG)
CHKMKTCLENDW(i,r) = VOM(i,r) - sum{j,PROD_COMM, VFM(i,j,r)}
  ;


coefficient
CHKSAVE # CHecK the equality of global SAVings and investment #
  ;
formula
CHKSAVE = sum{k,REG, SAVE(k)}
        - [sum{k,REG, sum{i,CGDS_COMM, VOA(i,k)} - VDEP(k)}]
  ;


coefficient
CHKTRANS # CHecK equality of global demand and supply of TRANsport services #
  ;
formula
CHKTRANS = sum{i,TRAD_COMM, sum{r,REG, sum{s,REG, VTWR(i,r,s)}}}
         - sum{i,TRAD_COMM, sum{r,REG, VST(i,r)}}
  ;


coefficient (all,j,PROD_COMM)(all,r,REG)
PROFITS(j,r) # check zero PROFITS #
  ;
formula (all,j,PROD_COMM)(all,r,REG)
```

```
PROFITS(j,r) = VOA(j,r) - sum{i,DEMD_COMM, VFA(i,j,r)}
  ;


coefficient (all,r,REG)
BOP(r) # check Balance Of Payments in region r. This should equal zero #
  ;
formula (all,r,REG)
BOP(r) = sum{i,TRAD_COMM, sum{s,REG, VSWD(i,r,s)} + VST(i,r)}
       + sum{i,CGDS_COMM, VOA(i,r)} - VDEP(r)
       - sum{i,TRAD_COMM, sum{k,REG, VDWS(i,k,r)}} - SAVE(r)
  ;


coefficient (all,s,REG)
SURPLUS(s) # check economic SURPLUS in region s. This should equal zero. #
  ;
formula (all,r,REG)
SURPLUS(r) =
   sum{i,ENDW_COMM, VOA(i,r)} - VDEP(r)
 + sum{j,MCOMP_COMM, VOA(j,r) - sum{i,TRAD_COMM, VFA(i,j,r)} - VA(j,r) }
 + sum{i,NSAV_COMM, VOM(i,r) - VOA(i,r)}
 + sum{i,ENDW_COMM, sum{j,PROD_COMM, VFA(i,j,r) - VFM(i,j,r) }}
 + sum{t,REG, sum{j,PROD_COMM, sum{i,TRAD_COMM,
                            VFAS(i,t,j,r) - VFMS(i,t,j,r) }}}
 + sum{t,REG, sum{i,TRAD_COMM, VPAS(i,t,r) - VPMS(i,t,r) }}
 + sum{t,REG, sum{i,TRAD_COMM, VGAS(i,t,r) - VGMS(i,t,r) }}
 + sum{t,REG, sum{i,TRAD_COMM, VSWD(i,r,t) - VSMD(i,r,t) }}
 + sum{t,REG, sum{i,TRAD_COMM, VDMS(i,t,r) - VDWS(i,t,r) }}
 - sum{t,REG, sum{i,TRAD_COMM, VPAS(i,t,r) + VGAS(i,t,r) }} - SAVE(r)
  ;


display chkmktcltrd ;   display chkmktclsl ;    display chkmktclendw ;
display chksave ;       display chktrans ;
display profits ;       display bop ;           display surplus ;

!---------------------------------------------------------------------------            !
!                                  Equations                                            !
!---------------------------------------------------------------------------            !


!   See  documentation  by  Swaminathan  and  Hertel  for  detailed  derivation  and   discussion
    of the equations describing product differentiation and economies of scale.

    See   documentation   by   Hertel   and   Tsigas   for   derivations   and  discussion  of  the
    equations that are common to the standard model. !


!---------------------------------------------------------------------------            !
!                          Market Clearing Equations                                    !
```

```
!----------------------------------------------------------------------                   !


!   The  following  equation  enforces  market  clearing  for  all  but  one  of  the  tradeable
    commodities,    while    checking    for    equilibrium    in    the    final    market
    (savings=investment).  Note  that  walraslack  must  be  endogenous  in  the  usual  general
    equilibrium  closure.  However,  in  any  of  the  partial  equilibrium  closures  it  will  be
    exogenous. !


EQUATION MKTCLTRD # MarKeT CLearing for TRaDable commodities #
! This equation assures market clearing in the traded goods markets. !
(all,i,TRAD_COMM)(all,r,REG)
VOM(i,r) * qo(i,r) = sum{s,REG, VSMD(i,r,s) * qs(i,r,s)}
                    + VST(i,r) * qst(i,r)
                    + VOM(i,r) * tradslack(i,r) ;


!   The  equation  MKTCLSLHM  checks  the  balancing  condition  for  every  bilateral  trade
    flow.  If  the  trade  flow  is  zero  for  any  (i,r,s)  triple  in  the  initial  data  base,
    then  this  equation  has  all  zero  coefficients,  causing  singularity  problems.  This
    problem  is  corrected  by  introducing  a  small  value,  DATAFIX(i,r,s),  in  place  of  the
    zero  trade  flow.  The  correction  preserves  the  homogeneity  of  the  equation  system.
    !


!   This  fix,  however,  can  cause  extremely  large  percentage  changes  in  flows  that  are
    initially  zero  -  qs(i,r,s),  and  therefore  in  qhmps(i,r,s),  qhmgs(i,r,s),  and
    qhmfs(i,r,j,s).  This  is  remedied  by  using  a  dummy  coefficient  in  the  derived  demand
    equation  for  sourced  homogeneous  goods  of  each  agent  -  PHLDSRCPC,  GOVSRCPC,  and
    INDSRCPC equations. !


coefficient (all,i,PCOMP_COMM)(all,r,REG)(all,s,REG)
DATAFIX(i,r,s) # fix the data problem of zero trade flow #
  ! DATAFIX assumes the value of 0.0001 million $, only if there is a zero
    trade flow, else 0.0 !
  ;
formula (all,i,PCOMP_COMM)(all,r,REG)(all,s,REG)
DATAFIX(i,r,s) = IF(VDMS(i,r,s) = 0.0, 0.0001)
  ;


EQUATION MKTCLSLHM
# MarKeT CLearing in the SaLe of HoMogeneous commodities #
(all,i,PCOMP_COMM)(all,r,REG)(all,s,REG)
[VDMS(i,r,s) + DATAFIX(i,r,s)] * qs(i,r,s)
  = [VPMS(i,r,s) + DATAFIX(i,r,s)] * qhmps(i,r,s)
  + [VGMS(i,r,s) + DATAFIX(i,r,s)] * qhmgs(i,r,s)
  + sum{j,PROD_COMM, [VFMS(i,r,j,s) + DATAFIX(i,r,s)] * qhmfs(i,r,j,s)}
  ;
```

```
EQUATION MKTCLSLDF
# MarKeT CLearing in the SaLe of DiFferentiated commodities #
(all,i,MCOMP_COMM)(all,r,REG)(all,s,REG)
VDMS(i,r,s) * qs(i,r,s) = VPMS(i,r,s) * qdfps(i,r,s)
                         + VGMS(i,r,s) * qdfgs(i,r,s)
                         + sum{j,PROD_COMM, VFMS(i,r,j,s) * qdffs(i,r,j,s)} ;


EQUATION MKTCLENDWM
# MarKeT CLearing for the Mobile ENDoWment commodities #
(all,i,ENDWM_COMM)(all,r,REG)
VOM(i,r) * qo(i,r) = sum{j,PROD_COMM, VFM(i,j,r) * qfe(i,j,r)}
                   + VOM(i,r) * endwslack(i,r) ;


EQUATION MKTCLENDWS
# MarKeT CLearing for the Sluggish ENDoWment commodities #
(all,i,ENDWS_COMM)(all,j,PROD_COMM)(all,r,REG)
qoes(i,j,r) = qfe(i,j,r);


EQUATION PRIVATEXP
# PRIVATe household EXPenditure #
(all,r,REG)
PRIVEXP(r) * yp(r) = INCOME(r) * y(r)
                   - SAVE(r) * [psave + qsave(r)]
                   - sum{i,TRAD_COMM, VGA(i,r) * [pg(i,r) + qg(i,r)]} ;


EQUATION REGIONALINCOME # REGIONAL INCOME #
(all,r,REG)
INCOME(r) * y(r)
 = sum{i,ENDW_COMM, VOA(i,r) * [ps(i,r) + qo(i,r)] }
 - VDEP(r) * [pcgds(r) + kb(r)]
 + sum{j,MCOMP_COMM, VOA(j,r) * [ps(j,r) + qo(j,r)]
 - sum{i,TRAD_COMM, VFA(i,j,r) * [pf(i,j,r) + qf(i,j,r)] }
 -                  VA(j,r) * [pva(j,r) + qva(j,r)] }
 + sum{i,NSAV_COMM, VOM(i,r) * [pm(i,r) + qo(i,r)]
                  - VOA(i,r) * [ps(i,r) + qo(i,r)] }
 + sum{i,ENDWM_COMM, sum{j,PROD_COMM, VFA(i,j,r) * [pfe(i,j,r) + qfe(i,j,r)]
                                    - VFM(i,j,r) * [pm(i,r) + qfe(i,j,r)] }}
 + sum{i,ENDWS_COMM, sum{j,PROD_COMM,
                                VFA(i,j,r) * [pfe(i,j,r) + qfe(i,j,r)]
                              - VFM(i,j,r) * [pmes(i,j,r) + qfe(i,j,r)] }}
 + sum{t,REG, sum{j,PROD_COMM, sum{i,PCOMP_COMM,
                     VFAS(i,t,j,r) * [pfs(i,t,j,r) + qhmfs(i,t,j,r)]
                   - VFMS(i,t,j,r) * [pms(i,t,r) + qhmfs(i,t,j,r)] }}}
 + sum{t,REG, sum{j,PROD_COMM, sum{i,MCOMP_COMM,
                     VFAS(i,t,j,r) * [pfs(i,t,j,r) + qdffs(i,t,j,r)]
                   - VFMS(i,t,j,r) * [pms(i,t,r) + qdffs(i,t,j,r)] }}}
```

```
      + sum{t,REG, sum{i,PCOMP_COMM, VPAS(i,t,r) * [pps(i,t,r) + qhmps(i,t,r)]
                            - VPMS(i,t,r) * [pms(i,t,r) + qhmps(i,t,r)] }}
   + sum{t,REG, sum{i,MCOMP_COMM, VPAS(i,t,r) * [pps(i,t,r) + qdfps(i,t,r)]
                            - VPMS(i,t,r) * [pms(i,t,r) + qdfps(i,t,r)] }}
   + sum{t,REG, sum{i,PCOMP_COMM, VGAS(i,t,r) * [pgs(i,t,r) + qhmgs(i,t,r)]
                            - VGMS(i,t,r) * [pms(i,t,r) + qhmgs(i,t,r)] }}
   + sum{t,REG, sum{i,MCOMP_COMM, VGAS(i,t,r) * [pgs(i,t,r) + qdfgs(i,t,r)]
                            - VGMS(i,t,r) * [pms(i,t,r) + qdfgs(i,t,r)] }}
   + sum{t,REG, sum{i,TRAD_COMM, VSWD(i,r,t) * [pfob(i,r,t) + qs(i,r,t)]
                            - VSMD(i,r,t) * [pm(i,r)     + qs(i,r,t)] }}
   + sum{t,REG, sum{i,TRAD_COMM, VDMS(i,t,r) * [pms(i,t,r)  + qs(i,t,r)]
                            - VDWS(i,t,r) * [pcif(i,t,r) + qs(i,t,r)] }}
    + INCOME(r) * incomeslack(r)
    ;


EQUATION KEND # ENDing capital stock #
(all,r,REG)
ke(r) = INVKERATIO(r) * qcgds(r) + [1.0 - INVKERATIO(r)] * kb(r) ;


EQUATION WALRAS_S # Supply of investment goods (extra equation) #
walras_sup = globalcgds ;


EQUATION WALRAS_D # Demand in the savings market (extra equation) #
GLOBINV * walras_dem = sum{r,REG, SAVE(r) * qsave(r)} ;


EQUATION WALRAS
# check WALRAS' law holds - endogenous walraslack must be zero #
walras_sup = walras_dem + walraslack ;


!-------------------------------------------------------------------------------                !
!                              Price Linkage Equations                                           !
!-------------------------------------------------------------------------------                !

!   The  following  equations  serve  to  link  prices  in  different  markets  taking    into
    account  taxes/subsidies.  There  are  6  types  of  taxes  in  this  model:   import  taxes,
    source-generic    variable    levies    on    inter-regional    imports,    export    taxes,
    destination-generic  variable  export  subsidies  on   inter-regional  exports,  output
    taxes,  income  taxes,  primary  factor  taxes   on  firms,  and  commodity  taxes  levied  both
    on  households  and  firms.  !


EQUATION SUPPLYPRICES
# Supply (Producer) price and market price linkage, TO(i,r) < 1 for tax #
(all,i,NSAV_COMM)(all,r,REG)
ps(i,r) = to(i,r) + pm(i,r) ;


EQUATION MPFACTPRICE
```

```
# firms' demand price and market price for Mobile Primary FACTors #
(all,i,ENDWM_COMM)(all,j,PROD_COMM)(all,r,REG)
pfe(i,j,r) = tf(i,j,r) + pm(i,r) ;


EQUATION SPFACTPRICE
# firms' demand price and market price for Sluggish Primary FACTors #
(all,i,ENDWS_COMM)(all,j,PROD_COMM)(all,r,REG)
pfe(i,j,r) = tf(i,j,r) + pmes(i,j,r) ;


EQUATION PHHDPRICE
# Private HouseHolD demand price and market price for tradable commodities #
(all,i,TRAD_COMM)(all,r,REG)(all,s,REG)
pps(i,r,s) = tps(i,r,s) + pms(i,r,s) ;


EQUATION GHHDPRICE
# Government demand price and market price for tradable commodities #
(all,i,TRAD_COMM)(all,r,REG)(all,s,REG)
pgs(i,r,s) = tgs(i,r,s) + pms(i,r,s) ;


EQUATION DMNDDPRICE
# firms' demand price and market price for tradable commodities #
(all,i,TRAD_COMM)(all,r,REG)(all,j,PROD_COMM)(all,s,REG)
pfs(i,r,j,s) = tfs(i,r,j,s) + pms(i,r,s)  ;


EQUATION MKTPRICES
# domestic and world market price for (source-specific) imports #
(all,i,TRAD_COMM)(all,r,REG)(all,s,REG)
pms(i,r,s) = [1 - DELTA(r,s)] * [tm(i,s) + tms(i,r,s)] + pcif(i,r,s)  ;


EQUATION EXPRICES
# domestic and world market price for (destination-specific) exports #
(all,i,TRAD_COMM)(all,r,REG)(all,s,REG)
pfob(i,r,s) = pm(i,r) - [1 - DELTA(r,s)] * [tx(i,r) + txs(i,r,s)] ;


!-----------------------------------------------------------------------------                  !
!                              Firm Behavioral Equations                                         !
!-----------------------------------------------------------------------------                  !


! Composite Intermediates Nest, qf(i,j,s), i IN PCOMP_COMM
   -------------------------------------------------------- !


EQUATION INDPCCOMPR
# INDustry PRice for Perfectly Competitive COMposite commodity #
(all,i,PCOMP_COMM)(all,j,PROD_COMM)(all,s,REG)
pf(i,j,s) = FMSHR(i,j,s) * pfm(i,j,s) + [1 - FMSHR(i,j,s)] * pfs(i,s,j,s) ;
```

```
EQUATION INDIMPPR
# INDustry PRice for composite IMPort commodity #
(all,i,PCOMP_COMM)(all,j,PROD_COMM)(all,s,REG)
pfm(i,j,s) = sum{r,REG, [1 - DELTA(r,s)] * FMSHRS(i,r,j,s) * pfs(i,r,j,s)} ;


EQUATION INDIMP
# INDustry demand for composite IMPort commodity #
(all,i,PCOMP_COMM)(all,j,PROD_COMM)(all,s,REG)
qfm(i,j,s) = qf(i,j,s) + ESUBD(i) * [pf(i,j,s) - pfm(i,j,s)] ;


EQUATION INDSRCPC
# INDustry demand for SouRCed Perfectly Competitive commodity #
(all,i,PCOMP_COMM)(all,r,REG)(all,j,PROD_COMM)(all,s,REG)
qhmfs(i,r,j,s) = D_VFMS(i,r,j,s)
                * [DELTA(r,s) * {qf(i,j,s)
                + ESUBD(i) * [pf(i,j,s) - pfs(i,s,j,s)]}
                + [1 - DELTA(r,s)] * {qfm(i,j,s) + ESUBM(i)
                * [pfm(i,j,s) - pfs(i,r,j,s)]}] ;


! Composite Intermediates Nest, qf(i,j,s), i IN MCOMP_COMM
  -------------------------------------------------------- !


EQUATION INDSRCDF
# INDustry demand for SouRCed DiFferentiated commodity #
(all,i,MCOMP_COMM)(all,r,REG)(all,j,PROD_COMM)(all,s,REG)
qdffs(i,r,j,s) = qf(i,j,s) + n(i,r)
                + SIGMA(i) * [pf(i,j,s) - pfs(i,r,j,s)] ;


EQUATION INDDFCOMPR
# INDustry PRice for DiFferentiated COMposite commodity #
(all,i,MCOMP_COMM)(all,j,PROD_COMM)(all,s,REG)
pf(i,j,s) = sum{r,REG, FTHETA(i,r,j,s) * pfs(i,r,j,s)}
          - {1/[SIGMA(i) - 1]} * vf(i,j,s) ;


EQUATION INDVARIN
# INDustry VARiety INdex #
(all,i,MCOMP_COMM)(all,j,PROD_COMM)(all,s,REG)
vf(i,j,s) = sum{r,REG, FTHETA(i,r,j,s) * n(i,r)} ;


! Value-added Nest, j IN PROD_COMM
  ------------------------------- !


EQUATION VAPRICE
# (Effective) PRICE of Value-Added composite #
(all,j,PROD_COMM)(all,r,REG)
pva(j,r) = sum{k,ENDW_COMM, SVA(k,j,r) * [pfe(k,j,r) - afe(k,j,r)]} ;
```

```
EQUATION ENDWDEMAND
# DEMAND for ENDoWment commodity #
(all,i,ENDW_COMM)(all,j,PROD_COMM)(all,r,REG)
qfe(i,j,r) = D_EVFA(i,j,r) * { - afe(i,j,r) + qva(j,r)
            - ESUBVA(j) * [pfe(i,j,r) - afe(i,j,r) - pva(j,r)] } ;


! Value-added Nest, j IN MCOMP_COMM
  -------------------------------- !


EQUATION VAFDEMAND
# imperfectly competitive industry DEMAND for Fixed Value-Added #
(all,j,MCOMP_COMM)(all,s,REG)
qvaf(j,s) = n(j,s) + ao(j,s) ;


EQUATION VATOT
# imperfectly competitive industry demand for TOTal Value-Added #
(all,j,MCOMP_COMM)(all,s,REG)
qva(j,s) = [VAV(j,s)/VA(j,s)] * qvav(j,s)
         + [VAF(j,s)/VA(j,s)] * qvaf(j,s) ;


! Total Output Nest
  ---------------- !


EQUATION VADEMAND
# perfectly competitive industry DEMAND for Value-Added composite #
(all,j,PCGDS_COMM)(all,r,REG)
qva(j,r) + ava(j,r) = qo(j,r) - ao(j,r);


EQUATION VAVDEMAND
# imperfectly competitive industry DEMAND for Variable Value-Added #
(all,j,MCOMP_COMM)(all,s,REG)
qvav(j,s) + avav(j,s) = qo(j,s) - ao(j,s) ;


EQUATION INTDEMAND
# industry DEMAND for composite INTermediate input #
(all,i,TRAD_COMM)(all,j,PROD_COMM)(all,r,REG)
qf(i,j,r) = D_VFA(i,j,r) * [ - af(i,j,r) + qo(j,r) - ao(j,r) ];


! Zero Profits Equations
  ---------------------- !


EQUATION PZEROPROFITS
# ZERO pure PROFIT condition for firms in the Perfectly competitive industry #
! This equation determines the endogenous output level in the perfectly competitive
  sector. !
(all,j,PCGDS_COMM)(all,r,REG)
```

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```
VOA(j,r) * [ps(j,r) + ao(j,r)] =
    sum{i,ENDW_COMM, VFA(i,j,r) * [pfe(i,j,r) - afe(i,j,r) - ava(j,r)]}
  + sum{i,TRAD_COMM, VFA(i,j,r) * [pf(i,j,r) - af(i,j,r)]}
  + VOA(j,r) * zppslack(j,r);


EQUATION MKUPRICE
# MarKup pricing (with constant markup) #
! This equation determines the endogenous output per firm in the monopolistically
  competitive industry. !
(all,j,MCOMP_COMM)(all,r,REG)
ps(j,r) = avc(j,r) + mkupslack(j,r) ;


EQUATION AVERAGEVC
# AVERAGE Variable Cost #
(all,j,MCOMP_COMM)(all,r,REG)
VC(j,r) * avc(j,r) = sum{i,TRAD_COMM, VFA(i,j,r) * pf(i,j,r)}
                    + VAV(j,r) * pva(j,r) + VC(j,r) * ao(j,r) ;


EQUATION SCLCONATC
# Average Total Cost at CONstant SCale #
(all,j,MCOMP_COMM)(all,r,REG)
VOA(j,r) * scatc(j,r) = sum{i,TRAD_COMM, VFA(i,j,r) * pf(i,j,r)}
                      + VA(j,r) * pva(j,r) + VOA(j,r) * ao(j,r) ;


EQUATION MZEROPROFITS
# ZERO pure PROFIT condition for firms in the Monopolistically comp industry #
! This equation determines the endogenous number of firms in the monopolistically
  competitive industry due to entry/exit of firms. !
(all,j,MCOMP_COMM)(all,r,REG)
VOA(j,r) * ps(j,r) = VOA(j,r) * scatc(j,r)
                    - VAF(j,r) * qof(j,r) + zpislack(j,r) ;


EQUATION INDOUTPUT
# INDustry OUTPUT in the monopolistically competitive industry #
(all,j,MCOMP_COMM)(all,r,REG)
qo(j,r) = qof(j,r) + n(j,r) ;


!------------------------------------------------------------------------------                    !
!                           Household Behavioral Equations                                         !
!------------------------------------------------------------------------------                    !


! Regional Utility
  --------------- !


EQUATION UTILITY
# per capita regional UTILITY #
```

```
(all,r,REG)
INCOME(r) * u(r) = PRIVEXP(r) * up(r)
                 + GOVEXP(r)  * [ ug(r) - pop(r) ]
                 + SAVE(r)    * [ qsave(r) - pop(r)] ;


! Regional Savings
  --------------- !

EQUATION SAVINGS
# regional demand for savings #
! This  is  derived  from  an  aggregate  Cobb-Douglas  utility  function  where  the  pop(r)
  terms again cancel. !
(all,r,REG)
qsave(r) = y(r) - psave + saveslack(r) ;


!---------------------------------------------------------------------------             !
!                             Government Behavioral Equations                             !
!---------------------------------------------------------------------------             !


! Government Utility
  ----------------- !

EQUATION GOVERTU
# Utility from regional government consumption #
! In  some  closures  this  index  of  government  activity  may  be  fixed,  in  which  case
  govslack is endogenized. In this case the mix of regional expenditures changes and
  the aggregate utility index no longer applies. !
(all,r,REG)
ug(r) = y(r) - pgov(r) + govslack(r) ;


! Government Demand for Composite Goods
  ------------------------------------ !

EQUATION GPRICEINDEX
# PRICE INDEX for aggregate Government purchases #
(all,r,REG)
pgov(r) = sum{i,TRAD_COMM, [VGA(i,r)/GOVEXP(r)] * pg(i,r)} ;


EQUATION GOVDMNDS
# Government demand for composite commodity #
! Note  that  the  pop(r)  argument  in  per  capita  income  and  that  in  per  capita
  consumption cancel due to homotheticity. !
(all,i,TRAD_COMM)(all,r,REG)
qg(i,r) = ug(r) - [ pg(i,r) - pgov(r) ] ;


! Government Demand for Sourced Tradables, qhmgs(i,r,s), i IN PCOMP_COMM
```

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```
    --------------------------------------------------------------------- !


EQUATION GOVPCCOMPR
# GOVernment PRice for Perfectly Competitive composite COMmodity #
(all,i,PCOMP_COMM)(all,s,REG)
pg(i,s) = GMSHR(i,s) * pgm(i,s) + [1 - GMSHR(i,s)] * pgs(i,s,s) ;


EQUATION GOVIMPPR
# GOVernment PRice for composite IMPort commodity #
(all,i,PCOMP_COMM)(all,s,REG)
pgm(i,s) = sum{r,REG, [1 - DELTA(r,s)] * GMSHRS(i,r,s) * pgs(i,r,s)} ;


EQUATION GOVIMP
# GOVernment demand for composite IMPort commodity #
(all,i,PCOMP_COMM)(all,s,REG)
qgm(i,s) = qg(i,s) - ESUBD(i) * [pgm(i,s) - pg(i,s)] ;


EQUATION GOVSRCPC
# GOVernment demand for SouRCed Perfectly Competitive commodity #
(all,i,PCOMP_COMM)(all,r,REG)(all,s,REG)
qhmgs(i,r,s) = D_VGMS(i,r,s)
               * [DELTA(r,s) * {qg(i,s) + ESUBD(i)
               * [pg(i,s) - pgs(i,s,s)]}
               + [1 - DELTA(r,s)] * {qgm(i,s) + ESUBM(i)
               * [pgm(i,s) - pgs(i,r,s)]}] ;


! Government Demand for Sourced Tradables, qdfgs(i,r,s), i IN MCOMP_COMM
    --------------------------------------------------------------------- !


EQUATION GOVSRCDF
# GOVernment demand for SouRCed DiFferentiated commodity #
(all,i,MCOMP_COMM)(all,r,REG)(all,s,REG)
qdfgs(i,r,s) = qg(i,s) + n(i,r)
               - SIGMA(i) * [pgs(i,r,s) - pg(i,s)] ;


EQUATION GOVDFCOMPR
# GOVernment PRice index for DiFferentiated COMposite commodity #
(all,i,MCOMP_COMM)(all,s,REG)
pg(i,s) = sum{r,REG, GTHETA(i,r,s) * pgs(i,r,s)}
         - {1/[SIGMA(i) - 1]} * vg(i,s) ;


EQUATION GOVVARIN
# GOVernment VARiety INdex #
(all,i,MCOMP_COMM)(all,s,REG)
  vg(i,s) = sum{r,REG, GTHETA(i,r,s) * n(i,r)} ;
```

```
!------------------------------------------------------------------------                    !
!                          Private Household Behavioral Equations                             !
!------------------------------------------------------------------------                    !


! Private Household Utility
  ----------------------- !

EQUATION PRIVATEU
# PRIVATE household Utility from consumption #
! This equation is based on the per capita private expenditure function. !
(all,r,REG)
yp(r) = sum{i,TRAD_COMM, [CONSHR(i,r) * pp(i,r)]}
      + sum{i,TRAD_COMM, [CONSHR(i,r) * INCPAR(i,r)]} * up(r)
      + pop(r) ;

! Private Household Demand for Composite Commodities
  -------------------------------------------------- !

EQUATION PRIVDMNDS
# PRIVate household demand for composite commodity #
! Demand system is on a per capita basis. Here, [yp(r) - pop(r)] is percentage change
  in per capita income. !
(all,i,TRAD_COMM)(all,r,REG)
qp(i,r) = sum{k,TRAD_COMM, EP(i,k,r) * pp(k,r)}
        + EY(i,r) * [ yp(r) - pop(r) ] + pop(r) ;

! Private Household Demand for Sourced Tradeable, qhmps(i,r,s),i IN PCOMP_COMM
  -------------------------------------------------------------------------!

EQUATION PHLDPCCOMPR
# Private HousehoLD PRice for Perfectly Competitive COMposite commodity #
(all,i,PCOMP_COMM)(all,s,REG)
pp(i,s) = PMSHR(i,s) * ppm(i,s) + [1 - PMSHR(i,s)] * pps(i,s,s) ;

EQUATION PHLDIMPPR
# Private HousehoLD PRice for composite IMPort commodity #
(all,i,PCOMP_COMM)(all,s,REG)
ppm(i,s) = sum{r,REG, [1 - DELTA(r,s)] * PMSHRS(i,r,s)*pps(i,r,s)} ;

EQUATION PHLDIMP
# Private HousehoLD demand for composite IMPort commodity #
(all,i,PCOMP_COMM)(all,s,REG)
qpm(i,s) = qp(i,s) - ESUBD(i) * [ppm(i,s) - pp(i,s)] ;

EQUATION PHLDSRCPC
```

```
# Private HousehoLD PRice for SouRCed Perfectly Competitive commodity #
(all,i,PCOMP_COMM)(all,r,REG)(all,s,REG)
qhmps(i,r,s) = D_VPMS(i,r,s)
            * [DELTA(r,s) * {qp(i,s) + ESUBD(i) * [pp(i,s) - pps(i,s,s)]}
            + [1 - DELTA(r,s)] * {qpm(i,s) + ESUBM(i)
            * [ppm(i,s) - pps(i,r,s)]}];

! Private Household Demand for Sourced Tradeable, qdfps(i,r,s),i IN MCOMP_COMM
  ---------------------------------------------------------------------------!

EQUATION PHLDSRCDF
# Private HousehoLD demand for SouRCed DiFferentiated commodity #
(all,i,MCOMP_COMM)(all,r,REG)(all,s,REG)
qdfps(i,r,s) = qp(i,s) + n(i,r)
            - SIGMA(i) * [pps(i,r,s) - pp(i,s)] ;

EQUATION PHLDDFCOMPR
# Private HousehoLD PRice for DiFferentiated COMposite commodity #
(all,i,MCOMP_COMM)(all,s,REG)
pp(i,s) = sum{r,REG, PTHETA(i,r,s) * pps(i,r,s)}
        - {1/[SIGMA(i) - 1]} * vp(i,s) ;

EQUATION PHLDVARIN
# Private HousehoLD VARiety INdex #
(all,i,MCOMP_COMM)(all,s,REG)
vp(i,s) = sum{r,REG, PTHETA(i,r,s) * n(i,r)} ;


!----------------------------------------------------------------------            !
!                       Sluggish Endowment Supply Equations                        !
!----------------------------------------------------------------------            !

EQUATION ENDW_PRICE
# composite PRICE for sluggish ENDoWment #
(all,i,ENDWS_COMM)(all,r,REG)
pm(i,r) = sum{k,PROD_COMM, REVSHR(i,k,r) * pmes(i,k,r)} ;

EQUATION ENDW_SUPPLY
# SUPPLY of sluggish ENDoWment across sectors #
(all,i,ENDWS_COMM)(all,j,PROD_COMM)(all,r,REG)
qoes(i,j,r) = qo(i,r) - endwslack(i,r) + ETRAE(i) * [pm(i,r) - pmes(i,j,r)] ;


!----------------------------------------------------------------------            !
!                   Capital Stock and Rate of Return Equations                     !
!----------------------------------------------------------------------            !

EQUATION KAPSVCES
```

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```
# supply of capital services (re-defined for convenience) #
(all,r,REG)
ksvces(r) =
sum{h,ENDWC_COMM, [VOA(h,r) / sum{k,ENDWC_COMM, VOA(k,r)}] * qo(h,r)} ;


EQUATION KAPRENTAL
# capital rental rate (re-defined for convenience) #
(all,r,REG)
rental(r) =
sum{h,ENDWC_COMM, [VOA(h,r) / sum{k,ENDWC_COMM, VOA(k,r)}] * ps(h,r)} ;


EQUATION CAPGOODS
# supply of gross investment (re-defined for convenience) #
(all,r,REG)
qcgds(r) = sum{h,CGDS_COMM, [VOA(h,r) / REGINV(r)] * qo(h,r)}  ;


EQUATION PRCGOODS
# price of investment (cgds) (re-defined for convenience) #
(all,r,REG)
pcgds(r) = sum{h,CGDS_COMM, [VOA(h,r) / REGINV(r)] * ps(h,r)} ;


EQUATION KBEGINNING
# beginning-of-period capital stock #
! This equation equates the change in capital services during the period to the change
  in beginning-of-period capital stock. Full capacity utilization is assumed. !
(all,r,REG)
kb(r) = ksvces(r) ;


EQUATION RORCURRENT
# CURRENT Rate Of Return on capital in region r #
(all,r,REG)
rorc(r) = GRNETRATIO(r) * [rental(r) - pcgds(r)] ;


EQUATION ROREXPECTED
# EXPECTED Rate Of Return (depends on current rate of return and investment) #
(all,r,REG)
rore(r) = rorc(r) - RORFLEX(r) * [ke(r) - kb(r)] ;


!---------------------------------------------------------------------------                    !
!                              Global Investment Equations                                       !
!---------------------------------------------------------------------------                    !


EQUATION RORGLOBAL
# global supply of investment/global rental rate on investment (RORDELTA=0/1) #
(all,r,REG)
    RORDELTA * rore(r)
```

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```
  + [1 - RORDELTA] * {[REGINV(r)/NETINV(r)] * qcgds(r)
  - [VDEP(r)/NETINV(r)] * kb(r)}
  = RORDELTA * rorg + [1 - RORDELTA] * globalcgds + cgdslack(r) ;


EQUATION GLOBALINV
# global investment/expected global rate of return on capital (RORDELTA=0/1) #
    RORDELTA * globalcgds
  + [1 - RORDELTA] * rorg
  = RORDELTA * [ sum{r,REG, [REGINV(r)/GLOBINV] * qcgds(r)
  - [VDEP(r)/GLOBINV] * kb(r)} ]
  + [1 - RORDELTA] * [ sum{r,REG, [NETINV(r)/GLOBINV] * rore(r)} ] ;


EQUATION PRICGDS
# price index for aggregate investment (global cgds composite) #
psave = sum{r,REG, [NETINV(r) / GLOBINV] * pcgds(r)} ;


!-------------------------------------------------------------------------------                                  !
!                        Global Transportation (Shipping Industry) Equations                                      !
!-------------------------------------------------------------------------------                                  !


EQUATION PTRANS
# price index for transportation services based on zero profits #
! Sales  to  international  transport  sector  are  not  subject  to  export  tax  and  hence
   these sales are evaluated at market prices. !
VT * pt = sum{i,TRAD_COMM, sum{r,REG, VST(i,r) * pm(i,r)}} ;


EQUATION TRANSVCES
# demand for regional supply of global transportation services #
! We  assume  a  unitary  elasticity  of  substitution  between  transportation  services
   inputs from different regions. !
(all,i,TRAD_COMM)(all,r,REG)
qst(i,r) = D_VST(i,r) * [ qt + [pt - pm(i,r)] ];


EQUATION QTRANS
# global demand for international transportation services #
! The  demand  for  services  along  any  particular  route  is  assumed  to  be  proportional  to
   the quantity of merchandise shipped. !
VT * qt = sum{i,TRAD_COMM, sum{r,REG, sum{s,REG, VTWR(i,r,s)
        * [qs(i,r,s) - atr(i,r,s)] }}} ;


EQUATION FOBCIF
# fob and cif price linkage for good i shipped from region r to s #
(all,i,TRAD_COMM)(all,r,REG)(all,s,REG)
pcif(i,r,s) = FOBSHR(i,r,s) * pfob(i,r,s)
            + TRNSHR(i,r,s) * [pt - atr(i,r,s)] ;
```

! The following equations do not affect equilibrium structure of the model. However,
  they calculate many useful summary statistics. The user is encouraged to go over
  these in some detail. Note that quantity indices are always derived by differencing
  the change in value and price. !

!--   !
!   Regional Terms of Trade Equations   !
!--   !

EQUATION REGSUPRICE
index of prices received for tradeable products produced in r
(all,r,REG)
VWLDSALES(r) * psw(r) = sum{i,TRAD_COMM, sum{s,REG, [1 - DELTA(r,s)]
                       * VSWD(i,r,s) * pfob(i,r,s)}
                       + VST(i,r) * pm(i,r)}
                       + NETINV(r) * pcgds(r) ;

EQUATION REGDEMPRICE
index of prices paid for tradeable products used in r
(all,r,REG)
VWLDDEMAND(r) * pdw(r) = sum{i,TRAD_COMM, sum{k,REG, [1- DELTA(k,r)]
                        * VDWS(i,k,r) * pcif(i,k,r)}}
                        + SAVE(r) * psave ;

EQUATION TOTeq
Terms of trade equation computed as difference in psw and pdw.
(all,r,REG)
tot(r) = psw(r) - pdw(r) ;

!--   !
!   Equivalent Variation Equations   !
!--   !

EQUATION EVREG
Equivalent Variation for the REGion
(all,r,REG)
EV(r) = [INC(r)/100] * [URATIO(r) * POPRATIO(r)] * [u(r) + pop(r)] ;

EQUATION EVWLD
Equivalent Variation for the WorLD
WEV - sum{r,REG, EV(r)} = 0 ;

! Consumer Price Index for Private Household
  -- !

EQUATION PHHLDINDEX

```
# price index for private household expenditures #
(all,r,REG)
PRIVEXP(r) * ppriv(r) = sum{i,TRAD_COMM, VPA(i,r)* pp(i,r)} ;


! GDP value, price and quantity indices
  ------------------------------------- !


EQUATION VGDP_r
# value of GDP in region #
(all,r,REG)
   GDP(r) * vgdp(r)
 = sum{i,TRAD_COMM, VGA(i,r) * [qg(i,r) + pg(i,r) ]}
 + sum{i,TRAD_COMM, VPA(i,r) * [qp(i,r) + pp(i,r) ]}
 + REGINV(r) * [qcgds(r) + pcgds(r)]
 + sum{i,TRAD_COMM, sum{s,REG, VSWD(i,r,s) * [qs(i,r,s) + pfob(i,r,s)]}}
 + sum{i,TRAD_COMM, VST(i,r) * [qst(i,r)  + pm(i,r)]}
 - sum{i,TRAD_COMM, sum{s,REG, VDWS(i,s,r)* [qs(i,s,r) + pcif(i,s,r)]}} ;


EQUATION PGDP_r
# gdp price index #
(all,r,REG)
   GDP(r) * pgdp(r)
 = sum{i,TRAD_COMM, VGA(i,r) * pg(i,r)}
 + sum{i,TRAD_COMM, VPA(i,r) * pp(i,r)}
 + REGINV(r) * pcgds(r)
 + sum{i,TRAD_COMM, sum{s,REG, VSWD(i,r,s) * pfob(i,r,s)}}
 + sum{i,TRAD_COMM, VST(i,r) * pm(i,r)}
 - sum{i,TRAD_COMM, sum{s,REG, VDWS(i,s,r) * pcif(i,s,r)}} ;


EQUATION QGDP_r
# gdp quantity index #
(all,r,REG)
qgdp(r) = vgdp(r) - pgdp(r) ;


!------------------------------------------------------------------------------                !
!                             Aggregate Trade indices Equations                                !
!------------------------------------------------------------------------------                !


! Value Indices
  ------------- !


! Defined over extraregional exports and imports ONLY. !


EQUATION VREGEX_ir
# the change in FOB value of exports of commodity i from r #
(all,i,TRAD_COMM)(all,r,REG)
```

```
VXW(i,r) * vxwfob(i,r) = sum{s,REG, [1 - DELTA(r,s)] * VSWD(i,r,s)
                          * [qs(i,r,s) + pfob(i,r,s)]}
                          + VST(i,r) * [qst(i,r) + pm(i,r)] ;


EQUATION VREGIM_is
# the change in CIF value of imports of commodity i into s #
(all,i,TRAD_COMM)(all,s,REG)
VIW(i,s) * viwcif(i,s) = sum{r,REG, [1 - DELTA(r,s)] * VDWS(i,r,s)
                          * [pcif(i,r,s) + qs(i,r,s)]} ;


EQUATION VREGEX_r
# computes % change in value of merchandise exports, by region #
(all,r,REG)
VXWREGION(r) * vxwreg(r) = sum{i,TRAD_COMM, VXW(i,r) * vxwfob(i,r)} ;


EQUATION VREGIM_s
# computes % change in value of imports, cif basis, by region #
(all,s,REG)
VIWREGION(s) * viwreg(s) = sum{i,TRAD_COMM, VIW(i,s) * viwcif(i,s)} ;


EQUATION VWLDEX_i
# computes % change in fob value of global exports, by commodity #
(all,i,TRAD_COMM)
VXWCOMMOD(i) * vxwcom(i) = sum{r,REG, VXW(i,r) * vxwfob(i,r)} ;


EQUATION VWLDIM_i
# computes % change in value of global imports, by commodity #
(all,i,TRAD_COMM)
VIWCOMMOD(i) * viwcom(i) = sum{s,REG, VIW(i,s) * viwcif(i,s)} ;


EQUATION VWLDEX
# computes % change in value of global exports #
VXWLD * vxwwld = sum{r,REG, VXWREGION(r) * vxwreg(r)} ;


EQUATION VWLDOUT
# change in value of world output of commodity i at fob prices #
(all,i,TRAD_COMM)
VWOW(i) * valuew(i) = sum{r,REG, VOW(i,r) * [pxw(i,r) + qo(i,r)]} ;


! Price Indices
  ------------- !


EQUATION PREGEX_ir
# the change in FOB price index of exports of commodity i from r #
(all,i,TRAD_COMM)(all,r,REG)
VXW(i,r) * pxw(i,r) = sum{s,REG, [1 - DELTA(r,s)] * VSWD(i,r,s) * pfob(i,r,s)}
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                    + VST(i,r) * pm(i,r) ;


EQUATION PREGIM_is
# the change in cif price index of imports of commodity i into s #
(all,i,TRAD_COMM)(all,s,REG)
VIW(i,s) * piw(i,s) = sum{r,REG, [1 - DELTA(r,s)]*VDWS(i,r,s) * pcif(i,r,s)} ;


EQUATION PREGEX_r
# computes % change in price index of exports, by region #
(all,r,REG)
VXWREGION(r) * pxwreg(r) = sum{i,TRAD_COMM, VXW(i,r) * pxw(i,r)} ;


EQUATION PREGIM_s
# computes % change in price index of imports, by region #
(all,s,REG)
VIWREGION(s) * piwreg(s) = sum{i,TRAD_COMM, VIW(i,s) * piw(i,s)} ;


EQUATION PWLDEX_i
# computes % change in price index of exports, by commodity #
(all,i,TRAD_COMM)
VXWCOMMOD(i) * pxwcom(i) = sum{r,REG, VXW(i,r) * pxw(i,r)} ;


EQUATION PWLDIM_i
# computes % change in price index of imports, by commodity #
(all,i,TRAD_COMM)
VIWCOMMOD(i) * piwcom(i) = sum{s,REG, VIW(i,s) * piw(i,s)} ;


EQUATION PWLDEX
# computes % change in price index of global exports #
VXWLD * pxwwld = sum{r,REG, VXWREGION(r) * pxwreg(r)} ;


EQUATION PWLDOUT
# change in index of world prices, fob, for total production of i #
(all,i,TRAD_COMM)
VWOW(i) * pw(i) = sum{r,REG, VOW(i,r) * pxw(i,r)} ;


! Quantity Indices
  ---------------- !


EQUATION QREGEX_ir
! The change in volume of exports of commodity i from r.
  This is generated by deflating a value aggregate. !
(all,i,TRAD_COMM)(all,r,REG)
qxw(i,r) = vxwfob(i,r) - pxw(i,r) ;


EQUATION QREGIM_is
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```
! The change in volume of imports of commodity i into s.
  This is generated by deflating a value aggregate. !
(all,i,TRAD_COMM)(all,s,REG)
qiw(i,s) = viwcif(i,s) - piw(i,s) ;


EQUATION QREGEX_r
# computes % change in quantity index of exports, by region #
(all,r,REG)
qxwreg(r) = vxwreg(r) - pxwreg(r) ;


EQUATION QREGIM_s
# computes % change in quantity index of imports, by region #
(all,s,REG)
qiwreg(s) = viwreg(s) - piwreg(s) ;


EQUATION QWLDEX_i
# computes % change in quantity index of exports, by commodity #
(all,i,TRAD_COMM)
qxwcom(i) = vxwcom(i) - pxwcom(i) ;


EQUATION QWLDIM_i
# computes % change in quantity index of imports, by commodity #
(all,i,TRAD_COMM)
qiwcom(i) = viwcom(i) - piwcom(i) ;


EQUATION QWLDEX
# computes % change in quantity index of global exports #
qxwwld = vxwwld - pxwwld ;


EQUATION QWLDOUT
# change in index of world production of i #
(all,i,TRAD_COMM)
qow(i) = valuew(i) - pw(i) ;


EQUATION TRADEBAL_i
# computes change in trade balance by commodity and by region #
(all,i,TRAD_COMM)(all,r,REG)
DTBALi(i,r) = [VXW(i,r)/100] * vxwfob(i,r)
            - [VIW(i,r)/100] * viwcif(i,r) ;


EQUATION TRADEBALANCE
# computes change in trade balance (X - M), by region #
(all,r,REG)
DTBAL(r) = [VXWREGION(r)/100] * vxwreg(r) - [VIWREGION(r)/100] * viwreg(r) ;


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