A Nested PE/GE Model for GTAP: Simulating the Disaggregated Impacts of Tariff-Liberalization on Automotive Industry in India[1]

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Abstract

Given that the General Equilibrium (GE) models such as GTAP are highly aggregated, it is difficult to capture the tariff and trade-flow variations at disaggregate levels in these models. On the other hand, Partial Equilibrium (PE) models, which can be used for analysis at disaggregate levels, deprive the researcher of the benefits of an economy-wide analysis, which are crucial to examine trade policy impacts. Therefore, a CGE framework that is nested with a Partial Equilibrium model is an ideal tool to carry out trade policy analysis at disaggregated levels. We develop a Partial Equilibrium model in this paper, using some CET and CES nests, market clearing conditions and price linkages and nest it within the standard GTAP model, calling it a PE-GE model. The primary advantage of this new work is that it is undertaken in conjunction with the standard GTAP model, thereby making it readily available to users of that model, along with all of the decomposition tools that have been developed for the standard model. . In particular, we extend the welfare decomposition of Huff and Hertel (2001) to this model in order to investigate the sources of welfare gain in this integrated, trade modeling framework. To illustrate the usefulness of this model, we examine the contentious issue of tariff-liberalization in Indian auto sector, using PE, GE and PE-GE models. Both the PE and the linked model show that the imports of Motorcycles and Automobiles change drastically with a unilateral and complete tariff-liberalization in the auto sector by India. While the PE and PE-GE models show strikingly diverse results across the sub-sectors of the Indian auto industry, which cannot be captured by the GE model, the PE model does a poor job predicting the overall size and price level in the industry, post-liberalization. Thus, we find that the linked model is superior to the GE model in terms of disaggregated impact-evaluation and to the PE model in terms of endogenous determination of aggregate supply and demand. In summary, there is considerable value in linking PE and GE models.

JEL Codes: C68, F13, F14, F17, O53.

Keywords: CGE modeling, Trade Policy, Partial Equilibrium, India, Auto Industry

1. **Introduction**

Examination of the impacts of tariff changes at highly disaggregated levels is very important for many reasons. Firstly, there are huge variations in tariff rates at different tariff lines for many commodities. Thus, there is a serious aggregation bias in many of the studies that examine trade policy impacts at an aggregate level. If one is only interested in aggregate impacts, one can use a specialized technique, such as the Trade Restrictiveness Index (TRI), to account for these differences (eg., Anderson and Neary, 1995), however, the appropriate index will depend on the objective in mind. If the goal is to estimate welfare effects, it is the TRI; if it is to estimate trade volume effects, it is the MTRI, etc. However, policy makers are increasingly requesting model results at a disaggregate level. A second problem with sectoral analysis in models such as GTAP is that the aggregation of sectors may result in 'false competition' in the analysis. For example, two countries can potentially face no direct competition at disaggregated commodity level (i.e., they do not ship the same product to the same market -- e.g., engine blocks and transmissions), but at an aggregate level, they may appear to be competitors, since they send different products within the broader sector aggregate (e.g., automobiles and parts) to the same market. Thirdly, many of the policies are targeted at, and framed for, very specific products that are not identified within the relatively aggregated sectors typically modeled in global economic analyses (e.g., those based on the GTAP data base). This limits the ability of authors to address the policy questions of direct interest to decision makers.

Finally, most trade policy negotiations between the countries are conducted on the basis of highly disaggregated "tariff lines". Therefore, the natural analytical framework to support such negotiations has been that of partial equilibrium analysis. This has generally meant that, as negotiations progress, the Computable General Equilibrium (CGE) models used to assess the broad gainers and losers under a given trade agreement are left behind, in favor of (often) spreadsheet-based, supply-demand models of trade at the tariff line. This transition has the disadvantage of leaving behind the firm, welfare-theoretic foundations of general equilibrium, as analysts move into the details of negotiations. It would obviously be attractive to be able to remain within the same broad CGE framework, even as one disaggregates selected sectors in the model in order to support the more detailed negotiations.

In recent work, Grant, Hertel and Rutherford (2007) have proposed just such a partial/general equilibrium (PE/GE) framework, building on the GTAP-in-GAMS global CGE model. Their work focuses particularly on the treatment of tariff rate quotas, which cannot readily be aggregated for use in a normal CGE model. Our paper draws inspiration from that earlier work; likewise implementing a PE/GE model within the GTAP modeling framework (Hertel, 1997). The primary advantage of this new work is that it is undertaken in conjunction with the standard GTAP model, thereby making it readily available to users of that model, along with all of the decomposition tools that have been developed for the standard model. We also seek to make it easy for the user to operate this model in stand-alone, partial equilibrium mode, if that is desired.

Using a three-region, ten-sector database derived from the GTAP 6.2 and MAcMap/TASTE databases, we illustrate the advantages of linking a structured PE model with the GE model, over using solely PE or GE models. By way of example, we analyze the impacts of complete tariff liberalization in the Indian auto industry, which is quite heterogeneous in terms of trade policy. Two major observations emerge from this study: both the PE and the linked model show strikingly diverse results across the sub-sectors of the auto industry, which cannot be captured by the GE model; on the other hand, the PE model does a poor job predicting the overall size and price level in the industry, post-liberalization. Thus, we find that the linked model is superior to the GE model in terms of disaggregated impact-evaluation and to the PE model in terms of endogenous determination of aggregate supply and demand. In summary, there is considerable value in linking PE and GE models.

This paper is organized as follows: Section 2 reviews the literature to motivate the central issues addressed by this work. Section 3 outlines the methodology followed and modeling framework. Section 4 dwells upon the data sources and adjustments made to arrive at the database used in this paper. Section 5 summarizes the results and Section 6 concludes.

2. **Literature Review**

Broadly, there are 3 strands of literature focusing on trade policy impacts. Here, we emphasize studies of South Asian trade for illustrative purposes. The first strand consists of studies such as Das (2007) and Taneja (2007) which examine the impacts of regional integration and trade policy in a descriptive and qualitative manner with little quantitative basis. The second strand comprises the numerous studies and reports that examine trade policy impacts at highly disaggregated levels using econometrics and data analysis, such as Batra and Khan (2005), Batra (2006) and various reports by consultancy organizations such as McKinsey. This strand also comprises studies based on comprehensive partial equilibrium models, such as Ramos et. al. (2007), who model EU import demand for different qualities of beef in the presence of tariff-rate-quotas and derives comparative static results for changes in many policy variables, focusing on MERCOSUR exports. The third category is the one that we focus on here, namely the literature of global trade analysis, which consists of global and economy-wide models, especially Computable General Equilibrium (CGE) models.

Recently Chadha (2007) has analysed the implications of liberalizing border trade in agriculture for South Asian Countries, while Chadha et. al. (2007) examines the impacts of liberalizing border trade on India's domestic agricultural markets. Weerahawa and Meilke (2007) analyse the impacts of Indo-China trade relationships on South Asian Economies, using the GTAP model. Kumar and Saini (2007) use standard static GTAP model to evaluate the impacts of South Asian Free Trade Agreement. Kawai and Wignaraja (2007) examine the impacts of various Preferential Trading Arrangements possible in Asia, in addition to ASEAN. Ananthakrishnan and Jain-Chandra (2005) assess the impacts of trade liberalization on India's textile and clothing sector, using the GTAP database and model. The goal of this paper is to supplement these studies of trade reform with a PE/GE analysis in the spirit of Grant et. al. (2007) who link a CGE model (GTAPinGAMS) with a PE model (mixed-complimentarity formulation) to represent US dairy trade policy at tariff-line, using different scenarios. Gohin and Laborde (2006) introduce a flexible functional form (Normalised Quadratic Expenditure System, NQES) that allows for zero-trade flows in an integrated CGE model, but in this paper, we stick to standard GTAP model features so as to highlight the additional contribution of the proposed model vis-à-vis the standard GTAP model.

In this paper, the focus is on impact of tariff-liberalization on India's automotive industry. This is an appropriate example to illustrate the usefulness of this model. Narayanan and Vashisht (2008) summarize various characteristics and recent trends in Indian auto sector. Here, we build upon some of them to examine the extent to which this sector is relevant for the context of this paper. Firstly, this is a diverse sector, not only structurally, but also in terms of the wide tariff variations across its sub-sectors that include various types of fully-built vehicles and auto-components. Thus, examining the sub-sectors in detail is of interest in itself.

Secondly, countries like India have been following clearly different policies as regards different sub-sectors of the auto industry. For example, most of the tariff policies have been more favorable to the vehicle assembly sub-sector than to the auto-component sub-sector. These have, over the years, led to "tariff-escalating" foreign investments, some of which make use of the low tariffs in auto-components sector to largely restrict their production to assembly by importing most of the auto-components (for example, as Complete Knock Down, i.e., CKD Kits). On the other hand, there are foreign firms that also create domestic capacity in auto-component production. In other words, the differential policies on different sub-sectors have changed the structure of the Indian auto industry over the years. Considering the Indian auto industry as an aggregate entity, in terms of tariffs, blurs these structural details. Even if one is interested in what is happening in the auto sector as a whole, it is important to explicitly factor in the tariff-variations across the sub-sectors, to arrive at more reliable numbers for the aggregate auto sector.

Thirdly, even in the future, tariff-reductions are expected to be sub-sector-specific, as evident from the negotiations that have been progressing, necessitating a framework wherein tariff simulations could be done at sub-sector level. Thus, it is difficult to understand the extent of distortions in the results if there is no provision to model the policies pertaining to particular sub-sectors of this industry in India. As a first step in this direction, this paper compares the results of complete tariff-liberalization in Indian Auto sector using the standard GTAP model, a simplified Partial Equilibrium model and a model that links the former with the latter.

Given that the Indian auto sector is a good example to illustrate our model, it is essential to explore India's tariff policies, so that our tariff simulations are close to the future realities. Since the late 1990s, India has been negotiating partial trade agreements with East Asian and South Asian countries, including China, Indonesia, Korea, Japan, Malaysia and Thailand, in various sectors, of which the auto-sector has been of primary concern to both Indian and South-East Asian policy-makers. The reason is that these countries have remained as India's competitors in global market for automobiles and auto-components, although there do exist some complementarities among them. Studies such as Iyer (2004) and Batra (2006) examine the prospects of existing agreements involving India, such as the Bangkok Agreement for PTAs in the Asia-Pacific region.

Narayanan and Vashisht (2008) show a mixed impact of FTAs by India on the auto industry, using econometric, descriptive and field-survey-based approaches. They pinpoint the winners and losers in a set of HS6-level sub-sectors of auto industry that were opened up with Thailand. One of the conclusions of these authors is that trade policy analysis should be based on very disaggregate sub-sector-level studies of impacts. They also note that effective rate of protection is about 18 times higher in auto-assembly than that in the auto-component sector, although the latter is much more labor-intensive and hence more employment-generating than the former.

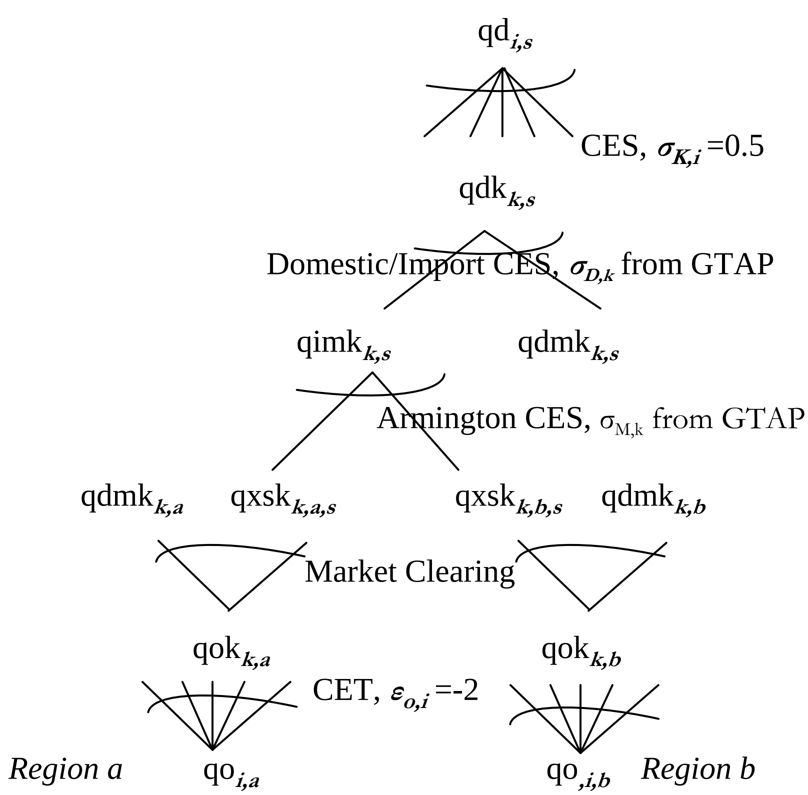
There are also many reports by consultancy organizations such as McKinsey (2005) and ICRA (2003, 2004a, 2004b, 2005), which have evaluated the impacts of India's FTA with countries and regions such as ASEAN, MERCOSUR, South Africa, etc., all of which indicate that the domestic auto sector is very sensitive to liberalization. On the other hand, given the irreversible nature of globalization and liberalization, the government of India has been gradually marching towards a much less protected regime in the auto industry, arguing that past tariff-reductions have been, on balance, beneficial for the industry in terms of improved competitiveness, growth and employment. Therefore, tariff-liberalization in this sector by India is a contentious issue, because it comprises sectors that employ a lot of people and those that are heavily protected.

Further, this issue is relevant in a global context as well, because India has been emerging as one of the world's fastest growing economies, with a demographic profile that is much more favorable to growth than China. Given its rapidly growing middle-class, improved access to finance and incredibly low vehicle penetration ratio (8.5 cars per thousand Indians, World Development Indicators, 2006), India has the potential to serve as one of the biggest markets for automobiles in the world. This has important implications for global auto companies which are currently in the process of restructuring.

3. **Modeling Framework**

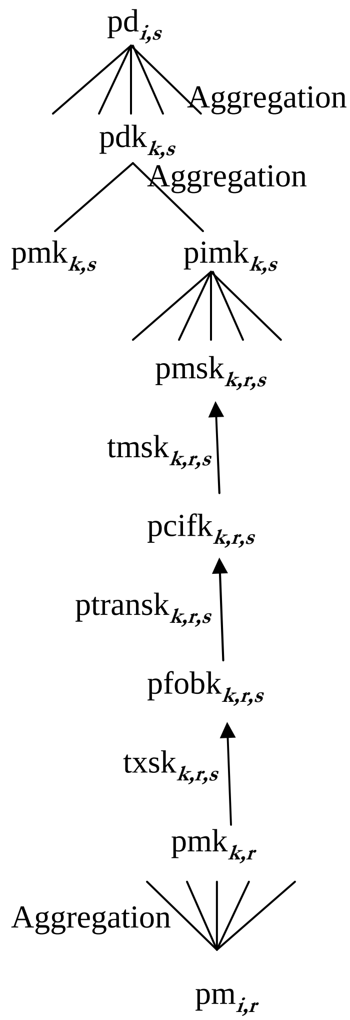
Some of the basic features of the PE-GE model developed in this paper are illustrated in Figures 1 and 2. Figure 1 illustrates the quantity flows in the model, while Figure 2 illustrates how the changes in different prices are transmitted in the model. The unit for all variables in this section is percentage change.

Figure 1: Diagrammatic Illustration of the Quantity Flows in the Model[2]



[2] Notations in Figures 1 and 2 follow standard GTAP notations (Hertel, 1997). In general, the variables starting with: '*q*' represent changes in quantities, '*t*' represent tax/tariff changes and '*p*' represent changes in prices. Those ending with '*k*' are at disaggregate level. In the variable-names, '*d*' stands for domestic, '*i*' for imports, '*x*' for exports, and '*o*' for output. Indices '*r*' and '*s*' denote source and destination regions, respectively; '*i*' denotes sectors at aggregate and '*k*' denotes those at disaggregate levels.

Figure 2: Illustration of Price Linkages in the Model



The PE/GE model used in this paper is developed as an extension of the standard GTAP model. With the exception of a few linking equations – which are neutralized via appropriate use of "slack variables"[3], this is may be viewed as a separate "module" which is appended to the bottom of the standard GTAP model. The quantity flows and price linkages in this module are illustrated in Figures 1 and 2. We follow

[3] When there are two sets of equations determining the same variable and we want different components of the variable determined by different sets of equations, we may introduce a "slack variable" in one set. When declared endogenous in some components, this variable forces the equation in which it appears, to determine itself. This makes the 'real' variable in question exogenous in the corresponding components. This ensures that the other components of this variable are determined by the other set of equations.

the earlier work of Grant, Hertel and Rutherford in treating production of disaggregated commodities is based on a Constant Elasticity of Transformation (CET) function. Products within the PE module are traded at the HS-6 level (or whatever level of disaggregation is desired), and this is the level at which import-domestic competition occurs. Aggregation of demands in the destination market occurs via a single, Constant Elasticity of Substitution (CES) function for each sector. In the equation for source-wise imported commodities, a slack variable is introduced, which when made endogenous, leads to the linking of this partial equilibrium module with remainder of the standard GTAP model. Similarly, there are slack variables that lead to the linking of this module, for aggregate imports and various export/import prices.

The supply-side features are not dealt with in detail in the partial equilibrium model, since we do not have data on factor usage at disaggregated level. Aggregation of output from sub-sector-level is facilitated by a single CET function for each sector. On the demand side, an Armington function combines domestic and imported commodities at the disaggregated level. A region-generic elasticity of substitution is defined at GTAP sector level for the aggregation of domestic consumption of disaggregated commodities back to the sector level in the model.

In the remainder of this section, we give a brief description of the PE-GE model. A complete explanation of the standard model and the features in this model that are identical to the standard GTAP model is beyond the scope and length of this paper. So, in all such instances that require elucidation of details from the standard GTAP model, we quote Hertel (1997) for reference. Although the explanations below presume that only one sector is disaggregated using the PE model, for the sake of simplicity in presentation, our framework facilitates any number of sectors to be disaggregated into any number of sub-sectors, subject to computational constraints, provided we derive a mapping from the set of disaggregated sectors to that of the aggregate ones.

We define a set SSECT of disaggregated sectors (indexed by *k*), set ASECT of aggregate sectors (indexed by *i*), one of which (DAGG) is the aggregation of elements in SSECT and a set of regions REG (indexed by *r* in most cases and if the region is source of exports/imports but by *s* if the region is destination of exports/imports). The following are the modules in the PE-part of this model:

1. International Trade and Margins

   a. Exports and Imports:

      All the standard GTAP variables (explained in Hertel, 1997) that pertain to international trade and margins enter this model with the same names and a *'k'* suffix. The change in imports of each region from each of the others is determined by three factors: import-augmented technical change that reduces further imports $amsk_{k,r,s}$, domestic penetration as captured by change in aggregate imports $qimk_{k,s}$ and substitution among different sources, based on the differential between import prices from specific sources and the sum of import-augmented technical change and aggregate import prices $pimk_{k,s}$[4], multiplied by the elasticity of substitution of imports between the sources $\sigma_{M,k}$, which is the corresponding elasticity for the *DAGG* sector as in GTAP 6. This is an equation that may be called "PE-counterpart" of the equation that determines $qxs_{i,r,s}$ in the standard GTAP model:

      For all sub-sectors k within the sector *DAGG*, regions r and s in REG:

$$qxsk_{k,r,s} = -amsk_{k,r,s} + qimk_{k,s} - \sigma_{M,k} * [pmsk_{k,r,s} - amsk_{k,r,s} - pimk_{k,s}] \quad \ldots\ldots\ldots\ldots\ldots (1)$$

[4] This is aggregated from $pmsk_{k,r,s}$, with the weights as import-shares of different exporters; so, the substitution effect for a particular flow *(k,r,s)* increases in divergence of import tariff for good *k* from regions *r* to *s*, from the weighted-average tariff of *s*. Since higher weight means lower divergence, this effect decreases in import-shares of region *r* in the total imports by region *s* of the good *k*.

The presence of disaggregated estimates of bilateral trade flows means that the standard GTAP model equation that determines the source-specific import change $qxs_{i,r,s}$ must now be altered, as it is redundant. Specifically, a slack variable named $qxslack_{i,r,s}$ enters this equation to enable the user to invoke the following equation instead to determine $qxs_{i,r,s}$ by summing the weighted import changes over the disaggregated sectors, if this slack is made endogenous. This plays a crucial role in linking the PE model with the standard GTAP model.

For the sector *DAGG*, subsectors k within *DAGG* and for all r and s in REG:

$$VIWS_{DAGG,r,s} * qxs_{DAGG,r,s} = \sum_k VIWSK_{k,r,s} * qxsk_{k,r,s} \quad \text{.........................} \quad (2)$$

b. Global Transport Margins and Price Linkages

In the PE module, we do not explicitly develop a new set of equations for global transport margins, but merely follow Hertel (1997). The flow-specific average rate of technical change in shipping ($atmfsdk_{k,r,s}$) is obtained by adding up the changes at different levels, which are directly translated from the aggregate changes in the corresponding variables[5]. This rate of technical change is subtracted from the actual change in price of composite margin services (*pt*) to determine the change in price of transportation ($ptransk_{k,r,s}$).

The price linkages are also, by and large, similar to the standard model, except for the fact that they are all defined at disaggregate level and equations similar to (2) are specified to ensure that changes in aggregate imports $qimk_{k,s}$, aggregate import prices $pimk_{k,r}$, import tariffs $tmsk_{k,r,s}$,

[5] This means that all the shipping-related technical change variables are endogenous in the PE model, as they are directly translated from their exogenous counterparts in the standard GTAP model.

export taxes $txsk_{k,r,s}$, export Freight On Board (FOB) prices $pfobk_{k,r,s}$, import Carriage, Insurance and Freight (CIF) prices $pcifk_{k,r,s}$ and import domestic market prices $pmsk_{k,r,s}$ add up to the aggregate level. With each of these variables, a slack variable goes together in a way similar to $qxslack_{i,r,s}$, in the standard GTAP model. Import tariff change $tmsk_{k,r,s}$ is one of the key policy variables here, as it affects import market prices $pmsk_{k,r,s}$ directly. Export tax change $txsk_{k,r,s}$ is another key variable as it affects $pfobk_{k,r,s}$. Figure 2 illustrates the price linkages and it can be seen that all these are identical to those explained in Hertel (1997).

2. Domestic Consumption

A new set of variables are introduced in the domestic consumption module: aggregate domestic consumption at both '*i*' (aggregated) and '*k*' (disaggregated) levels $qd_{i,r}$ and $qdk_{k,r}$ and the corresponding price changes $pd_{i,r}$ and $pdk_{k,r}$. Domestic consumption of a good *k* in *r* is determined by the following equation:

For a all subsectors *k* within the sector *DAGG* in region *r:*

$$qdk_{k,r} = qd_{DAGG,r} - \sigma_{K,DAGG} * [pdk_{k,r} - pd_{DAGG,r}] \qquad \text{.......................... (3)}$$

Equation (3) nests domestic consumption at disaggregated sub-sector-level within that at aggregate sectoral level, using the price differential and the elasticity of substitution σ_K *(i)* among the sub-sectors in each sector *i*. As for prices at aggregate level, they are expressed as weighted aggregation of those at disaggregate level as shown in equation (4). Here $VDK_{k,r}$ is the total domestic consumption at sub-sector level, which is the sum of domestic consumption of domestic goods $VDMK_{k,r}$ and domestic consumption of imported goods $VIMK_{k,r}$. $VDM_{i,r}$ and $VIM_{i,r}$ are the aggregate sector counterparts of $VDMK_{k,r}$ and $VIMK_{k,r}$, respectively.

For the sector *DAGG*, all *k* in *DAGG* and *r in* REG:

$$[VDM_{i,r}+VIM_{i,r}]*pd_{i,r} = \Sigma_k VDK_{k,r} * pdk_{k,r} \qquad \dots\dots\dots\dots (4)$$

3. Domestic Production

Similar to the domestic consumption module, this module nests domestic sub-sector-level production within aggregate sector-level production, with CET elasticity $\varepsilon_{o,i}$, as shown in (5) below. A production-counterpart of equation (4) is also specified as in (6), involving market prices $pm_{i,r}$ and $pmk_{k,r}$ and value of output at aggregate $(VOM_{i,r})$ and sub-sector level $(VOMK_{k,r})$.

For the sector *DAGG*, all k in *DAGG* and r in REG:

$$qok_{k,r} = qo_{DAGG,r} + \varepsilon_{o,DAGG} * [pm_{DAGG,r} - pmk_{k,r}] \qquad \dots\dots\dots\dots (5)$$

$$VOM_{DAGG,r} * pm_{DAGG,r} = \Sigma_k VOMK_{k,r} * pmk_{k,r} \qquad \dots\dots\dots\dots (6)$$

4. Links between Production, Consumption and International Trade:

The modules explained above are, as in any economy-wide model, not insulated from each other. There are a few links between them, as explained in this module. These links may further be classified into demand-side nests and market clearing of supply and demand.

Sub-sector-level domestic consumption change $qdmk_{k,s}$, whose corresponding price change is $pmk_{k,s}$, is substituted with import consumption change $qimk_{k,s}$, with corresponding price change $pimk_{k,s}$. The CES elasticity between these two variables is $\sigma_{D,k}$, and this substitution takes place based on their respective price differentials from the sub-sector-level domestic prices $pdk_{k,s}$, as illustrated by equations (7) and (8):

For all *k* in *DAGG* and *s in* REG:

$$qimk(k,s) = qdk(k,s) - \sigma_D(k) * [pimk(k,s) - pdk(k,s)] \quad \text{………………………} (7)$$

$$qdmk(k,s) = qdk(k,s) - \sigma_D(k) * [pmk(k,s) - pdk(k,s)] \quad \text{………………………} (8)$$

Domestic market and import price changes are aggregated to domestic price changes by weighting according to their respective shares. $VDK_{k,r}$ is the total value of domestic consumption of goods corresponding to the sub-sector *k* in the region *r*, $VDMK_{k,r}$ is the value of domestic consumption of goods produced by the domestic sub-sector *k* in the region *r* and $VIMK_{k,s}$ is the value of imports of goods produced by the sub-sector *k* to the region *s*.

$$pdk_{k,s} = \alpha D_{k,s} * pmk_{k,s} + \alpha M_{k,s} * pimk_{k,s} \quad \text{………………………} (9)$$

where:

$$\alpha D_{k,s} = VDMK_{k,s} / VDK_{k,s} \text{ and } \alpha M_{k,s} = VIMK_{k,s} / VDK_{k,s}$$

Finally, the total changes in supply and demand are equalized to ensure balance in the system, by equating the total output change $qok_{k,r}$ with the share-weighted sum of imports and domestic consumption for all sub-sectors *k* in DAGG and regions *r* in REG:

$$qok_{k,r} = \beta D_{k,r} * qdmk_{k,r} + \sum_s \beta M_{k,r,s} * qxsk_{k,r,s} + tradslackk_{k,r} \quad \text{………………………} (10)$$

In Equation (10), the slack variable $tradslackk_{k,r,}$ is the PE-counterpart of a similar slack variable defined in the GTAP model. When this is exogenized, this equation would determine the change in market prices, $pmk_{k,r}$ since $qok_{k,r}$ is determined by Equation (5).

At this point, it is important to note the difference between this model acting independently and acting in tandem with the GE model. When the PE model operating in isolation, we adopt a PE closure in which the aggregate change in quantities supplied $qo_{i,r}$ and demanded $qd_{i,r}$ are fixed. Thus, when $tmsk_{k,r,s}$ is shocked, owing to the fixation of these quantities, prices get adjusted in order to maintain the market clearing relationships and equilibria. However, when the PE model is linked with the GE model, $qo_{i,r}$ and $qd_{i,r}$ become endogenous and hence price adjustments are not expected to be as big as in the simple PE model.

5. Welfare decomposition

A sub-sector-level welfare decomposition module is developed. This module draws entirely from the one in the standard GTAP model, described in Huff and Hertel (1997). Subsector-level counterparts are built for two different parts of this module: Terms of Trade (TOT) Effects and Allocative Efficiency (AE) Effects of welfare analysis. Even within these two parts of the module, we focus on the equations and variables that involve changes in international trade prices and quantities, since this is where the basis of the PE model and data is laid. Therefore, for AE decomposition, we define equations at sub-sector-level to compute the contribution to Equivalent Variations (EV) of changes in exports and imports. As for TOT decomposition, we define equations that compute import price effects, world price effects and export price effects.

All the endogenous welfare-related variables at the disaggregated level in this module add up to those at the aggregated level. Similar to the other modules, we introduce slack variables in order to invoke the sub-sector part of this module for the standard sector that is being disaggregated. While defining the closure, we need to ensure that these are made exogenous for all components other than those involving the DAGG sector.

The PE-GE linked model includes all the PE modules explained above and the standard GTAP model with slack variables introduced in their respective equations.

4. Database and its Sources

GTAP Data Base Version 6.2 is the main source of data used in this study. This is a comprehensive database of trade, assistance/protection, production and consumption, well-documented in Dimaranan (2006) and comes with 57 sectors and 96 regions with base year 2001. To keep things simple in this paper, the PE model for the auto sector is broken down to plausible aggregations[6] of HS-6 level sub-sectors using the CEPII data set (Bouët et al., 2004). We then use the new *TASTE* software package (Horridge and Laborde, 2008) to obtain bi-lateral trade and tariff data of HS6 sectors within auto industry. *TASTE* also provides a mapping of HS6 level data on bi-lateral trade (Value of Imports at CIF prices: $VIWSK_{k,r,s}$) and tariffs ($TMSK_{k,r,s}$) to GTAP (Version 6.2) sector-level or at an aggregated level mapped to GTAP sectoral level. Since GTAP currently consists of just aggregated motor vehicles and other transport equipments sectors, we use the PE model to capture the behavior of aggregated sub-sectors in the auto industry, under the following 5 headings:

1. Motor Cycles
2. Motor Cycle Parts

[6] Detailed aggregations and mappings are available from the authors on request.

3. Automobiles other than motorcycles
4. Engines and other Parts of Automobiles
5. Other Transport Equipment

Other aggregated sectors (Other than Auto Industry) in this framework are the following:

1. Food
2. Industries that supply Raw Materials to Auto Industry
3. Energy Sectors
4. Manufactures and Services

There are 3 regions in this framework:

1. India (IND),
2. South-East Asian Countries and other Auto-sector competitors of India: ASEAN member countries, China, Japan and Korea (SEA)
3. Rest of the World (ROW).

Although it is possible to do the analysis at a much more disaggregated level, in terms of both regions and sectors, we focus only on these few sectors and regions for the sake of illustration and easy comparison of the results from different models. In order to build a consistent database, the aggregate tariffs were re-constructed by computing the weighted average of sub-sector-level tariffs from TASTE database. This also meant revising the data on different variables in the GTAP database on bi-lateral trade, namely, $VIMS_{i,r,s}$ (Imports at domestic market prices), $VXWD_{i,r,s}$ (Exports at FOB Prices) and $VXMD_{i,r,s}$ (Exports at domestic market prices).

In addition, as the model requires some data on domestic consumption ($VDMK_{k,r}$), we computed it at sub-sectoral level by assuming the ratio of domestic consumption to imports at the GTAP-level to be preserved at the disaggregate level as well. Similarly, using the disaggregated data on imports at CIF prices ($VIWSK_{k,r,s}$) and tariffs ($TMSK_{k,r,s}$), we computed other variables of exports and imports ($VIMSK_{k,r,s}$, $VXWDK_{k,r,s}$ and $VXMDK_{k,r,s}$). International transport margins at disaggregated level were computed by using trade-weights (based on $VIWSK_{k,r,s}$) to split the margins data from GTAP level. All the variables in the database were then re-adjusted using GTAP Altertax simulation[7] to alter the sector-level tariffs ($TMS_{i,r,s}$) such that the trade-weighted tariffs in auto sub-sectors equal auto sector's aggregate tariff.

In order to reflect the realities in auto industry in India, we make suitable assumptions as regards the elasticities. CES of demand among auto sub-sectors $\sigma_K(i)$ is assumed to be 0.5, since, for example, motor cycle parts can never substitute automobiles, for an end-user. CET among the sub-sectors $\varepsilon_o(i)$, however, is assumed to be quite high: -2, because producers can usually transform from one end of the auto products spectrum to another end much more easily than customers can substitute one with another. Elasticity parameters for CES between domestic and imports $\sigma_D(k)$ and that among imports from different sources $\sigma_M(k)$ are borrowed from the corresponding ones in the GTAP model, which in turn, derives them based on the literature (Dimaranan, 2006).

The initial levels of tariffs and the sub-sector-wise shares of imports in total imports in Indian auto industry from the regions SEA and ROW are summarized respectively in the first and the second 2x2 panels in Table 1. The last 2x2 panel shows the product of sub-sector-wise import share and tariffs at

[7] Malcolm (1998) explains the detailed procedure involved in an altertax simulation. This is done to ensure that all the variables are readjusted such that the database remains balanced. We required to do this in this paper, because the sub-sector-level tariff data from CEPII does not add up to GTAP sector-level tariff data, even with trade weights. Therefore, we alter the tariff in auto-sector so that it agrees with the CEPII data.

sub-sector-level for SEA and ROW. The sum of elements in each column in this panel gives the weighted tariff in aggregate auto industry in India, for SEA and IND.

Table 1: Initial levels of Tariffs and import shares in Indian Auto sector

	India's Tariff Rates of Imports from:		**Share of Imports of Sub-sectors in India's Auto Imports from:**		**Import-weighted Tariff Average**		**Shares of India's Imports in Each Sub-sector in India's Total Imports, from:**		
Region➔	SEA	ROW	SEA	ROW	SEA	ROW	SEA	ROW	Total
Motorcycles	59.7	48.164	0.001	<0.001	0.06	0.008	0.779	0.221	1
McycleParts	19.794	16.055	0.047	0.002	0.929	0.023	0.949	0.051	1
Automobiles	51.971	33.561	0.031	0.062	1.616	2.066	0.241	0.759	1
EnginesParts	19.796	16.055	0.593	0.206	11.74	3.307	0.622	0.378	1
OtherTrans	12.857	7.928	0.328	0.731	4.216	5.794	0.206	0.794	1
Total			1	1	18.56	11.199	0.371	0.629	1

Note: Since, the third 2X2 panel comprises the products of corresponding elements of the first two 2X2 panels, the two totals in this panel are actually import-weighted totals of the two columns in the first 2X2 panel. Therefore they are, in effect, *average tariff rates* in Indian auto sector.

A noteworthy observation from this table is that imports in sub-sectors that are most protected, namely Motorcycles and Automobiles are the ones that are among the smallest relative to aggregate auto imports from SEA and ROW. This is expected because larger tariffs result in lower imports and hence lower import shares. Therefore, the weighted-average tariffs are much lower than the highest tariffs seen at the sub-sector-level. This, in turn, implies that complete tariff liberalization at sub-sector-level involves much more drastic tariff reduction in the individual sub-sectors than in the aggregate sub-sector. This information can only be captured by PE and PE-GE models.

Another important observation is about the import shares of different regions in India's auto imports at sub-sector-level shown in this table. SEA is the source of 78%, 95% and 62% of India's imports of Motorcycles, Motorcycle parts and Engines/Parts, respectively. ROW is the source of 76% of India's

Automobiles imports and 79% of its imports of Other Auto. However, the aggregated sector-level data shows that only 37% of India's total auto imports come from SEA and the remaining 63% come from ROW. This illustrates the richness of detail and comprehension added by the disaggregate sub-sector-level data and also explains many results summarized in the next section.

5. Results

Using the modeling framework explained in Section 3 we carry out a policy experiment using three different models. The experiment is a simulation that removes all tariffs in India's disaggregated sub-sectors of Auto industry. Although it is unlikely in reality that India will totally eliminate all its auto tariffs in the near future, this is an extreme case of the ongoing debate in India about reducing tariffs in this sector. The models used for this experiment are the PE, PE-GE and the standard GTAP (GE) models.

The simple PE closure assumes $qo_{i,r}$ and $qd_{i,r}$ as exogenous has no link with the GE model. All variables at the aggregate level pertaining to the sectors other than the one being disaggregated, which is auto in this case, are exogenized. All technical change variables at aggregate level and tax/tariff change variables and import-augmenting technical change at disaggregate level are also exogenized.

The same tariff simulation is also run using the standard GTAP model closure, in which the major difference from PE closure is the endogeneity of change variables for all quantities and prices, of course, only at aggregate level, since no disaggregate-level variable is defined in this model.[8] In the closure for PE model linked with the standard GTAP model (PE-GE), aggregate supply and demand, ($qo_{i,r}$ and $qd_{i,r}$,

[8] This is the closure in which some relevant slack variables, population change, technical change variables, tax/tariff variables and change in output *qo* for endowment commodities for all regions are made exogenous. See Hertel (1997) for more details.

respectively) are endogenous. In PE-GE, all the slack variables' (including those in the Welfare Decomposition Module) components pertaining to the disaggregated sector(s) from the set of aggregate sectors, tariff changes at aggregate sectoral level and all prices are made endogenous, while tariff changes at sub-sectoral level and other components of slack variables are made exogenous so as to facilitate the operation of the standard GE model for all non-disaggregated sectors. The slack variable used in the market clearing conditions (*tradslack*) is made exogenous both at aggregate and disaggregate levels, so as to facilitate endogenous determination of market prices, in all closures.

Using the closures and shock explained above, experiments are run for all the three models. The results are then compared and inferences are drawn on the impacts of this shock on different variables and differences across these models' results. We use the non-linear Gragg 2-4-6 extrapolation method for the solution, as mentioned in Pearson and Horridge (2005).

Table 2 outlines the results pertaining to Equation (1) described in Section 3, which determines percentage changes in source-wise imports of sub-sectors as a function of the tariff cuts. First five columns are the results at the sub-sector level and the last 2X2 panel shows the percentage changes in the aggregate auto sector as derived from different models. In all models, there is a relatively big and positive domestic penetration effect that contributes to increased imports in all sectors/sub-sectors and from all regions. In both PE-GE and GE models, substitution effect is relatively small, negative for imports from ROW and positive for imports from SEA, implying that India's imports from ROW are substituted by those from SEA. Imports from ROW increase to a smaller extent than those from SEA, according to all the models.

Table 2: India's Import-changes shown by PE-GE, GE and PE models (% Changes post-simulations)

	Sub-sectors in Auto Industry					Aggregate Auto	
	Motor-cycles	Motor-cycle Parts	Auto-mobiles	Engines & Parts	Other Trans	**PE-GE / PE model Results**	**GE Model Results**
Imports from ROW							
Results from PE-GE Model							
Domestic Penetration Effect	201.9	34.3	113.1	44.1	20.5	33.3	28.0
Substitution Effect among sources	-16.0	-11.5	-13.5	-9.0	-5.4	-12.0	-10.9
Total Change in Imports by India *(qxsk)*	185.9	22.8	99.6	35.1	15.1	24.5	17.1
Results from PE Model							
Domestic Penetration Effect	156.5	19.5	85.0	27.3	52.3	25.7	28.0
Substitution Effect among sources	-15.5	-9.5	-13.0	-8.5	-50.3	N.A.	-10.9
Total Change in Imports by India *(qxsk)*	141.0	10.0	72.0	18.8	1.9	9.7	17.1
Imports from SEA							
Results from PE-GE Model							
Domestic Penetration Effect	356.6	49.4	285.4	58.6	28.5	52.1	49.9
Substitution Effect among sources	6.3	0.8	70.4	6.7	24.9	9.5	26.8
Total Change in Imports by India *(qxsk)*	362.9	50.2	355.8	65.2	53.4	70.0	76.7
Results from PE Model							
Domestic Penetration Effect	282.6	33.6	222.5	38.5	7.5	25.7	49.9
Substitution Effect among sources	6.3	0.8	69.4	6.6	28.0	N.A.	26.8
Total Change in Imports by India *(qxsk)*	288.9	34.4	291.9	45.1	35.5	49.3	76.7

Note: Decomposition of *qxs* and *qxsk* into domestic penetration and substitution effects was done by adjusting the actual output from GTAP's AnalyseGE (Pearson et. al, 2002), to ensure that these components sum to actual totals of *qxs* and *qxsk*. The original components do not sum up to actual *qxs/qxsk*, thanks to the non-linear solution procedure of Gragg.

One reason for this substitution is that the initial tariffs are lower in ROW than in SEA, as shown in Table 1. As shown in Equation (1), the substitution effect is a monotonic function of divergences in applied tariffs across exporters and it decreases in import shares. Table 1 shows that the Automobiles sub-sector has the highest differential of India's import tariffs, between SEA and ROW. It can also be inferred from Table 1 that SEA's share in India's Automobile imports is less than 24%. These observations explain why India's Automobiles' imports from SEA are the most influenced by substitution effect as shown in Table 2. Similarly, owing to the facts that tariff differentials are low and that SEA already possesses 95% of India's imports of Motorcycle Parts (Table 1), the substitution effect attributed to rise in SEA's exports of Motorcycle parts to India is the least. Although the tariff differentials are the same for 'Other Trans', since SEA's share in its total imports by India is lower to begin with (62%), the substitution effect is larger in this case, for both SEA and ROW.

Motorcycles and Automobiles are the sub-sectors that face dramatic changes due to domestic penetration effect, because they both have very high initial tariffs. Even the substitution effects in imports of these sub-sectors from both SEA and ROW are high, because tariff-differences between imports from SEA and ROW for these sub-sectors are much higher than those in other sub-sectors. Although the tariff-difference is not so high in "Other Auto" sub-sector, this is the biggest import sub-sector (comprising more than 73%) within the auto imports from ROW, as shown in Table 1, and hence substitution effect is higher for this sub-sector, than in the others except Automobiles, for which the initial tariff-difference between SEA and ROW is the biggest among all sub-sectors.

For the Motorcycle Parts, both the domestic penetration effects and the substitution effects are lower in both SEA and ROW, because the tariffs for these regions are not as divergent as in the case of other sub-sectors and their import shares are negligible. Although Engines and Parts constitute sizable shares in auto imports in both regions, the substitution effects are less pronounced than penetration effects due to the relatively low initial tariff differences, similar to those in Motorcycle Parts. Given that import share of this sub-sector in total auto imports from ROW is much lower (about 21%) than the corresponding share for SEA (about 59%), it is plausible why this sub-sector has far lower substitution effect than Motorcycle parts in ROW and has far higher substitution effect than Motorcycle parts in SEA.

While the differences in substitution effects among PE and PE-GE models are not significant, it clearly emerges from Table 2 that the domestic penetration (based on both *qimk* and *qim*) levels are considerably lower in almost all of the PE model results.[9] This follows directly from the main difference between the PE and PE-GE models: the aggregate output and demand are fixed in the PE model, hence the limited adjustment of all quantities, while the endogenous nature of the aggregate output and demand results in more dramatic changes in all quantities in the PE-GE model. This is further explored later in Table 3.

According to the GE model, changes in imports from both SEA and ROW are much lower than what the other models show at sub-sector-level. The reason for this difference is that all the sub-sector-level tariffs are far higher than the aggregate tariffs, the only exception being OtherTrans. Similarly, the tariffs are much higher in SEA than in ROW at sub-sector-level, while the differences between these tariffs are not so high for the aggregate auto sector, as shown in Table 1. Thus, the differences in tariff cuts arising from the same experiment are much higher in the sub-sectors than in the aggregate auto sector. These are carried forward to other price variables as illustrated in Table 3, resulting in much higher changes in imports, according to the PE/PE-GE models.

Further, both domestic penetration and import changes in the aggregate auto sector are much smaller in the PE model than in both GE and PE-GE models, as seen in Table 2, much because of the same reasons mentioned above. There is no substitution effect in the PE model at the aggregate level and the aggregate change in imports is merely the import-weighted sum of changes at the sub-sector level. Import-penetration effects are slightly higher in the PE-GE model than in the GE model for both regions. However, the substitution effect is far lower in the PE-GE model than in the GE model, for imports from SEA. This is because SEA's share in aggregate auto imports is lower (37%) than ROW's share (63%), which means higher contribution of substitution effect to changes in imports from SEA in

[9] The only exception for this is the substitution effect in ROW for Other Trans, which is rather higher in PE (-50.3) than in PE-GE (-5.4). Though the adjusted figures for contribution to *qxsk* are indicative in all other cases, they diverged in this case, as the "implicit" *qxsk* was about 0.2, while the actual was about 2.

the GE model than in the PE-GE model, wherein the import changes are the aggregations from sub-sector level results explained above.[10]

Table 3 provides an overview of the results pertaining to India's auto imports, to explain the differences across the models. As seen from the first three rows of this table, all the price changes in the auto-sector, according to the PE model, are higher than their counterparts in the GE and PE-GE models. Quantity changes are higher in the GE and PE-GE models than in the PE model. The main reason for this is that the aggregate supply and demand is fixed in the PE model, causing dramatic price adjustments with restrained changes in the quantity variables. This is also evident from the sub-sector-level comparison of PE and PE-GE model results in the same table.

Table 3: Changes in Prices and Quantities in Inda's Auto Sector (in % Changes Post-simulation)

Sub-Sectors	India's Imports From (*qxsk*) :		India's Imports	Import Prices	Domestic Prices	Market Prices	Import Prices From (*pmsk*):	
	SEA	ROW	(*qimk*)	(*pimk*)	(*pdk*)	(*pmk*)	SEA	ROW
Auto: PE-GE	70.0	24.5	42.0	-12.9	-2.3	-0.5	-16.3	-10.5
Auto: GE	76.7	17.1	38.7	-12.4	N.A.	-0.4	-15.6	-10.1
Auto: PE	49.3	9.7	24.0	-20.5	-12.8	-12.1	-16.7	-11.0
PE-GE								
Motorcycles	362.9	185.9	322.7	-36.5	1.0	1.1	-37.4	-32.5
MCycleparts	50.2	22.8	48.7	-16.4	-5.5	-2	-16.5	-13.8
Automobiles	355.8	99.6	158.4	-28.1	-2.8	-0.7	-34.2	-25.1
EnginesParts	65.2	35.1	53.7	-15.5	-3.2	-0.9	-16.5	-13.8
OtherTrans	53.4	15.1	22.9	-8.3	-1.9	-0.3	-11.4	-7.3
PE								
Motorcycles	288.9	141.0	255.3	-36.8	-5.4	-5.3	-37.7	-32.8
MCycleparts	34.4	10.0	33.1	-16.8	-9.3	-7.1	-17.0	-14.3
Automobiles	291.9	72.0	122.4	-28.5	-8.0	-6.5	-34.4	-25.6
EnginesParts	45.1	18.8	35.1	-16.0	-7.8	-6.4	-17.0	-14.3
OtherTrans	35.5	1.9	8.7	-8.8	-6.3	-5.7	-11.9	-7.9

[10] The differences between the results in PE-GE and GE models are absorbed in the slack variables in the model. We do not present them in this paper, however, since they do not add much to the inferences, other than what we have already explained in this section, that PE-GE model results are quite different from GE model results.

Similarly, domestic and market price-change variables change to a very smaller extent in the PE-GE and GE models, because the aggregate supply and demand quantities, which are endogenous in both frameworks, get adjusted to the tariff-shock. This also explains why quantity changes are higher in economy-wide frameworks. The differences between PE-GE and GE model results arise mainly from the fact that PE-GE variables compared herein with their GE counterparts are, in fact, aggregations of their counterparts at the sub-sector-level. Explanation for lower aggregate import price changes in GE can be traced back to one of the reasons why substitution effects in determining source-wise imports are different in these two models. Higher import share of ROW in total imports by India, coupled with the lower tariff cuts for imports from ROW and hence lower domestic price changes of imports from ROW, result in lower value for aggregate import prices in GE model.

The results for the sub-sectors from both PE-GE and PE models shed light on the fact that the changes in import prices and quantities are much higher for Motorcycles and Automobiles, arising from the high tariffs in both these sub-sectors. Since domestic price change is the weighted average of market and import price changes as seen in Equation (9), predominantly domestic sub-sectors tend to move along with market prices. Given that the domestic shares are very high for all sub-sectors (80-100%), domestic price changes for all these sub-sectors are derived more from the market price changes than from the import price changes. As in the aggregate auto sector, PE model shows much steeper decline in all prices at sub-sector level, in order to keep aggregate quantities unchanged.

The most characteristic feature of any CGE Model is welfare-decomposition analysis. Using the module that we developed by modifying the one explained in Huff and Hertel (1997) to suit the requirements of our PE-GE model so as to enable sub-sector level analysis, we compare the results for GE and PE-GE models. As shown in Table 4, we find that they are somewhat different at the aggregate level. Comparing the overall welfare results for both these models, we infer that total welfare gain inferred from the PE-GE model is higher than that inferred from the GE model. All of this can be traced to the Allocative Efficiency (AE) gains. As for region-wise welfare changes, the welfare results are entirely explained by AE gains, Terms of Trade (TOT) changes and Investment-Savings (I-S) adjustments. According to the PE-GE model, AE gains are higher for SEA and ROW and lower for IND, than those shown by GE model. ROW gains substantially more from TOT changes, India loses more and SEA gains less in the PE-GE model, when compared with the GE model's results. SEA loses less, India gains a bit more and ROW gains slightly more, in terms of I-S changes in the PE-GE model.

Table 4. Welfare Decomposition: An Overall Comparison of GE and PE-GE Models

	Allocative Efficiency		Terms of Trade		Investment-Savings		Total Welfare Gain	
	GE	PE-GE	GE	PE-GE	GE	PE-GE	GE	PE-GE
SEA	4.7	6.8	75.1	63.5	-12.0	-11.7	67.8	58.6
IND	11.3	6.1	-96.2	-101.4	4.1	4.2	-80.9	-91.2
ROW	15.9	23.3	21.0	37.9	7.9	7.6	44.9	68.7
Total	31.9	36.2	0.0	0	0.0	0	31.8	36.1

Note: All figures in Tables 4 and 5 are in US$ Million

Table 5 summarizes the tax-related allocative-efficiency effects of welfare changes, focusing on import tax and Indian auto imports, which is the sector directly affected by the tariff-cut in this simulation. Understandably in both models, welfare count is much higher for imports from SEA as the corresponding base import tariff and hence the changes in import volume are much higher than those for the imports from ROW. However, the extent of welfare gain is higher in the PE-GE model than in the GE model. Although the changes in imports from SEA are lower in the PE-GE model than in the GE model, the welfare count is higher in the former. As for imports from ROW, both change in imports and welfare count are higher in the PE-GE model.

Table 5 also traces back the sub-sectors to possibly identify why the AE-related welfare gain shows up as higher in the PE-GE model. This is perhaps because of the huge welfare gains in three sub-sectors:

Automobiles, Engines and Parts and Other transport Equipments, which have considerable import shares (shown in Table 1) and base tariff-levels in terms of India's imports from both SEA and ROW, which also means that total import taxes are very high to begin with. For Motorcycles and their parts, since the initial import shares in total auto are low, the total import taxes are not as high as in other sub-sectors and hence welfare counts corresponding to them are also low for the imports from both regions. Owing to the high welfare counts from some sub-sectors, the aggregate welfare count of imports from SEA is higher in the PE-GE model, despite the lower import change. For the imports from ROW, the aggregate welfare count is about twice in the PE-GE model, compared to that in the GE model and the import change is also much higher in the PE-GE model.

Table 5. Import-tax-related Allocative Efficiency Effects for India's Auto Imports at Sub-sector Level

	Imports from SEA			Imports from ROW			Total Auto Imports by India	
Sub-sector	Base Tariff	Import Change	Welfare Count	Base Tariff	Import Change	Welfare Count	Import Change	Welfare Count
Motorcycles	59.7	2.8	0.6	48.2	0.4	0.1	3.2	0.7
MCycleparts	19.8	18.3	1.7	16.1	0.5	0.0	18.7	1.8
Automobiles	52.0	85.9	17	33.6	85.7	13.2	171.6	30.2
EnginesParts	19.8	300.3	27.6	16.1	101.0	8.0	401.3	35.6
OtherTrans	12.9	136.0	8.3	7.9	154.2	6.3	290.3	14.5
Auto: PEGE	**18.6**	**543.4**	**54.3**	**11.2**	**341.8**	**27.6**	**885.2**	**82.0**
Auto: GE	**18.6**	**595.2**	**50.7**	**11.2**	**238.7**	**14.2**	**833.9**	**64.9**

Further breaking up the TOT effects in the Indian auto industry as shown in Table 6, we find that the export prices contribute the most to these effects, according to both PE-GE and GE models, for all regions. However, all the price effects are higher according to the PE-GE model. Nevertheless, India's auto industry appears to be almost unaffected by the world prices according to both models and import prices play a small but significant role in both models. Welfare loss in the PE-GE model, arising from the export price-related TOT loss is the most enormous of all price-related TOT effects in auto sectors of all regions in this simulation. Digging deeper to figure out what contributes India's huge welfare loss in terms of export-prices in PE-GE model, we find that most of these losses can be seen in Automobiles, Engines and Parts and Other Transport Equipments. The differences between the two models is well-captured by the differences in the price-changes. Export price index, which is based on the changes in FOB prices, falls significantly in both models, while this change is higher according to the PE-GE model. The reason for this difference is the fact that FOB prices have adjusted more sharply in PE-GE than in GE, because of the sub-sector-level changes in both FOB prices and market prices.

Table 6. Terms of Trade Effects of India's Auto Industry at Sub-sector Level

Model	Sub-sector	World Prices	Export Prices	Import Prices	Total price effects
PE-GE	Motorcycles	0	9.6	0.1	9.7
	MCycleparts	-1.5	-2.1	-2.8	-6.3
	Automobiles	0.6	-11.3	-5.7	-16.5
	EnginesParts	-16.3	-32.1	-36.3	-84.7
	OtherTrans	12	-10.4	-5.2	-3.6
	Auto	**0**	**-6.0**	**-0.3**	**-6.3**
GE	**Auto**	**0**	**-5.4**	**-0.1**	**-5.4**
PE-GE	**Price changes**	**0**	**-0.5**	**0**	**NA**
GE	**Price changes**	**0**	**-0.4**	**0**	**NA**

Note: All figures in the rows pertaining to sub-sectors and welfare changes in Auto are in US$ Million; price changes are in percentage.

Therefore, essentially it is evident from all the results in this section that linking with the PE model that has more disaggregated sectors makes a huge difference in all results, especially those pertaining to welfare-decomposition. Nesting, price linkages, market-clearing conditions and the GE-linking features in the PE part of the PEGE model do play an important role in defining the results in terms of quantity and price changes.

6. Conclusions

Given the enormous variations of tariffs and trade flows across sub-sectors in various economies, it is essential to analyze the impact of trade policy at fairly disaggregated levels. However, it is also useful to retain the benefits of consistent, economy-wide analysis. In an attempt to achieve the best of both worlds – specificity to sub-sectors and economy-wide analysis, we find the PE-GE model to be an interesting way of performing this task. With a PE model that incorporates price linkages, CET and CES nests and market clearing equations, in addition to some linking features that provide the much-needed blend with economy-wide treatment, we arrive at much more plausible results than we do using either isolated PE or GE models.

Our PE-GE model is superior to simple PE model, because it endogenously determines aggregate supply and demand, as expected in most real-world economies. It is also superior to a comparable standard GE model, because it gives the modeler a rich set of information related to the impacts of the simulations, at disaggregated sub-sector levels, which is again much closer to real-world situations where the policies are specific to such sub-sectors.

As an illustration, our results from complete tariff liberalization in Indian auto industry show two major inferences that further strengthen the evidence for the usefulness of this approach: Firstly, the PE model in isolation shows far lower changes in imports and far higher changes in prices, although it still captures, to a large extent, the disaggregate impacts in sub-sectors. Secondly, the stand-alone GE model shows somewhat different changes in imports and does not provide any information about the sub-sectors, which is found to be very crucial in the PE and PE-GE models, in terms of the heavy influx of imports in the automobiles and motorcycles sector from South-East and East Asian economies.

GE model shows just the aggregate change which is not very high and may give a wrong signal, if taken seriously, to the policy-maker that complete tariff liberalization in Indian auto sector may cause significant but not drastic changes. Thus, on both counts, PE-GE model clearly emerges as the preferred framework to address a policy issue that relies much upon the sub-sectors, which also have an economy-wide relevance.

Furthermore, we extend the welfare decomposition of Huff and Hertel (2001) to the PE/GE model in order to investigate the sources of welfare gain. Comparing the welfare changes with the GE model, we find the overall welfare gains to be somewhat higher in PE-GE model. There are many other notable differences, of which we highlight those in the import-tax-related allocative efficiency effects and the terms of trade effects. In both cases, all the differences could be traced back to the changes happening at the disaggregated model that result in different sets of changes in prices and quantities. This further illustrates the usefulness of PE/GE models for policy analysis, as welfare analysis is perhaps the most policy-relevant tool offered by CGE models. In future, we could also explore other issues such as false competition using HS6-level information.

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