Linking Partial and General Equilibrium Models:
A GTAP Application Using TASTE[1]

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Abstract

CGE models are utilized for the evaluation of trade policy reforms, yet they are typically highly aggregated, limiting their usefulness to trade negotiators interested in impacts at the tariff line. Partial Equilibrium (PE) models used for disaggregate analysis lack the benefits of an economy-wide analysis required to examine the overall impact of trade policy reforms. This suggests the need for a PE-GE, nested modeling framework to support trade policy analysis. In this paper, we develop a PE model that captures international trade, domestic consumption and output, using CET and CES structures, market clearing conditions and price linkages, nested within the standard GTAP Model. In addition, we extend the welfare decomposition of Huff and Hertel (2001) to this PE-GE model to contrast the sources of welfare gain among models. To illustrate the value-added of this model, we examine the impact of multi-lateral tariff liberalization on the Indian economy, with special focus on the auto sector, using PE, GE and PE-GE models. The PE model does not predict the change in overall size and price level for the industry well, while the GE model underestimates the aggregate welfare gain due to tariff averaging. It also fails to account for the change in industry composition resulting from trade reform. These findings are robust to wide variation in model parameters. We conclude that the linked model is superior to both the GE and PE counterparts.

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1.   Introduction

Examination of the impacts of tariff changes at a disaggregated level is important for many reasons. First, there are huge variations in tariff rates at different tariff lines for many commodities, causing serious aggregation bias in aggregate-sector-based studies.[2] Second, the aggregation of sectors may result in 'false competition': Two countries that do not compete in a third market at the disaggregated level (e.g., country one exports engine blocks while country two exports auto transmissions), may appear as competitors at an aggregate (auto parts) level.[3] False competition may also appear when the details of interactions between domestic producers and imports at the disaggregated level get distorted via aggregation. Third, many policies are framed for specific products that are not identified among the relatively aggregated sectors. Credible trade policy analysis must disaggregate these individual products. Finally, most trade policy negotiations are conducted at highly disaggregated "tariff lines",[4] which is why there has been a strong preference for partial equilibrium (PE) analysis (e.g. Ramos et. al. 2007 and Evans et. al 2007) as negotiations begin to get seriously under way.[5] As Lloyd and MacLaren (2004) note, the inability to support disaggregate analysis is a major shortcoming of CGE models. The reason is, of course, due to the fact that the detailed Input-Output data required for such CGE model[6] is not available at the tariff-line level. On the other hand, while comprehensive PE models may show approximate welfare measures for small exogenous changes (Kokoski and Smith, 1987), they are unable to offer a comprehensive assessment of the impact of trade policy reforms on economy-wide welfare, wages, employment and other variables of interest to policy makers. These policy indicators are typically produced by Computable General Equilibrium (CGE) models. This paper utilizes a combined PE-GE approach to trade policy analysis, thereby offering an integrated framework which combines the strength of both approaches.

One of the first attempts to perform a disaggregated analysis in a CGE framework was done by Basevi (1966, 1968). The increased availability of disaggregate data, coupled with increased computing power, has led to a recent surge in research efforts aimed at linking PE and CGE models. Such model linking has become common in the poverty/micro-simulation literature (Herault, 2007;

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[2] Those interested in aggregate impacts can use a specialized technique, such as the Trade Restrictiveness Index (TRI), to account for these differences (eg., Anderson and Neary, 1996), however, the appropriate index will depend on the objective in mind. For example, see Bach and Martin (2001) for an aggregation methodology that factors in expenditure, input costs and tariff-revenue; Anderson and Neary (2003) for Mercantilist TRI (MTRI); and Anderson (2008) for the consequences of atheoretic tariff aggregation in trade policy modeling.

[3] Welsch (2006) finds that intra-industry specialization of the countries over the years leads to the reduction in the heterogeneity of aggregate commodity groups and hence the decline in estimated Armington elasticities.

[4] See Narayanan and Vashisht (2008) for example, for the Free Trade Agreement (FTA) that has been negotiated between India and Thailand. This involves tariff cut proposals at HS-6 level.

[5] Although there have been attempts to model, for example, as many as 530 sectors in a Computable General Equilibrium (CGE) framework by USITC (2009) and Winston (2009), they are still far more aggregate than what is required for tariff-line negotiations.

[6] Although GTAP Data Base and associate models are quite flexible, dealing with sub-sectors requires detailed input-output data for each of them, which is not practically available. One could use the "splitcom" tool (See Horridge, 2005) if (e.g.) disaggregated production and consumption data were available.

Hertel et. al., 2007b), in sub-regional economic modeling (Madsen and Jensen-Butler, 2004) as well as in the application of econometrics to CGE models (Han and Woodland, 2003; Hertel et. al., 2007a; Bhattarai and Whalley, 1999; Arndt et. al., 2002; and McKitrick, 1998). More recently, authors have begun to link CGE and PE models for disaggregated trade policy analysis. In particular, Grant, Hertel and Rutherford (2007) have proposed a partial/general equilibrium (PE/GE) framework, building on the GTAP-in-GAMS global CGE model (Rutherford and Paltsev, 2000) and focusing on the treatment of tariff rate quotas, which cannot readily be aggregated for use in a normal CGE model. Our paper draws inspiration from this work; likewise implementing a PE/GE model within the GTAP modeling framework (Hertel, 1997). The value-added in our paper is that this framework is added on to the standard GTAP Model in a way that permits the user to readily turn it on and off. We have also extended the very useful welfare decomposition tool to include the PE component of the model.

We focus this paper on analysis of the impacts of multi-lateral tariff liberalization on India's automotive industry. This is an apt example for several reasons. Firstly, this is a diverse sector, not only structurally, but also in terms of the wide tariff variations across its sub-sectors.[7] Secondly, India has been actively pursuing different policies for different sub-sectors of the auto industry.[8] This has resulted in policy-driven structural changes in the Indian auto industry.[9] Thirdly, the ongoing tariff negotiations in India are sub-sector-specific[10], necessitating a framework wherein tariff simulations could be done at sub-sector level.

Since the late 1990s, India has been negotiating trade agreements with East and South-East Asian countries, which are both competitors and partners in the global market for autos.[11] There is a widespread concern that the domestic auto sector is very sensitive to liberalization.[12] However, the government of India has been cutting auto tariffs, arguing that past tariff cuts have improved the industry competitiveness, growth and employment (Ministry of Heavy Industries, 2006). So, tariff liberalization in this sector is a contentious issue. Further, the debate over auto sector reforms is also relevant in a global context, with the potential for India to emerge as a global auto production hub as well as an important consumer market. Growth in the Indian auto market is being fuelled by a rapidly growing middle-class, improved access to finance and a very low vehicle penetration ratio.[13] Many studies have recently assessed the impacts of FTAs being negotiated by India within a CGE

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[7] See Table 1 for this aspect and Goldberg(1995) for variations in US automobile tariff. The choice of India as an example is further justified by the conclusions of Anderson (2008), which emphasize that the atheoretic aggregation in a multi-country model leads to an overstatement of India's real income by thrice the global gains from free trade. Thus, aggregation is a very important issue in the context of India's tariff analysis, more so for auto sector in particular as explained herein.

[8] For example, most of the tariff policies have been more favorable to the vehicle assembly sub-sector than to the auto-component sub-sector.

[9] 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 from imported 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. See Narayanan and Vashisht (2008) for more details on this aspect.

[10]See Iyer (2004), Batra (2006) and Narayanan and Vashisht (2008), for example, for more details on these.

[11]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.

[12] For example, see the consultancy reports such as McKinsey (2005), ICRA (2003, 2004a, 2004b, 2005), which have evaluated the impacts of India's FTA with countries and regions such as ASEAN, MERCOSUR and South Africa.

[13] This was around 8.5 cars per thousand Indians in 2005, according to World Bank (2006).

framework (Weerahawa and Meilke, 2007; Kumar and Saini, 2007 and Kawai and Wignaraja, 2007). However, none of them have utilized the kind of PE/GE framework offered by Grant et. al (2007), and developed in this paper.

Using a three-region, ten-sector database derived from the GTAP 6.2 (Dimaranan, 2006), MAcMap (Bouet et. al., 2004) and TASTE (Horridge and Laborde, 2008) databases, we provide an integrated, PE/GE assessment of multi-lateral tariff liberalization in the auto industry. In order to further highlight the added value of this work, we compare the PE/GE results with somewhat stylized PE and GE models. Both the PE and the PE/GE models show strikingly diverse results across the sub-sectors of the auto industry, which cannot be captured by the GE models. On the other hand, our simple PE model does a poor job of predicting the changes in the size and price level of the industry. Although this could be improved by building a more complex PE model, that would still not capture economy-wide effects, which are the focus of this study. Thus, we find that the PE/GE model is superior to the GE model in terms of disaggregated impact-evaluation and dominates the PE model in terms of endogenous determination of aggregate supply and demand as well as aggregate welfare assessment. More importantly, when compared to the simple, aggregated GE model, the integrated PE/GE model shows higher allocative efficiency gains and lower terms of trade losses, because the GE model ignores disaggregated details of trade flows and tariffs.

Apart from being among the first pieces of work developing PE/GE model to perform disaggregate analysis after Grant et al. (2007), this work contributes to the existing literature in other ways. Firstly, this is the first paper to extend the analytical welfare decomposition of Huff and Hertel to the PE/GE framework. Secondly, the model is implemented as an extension of the widely-used GTAP framework, thereby aiding this large community of users in performing similar analyses in the future. Thirdly, our auto industry example effectively illustrates some key issues including the false competition involved in a more aggregate GE model. Finally, the comparisons of the results done across the PE, PE/GE and GE models in this exercise highlight the different shortcomings of PE and GE frameworks compared to our proposed PE/GE framework.

This paper is organized as follows: Section 2 outlines the modeling framework and methodology. Section 3 discusses the data sources. Section 4 summarizes the results and Section 5 concludes.

2.   Modeling Framework, Methodology and Data Sources

Figure 1 illustrates the production and demand structure in the PE model, while Figure 2 shows the price linkages.[14] We will refer to these figures and the associated variables as we discuss the detailed structure of the PE model. This may be viewed as an extension of the standard GTAP Model (Hertel, 1997).[15] When linked with the standard GTAP GE Model, it forms the PE-GE Model. Apart from a few linking equations – which may be neutralized via appropriate use of "slack variables"[16]-- the PE

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[14] The unit of measurement for all variables explained in this section is percentage change.

[15] For the standard GTAP Model, refer Hertel (1997). This model has been adapted by many studies such as Tyers and Yang (2004), to suit their particular requirements.

[16] 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.

model is treated as a separate "module" which is appended to the bottom of the GTAP Model code. We turn now to a discussion of the most important features of the PE Model and then explain how this is linked with the standard GTAP Model, resulting in a PE/GE Model.

Figure 1. Illustration of Some Quantity and Price Linkages in the Model

$qd_{i,s}$, $pd_{i,s}$

NEST A

CES, $\sigma_{k,AUTO} = 0.5$

$qdk_{k,s}$, $pdk_{k,s}$

NEST B

Domestic/Import CES, $\sigma_{D,k}$ from GTAP

$qdmk_{k,s}$ $pmk_{k,s}$

$qimk_{k,s}$, $pimk_{k,s}$

$qdmk_{k,a}$, $pmk_{k,a}$

NEST C

Armington CES, $\sigma_{M,k}$ from GTAP

$qdmk_{k,b}$, $pmk_{k,b}$

$qxsk_{k,a,s}$, $pmsk_{k,a,s}$

$qxsk_{k,b,s}$, $pmsk_{k,b,s}$

← Market Clearing →

$qok_{k,a}$ $pmk_{k,a}$

$qok_{k,b}$, $pmk_{k,b}$

← CET, $\varepsilon_{O,AUTO} = -2$ →
← NEST D →

$qo_{i,a}$, $pmk_{k,a}$

Region a

$qo_{i,b}$, $pmk_{k,b}$
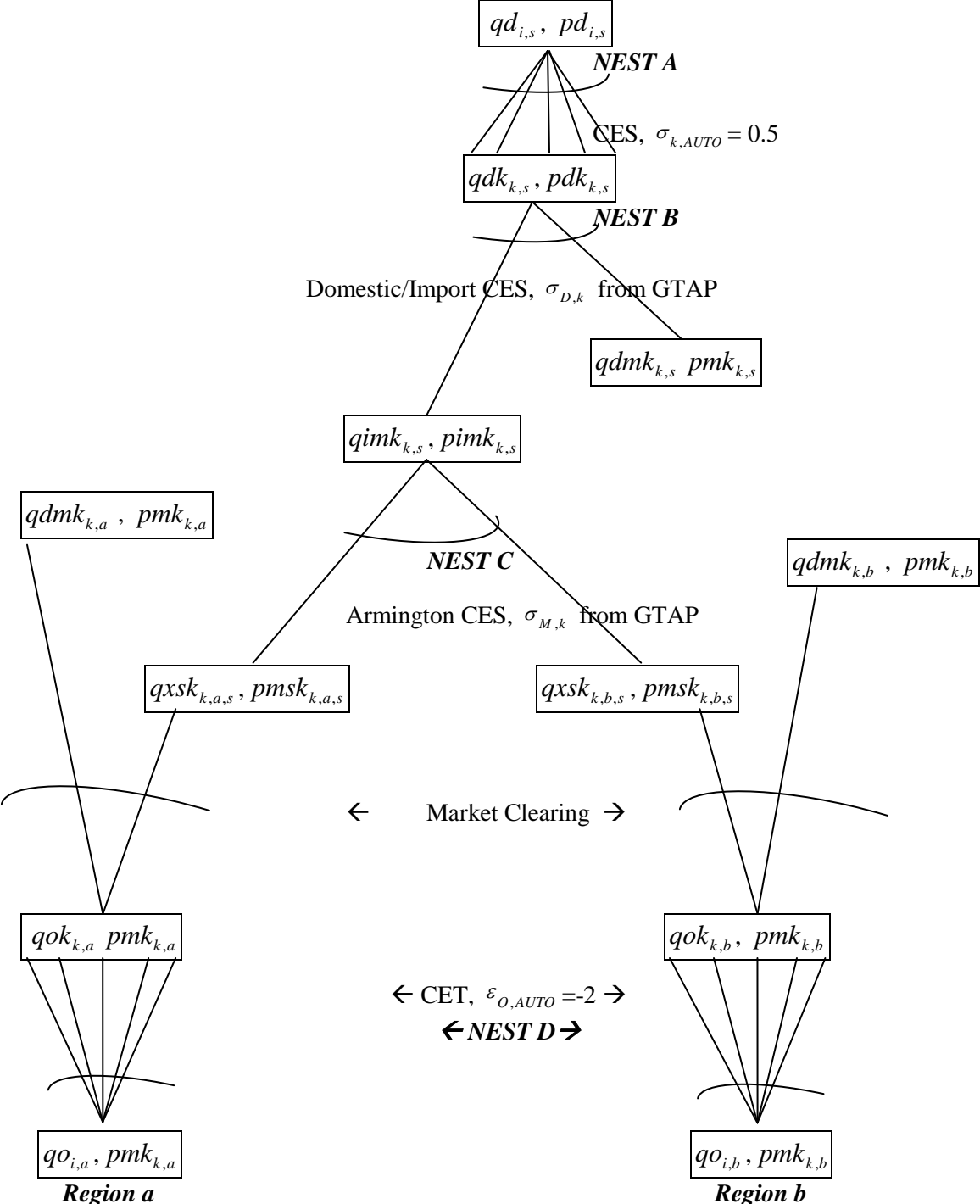
Region b

Figure 2. Illustration of Price Linkages in the Model

$$pd_{i,s}$$

Aggregation

$$pdk_{k,s}$$

Aggregation

$$pmk_{k,s} \qquad pimk_{k,s}$$

$$pmsk_{k,r,s}$$

$$\uparrow tmsk_{k,r,s}$$

$$pcifk_{k,r,s}$$

$$\uparrow ptransk_{k,r,s}$$

$$pfobk_{k,r,s}$$

$$\uparrow tmsk_{k,r,s}$$

$$pmk_{k,r}$$

Aggregation

$$pm_{i,r}$$
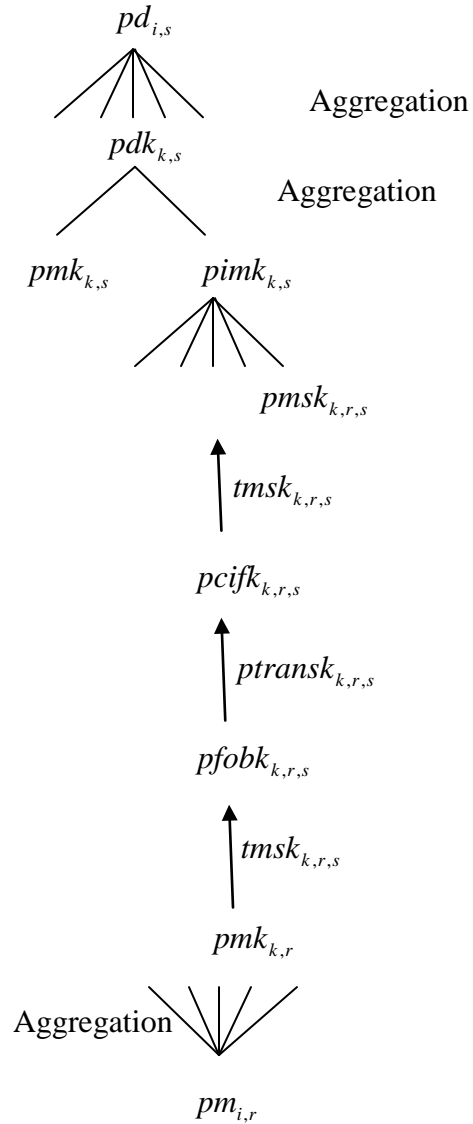
We define the sets: *DSECT* of disaggregated sectors (indexed by k); *ASECT* of aggregate sectors (indexed by i), one of which, *DAGG*[17] is the aggregation of elements in *DSECT*; and *REG* of regions (indexed by r generally and if the region is the source of exports/imports but by s if the region is destination of exports/imports). We show the level equations in caps and linearized equations in lowercase, as they appear in the GTAP Model (Hertel, 1997). Conventions followed for the levels-equations are as follows: 'P', 'Q' and 'θ', represent the levels values of different prices, quantities and value-shares, respectively; subscripts/indices r and s denote regions that are sources

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[17] 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 in the set DAGG 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.

and destinations, respectively; superscripts D, O, IM, XM, DD and ID indicate domestic demand, output, imports, source-destination-wise exports, domestic demand for domestically produced goods and domestic demand for imported goods, respectively. In addition, the superscripts CIF, M, FOB and D represent Carriage-In-Freight, Market, Freight-On-Board and Domestic prices respectively. As for the linearized equations, all the standard GTAP percent change variables of Hertel (1997), pertaining to international trade and margins, enter our model with the same names adding a 'k' suffix to denote disaggregated subsectors treated in the PE model. The variables starting with: 'q' represent changes in quantities, 't' represent tax/tariff changes and 'p' represent changes in prices. For variable names, 'd' stands for domestic, 'i' for imports, 'x' for exports, and 'o' for output. Box 1 shows the main features of this framework, comparing PE-GE and standard GTAP Models.

Box 1. Comparison of the Salient Features in Different Models

Feature	Standard GTAP Model	PE and PE-GE Models
Substitution among domestic composite commodities' consumption *(Nest A in Figure 1)*	No such feature	An aggregate user substitutes between disaggregate commodities
Substitution between domestic and imports *(Nest B in Figure 1)*	Each firm and final user separately substitutes domestic and imports at sector-level	An aggregate user substitutes domestic and imports at both sector and sub-sector levels.
Substitution between imports from different sources *(Nest C in Figure 1)*	An aggregate user substitutes imports from different sources at the sector-level	An aggregate user substitutes imports from different sources at both sub-sector and sector-levels.
Transformation of domestic commodities production *(Nest D in Figure 1)*	Each domestic firm makes its own sector-level output	Each domestic firm makes a mixture of sub-sectors that are transformed from the aggregate sector-level production

2.1 The PE Model
Following Grant et al. (2007), we develop a distinct PE model to analyze policies at tariff-line level. We are forced to deviate from the design of most standard CGE models (like GTAP), because the Input-Output data required for any CGE model are not available at the tariff-line level. In other words, we could have conducted the CGE analysis using the tariff-line data merely using GTAP Model; however, the assumptions required to carry out this analysis would include those on the I-O structure at the sub-sector level. It is not possible to arrive at appropriate I-O coefficients for these sectors with the available data. Therefore we develop a PE model that focuses solely on international trade and transport, total domestic consumption and transformation into sub-sector products. As is the case in most PE models, income formation and changes in factor markets are not explicitly modeled in the PE framework.

a. *International Trade*
As shown in equation (1) and Nest C in Figure 1, the CES elasticity of substitution amongst imports from different sources σ_{Mk}, the bi-lateral import prices $P_{k,r,s}^{IM}$ and a calibrated distribution parameter '$\alpha_{k,r,s}^{IM*}$' distribute the aggregate imports across sources. Further, the import-augmented technology that is specific to the bilateral flow $AMS_{k,r,s}^{\sigma_{Mk}}$ affects the level of this trade-flow.

$$Q_{k,r,s}^{XM} = Q_{k,s}^{IM} \left(\frac{\alpha_{k,r,s}^{IM*}}{P_{k,r,s}^{IM}} \right)^{\sigma_{Mk}} \left[\sum_k \left((\alpha_{k,r,s}^{IM*})^{\sigma_{Mk}} (P_{k,r,s}^{IM})^{1-\sigma_{Mk}} \right) \right]^{\frac{\sigma_{Mk}}{1-\sigma_{Mk}}} AMS_{k,r,s}^{\sigma_{Mk}} \qquad (1)$$

Equation (2) is the linearized form of (1) above. The percentage change in imports by each region from each of the others is determined by three factors: (i) substitution among different sources, based on the difference between import prices from specific sources to the sum of import-augmented technical change and aggregate import prices $pimk_{k,s}$[18], multiplied by σ_{Mk}, which is the corresponding elasticity for the aggregated sector as in GTAP 6 Data Base, (ii) import-augmenting technical change, $amsk_{k,r,s}$, that lowers the effective price of a good in the destination market, and (iii) the change in composite imports of subsector commodity k, $qimk_{k,s}$.

This equation drives changes in imports at the subsector level. The substitution effects can potentially be lower (or higher or even zero) in a subsector than the substitution effect in the aggregate sector. The phenomenon of 'false competition' arises when two countries do not export the same disaggregated commodities to a given destination, but they are both significant exporters to the sector as a whole (e.g., one exporter sends engine blocks to India, while the other exports transmissions). Without subsector disaggregation, these two exporters will appear to be competing in the Indian market.

$$qxsk_{k,r,s} = -amsk_{k,r,s} + qimk_{k,s} - \sigma_{Mk}[pmsk_{k,r,s} - amsk_{k,r,s} - pimk_{k,s}], \forall k \in SSECT; r,s \in REG \quad (2)$$

Equation (2) may be termed the "PE-counterpart" of the equation that determines $qxs_{i,r,s}$ in the standard GTAP Model. By providing disaggregated predictions of trade volume changes within the aggregate sector, this equation offers an improved estimate of change in bilateral trade flow of good i from region r to s. In both the PE and PE-GE models, aggregate sectoral imports are not determined by the "GE-counterpart" of equation (2), but by the aggregation condition shown in equation (3), wherein '$\theta_{k,r,s}^{IM}$' is the share of the value at world prices of a sub-sector's imports in total imports of the corresponding aggregate sector.[19] It should be noted that this weight gets updated as the model is solved, since the prices and quantities change.

$$qxs_{DAGG,r,s} = \sum_{k \in SSECT}[\theta_{k,r,s}^{IM} qxsk_{k,r,s}], \forall r,s \in REG, \theta_{k,r,s}^{IM} = P_{k,r,s}^{CIF} Q_{k,r,s}^{CIF} / P_{DAGG,r,s}^{CIF} Q_{DAGG,r,s}^{CIF} \qquad (3)$$

Global transport margins are treated in the same manner as in the standard GTAP Model, with the quantity of international trade, transport and insurance services required being proportional to the volume of goods shipped. Technical change in this sector is represented with the variable $atmfsdk_{k,r,s}$ is obtained by adding up the changes at different levels, which are directly translated from the

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[18] As indicated in equation (1), 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*.

[19] When the PE only, or GE only, closure is sought, then $qxslack_{i,r,s}$ is made exogenous, and there is no feedback from PE to GE models.

aggregate changes in the corresponding variables.[20] As with the global GTAP Model, trade and transport services are provided at a common price, pt_r, which represents a Cobb-Douglas aggregation of trade and transport services exports from all regions in the model. Deducting the rate of technical progress from this price change gives the percentage change in the commodity and route-specific transport margin, $ptransk_{k,r,s}$.

The price linkages, as shown in Figure 2, mirror those in the standard model, except for the fact that they are all defined at a disaggregate level and equations similar to (3) are specified to ensure that changes in disaggregate imports $qimk_{k,s}$, disaggregate import prices $pimk_{k,s}$, import tariffs $tmsk_{k,r,s}$, export taxes $txsk_{k,r,s}$, export *fob* prices $pfobk_{k,r,s}$, import *cif* prices $pcifk_{k,r,s}$ and import domestic market prices $pmsk_{k,r,s}$ are appropriately aggregated. Changes in import tariffs and export taxes are the crucial policy variables here. Box 2 shows an excerpt from the TAB file pertaining to international trade. Equation names in this TAB file follow the TABMATE convention in which the variable determined by the equation is given the prefix E_.

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[20] 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.

Box 2. International Trade: An Excerpt from the TAB file

Equation E_QXSK
 # Regional demand for disaggregated imported commodities by source (HT 29) #
(**all**,k,SSECT_COMM[21])(**all**,r,REG)(**all**,s,REG)
 qxsk(k,r,s)= -amsk(k,r,s) + qimk(k,s)- ESUBMK(k) * **[**pmsk(k,r,s) - amsk(k,r,s)
 - pimk(k,s)**]**;

Equation E_QXS
 # Regional demand for disaggregated imported commodities by source (HT 29) #
(**all**,i,SPLT_COMM[22])(**all**,r,REG)(**all**,s,REG)
 VIWS(i,r,s) * qxs(i,r,s) = **sum{**k,SSECT_COMM:MPSP_COMM(k)=i,
VIWSK(k,r,s) * qxsk(k,r,s)**}**;

Equation E_PMSK
 # Eq'n links domestic and world prices (HT 24) #
(**all**,k,SSECT_COMM)(**all**,r,REG)(**all**,s,REG)
 pmsk(k,r,s) = tmk(k,s) + tmsk(k,r,s) + pcifk(k,r,s);

Equation E_PCIFK
#Eq'n links FOB and CIF prices for k shipped from region r to s (HT 26')#
(**all**,k,SSECT_COMM)(**all**,r,REG)(**all**,s,REG)
 pcifk(k,r,s) = FOBSHRK(k,r,s) * pfobk(k,r,s)+ TRNSHRK(k,r,s) * ptransk(k,r,s);

Equation E_PFOBK
 # Eq'n links agent's and world prices (HT 27) #
(**all**,k,SSECT_COMM)(**all**,r,REG)(**all**,s,REG)
 pfobk(k,r,s) = pmk(k,r) - txk(k,r) - txsk(k,r,s);

Equation E_PIMK
 # Price for aggregate imports (based on HT 28) #
(**all**,k,SSECT_COMM)(**all**,s,REG)
 pimk(k,s) = **sum{**r,REG, MSHRSK(k,r,s) * **[**pmsk(k,r,s) - amsk(k,r,s)**]}**;

Equation E_PCIF
(**all**,i,SPLT_COMM)(**all**,r,REG)(**all**,s,REG)
VIWS(i,r,s) * pcif(i,r,s)=**sum{**k,SSECT_COMM:MPSP_COMM(k)=i,
VIWSK(k,r,s) * pcifk(k,r,s)**}**;

Equation E_PFOB
(**all**,i,SPLT_COMM)(**all**,r,REG)(**all**,s,REG)
VXWD(i,r,s) * pfob(i,r,s)=**sum{**k,SSECT_COMM:MPSP_COMM(k)=i,
 VXWDK(k,r,s) * pfobk(k,r,s)**}**;

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[21] This set is the same as DSECT in the model described in the text
[22] This set is the same as DAGG in the model described in the text

Equation E_TMS
(**all**,i,SPLT_COMM)(**all**,r,REG)(**all**,s,REG)
VIMS(i,r,s)*tms(i,r,s)=**sum**{k,SSECT_COMM:MPSP_COMM(k)=i,
VIMSK(k,r,s) * tmsk(k,r,s)**}**;

Equation E_PMS
(**all**,i,SPLT_COMM)(**all**,r,REG)(**all**,s,REG)
VIMS(i,r,s)*pms(i,r,s)=
sum{k,SSECT_COMM:MPSP_COMM(k)=i, VIMSK(k,r,s) * pmsk(k,r,s)**}**;

Equation E_PIM
(**all**,i,SPLT_COMM)(**all**,s,REG)
VIM(i,s)*pim(i,s)=**sum**{k,SSECT_COMM:MPSP_COMM(k)=i, VIMK(k,s) * pimk(k,s)**}**;

Equation E_QIM
(**all**,i,SPLT_COMM)(**all**,s,REG)
VIM(i,s)*qim(i,s)=**sum**{k,SSECT_COMM:MPSP_COMM(k)=i, VIMK(k,s) * qimk(k,s)**}**;

Equation E_PTRANS
(**all**,m,MARG_COMM)(**all**,i,SPLT_COMM)(**all**,r,REG)(**all**,s,REG)
VTMFSD(m,i,r,s)*ptrans(i,r,s)=
sum{k,SSECT_COMM:MPSP_COMM(k)=i, VTMFSDK(m,k,r,s) * ptransk(k,r,s)**}**;

! Equating qtmfsdk to GTAP-level!
Equation E_QTMFSDK
(**all**,m,MARG_COMM)(**all**,k,SSECT_COMM)(**all**,r,REG)(**all**,s,REG)
qtmfsdk(m,k,r,s)=qtmfsd(m,MPSP_COMM(k),r,s);

! Calculating flow-specific transport cost index at k-level!
Equation E_PTRANSK
 # Generates flow-specific modal average cost of transport index (cf. HT7) #
(**all**,k,SSECT_COMM)(**all**,r,REG)(**all**,s,REG)
 ptransk(k,r,s)
 = **sum**{m,MARG_COMM, VTFSD_MSH(m,MPSP_COMM(k),r,s) *
[pt(m) - atmfsdk(m,k,r,s)]**}**;

! Equating atfk to GTAP-level!
Equation E_ATFK
(**all**,k,SSECT_COMM)
atfk(k)=atf(MPSP_COMM(k));

! Equating atallk to GTAP-level!
Equation E_ATALLK
(**all**,m,MARG_COMM)(**all**,k,SSECT_COMM)(**all**,r,REG)(**all**,s,REG)
atallk(m,k,r,s)=atall(m,MPSP_COMM(k),r,s);

```
! Generating atmfsdk from GTAP-level and HS6 level variables!
Equation E_ATMFSDK
# Generates flow-specific average rate of technical change #
(all,m,MARG_COMM)(all,k,SSECT_COMM)(all,r,REG)(all,s,REG)
 atmfsdk(m,k,r,s) = atm(m) + ats(r) + atd(s) + atfk(k) +
atallk(m,k,r,s);


Equation E_AMS
(all,i,SPLT_COMM)(all,r,REG)(all,s,REG)
VIWS(i,r,s)*ams(i,r,s)=
sum{k,SSECT_COMM:MPSP_COMM(k)=i, VIWSK(k,r,s) * amsk(k,r,s)};


Equation E_TM
(all,i,SPLT_COMM)(all,s,REG)
VXW(i,s)*tm(i,s)=sum(k,SSECT_COMM:MPSP_COMM(k)=i, VXWK(k,s) * tmk(k,s));


Equation E_TX
(all,i,SPLT_COMM)(all,r,REG)
VXW(i,r)*tx(i,r)=sum(k,SSECT_COMM:MPSP_COMM(k)=i, VXWK(k,r) * txk(k,r));


! Aggregating txs from HS6 level!
Equation E_TXS
(all,i,SPLT_COMM)(all,r,REG)(all,s,REG)
VXWD(i,r,s)*txs(i,r,s)=
sum{k,SSECT_COMM:MPSP_COMM(k)=i, VXWDK(k,r,s) * txsk(k,r,s)};
```

b. Domestic Consumption

Following Grant et al. (2007), a central point of our specification of consumption (and production – see below) is that imports and domestic goods *compete at the disaggregated level*. This is critical if one wishes to capture the full impact of tariff line variation in protection. If we were to aggregate imports before substituting them for domestic goods, we would obscure the potential for tariff line competition between domestic and imported goods, thus raising the specter of false competition discussed previously, as well as mis-estimating the welfare costs of uneven tariff structures within the sector. When we aggregate the subsector goods, we are aggregating the import-domestic composite. Local consumption of disaggregated goods k in region r is determined by introducing a CES aggregator function (recall Nest A in Figure 1). For this purpose, a new set of variables are introduced in the domestic consumption module: aggregate domestic consumption at both ' k ' (disaggregated) and ' i ' (aggregated) levels $Q_{k,r}^D$ and $Q_{DAGG,r}^D$, as well as the associated prices: $P_{k,r}^D$ and $P_{DAGG,r}^D$. A CES

nest with elasticity $\sigma_{k,DAGG}$ is defined as in equation (4), with a calibration distribution parameter ' $\alpha_{k,r}^{D*}$ '.

$$Q_{k,r}^D = Q_{DAGG,r}^D \left(\frac{\alpha_{k,r}^{D*}}{P_{k,r}^D} \right)^{\sigma_{k,DAGG}} \left[\sum_k \left((\alpha_{k,r}^{D*})^{\sigma_{k,DAGG}} (P_{k,r}^D)^{1-\sigma_{k,DAGG}} \right) \right]^{\frac{\sigma_{k,DAGG}}{1-\sigma_{k,DAGG}}} \qquad (4)$$

The percentage change in aggregate domestic consumption at both 'i' (aggregated) and 'k' (disaggregated) levels are $qd_{i,r}$ and $qdk_{k,r}$, and the associated price changes are $pd_{i,r}$ and $pdk_{k,r}$. Here, the percentage change in the ratio of sub-sector to aggregate sector prices, pre-multiplied by the elasticity of substitution in consumption $\sigma_{k,DAGG}$, determines the substitution effect[23], which is augmented by the general expansion effect of a change in the consumption of the aggregate good:

$$qdk_{k,r} = qd_{DAGG,r} - \sigma_{k,DAGG}[pdk_{k,r} - pd_{DAGG,r}], \forall k \in DSECT; r \in REG \qquad (5)$$

Prices at the aggregate level are based on CES indices of disaggregate prices. In percentage change form, equation (6) weights the disaggregated price changes by $\theta_{k,r}^D$, the value share for domestic goods in the aggregate sector-level value. Box 3 shows a TAB file excerpt for aspects including domestic demand.

$$pd_{DAGG,r} = \sum_{k \in DSECT}[\theta_{k,r}^D pdk_{k,r}], \forall r \in REG, \theta_{k,r}^D = (P_{k,r}^D Q_{k,r}^D)/(P_{DAGG,r}^D Q_{DAGG,r}^D) \qquad (6)$$

Box 3. An excerpt from the TAB file pertaining to domestic demand, production and other linkages.

Equation E_PD
(**all**,i,SPLT_COMM)(**all**,r,REG)
[VDM(i,r)+VIM(i,r)**]***pd(i,r)= **sum{**k,SSECT_COMM:MPSP_COMM(k)=i, VDK(k,r)*pdk(k,r)**}**;

! This captures CES among the HS6 goods!
Equation E_QDK
 # Demand for composite domestic good k #
(**all**,k,SSECT_COMM)(**all**,r,REG)
qdk(k,r) = qd(MPSP_COMM(k),r)-ESUBK(MPSP_COMM(k)) *
[pdk(k,r)–pd(MPSP_COMM(k),r)**]**;

Equation E_QOK
 # Eq'n distributes the HS6 commodities across SPLT_COMM (HT 51) #
(**all**,k,SSECT_COMM)(**all**,r,REG)
qok(k,r)=qo(MPSP_COMM(k),r)+ETRAHS6(MPSP_COMM(k))*pm(MPSP_COMM(k),r)
-pmk(k,r)**]**;

! This aggregates market prices to GTAP level!
Equation E_PM
(**all**,i,SPLT_COMM)(**all**,r,REG)
VOM(i,r)*pm(i,r)=**sum{**k,SSECT_COMM:MPSP_COMM(k)=i, VOMK(k,r) * pmk(k,r)**}**;

Equation E_PMK

---

[23] For example, below we posit that the CES between motorcyles and cars (both subsectors of the broad Auto sector) is 0.5.

```
# eq'n assures market clearing for the SSECT commodities (HT 1) #
(all,k,SSECT_COMM)(all,r,REG)
qok(k,r) = SHRDMK(k,r) * qdmk(k,r) + sum(s,REG, SHRXMDK(k,r,s) * qxsk(k,r,s))
    + tradslackk(k,r);


! Determines composite import demand!
Equation E_QIMK
# Demand for composite import k #
(all,k,SSECT_COMM)(all,s,REG)
 qimk(k,s) = qdk(k,s) - ESUBDK(k) * [pimk(k,s) - pdk(k,s)];


! Determines domestic demand!
Equation E_QDMK
# Demand for domestic commodity k #
(all,k,SSECT_COMM)(all,s,REG)
 qdmk(k,s) = qdk(k,s) - ESUBDK(k) * [pmk(k,s) - pdk(k,s)];


! Price weighting in demand-side, to go with the above CES Nests!
Equation E_PDK
(all,k,SSECT_COMM)(all,r,REG)
pdk(k,r)=SHRDMDK(k,r)*pmk(k,r)+SHRIMDK(k,r)*pimk(k,r);
```

c. Domestic Production

This sub-module nests domestic sub-sector-level production within aggregate sector-level production, with a CET[24] elasticity $\varepsilon_{O,DAGG}$ and the calibrated transformation parameter ' $\beta_{k,r}^{O*}$ ', as shown in (7) below and in Nest D in Figure 1. This is the production counterpart of (4).

$$Q_{k,r}^{O} = Q_{DAGG,r}^{O} \left(\frac{\beta_{k,r}^{O*}}{P_{k,r}^{O}} \right)^{\varepsilon_{O,DAGG}} \left[\sum_{k} \left((\beta_{k,r}^{O*})^{\varepsilon_{O,DAGG}} (P_{k,r}^{O})^{1+\varepsilon_{O,DAGG}} \right) \right]^{\frac{\varepsilon_{O,DAGG}}{1+\varepsilon_{O,DAGG}}} \qquad (7)$$

In linearized form, we can see the relative changes in market prices of composite ($pm_{i,r}$) and disaggregated ($pmk_{k,r}$) goods determining the supply response, $qok_{k,r}$, conditional on aggregate capacity in the industry, $qo_{DAGG,r}$ the revenue share of sub-sector-level output in total sales of the sector that is being disaggregated $\theta_{k,r}^{O}$, as shown in equation (8) and (9), wherein the sub-sector-level price changes are aggregated to sector-level.

$$qok_{k,r,} = qo_{DAGG,r} + \varepsilon_{O,DAGG}[pm_{DAGG,r} - pmk_{k,r}], \forall k \in DSECT; r \in REG \qquad (8)$$

---

[24] For example, below we posit that producers switch between making motorcyles and cars (both subsectors of the broad Auto sector) with a CET of -2.0.

$$pm_{DAGG,r} = \sum_{k \in DSECT} [\theta_{k,r}^{O} pmk_{k,r}], \forall r \in REG, \theta_{k,r}^{O} = P_{k,r}^{M} Q_{k,r}^{O} / P_{DAGG,r}^{M} Q_{DAGG,r}^{O} \qquad (9)$$

d.Links between Production, Consumption and International Trade:

The sub-modules explained above are linked with each other. For non-export use, the CES elasticity between domestic and import goods is $\sigma_{D,k}$. Equation (10) shows how local demands for domestic ($Q_{k,s}^{DD}$) and for imported goods ($Q_{k,s}^{ID}$) are determined by their calibrated distribution parameters ($\alpha_{k,s}^{DD*}$ and $\alpha_{k,s}^{ID*}$), prices ($P_{k,s}^{DD}$ and $P_{k,s}^{ID}$) and the CES elasticity (Nest B in Figure 1).

$$Q_{k,s}^{iD} = Q_{k,s}^{D} \left(\frac{\alpha_{k,s}^{iD*}}{P_{k,s}^{iD}} \right)^{\sigma_{DK}} \left[(\alpha_{k,s}^{DD*})^{\sigma_{Dk}} (P_{k,s}^{DD})^{1-\sigma_{Dk}} + (\alpha_{k,s}^{ID*})^{\sigma_{Dk}} (P_{k,s}^{ID})^{1-\sigma_{Dk}} \right]^{\frac{\sigma_{Dk}}{1-\sigma_{Dk}}} ; i = D, I \qquad (10)$$

In terms of linearized equations (11) and (12), we can see that the percentage change in sub-sector-level domestic consumption, $qdmk_{k,s}$, with corresponding price change $pmk_{k,s}$, substitutes for imported subsector goods, $qimk_{k,s}$, with corresponding price change $pimk_{k,s}$. This substitution takes place based on their respective price differentials from the sub-sector-level domestic prices $pdk_{k,s}$. Domestic market and import price changes are aggregated to domestic price changes by weighting according to their respective shares, as shown in equation (13). $\theta_{k,s}^{DD}$ and $\theta_{k,s}^{ID}$ are the value shares of domestic and imports respectively in total local consumption.

$\forall k \in DSECT ; s \in REG :$

$$qimk_{k,s} = qdk_{k,s} - \sigma_{D,k} [pimk_{k,s} - pdk_{k,s}] \qquad (11)$$

$$qdmk_{k,s} = qdk_{k,s} - \sigma_{D,k} [pmk_{k,s} - pdk_{k,s}] \qquad (12)$$

$$pdk_{k,s} = \theta_{k,s}^{DD} pmk_{k,s} + \theta_{k,s}^{ID} pimk_{k,s} ; \theta_{k,s}^{DD} = P_{k,s}^{M} Q_{k,s}^{DD} / P_{k,s}^{D} Q_{k,s}^{D} ; \theta_{k,s}^{ID} = P_{k,s}^{M} Q_{k,s}^{IM} / P_{k,s}^{D} Q_{k,s}^{D} \qquad (13)$$

Finally, the market clearing condition is defined as in equation (14). Total value of output is equalized with total value of domestic consumption and exports, with a slack variable.[25]

$$Q_{k,r}^{O} = \underbrace{Q_{k,r}^{D}}_{DOMESTIC} + \underbrace{\sum_{s} Q_{k,r,s}^{XM}}_{EXPORT} + TRADESLACK_{k,r} \qquad (14)$$

In linearized form shown in equation (15), the percentage change in total output $qok_{k,r}$ is equated with the share-weighted sum of exports and domestic consumption for all sub-sectors k and regions r. Here, $\theta_{k,r}^{DO}$ represents the share of local consumption in output and $\theta_{k,r,s}^{XO}$ denotes the share of

---

[25] Note that value shares and quantity shares are equivalent in equation (14) because all values are in a common, market price.

exports to the region s in the total output of region r. When the slack variable $tradslackk_{k,r}$[26]is exogenized, this equilibrium condition determines the change in market prices, $pmk_{k,r}$ and that in output, $qok_{k,r}$, is determined by equation (8).

$$qok_{k,r} = \theta_{k,r}^{DO} qdmk_{k,r} + \sum_{s \in REG}[\theta_{k,r,s}^{XO} qxsk_{k,r,s}] + tradslackk_{k,r}, \forall k \in DSECT; r \in REG;$$

$$\theta_{k,r,s}^{XO} = P_{k,r,s}^{XM} Q_{k,r,s}^{XM} / P_{k,r}^{M} Q_{k,r}^{O}; \theta_{k,r,s}^{DO} = P_{k,r}^{M} Q_{k,r}^{DD} / P_{k,r}^{M} Q_{k,r}^{O}$$

(15)

It is important to note the difference in closures when the PE module acts independently as opposed to when it operates in tandem with the GE model. When this module operates in isolation, we adopt a PE closure in which the aggregate changes in industry activity, $qo_{i,r}$ as well as in industry demand, $qd_{i,r}$, are fixed. Thus, when $tmsk_{k,r,s}$ is shocked, owing to the fixing of these quantities, prices must bear all the adjustment to ensure market clearing. However, when the PE model is linked with the GE model, $qo_{i,r}$ and $qd_{i,r}$ become endogenous, with the industry expanding in the face of excess profits, and contracting when presented with losses. The response of aggregate demand is governed by the aggregate demand system in the model. Both of these factors will dampen the extent of price adjustment in the GE and PE-GE models vis-à-vis the PE model. Price adjustment could be controlled in the PE model by introducing structural improvements such as endogenous supply-side features, which are beyond the scope of this paper; we rather focus on economy-wide analysis.

2.2 PE-GE Model
a. Linking Features: Slack Variables
When we integrate the code in the PE model with that in the standard GTAP Model, some endogenous quantity and price change variables in the international trade module are predicted by two equations each (e.g., bilateral trade at the sector level). Of course no model can accommodate two competing predictions of these changes, so the corresponding GE equation must be dropped. This is accomplished via inclusion of so-called slack variables in the GE counterpart equations of the standard GTAP Model, as shown in Box 4. When these variables are endogenous, they effectively eliminate the associated equation from the model and the left hand side variable is determined by the corresponding aggregation equation, as discussed in section 2.1. Refer Box 6 for a summary of the PE-GE closure swaps.

[26] Note that $tradslackk_{k,r}$ is not the percentage change in $TRADESLACK_{k,r}$, as it depends on the percentage change in output.

Box 4. Excerpt from the TAB file showing the linking equations between PE and GE Models

*!If qxsslack is made exogenous, this activates E_QXS that aggregates qxs from SSECT level based on t
PE part!*

Equation E_QXSSLACK
 # regional demand for disaggregated imported commodities by source (HT 29) #
(**all**,i,TRAD_COMM)(**all**,r,REG)(**all**,s,REG)
qxs(i,r,s)= -ams(i,r,s) + qim(i,s) - ESUBM(i) * [pms(i,r,s) - ams(i,r,s) - pim(i,s)]
 + qxsslack(i,r,s);

Equation E_PMSLACK
(**all**,i,TRAD_COMM)(**all**,r,REG)(**all**,s,REG)
  pms(i,r,s) = tm(i,s) + tms(i,r,s) + pcif(i,r,s) + pmslack(i,r,s);

Equation E_PIMSLACK
(**all**,i,TRAD_COMM)(**all**,s,REG)
  pim(i,s) = **sum**(k,REG, MSHRS(i,k,s) * [pms(i,k,s) - ams(i,k,s)])
  +pimslack(i,s);

Equation E_PFOBSLACK
(**all**,i,TRAD_COMM)(**all**,r,REG)(**all**,s,REG)
  pfob(i,r,s) = pm(i,r) - tx(i,r) - txs(i,r,s)+pfobslack(i,r,s);

Equation E_PCIFSLACK
(**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) * ptrans(i,r,s)+pcifslack(i,r,s);

Equation E_PTRANSLACK
(**all**,i,TRAD_COMM)(**all**,r,REG)(**all**,s,REG)
  ptrans(i,r,s)
    = **sum**(m,MARG_COMM, VTFSD_MSH(m,i,r,s) * [pt(m) - atmfsd(m,i,r,s)])
      +ptranslack(i,r,s);

As shown in Box 4, in the PE-GE model, the standard GTAP equations determining the variables $qxs_{i,r,s}$, $pms_{i,r,s}$, $pim_{i,r}$, $pfob_{i,r,s}$, $pcif_{i,r,s}$ and $ptrans_{i,r,s}$ are de-activated by the unique slack variables, namely, $qxsslack_{i,r,s}$, $pmslack_{i,r,s}$, $pimslack_{i,r}$, $pfobslack_{i,r,s}$, $pcifslack_{i,r,s}$ and $ptranslack_{i,r,s}$, respectively.[27]

b. Welfare decomposition

---

[27] Ideally, these slack variables may be expected to capture the deviations of the PE-GE model results for the changes in corresponding variables, from their counterparts in the standard GTAP Model simulations. However, since all these adjustments in different related price and quantity change variables take place simultaneously, they cannot be interpreted in this way. So we do not show them in the results and they are merely used as switch-variables here.

We are particularly interested in the welfare impacts of trade policy reform. Beyond suggesting that the PE-GE model shows higher welfare gains, we would like to be able to explain where these gains originate, and track them back to key features of the trade and protection data base. For this reason we extend the welfare decomposition of Huff and Hertel (2001) to encompass the sub-sector flows. Equation (16) shows the decomposition of welfare in the GTAP Model when the only policy intervention is that of tariffs and endowments, technology and population are held fixed.[28] In this case, the regional equivalent variation EV_s is decomposed into the Allocative Efficiency (AE) effect and the Terms of Trade (TOT) effect. These are all pre-multiplied by ψ_s, a welfare scaling factor with an initial value of one, which changes with the marginal cost of utility as explained in McDougall (2002).

Considering first the AE effect: τ represents the *ad valorem* tax and tariff rates, corresponding to the sectors and regions implied by the subscripts and superscripts as mentioned earlier in this section. When the quantity of imports flowing across a given tariff barrier rises, this generates a positive efficiency gain. When it falls, this generates a loss. When a tariff reduction generates a net gain, it is said to be trade-creating, while when it generates a loss, it is trade-diverting. By disaggregating the trade flows in the PE-GE model, we obtain a richer set of interactions between these tariff rates and the associated trade flows, but otherwise the decomposition is unchanged. The terms of trade (TOT) effect for the region *s* is represented by the second and third terms in this equation. It simply evaluates the change in export prices, relative to import prices, where these are weighted by the associated trade flows. The set $NSECT$ in equation (16)[29] includes all sectors in $ASECT$ except $DAGG$. Box 5 shows an excerpt from welfare decomposition module in the TAB file.

$$EV_s = \left(\psi_s\right)\begin{bmatrix} \overbrace{\sum_{i \in NSECT}\sum_{r \in REG}\left(\tau_{i,r,s}^{IM}P_{i,r,s}^{CIF}dQ_{i,r,s}^{IM}\right) + \sum_{k \in DSECT}^{K}\sum_{r \in REG}^{R}\left(\tau_{k,r,s}^{IM}P_{k,r,s}^{CIF}dQ_{k,r,s}^{IM}\right)}^{ALLOCATIVE-EFFICIENCY-EFFECT} \\ \underbrace{+ \sum_{k \in ASECT}\sum_{r \in REG}^{R}\left(Q_{k,s,r}^{XM}dP_{k,s,r}^{FOB}\right) - \sum_{k \in ASECT}\sum_{r \in REG}^{R}\left(Q_{k,r,s}^{XM}dP_{k,r,s}^{CIF}\right)}_{TERMS-of-TRADE-EFFECT} \end{bmatrix} \quad (16)$$

---

[28] We also abstract from the terms-of-trade effect associated with the savings and investment goods in this model.

[29] In this and other equations that require aggregation from the disaggregated to the aggregated level, the aggregation takes place based on the mapping from the set of disaggregated sectors to that of aggregated ones. This allows the possibility of having more than one aggregated sector in the model.

Box 5. An Excerpt from the TAB file showing Welfare Decompositoin Module

!Appendix: Welfare Decomoposition: Allocative Efficiency!
Equation E_CNTqxskrs
(**all**,k,SSECT_COMM)(**all**,r,REG)(**all**,s,REG)
CNTqxskrs(k,r,s) = XTAXDK(k,r,s) * [0.01 * EVSCALFACT(r)] *
[qxsk(k,r,s) - pop(r)];

Equation E_CNTqimksr
(**all**,k,SSECT_COMM)(**all**,s,REG)(**all**,r,REG)
CNTqimksr(k,s,r) = MTAXK(k,s,r) * [0.01 * EVSCALFACT(r)] *
[qxsk(k,s,r) - pop(r)];

Equation E_CNTqimisr_1
(**all**,i,SPLT_COMM)(**all**,s,REG)(**all**,r,REG)
CNTqimisr(i,s,r)=**sum**(k,SSECT_COMM:MPSP_COMM(k)=i,CNTqimksr(k,s,r));

Equation E_CNTqxsirs_1
(**all**,i,SPLT_COMM)(**all**,r,REG)(**all**,s,REG)
 CNTqxsirs(i,r,s) = **sum**(k,SSECT_COMM:MPSP_COMM(k)=i,CNTqxskrs(k,r,s));

! Appendix: Welfare Decomposition: Terms of Trade Decomposition!
Equation E_PX_KR
 # price index for total exports of k from r #
(**all**,k,SSECT_COMM)(**all**,r,REG)
   px_kr(k,r) = **sum**(s,REG, SX_KRS(k,r,s) * pfobk(k,r,s));

Equation E_PM_KR
 # price index for total imports of k in s -- non-margins commodities #
(**all**,k,SSECT_COMM)(**all**,s,REG)
   pm_kr(k,s) = **sum**(r,REG, SM_KRS(k,r,s) * pfobk(k,r,s));

Equation E_PX_K
 # world export price index for good k #
(**all**,k,SSECT_COMM)
   px_k(k) = **sum**(r,REG, SW_KR(k,r) * px_kr(k,r));

Equation E_c1_kr
 # contribution of world export price index of good i to ToT for region r #
(**all**,k,SSECT_COMM)(**all**,r,REG)
   c1_kr(k,r) = [SX_KR(k,r) - SM_KR(k,r)] * [px_k(k) - px_];

Equation E_c2_kr
 # contribution of regional export price of good k for region r #
(**all**,k,SSECT_COMM)(**all**,r,REG)
   c2_kr(k,r) = SX_KR(k,r) * [px_kr(k,r) - px_k(k)];
Equation E_c3_kr

```
# contribution of imports price index of good k for region r #
(all,k,SSECT_COMM)(all,r,REG)
   c3_kr(k,r) = SM_KR(k,r) * [pm_kr(k,r) - px_k(k)];


Equation E_c1k_r
# contribution of world price indexes of all SSECT goods to ToT for r #
(all,r,REG)
   c1k_r(r) = sum(k,SSECT_COMM, c1_kr(k,r));


Equation E_c2k_r
# contribution of regional exports prices to ToT for r #
(all,r,REG)
   c2k_r(r) = sum(k,SSECT_COMM, c2_kr(k,r));


Equation E_c3k_r
# contribution of regional import prices to ToT for r #
(all,r,REG)
   c3k_r(r) = sum(k,SSECT_COMM, c3_kr(k,r));


Equation E_TOT2K
# trade terms for region r, computed from components #
(all,r,REG)
   tot2k(r) = c1k_r(r) + c2k_r(r) - c3k_r(r);
```

The only substitution parameters employed in the PE model are elasticities of substitution: among imports from different sources, between domestic production and imports, and among the subsectors in consumption. We also introduce an elasticity of transformation among the sub-sector goods. These parameters are the same in both the PE and the nested PE/GE models. Thus the differences in these two sets of model results stem from interactions with the remainder of the GE model wherein other parameters, such as the income elasticities and uncompensated price elasticities of private household demand come into play.[30]

3.   Data Sources and Description

GTAP Data Base Version 6.2 is the main source of data used in this study. This is documented in Dimaranan (2006) and covers 57 sectors and 96 regions with base year 2001. For the sake of simplicity, the PE model for the auto sector is broken down into plausible aggregations of HS-6 level sub-sectors using the *TASTE* software package (Horridge and Laborde, 2008), which is based on the MacMAP_2001 data set[31] (Bouët et al., 2004). *TASTE* also provides HS6 level data on bi-lateral trade (Value of Imports at *cif* prices of good k from regions r to s: $VIWSK_{k,r,s}$), tariffs ($RTMSK_{k,r,s}$) and their mappings to GTAP (Version 6.2) sector-level or at an aggregated level mapped to GTAP sectoral level. All these detailed aggregations and mappings are shown in Appendix Table A.1.

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[30] See Hertel, 1997 for more details on the standard GTAP Model's elasticities
[31] A later, 2009, version of TASTE uses 2004 data, to go with version 7 of the GTAP data.

Since GTAP currently aggregates motor vehicles and other transport equipment into a single sector, we use the PE model to capture the differential levels of protection across these sub-sectors in the auto industry, disaggregating: 1) Motor Cycles; 2) Motor Cycle Parts; 3) Automobiles other than motorcycles; 4) Engines and other Parts of Automobiles; and 5) Other Transport Equipment.

Other aggregated sectors (Other than Auto Industry) in this framework are: 1) Food; 2) Industries that supply Raw Materials to the Auto Industry; 3) Energy Sectors; and 4) Other Manufactures and Services.

The detailed sectoral aggregation and mappings to the standard GTAP sectors are shown in the Appendix, Table A.2. To keep things simple, there are 3 regions in the model: 1) India (IND); 2) South-East Asian Countries and other Auto-sector competitors of India: ASEAN member countries, China, Japan and Korea (SEA); and 3) Rest of the World (ROW). The detailed regional aggregation and mappings to the standard GTAP regions are shown in the Appendix, Table A.3.

With Indian economy in mind, we make suitable assumptions regarding the behavioral elasticities.

The Constant Elasticity of Substitution in demand among auto sub-sectors $\sigma_{k,AUTO}$ is assumed to be 0.5, since, for example, motor cycle parts rarely substitute for automobiles, for an end-user – although autos and parts might substitute for one another in a vertically integrated industry, but this has no empirical basis.[32] The Constant Elasticity of Transformation among the sub-sectors $\varepsilon_{O,AUTO}$, however, is assumed to be quite high: -2, because producers can usually transform some equipment and labor from one auto product to another.

Alternatively, $\sigma_{k,AUTO}$ could be either lower, say zero, or higher as some extent of demand substitutability is plausible across these sub-sectors, driven by diminishing price-differentials between motorcycles and cars,[33] for example. Similarly for producers, it is also plausible that switching from, say, automobiles production to motorcycles or auto parts is not straight-forward,[34] which means even a zero-CET ($\varepsilon_{O,AUTO}$) is a possibility. To identify whether our results are sensitive to varying both these elasticities together or separately, we carry out a Systematic Sensitivity Analysis (SSA) exercise

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[32] Hertel et. al (2007a) emphasizes on the importance of econometrically estimating the elasticity parameters in assessing Free Trade Agreements using CGE models. Boussard et. al (2006), Gohin (2005) and Willenbockel (2004) show that elasticities are crucial for CGE simulation results. However, estimates are scarce, so here we conduct sensitivity analysis over a range of plausible elasticities instead.

[33] Many Indians can afford motorcycles but not cars, but cheaper cars may cause some to switch, as happened when the relatively cheap Maruti-800 car was introduced in the market in the 1990s. With the introduction of world's cheapest car *Tata Nano* now in India, this is expected to happen.

[34] See Narayanan and Vashisht (2008) for more details on production structure in different sub-sectors. Although the players in one sub-sector may diversify into production in others, it is somewhat unusual to see a firm shifting its production from one sub-sector to another with its existing plant and infrastructure.

that varies them with all values over a 100% range, i.e., the CES elasticity $\sigma_{k,AUTO}$ is varied between 0 and 1, while the CET elasticity $\varepsilon_{O,AUTO}$ is varied between -4 and 0.[35]

We used the values estimated by Hertel et. al. (2006) from disaggregated bilateral trade and transport data and which are used in the current GTAP Data Base (Dimaranan, 2006). Lack of data on domestic usage at the subsector level makes it difficult to estimate the CES between domestic and imported goods, σ_{Dk}. So this elasticity of substitution is assumed to be one-half as large as the estimates for σ_{Mk}.

Let us consider $HS6$ as the set of HS6 sectors and let h be its corresponding subscript and let $NSSECT$ be the number of sub-sectors. Let $HS6k$ be the set of HS6 sectors mapped to the subsector k (see Table A.1 for these mappings). Tariff-rates at sub-sector level $RTMSK_{k,r,s}$ were calculated by dividing the tariff revenue ($TAREV_{h,r,s}$) by the imports at world prices at sub-sector level ($TRADE_{h,r,s}$) as mapped and aggregated from HS6-level (see equation 17) and then by re-scaling the resulting tariff-rates such that their average is the same as the aggregate automotive tariffs in GTAP 6.2 Data Base $RTMS_{i,r,s}$, as shown in equation 18. Beginning with HS6-level data on imports at world prices available from TASTE and using the shares of these flows in the corresponding total automotive imports, we split the aggregate imports at world prices ($VIWS_{i,r,s}$) into sub-sectoral level imports ($VIWSK_{k,r,s}$). These steps are summarized in the equations below:

$$RTMSK1_{k,r,s} = \sum_{h \in HS6k}[TAREV_{h,r,s} / TRADE_{h,r,s}] \tag{17}$$

$$RTMSK_{k,r,s} = RTMS_{DAGG,r,s} * RTMSK1_{k,r,s} /(\sum_{k \in SSECT}[RTMSK1_{k,r,s}]/ NSSECT) \tag{18}$$

$$VIWSK_{k,r,s} = (\sum_{h \in HS6k}TRADE_{h,r,s} / \sum_{h \in HS6}TRADE_{h,r,s})*VIWS_{i,r,s} \tag{19}$$

Using this variable and tariff ($RTMSK_{k,r,s}$), we go on to construct all other trade variables. Imports at market prices $VIMSK_{k,r,s}$ is obtained by adding the tariff revenue to the imports at world prices. International transport margins $VTMFSDK_{k,r,s}$ at the disaggregated level were computed from the margins data from the aggregated GTAP level, by assuming that their shares in total transport margin in auto industry are equal to the corresponding sub-sector-level import shares in total auto imports. Subtracting transport margins from imports at world prices and then multiplying their corresponding shares in aggregated auto imports with the aggregate exports at FOB Prices $VXWD_{i,r,s}$, we get the sub-sector-level exports at world prices $VXWDK_{k,r,s}$. Similarly we compute the exports at market prices $VXMDK_{k,r,s}$ using the transport margins and the other trade flows. The following equations summarize these calculations.

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[35] We assume triangular distribution and use Liu quadrature, which solves the model 4 times for each uncertain parameter. See Arndt and Pearson (1998) for more details.

$$VIMSK_{k,r,s} = VIMS_{DAGG,r,s} * (1 + RTMSK_{k,r,s}/100) * VIWSK_{k,r,s} / \sum_{k \in DSECT}(1 + RTMSK_{k,r,s}/100) * VIWSK_{k,r,s}$$

(20)

$$VTMFSDK_{k,r,s} = (VIWSK_{k,r,s}/VIWS_{DAGG,r,s}) * VTMFSD_{DAGG,r,s} \tag{21}$$

$$VXWDK_{k,r,s} = VXWD_{DAGG,r,s} * \{VIWSK_{k,r,s} - VTMFSDK_{k,r,s})/\sum_{k \in DSECT}\{VIWSK_{k,r,s} - VTMFSDK_{k,r,s}) \tag{22}$$

$$VXMDK_{k,r,s} = VXMD_{DAGG,r,s} * \{1 + RTXS_{DAGG,r,s}/100) * VXWDK_{k,r,s} / \sum_{k \in DSECT}(1 + RTXS_{DAGG,r,s}/100) * VXWDK_{k,r,s} \tag{23}$$

Figure 3. Summary of The Adjustments made in the Data Base
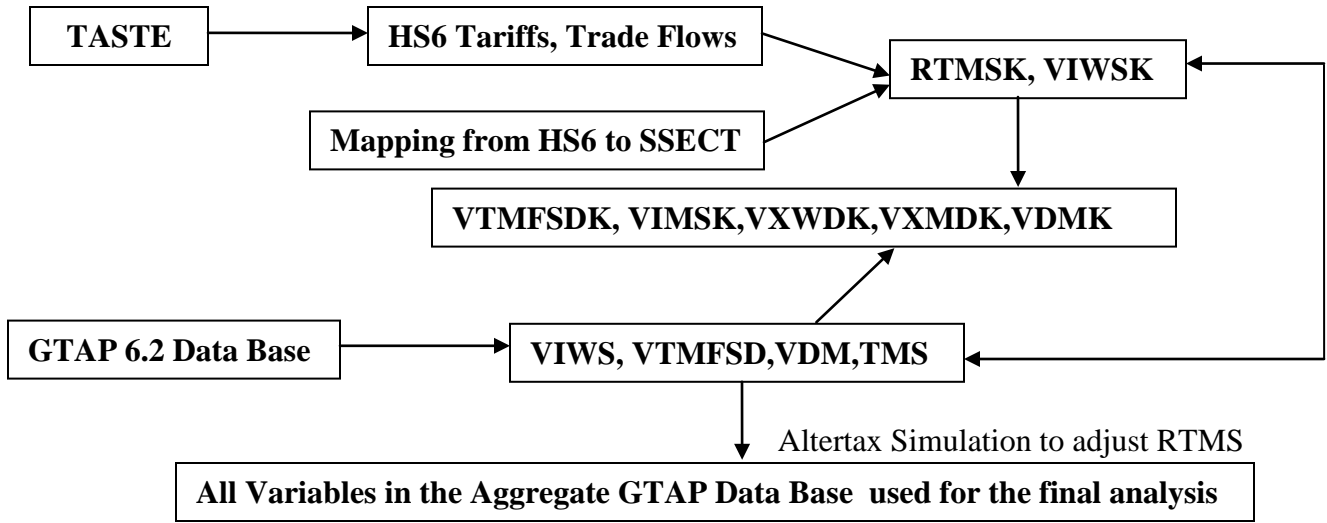
In addition, the model requires sub-sector data on total domestic consumption ($VDMK_{k,r}$). This was computed at the sub-sector level by assuming the ratio of domestic consumption to imports at the GTAP-level to be preserved at the disaggregate level as well, as shown in the equation below. This is one of the most limiting assumptions in our analysis. We strongly encourage future users of the PE-GE approach to obtain independent estimates of these shares. The value of sub-sectoral production $VOMK_{k,r}$ is obtained in the model as the sum of domestic consumption of locally produced goods and exports.

$$VDMK_{k,r} = (VDM_{DAGG,r} / \sum_{s \in REG}VIMS_{DAGG,r,s}) * \sum_{s \in REG}\{VIMSK_{k,r,s}) \tag{24}$$

In order to build a consistent database, the aggregate sector-level tariffs were re-constructed by computing the weighted average of sub-sector-level tariffs from the TASTE database. This also meant revising the corresponding aggregate flows 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). For this, all the variables in the database were re-

adjusted via a GTAP "*Altertax*" simulation[36] 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. Figure 3 summarizes the adjustments made in this process. Table A.4 shows all the variables involved in the construction procedure outlined in this section, after the *Altertax* adjustments.

The initial level of tariffs and the subsector shares of imports in total imports in the Indian auto industry from the regions SEA and ROW are summarized respectively in the first and the second 2-column panels in Table 1. The last 2-column panel shows the product of subsector import share and tariffs at 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[37]

Region→	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:		
	SEA	ROW	SEA	ROW	SEA	ROW	SEA	ROW	Total
Motorcycles	59.7	48.2	0.001	<0.001	0.060	0.008	0.766	0.234	1
McycleParts	19.8	16.1	0.047	0.002	0.929	0.023	0.947	0.053	1
Automobiles	52.0	33.6	0.031	0.062	1.616	2.066	0.219	0.781	1
EnginesParts	19.8	16.1	0.593	0.206	11.74	3.307	0.614	0.386	1
OtherTrans	12.9	7.9	0.328	0.731	4.216	5.794	0.199	0.801	1
Total			1	1	18.6	11.2	0.356	0.644	1

An observation from this table is that imports in more protected sub-sectors, namely Motorcycles and Automobiles tend to be smaller volumes. This is natural as larger tariffs result in lower imports and hence lower import shares. This endogeneity of imports with respect to tariffs means that the welfare gains from tariff liberalization will be understated if we conduct our analysis at the aggregated level, using trade-weighted tariffs (example: Young and Magee, 1986; Lai and Zhu, 2004). This problem has been documented extensively in the literature for trade costs and flows in general (Anderson and van Wincoop, 2004; Hillberry, 2002; Pomfret, 1985) and tariffs in particular (Basevi, 1966, 1968; Ray, 1987; Trefler, 1993; Gaston and Trefler, 1994, 1997; Beghin and Kherallah. 1994; Goldberg, 1995; Olarreaga and Soloaga, 1998; Beghin and Fang, 2002). Indeed, the sector-level weighted-average tariffs are much lower than the highest tariffs seen at the sub-sector-level.

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[36] 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 had to do this because the HS6 tariff revenue from CEPII does not add up to GTAP sector-level tariff revenue. Therefore, we alter the GTAP data to agree with the CEPII data.

[37] Since the third 2-column panel comprises the products of corresponding elements of the first two2-column panels, the two totals in this panel are actually import-weighted totals of the two columns in the first 2-column panel. Therefore they are, in effect, *average tariff rates* in Indian auto sector.

We can see that SEA is the major source of India's imports of Motorcycles, Motorcycle parts and Engines/Parts, while ROW is the major source of Automobiles and OtherTrans imports. 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 data.

4. Results

Using the modeling framework explained in Section 3 we carry out a policy experiment using PE, PE-GE and the standard GTAP (GE) models. The experiment is a simulation that removes all tariffs in all disaggregated sub-sectors of the Auto industry in all regions as shown in Box 7. Although it is unlikely in reality that all countries will eliminate their auto tariffs in the near future, there is an active, ongoing debate in India and other countries about reducing tariffs in this sector.[38] The simple PE closure assumes $qo_{i,r}$ and $qd_{i,r}$ are exogenous and have no link with the GE model (Boxes 6 and 7). Of course we could improve upon this PE model by making aggregate supply and demand price responsive. However, absent additional econometric work, or absent special simulations of the GE model, these elasticities are unknown. Furthermore, by fixing these variables exogenously, we draw a sharp distinction between the PE and PE/GE models. All variables at the aggregate level pertaining to the sectors other than the one being disaggregated, which is autos in this case, are also exogenized. All technical change variables at the aggregate level and tax/tariff change variables and import-augmenting technical change at disaggregate level are exogenous and fixed in this PE closure.

Box 6. Closures Used in Different Models

PE Model	GE Model	PE-GE Model
Exogenous: Changes in total output and demand in all sectors and regions. Changes in all price, tax and quantity variables for non-Auto sectors at i level. Changes in import tax and import-augmented technical-change ($amsk_{krs}$) variables at k-level. Slack variable for tradeables market-clearing at k-level. **Endogenous:** All other price, tax and quantity changes and slack variables.	**Exogenous:** Changes in endowment output, world price index for primary factors, distribution parameters for savings, government and private consumption and population. Slack variables for consumer goods, endowments, income, profits, savings price and tradeables' market clearing; All technical and tax change variables. **Endogenous:** All other price and quantity changes and slack variables.	**Exogenous:** Changes in endowment output, world price index for primary factors, distribution parameters for savings, government and private consumption and population. Slack variables for consumer goods, endowments, income, profits, savings price and tradeables' market clearing; Slack variables for different prices, quantities and welfare-count-variables are exogenous for non-Auto sectors. All technical and tax change variables at i level, except tms_{irs} txs_{irs} tm_{ir} tx_{ir} and ams_{irs} that are exogenous for non-Auto sectors. **Endogenous:** All other price, tax, technical and quantity changes and slack variables.

[38] This is also justified in the literature. For example, Malakellis (1998) shows that tariff reductions that take place without warning have better macro- and structural implications than those take place by steps based on a previously announced schedule. Given this and the current FTA negotiations, even this may perhaps not be an extreme case, at least in the long-run.

Box 7. Experiment Details for Different Models

PE Model (contains only the equations specific to PE-model)	GE Model (contains only the equations specific to GE-model)	PE-GE Model (contains the complete model that has equations for PE-model, those for GE model and the linking equations)

Exogenous:
qo amsk atall atd atf atm ats qd qst qtmfsd tmk tmsk pt txk txsk
pm(ASECT_COMM,REG)
tx(ASECT_COMM,REG)
txs(ASECT_COMM,REG,REG)
tm(ASECT_COMM,REG)
tms(ASECT_COMM,REG,REG)
pcif(ASECT_COMM,REG,REG)
pfob(ASECT_COMM,REG,REG)
pim(ASECT_COMM,REG)
qim(ASECT_COMM,REG)
qxs(ASECT_COMM,REG,REG)
pms(ASECT_COMM,REG,REG)
ptrans(ASECT_COMM,REG,REG)
ams(ASECT_COMM,REG,REG);
Rest Endogenous;
 	
Shock tmsk (SSECT_COMM,REG,"INDIA") = target% 0 from file tmsk.shk;
 	
Shock tmsk (SSECT_COMM,REG,"SEAsiaOther") = target% 0 from file tmsk.shk;
 	
Shock tmsk (SSECT_COMM,REG,"ROW") = target% 0 from file tmsk.shk;
	Exogenous pop
	psaveslack pfactwld
	profitslack incomeslack
	endwslack cgdslack
	tradslack
	ams atm atf ats atd aosec
	aoreg avasec avareg
	afcom afsec afreg afecom
	afesec afereg aoall afall
	afeall
	au dppriv dpgov dpsave to
	tp tm tms tx txs
	qo(ENDW_COMM,REG) ;
	Rest Endogenous;
	
	Shock
	tms("AutoIndustry",REG, "INDIA") = target% 0 from file tms.shk;
	
	Shock
	tms("AutoIndustry",REG, "SEAsiaOther") = target% 0 from file tms.shk;
	
	Shock
	tms("AutoIndustry",REG, "ROW") = target% 0 from file tms.shk;
		Exogenous afall afcom afeall afecom afereg
		afesec afreg afsec amsk aoall aoreg
		aosec atall atd atf atm ats au avaall avareg
		avasec cgdslack dpgov dppriv dpsave
		endwslack incomeslack pop profitslack
		psaveslack tf tfd tfm tgd tgm tmk tmsk to tp
		tpd tpm txk txsk tm(ASECT_COMM,REG)
		tms(ASECT_COMM,REG,REG) tradslack
		tradslackk tx(ASECT_COMM,REG)
		txs(ASECT_COMM,REG,REG)
		ams(ASECT_COMM,REG,REG)
		pcifslack(ASECT_COMM,REG,REG)
		pfobslack(ASECT_COMM,REG,REG)
		pimslack(ASECT_COMM,REG)
		qimslack(ASECT_COMM,REG)
		pmslack(ASECT_COMM,REG,REG)
		ptranslack(ASECT_COMM,REG,REG)
		qxsslack(ASECT_COMM,REG,REG)
		CNTqxsslack(ASECT_COMM,REG,REG)
		CNTqimslack(ASECT_COMM,REG,REG)
		qo(ENDW_COMM,REG) pfactwld;
		Rest endogenous;
		
		Shock tmsk(SSECT_COMM,REG,"INDIA") = target% 0 from file tmsk.shk;
		
		Shock tmsk(SSECT_COMM,REG,"SEAsiaOther") = target% 0 from file tmsk.shk;
		
		Shock tmsk(SSECT_COMM,REG,"ROW") = target% 0 from file tmsk.shk;

As shown in Box 6, the standard GTAP Model closure determines all quantities and prices endogenously.[39] In the closure for the PE model linked with the standard GTAP Model (PE-GE), aggregate supply and demand, ($qo_{i,r}$ and $qd_{i,r}$, respectively) are endogenous. In the PE-GE model, all the slack variables pertaining to the set DAGG, tariff changes at aggregate sectoral level, and all prices, are made endogenous, while tariff changes at sub-sector level and other components of slack

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[39] 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.

variables are made exogenous to facilitate the operation of the standard GE model for all aggregate sectors except those in DAGG. The slack variable used in the market clearing conditions is made exogenous both at aggregate ($tradslack_{i,r}$) and disaggregate ($tradslackk_{k,r}$) levels, to facilitate endogenous determination of market prices, in all closures. We now turn to a comparison of results from all the three models.[40]

Table 2. India's Import-changes shown by PE-GE, GE and PE models (% Changes post-simulations of complete multi-lateral tariff liberalization in the auto industry)

	Sub-sectors in Auto Industry					Aggregate Auto	
	Motor-cycles	Mcycle Parts	Auto mobiles	Engines & Parts	Other Trans	Results from PE-GE & PE models	Results from GE model
Imports from ROW							
Results from PE-GE Model							
Domestic Penetration Effect	210.9	39.1	121.8	45.1	22.0	44.8	29.6
Substitution Effect among sources	-15.0	-11.5	-12.2	-10.6	-5.4	-18.7	-11.0
Total Change in Imports by India *(qxsk)*	196.0	27.8	109.6	34.5	16.6	26.1	18.6
Results from PE Model							
Domestic Penetration Effect	234.1	36.1	127.9	37.7	19.0	41.0	29.6
Substitution Effect among sources	-11.4	-6.8	-8.0	-9.7	-4.1	N.A.	-11.0
Total Change in Imports by India *(qxsk)*	222.7	29.3	119.9	28.0	14.9	24.1	18.6
Imports from SEA							
Results from PE-GE Model							
Domestic Penetration Effect	354.5	54.4	280.6	64.3	30.9	44.8	52.7
Substitution Effect among sources	6.1	0.8	62.8	8.2	24.3	29.9	27.0
Total Change in Imports by India *(qxsk)*	360.6	55.3	343.4	72.4	55.2	74.7	79.7
Results from PE Model							
Domestic Penetration Effect	333.9	42.7	219.2	54.7	25.2	41.0	52.7
Substitution Effect among sources	4.0	0.3	34.8	7.0	14.1	N.A.	27.0
Total Change in Imports by India *(qxsk)*	337.9	43.0	254.0	61.7	39.3	59.9	79.7

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*, due to the non-linear solution procedure of Gragg. [41]

Table 2 outlines the results pertaining to Equation (2) of Section 3, which determines percentage changes in bilateral imports of sub-sectors as a function of the tariff cuts. In all models, there is a relatively big and positive domestic penetration effect that contributes to increased imports in all sectors and from all regions. In both PE-GE and GE models, the substitution effect is relatively small -- negative for imports from ROW and positive for imports from SEA, implying that India's imports from ROW are replaced by those from SEA. Consequently, imports from ROW increase to a smaller extent than those from SEA, according to all the models.

The reason for this substitution is that initially ROW goods face lower tariffs than those from SEA, as shown in Table 1. As shown in Equation (2), the percentage substitution effect increases with the

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[40] We use the non-linear Gragg 2-4-6 extrapolation method for the solution, as mentioned in Pearson and Horridge (2005).

[41] We do not show SSA results in this table, because of this adjustment, for a better presentation of the results. Table 3 and 4 show some SSA results.

divergences of applied tariffs across exporters and decreases with import value shares. Table 1 shows that the Automobile 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 low. These observations explain why India's Automobiles imports from SEA are the most influenced by the substitution effect as shown in Table 2. Similarly, owing to the fact that tariff differentials are low and that SEA dominates 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. Though the tariff differentials are the same for 'OtherTrans', since SEA's share in its total imports by India is lower to begin with, the substitution effect is larger here for SEA.

Imports of Motorcycles and Automobiles face a dramatic rise due to the domestic penetration effect, as they both have very high initial tariffs. Even the substitution effects in their imports from SEA and ROW are high, as tariff-differences between imports from SEA and ROW in these sub-sectors are much higher than those in other sub-sectors. Although the tariff-difference is not so high in the "OtherTrans" sub-sector, this is the biggest import sub-sector within the auto imports from ROW, as shown in Table 1, and hence the substitution effect for the imports from SEA 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 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 higher substitution effect than Motorcycle parts in SEA.

It clearly emerges from Table 2 that both the substitution effects and the domestic penetration (based on both $qimk_{k,r}$ and $qim_{i,r}$) levels are considerably lower in most of the PE model results, compared to the other models.[42] 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 limiting 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 (Table 3). Domestic and market prices change to a 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.

In the GE model, changes in imports from ROW are more modest than predicted by the sub-sector-level models, while those from SEA are more pronounced (Table 2). The reason for this is while the domestic penetration effect is the lowest in the GE model, the substitution effects are much higher in it. The initial tariff-differences between SEA and ROW (Table 1) ensure that the imports are substitued away from ROW to SEA, in all of the models. Since the degree of substitution is higher in

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[42] As an exception, rise in imports from ROW is higher in PE, due to lower substitution to SEA. 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.

the GE model (Table 2), the rise in imports from ROW is lower and that in imports from SEA is higher. This is because of the fact that there is 'false competition' in the simple GE model. Specifically, SEA exports mainly Engines and Parts to India, whereas ROW exports Other Transport Equipment, but at the aggregate level the only information available is that ROW is a bigger exporter than SEA (Table 1), which means higher contribution of substitution effect to changes in imports from SEA in the GE model than in the PE-GE model, wherein the import changes are the aggregations from sub-sector level results explained above.[43]

The differences between PE-GE and GE model results arise mainly because the variables pertaining to auto industry in the PE-GE model are aggregations of their counterpart-variables at the sub-sector-level. The import share of ROW in total imports by India is lower than the share of imports from SEA. This, in addition to the lower tariff for imports from ROW, implies lower tariff-cuts for imports from ROW, in our scenario of complete tariff liberalization. This results in lower domestic price changes of imports from ROW and hence lower changes in aggregate import prices from ROW in all the results. However, the changes are sharper in the PE-GE model than in the GE model, since the much sharper changes at the sub-sector-level are reflected in the aggregated price variables in the PE-GE model.

All these results are found to not be sensitive to the assumed CES or CET elasticities, as shown by the bounds for PE-GE results obtained from the Systematic Sensitivity Analysis (SSA) exercise in Table 3.[44] For example, imports from SEA change to a lesser extent in the PE-GE model than in the GE model, even when we consider the Upper Bound of this variable in the former, which is lower than the corresponding figure in the GE model.

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 ($qimk$)	Import Prices ($pimk$)	Domestic Prices (pdk)	Market Prices (pmk)	Import Prices From ($pmsk$):	
	SEA	ROW					SEA	ROW
Auto: PE-GE								
Lower Bound	73.9	25.5	44.0	-13.4	-2.3	-0.4	-17.0	-11.0
Upper Bound	75.5	26.5	45.6	-13.2	-2.3	-0.4	-16.6	-10.8
Auto: GE	79.6	18.5	40.7	-12.7	N.A.	-0.4	-16.0	-10.4
Auto: PE	60.7	25.2	42.2	-16.6	-5.9	-4.3	-18.6	-13.8
PE-GE								
Motorcycles	360.6	196.0	323.3	-36.9	0.2	0.3	-37.7	-33.2
MCycleparts	55.3	27.8	53.9	-16.6	-4.8	-0.9	-16.7	-14.2
Automobiles	343.4	109.6	163.5	-28.0	-2.1	0.0	-33.6	-25.4
EnginesParts	72.4	34.5	57.9	-16.1	-3.2	-0.7	-17.3	-14.0
OtherTrans	55.2	16.6	24.4	-8.7	-2.1	-0.4	-11.8	-7.7
PE								

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[43] 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.

[44] We do not show the Systematic Sensitivity Analysis results for the PE model because the results in PE are already way different from others and we are more interested in seeing if PE-GE and GE results differ enough.

Motorcycles	337.9	222.7	311.9	-38.2	-2.6	-2.5	-38.8	-35.8
MCycleparts	43.0	29.4	42.6	-18.1	-8.9	-5.9	-18.2	-16.9
Automobiles	254.0	119.9	151.2	-29.4	-5.4	-3.5	-33.1	-27.9
EnginesParts	61.7	28.0	49.3	-18.5	-7.7	-5.8	-19.6	-16.6
OtherTrans	39.3	14.9	21.2	-11.4	-5.8	-4.3	-13.4	-10.8

Note: The Lower and Upper Bounds for the results from the PE-GE model are calculated at 95% Confidence Interval, using Chebyshev's inequality, based on a systematic sensitivity analysis that varied the elasticity of substitution among sub-sectors between 0 and 1 and elasticity of transformation among them between -4 and 0.

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, due to the high tariffs in these sub-sectors. Since the domestic price change is the weighted average of market and import price changes as seen in Equation (13), domestic prices 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, the PE model shows much steeper decline in all prices at sub-sector level, in order to keep aggregate quantities unchanged.

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

REG	Allocative Efficiency		Investment-Savings		Terms of Trade		Total Welfare Gain	
	GE	PE-GE	GE	PE-GE	GE	PE-GE	GE	PE-GE
SEA	1410.3	(1587.7,1844.9)	152.8	(196.5,203.4)	1748.1	(1284.8,1565.7)	3311.3	(3069.0, 3614.0)
IND	46.8	(65.0,69.2)	11.5	(9.7,10.1)	-26.6	(-23.5,-16.0)	31.6	(51.2.4,63.2)
ROW	-7.2	(540.5, 670.5)	-164.4	(-212.7,-206.1)	-1723.2	(-1544.2,-1269.3)	-1894.8	(-1216.5,-804.8)
Total	1450.0	(2193.2,2584.6)	-0.1	(-6.5,7.3)	-1.8	(-282.9,280.4)	1448.1	(1903.7,2872.4)

Note: All figures in Tables 4 and 5 are in US$ Million; for the PE-GE results, we show the range between lower and upper bounds within the parentheses, as explained in the note in Table 3. Total welfare gain is the sum of AE, I-S and TOT gains shown in the first three column-panels in this table.

One of the great strengths of CGE analysis is the ability to provide an exhaustive accounting of economic welfare. As shown in Table 4, the welfare results in PE-GE (based on a more complex version of equation 16 which allows for other distortions as well as accounting for changes on the capital account, i.e. the investment-savings effect) are considerably different from those in GE 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 much higher than that inferred from the GE model. Most of this can be traced to the Allocative Efficiency (AE) gains. Regional welfare changes 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 all regions, than those shown by the GE model. In fact, even the lower bound for AE gains in the PE-GE model results are higher than those in the GE model results except in SEA where the GE model result lies in the range of PE-GE model result.[45] ROW loses less from TOT changes, India loses less and SEA gains less in the PE-GE

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[45] For example, the minimum AE gain for India predicted by our PE-GE model, with 95% confidence and varying the assumed elasticities by 100%, (65 Billion US Dollars) is more than that predicted by the GE model (46.8 Billion US Dollars).

model, when compared with the GE model's results. India's lower loss in TOT shown by the PE-GE model is accentuated by its far greater AE gain, resulting in a higher aggregate welfare gain for India than what the GE model shows, despite a lower I-S gain in the PE-GE model. SEA gains more from I-S adjustment, while ROW loses less from the same, in PE-GE model, compared to the GE model.

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

Sub-sector	Imports from SEA			Imports from ROW			All Auto Imports by IND	
	Base Tariff rate	Change in Imports	Change in Welfare	Base Tariff rate	Change in Imports	Change in Welfare	Change in Imports	Change in Welfare
Motorcycles	59.7	2.8	0.6	48.2	0.5	0.1	3.3	0.7
MCycleparts	19.8	20.1	1.9	16.1	0.6	0.1	20.7	1.9
Automobiles	52.0	82.7	15.7	33.6	94.1	14.1	176.8	29.8
EnginesParts	19.8	333.5	30.3	16.1	99.2	7.9	432.7	38.2
OtherTrans	12.9	141.5	8.5	7.9	173.3	7.0	314.8	15.6
Auto: PEGE	**18.6**	**581.1**	**(56.0,57.8)**	**11.2**	**367.6**	**(28.7,29.5)**	**948.7**	**(84.7,87.2)**
Auto: GE	**18.6**	**617.7**	**52.3**	**11.2**	**258.6**	**15.2**	**876.3**	**67.5**

Note: All figures except the tariff rates are in US$ Million; for PE-GE Welfare Change results, we show the range between lower and upper bounds within the parentheses as explained in the note in Table 3.

Table 5 summarizes the tax-related AE 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, the welfare change 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 total welfare gain is also higher in the PE-GE model than in the GE model. Although the changes in imports from SEA are lower in PE-GE than in GE, the welfare change is higher in the former. As for imports from ROW, both change in imports and welfare change are higher in the PE-GE model.

Table 5 also traces back the sub-sectors to identify why the AE-related welfare gain shows up as higher in the PE-GE model. This is largely because of the sizable welfare gains in three sub-sectors: Automobiles, Engines and Parts and Other transport Equipments, which have large import shares and base tariff-levels (Table 1) in terms of India's imports from both SEA and ROW, which also means that total import taxes are very high to begin with and *vice-versa* for other sub-sectors. Owing to the high welfare changes from these sub-sectors, the aggregate welfare change of imports from SEA is higher in the PE-GE model, despite the lower import change. For the imports from ROW, the aggregate welfare change is about twice in the PE-GE model, compared to that in the GE model. All these results are robust to our SSA, as explained in the previous paragraphs and shown in Table 5.

It is evident from the results in this section that linking the GE with the PE model that has more disaggregated sectors makes an important difference in the results, especially those pertaining to economic welfare. 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 and also in eliminating the ills of aggregate analysis such as false competition. Further, all of these findings are qualitatively robust to the values chosen for the crucial elasticities.

5. Conclusions

In this paper, we offer an extension to the standard GTAP Model which permits the user to add "tariff line" detail to their analysis of specific sub-sectors of interest. In practice trade policy discussions often begin with broad, CGE-based assessments of potential gains from a crudely defined trade agreement. The detailed negotiations that follow typically drill down to the tariff line in the case of particular, sensitive sectors. This PE/GE framework allows a GTAP user to follow this evolution in a consistent manner, beginning with the usual CGE-based results, but then adding PE detail as needed to support the negotiations. In so doing, they can rest assured that their overall framework is still consistent with the original GE results, and their subsequent analysis may be viewed as a refinement of these initial results.

By way of illustration, we show how our PE-GE model is superior to a stylized PE model, in which aggregate supply and demand are exogenous. Use of the PE model in isolation shows far larger changes in prices and far less pronounced source-wise substitution effects, although it still captures, to a large extent, the disaggregate impacts across sub-sectors. The PE/GE model is also contrasted with a standard GE model. Here, the stand-alone GE model shows lower changes in the aggregate 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 into India. Further, the substitution effect appears more pronounced in the GE model, because of 'false competition', as the exporters do not actually compete in the sub-sector-level as much as it appears from the aggregate level. 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 those in the GE model, we find the overall welfare gains to be higher in the PE-GE model. There are many other notable differences, of which we highlight those in the import-tax-related AE effects and the TOT effects. In both cases, all the differences could be traced back to the changes in 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 a very policy-relevant tool offered by CGE models. Given the lack of empirical support for the CET and CES elasticities utilized in our PE-GE model, we carried out a Systematic Sensitivity Analysis by varying them and found that all our results are clearly robust to a very broad plausible range of these elasticities. However, future econometric work aimed at estimation of these parameters would further strengthen the case for such PE/GE modeling.

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Appendix: Detailed Information on Mapping and Data

Table A.1. Mapping between HS-6 Sectors and the Sub-sectors considered in this study

HS6 Code	Description	Sub-sector
871110	Motorcycles, spark ignition engine of < 50 cc	Motorcycles
871120	Motorcycles, spark ignition engine of 50-250 cc	
871130	Motorcycles, spark ignition engine of 250-500 cc	
871140	Motorcycles, spark ignition engine of 500-800 cc	
871150	Motorcycles, spark ignition engine of > 800 cc	
871190	Motorcycles with other than a spark ignition engine	
871411	Motorcycle saddles	MCycle Parts
871419	Motorcycle parts except saddles	
840731	Engines, spark-ignition reciprocating, <50 cc	AutoEnginesParts
840732	Engines, spark-ignition reciprocating, 50-250 cc	
840733	Engines, spark-ignition reciprocating, 250-1000 cc	
840734	Engines, spark-ignition reciprocating, over 1000 cc	
840820	Engines, diesel, for motor vehicles	
840991	Parts for spark-ignition engines except aircraft	
840999	Parts for diesel and semi-diesel engines	
870600	Motor vehicle chassis fitted with engine	
870710	Bodies for passenger carrying vehicles	
870790	Bodies for tractors, buses, trucks etc	
870810	Bumpers and parts thereof for motor vehicles	
870821	Safety seat belts for motor vehicles	
870829	Parts and accessories of bodies nes for motor vehicles	
870831	Mounted brake linings for motor vehicles	
870839	Brake system parts except linings for motor vehicles	
870840	Transmissions for motor vehicles	
870850	Drive axles with differential for motor vehicles	
870860	Non-driving axles/parts for motor vehicles	
870870	Wheels including parts/accessories for motor vehicles	
870880	Shock absorbers for motor vehicles	
870891	Radiators for motor vehicles	
870892	Mufflers and exhaust pipes for motor vehicles	
870893	Clutches and parts thereof for motor vehicles	
870894	Steering wheels, columns & boxes for motor vehicles	

870899	Motor vehicle parts nes	
870600	Motor vehicle chassis fitted with engine	
870710	Bodies for passenger carrying vehicles	
870790	Bodies for tractors, buses, trucks etc	
870810	Bumpers and parts thereof for motor vehicles	
870821	Safety seat belts for motor vehicles	
870829	Parts and accessories of bodies nes for motor vehicles	
870831	Mounted brake linings for motor vehicles	
870839	Brake system parts except linings for motor vehicles	
870840	Transmissions for motor vehicles	
870850	Drive axles with differential for motor vehicles	
870860	Non-driving axles/parts for motor vehicles	
870870	Wheels including parts/accessories for motor vehicles	
870880	Shock absorbers for motor vehicles	
870891	Radiators for motor vehicles	
870892	Mufflers and exhaust pipes for motor vehicles	
870893	Clutches and parts thereof for motor vehicles	
870894	Steering wheels, columns & boxes for motor vehicles	
860900	Cargo containers designed for carriage	Automobiles
870120	Road tractors for semi-trailers (truck tractors)	
870210	Diesel powered buses	
870290	Buses except diesel powered	
870310	Snowmobiles, golf cars, similar vehicles	
870321	Automobiles, spark ignition engine of <1000 cc	
870322	Automobiles, spark ignition engine of 1000-1500 cc	
870323	Automobiles, spark ignition engine of 1500-3000 cc	
870324	Automobiles, spark ignition engine of >3000 cc	
870331	Automobiles, diesel engine of <1500 cc	
870332	Automobiles, diesel engine of 1500-2500 cc	
870333	Automobiles, diesel engine of >2500 cc	
870390	Automobiles nes including gas turbine powered	
870421	Diesel powered trucks weighing < 5 tonnes	
870422	Diesel powered trucks weighing 5-20 tonnes	
870423	Diesel powered trucks weighing > 20 tonnes	
870431	Spark ignition engine trucks weighing < 5 tonnes	
870432	Spark ignition engine trucks weighing > 5 tonnes	
870490	Trucks nes	
870510	Mobile cranes	
870520	Mobile drilling derricks	
870530	Fire fighting vehicles	
870540	Mobile concrete mixers	
870590	Special purpose motor vehicles nes	
871610	Trailers for housing or camping	Other trans

871631	Tanker trailers and semi-trailers
871639	Trailers nes for the transport of goods
871640	Trailers, semi-trailers nes
871690	Trailer/non-mechanically propelled vehicle parts nes
870899	Motor vehicle parts nes
871610	Trailers for housing or camping
871631	Tanker trailers and semi-trailers
871639	Trailers nes for the transport of goods
871640	Trailers, semi-trailers nes
871690	Trailer/non-mechanically propelled vehicle parts nes
840710	Aircraft engines, spark-ignition
840910	Parts for spark-ignition aircraft engines
841111	Turbo-jet engines of a thrust < 25 KN
841112	Turbo-jet engines of a thrust > 25 KN
841121	Turbo-propeller engines of a power < 1100 kW
841122	Turbo-propeller engines of a power > 1100 kW
841191	Parts of turbo-jet or turbo-propeller engines
841210	Reaction engines other than turbo jets
860110	Rail locomotives, externally electrically powered
860120	Rail locomotives powered by electric accumulators
860210	Rail locomotives, diesel-electric
860290	Rail locomotives non-electric and locomotive tenders
860310	Self-propelled railway cars, external electric power
860390	Self-propelled railway cars except external electric
860400	Railway maintenance-of-way service vehicles
860500	Railway passenger and special purpose coaches
860610	Railway tank cars
860620	Railway wagons, insulated/refrigerated except tank car
860630	Railway cars, self-discharging, nes
860691	Railway cars nes, closed and covered
860692	Railway cars nes, open, with sides > 60 cm high
860699	Railway cars nes
860711	Railway & tramway driving bogies & bissel-bogies
860712	Railway & tramway bogies & bissel-bogies, non-driving
860719	Railway & tramway axles, wheels and parts
860721	Air brakes, parts for railway rolling stock
860729	Brakes except air, parts for railway rolling stock
860730	Coupling devices, parts for railway rolling stock
860791	Railway locomotive parts nes
860799	Railway rolling stock parts nes
860800	Signals etc for rail, tram, water-way, port, airfield
871200	Bicycles, other cycles, not motorized
871310	Wheelchairs not mechanically propelled

871390	Wheelchairs, mechanically propelled	
871411	Motorcycle saddles	
871419	Motorcycle parts except saddles	
871420	Wheelchair parts	
871491	Bicycle frames and forks, and parts thereof	
871492	Bicycle wheel rims and spokes	
871493	Bicycle hubs, free-wheel sprocket wheels	
871494	Bicycle brakes, parts thereof	
871495	Bicycle saddles	
871496	Bicycle pedals/crank-gear, parts thereof	
871499	Bicycle parts nes	
871680	Wheelbarrows, hand-carts, rickshaws etc	
880110	Gliders, hang gliders	
880190	Balloons, dirigibles, non-powered aircraft nes	
880211	Helicopters of an unladen weight < 2,000 kg	
880212	Helicopters of an unladen weight > 2,000 kg	
880220	Fixed wing aircraft, unladen weight < 2,000 kg	
880230	Fixed wing aircraft, unladen weight 2,000-15,000 kg	
880240	Fixed wing aircraft, unladen weight > 15,000 kg	
880260	Spacecraft (including sa	
880310	Aircraft propellers, rotors and parts thereof	
880320	Aircraft under-carriages and parts thereof	
880330	Aircraft parts nes	
880390	Parts of balloons, dirigibles, spacecraft	
880510	Aircraft launching and deck-arrestor gear, parts	
880520	Flight simulators, parts thereof	
890110	Cruise ships, excursion boats, ferry boats	
890120	Tankers	
890130	Refrigerated vessels other than tankers	
890190	Cargo vessels other than tanker or refrigerated	
890200	Fishing vessels and factory ships	
890310	Inflatable pleasure craft	
890391	Sailboats, with or without auxiliary motor	
890392	Motorboats, other than outboard motorboats	
890399	Rowing boats, canoes, pleasure boats except sail/power	
890400	Tugs and pusher craft	
890510	Dredgers	
890520	Floating, submersible drilling or production platforms	
890590	Floating docks, special function vessels nes	
890600	Warships, lifeboats, hospital ships, vessels nes	
890710	Inflatable rafts	
890790	Buoys, beacons, coffer-dams, pontoons, floats nes	
890800	Vessels and other floating structures for breaking up	

Table A.2 Mappings between GTAP Sectors and the aggregated sectors included in this study

GTAP Sector	Aggregated Sector	Description
pdr	Food	Food and Agricultural Sector
wht	Food	Food and Agricultural Sector
gro	Food	Food and Agricultural Sector
v_f	Food	Food and Agricultural Sector
osd	Food	Food and Agricultural Sector
c_b	Food	Food and Agricultural Sector
pfb	Food	Food and Agricultural Sector
ocr	Food	Food and Agricultural Sector
ctl	Food	Food and Agricultural Sector
oap	Food	Food and Agricultural Sector
rmk	Food	Food and Agricultural Sector
wol	Food	Food and Agricultural Sector
frs	Food	Food and Agricultural Sector
fsh	Food	Food and Agricultural Sector
coa	Energy	Energy Sector
oil	Energy	Energy Sector
gas	Energy	Energy Sector
omn	Mnfcs	Manufactures
cmt	Food	Food and Agricultural Sector
omt	Food	Food and Agricultural Sector
vol	Food	Food and Agricultural Sector
mil	Food	Food and Agricultural Sector
pcr	Food	Food and Agricultural Sector
sgr	Food	Food and Agricultural Sector
ofd	Food	Food and Agricultural Sector
b_t	Food	Food and Agricultural Sector
tex	Mnfcs	Manufactures
wap	Mnfcs	Manufactures
lea	Mnfcs	Manufactures
lum	Mnfcs	Manufactures
ppp	Mnfcs	Manufactures
p_c	Energy	Energy Sector
crp	Autorms	Raw Materials to Automotive Industry
nmm	Mnfcs	Manufactures
i_s	Autorms	Raw Materials to Automotive Industry
nfm	Autorms	Raw Materials to Automotive Industry
fmp	Autorms	Raw Materials to Automotive Industry
mvh	AutoIndustry	Automotive Industry
otn	AutoIndustry	Automotive Industry
ele	Mnfcs	Manufactures

ome	Autorms	Raw Materials to Automotive Industry
omf	Mnfcs	Manufactures
ely	Svces	Services Sector
gdt	Svces	Services Sector
wtr	Svces	Services Sector
cns	Svces	Services Sector
trd	Svces	Services Sector
otp	Svces	Services Sector
wtp	Svces	Services Sector
atp	Svces	Services Sector
cmn	Svces	Services Sector
ofi	Svces	Services Sector
isr	Svces	Services Sector
obs	Svces	Services Sector
ros	Svces	Services Sector
osg	Svces	Services Sector
dwe	Svces	Services Sector

Table A.3 Mappings between GTAP Regions and the Aggregated Regions included in this study

GTAP Region	Description	Aggregated Region
AUS	Australia	ROW
NZL	Newzealand	ROW
XOC	Rest of Oceania	ROW
CHN	China	SEAsiaOther
HKG	Hong Kong	SEAsiaOther
JPN	Japan	SEAsiaOther
KOR	Korea	SEAsiaOther
TWN	Taiwan	SEAsiaOther
XEA	Rest of East Asia	ROW
KHM	Cambodia	ROW
IDN	Indonesia	SEAsiaOther
MYS	Malaysia	SEAsiaOther
PHL	Philippines	ROW
SGP	Singapore	SEAsiaOther
THA	Thailand	SEAsiaOther
VNM	Vietnam	ROW
XSE	Rest of Southeast Asia	SEAsiaOther
BGD	Bangladesh	ROW
IND	India	INDIA
PAK	Pakistan	ROW
LKA	Sri	ROW
XSA	Rest of South Asia	ROW

CAN	Canada	ROW
USA	United	ROW
MEX	Mexico	ROW
XNA	Rest	ROW
BOL	Bolivia	ROW
COL	Colombia	ROW
ECU	Ecuador	ROW
PER	Peru	ROW
VEN	Venezuela	ROW
ARG	Argentina	ROW
BRA	Brazil	ROW
CHL	Chile	ROW
PRY	Paraguay	ROW
URY	Uruguay	ROW
XSM	Rest of South America	ROW
XCA	Central America	ROW
XFA	Rest of Free Trade Areas of America	ROW
XCB	Rest of the Caribbean	ROW
AUT	Austria	ROW
BEL	Belgium	ROW
DNK	Denmark	ROW
FIN	Finland	ROW
FRA	France	ROW
DEU	Germany	ROW
GBR	United Kingdom	ROW
GRC	Greece	ROW
IRL	Ireland	ROW
ITA	Italy	ROW
LUX	Luxembourg	ROW
NLD	Netherlands	ROW
PRT	Portugal	ROW
ESP	Spain	ROW
SWE	Sweden	ROW
CHE	Switzerland	ROW
XEF	Rest of EFTA	ROW
XER	Rest of Europe	ROW
ALB	Albania	ROW
BGR	Bulgaria	ROW
HRV	Croatia	ROW
CYP	Cyprus	ROW
CZE	Czech Republic	ROW
HUN	Hungary	ROW
MLT	Malta	ROW

POL	Poland	ROW
ROM	Romania	ROW
SVK	Slovakia	ROW
SVN	Slovenia	ROW
EST	Estonia	ROW
LVA	Latvia	ROW
LTU	Lithuania	ROW
RUS	Russian Federation	ROW
XSU	Rest of Former Soviet Union	ROW
TUR	Turkey	ROW
IRN	Iran, Islamic Republic of	ROW
XME	Rest of Middle East	ROW
EGY	Egypt	ROW
MAR	Morocco	ROW
TUN	Tunisia	ROW
XNF	Rest	ROW
BWA	Botswana	ROW
ZAF	South	ROW
XSC	Rest of South African Customs Union	ROW
MWI	Malawi	ROW
MUS	Mauritius	ROW
MOZ	Mozambique	ROW
TZA	Tanzania	ROW
ZMB	Zambia	ROW
ZWE	Zimbabwe	ROW
XSD	Rest of Southern African Development Community	ROW
MDG	Madagascar	ROW
NGA	Nigeria	ROW
SEN	Senegal	ROW
UGA	Uganda	ROW
XSS	Rest of Sub-Saharan Africa	ROW

Table A.4 Key variables in the Data Base (RTMSK in %, others in USD Millions)

DSECT	r	s	RTMSK	VIWSK	VTMFSDK	VIMSK	VXWDK	VXMDK	VDMK
Motorcycles	SEA	SEA	18.2	327.1	12.8	388.1	314.4	314.4	17957.1
MCycleParts	SEA	SEA	12.9	461.3	18.0	522.2	443.3	443.3	4765.3
Automobiles	SEA	SEA	33.7	4414.1	172.3	5938.7	4241.8	4241.8	28781.3
EnginesParts	SEA	SEA	14.0	7876.0	307.5	9003.4	7568.5	7568.5	87451.4
OtherTrans	SEA	SEA	3.8	4801.4	187.4	4894.0	4614.0	4614.0	258742.4
Total Auto	**SEA**	**SEA**	**16.2**	**17879.9**	**698.0**	**20746.5**	**17181.8**	**17181.9**	**397697.4**
Motorcycles	IND	SEA	16.5	2.2	0.1	2.6	2.2	2.2	17957.1
MCycleParts	IND	SEA	6.9	1.0	0.0	1.1	1.0	1.0	4765.3
Automobiles	IND	SEA	16.4	12.9	0.4	15.1	12.4	12.4	28781.3
EnginesParts	IND	SEA	5.0	43.2	1.4	45.5	41.8	41.8	87451.4
OtherTrans	IND	SEA	4.8	50.9	1.7	52.4	49.2	49.2	258742.4
Total Auto	**IND**	**SEA**	**6.5**	**110.2**	**3.6**	**116.6**	**106.6**	**106.6**	**397697.4**
Motorcycles	ROW	SEA	1.7	144.9	2.6	147.3	142.3	139.7	17957.1
MCycleParts	ROW	SEA	3.2	5082.8	91.3	5247.3	4991.5	4899.0	4765.3
Automobiles	ROW	SEA	13.5	452.0	8.1	513.1	443.8	435.6	28781.3
EnginesParts	ROW	SEA	13.9	23414.2	420.7	26678.3	22993.4	22567.5	87451.4
OtherTrans	ROW	SEA	1.2	12619.5	226.8	12769.4	12392.8	12163.2	258742.4
Total Auto	**ROW**	**SEA**	**8.7**	**41713.4**	**749.5**	**45355.4**	**40963.9**	**40205.0**	**397697.4**
Motorcycles	SEA	IND	60.0	0.8	0.0	1.3	0.8	0.8	2061.3
MCycleParts	SEA	IND	19.8	37.8	1.4	45.3	36.4	36.4	190.9
Automobiles	SEA	IND	52.0	25.0	0.9	38.1	24.1	24.1	3336.4
EnginesParts	SEA	IND	19.8	477.6	17.1	572.2	460.5	460.5	6366.2
OtherTrans	SEA	IND	12.9	264.1	9.5	298.1	254.6	254.6	6441.1
Total Auto	**SEA**	**IND**	**18.6**	**805.4**	**28.9**	**954.8**	**776.5**	**776.5**	**18393.0**
Motorcycles	ROW	IND	44.0	0.2	0.0	0.4	0.2	0.2	2061.3
MCycleParts	ROW	IND	16.0	2.1	0.0	2.5	2.1	2.0	190.9
Automobiles	ROW	IND	33.6	89.6	1.7	119.6	87.8	86.1	3336.4
EnginesParts	ROW	IND	16.1	299.7	5.8	347.8	293.8	287.9	6366.2
OtherTrans	ROW	IND	7.9	1063.3	20.7	1147.6	1042.7	1021.7	6441.1
Total Auto	**ROW**	**IND**	**11.2**	**1454.9**	**28.3**	**1617.9**	**1426.6**	**1398.0**	**18393.0**
Motorcycles	SEA	ROW	5.3	6439.5	174.6	6782.0	6264.9	6264.9	3614.0
MCycleParts	SEA	ROW	5.4	1266.7	34.4	1335.6	1232.4	1232.4	10482.8
Automobiles	SEA	ROW	18.1	4670.7	126.6	5517.5	4544.1	4544.1	439196.0
EnginesParts	SEA	ROW	2.1	24839.6	673.5	25349.3	24166.1	24166.1	320037.4
OtherTrans	SEA	ROW	2.8	95506.6	2589.6	98140.3	92916.9	92916.9	329163.6
Total Auto	**SEA**	**ROW**	**3.3**	**132723.2**	**3598.7**	**137124.6**	**129124.4**	**129124.4**	**1102493.8**
Motorcycles	IND	ROW	16.7	125.7	4.9	147.7	120.8	120.8	3614.0
MCycleParts	IND	ROW	8.3	11.8	0.5	12.8	11.4	11.4	10482.8
Automobiles	IND	ROW	17.4	193.0	7.6	228.3	185.4	185.4	439196.0
EnginesParts	IND	ROW	3.8	402.9	15.8	418.9	387.1	387.1	320037.4
OtherTrans	IND	ROW	9.5	389.1	15.2	417.4	373.8	373.8	329163.6
Total Auto	**IND**	**ROW**	**9.6**	**1122.6**	**44.0**	**1225.2**	**1078.4**	**1078.4**	**1102493.8**
Motorcycles	ROW	ROW	2.4	1820.6	30.0	1864.2	1790.6	1786.8	3614.0
MCycleParts	ROW	ROW	2.4	572.5	9.4	586.0	563.0	561.9	10482.8
Automobiles	ROW	ROW	2.1	238807.6	3938.3	243867.4	234869.5	234369.3	439196.0
EnginesParts	ROW	ROW	1.3	149220.3	2460.8	151138.5	146759.2	146446.7	320037.4
OtherTrans	ROW	ROW	0.9	167785.0	2767.0	169328.0	165018.1	164666.7	329163.6
Total Auto	**ROW**	**ROW**	**1.5**	**558205.7**	**9205.6**	**566784.1**	**549000.4**	**547831.4**	**1102493.8**

Appendix 2: Glossary of Disaggregated sector-level Variables[46] used in the model

```
pfobk(k,r,s) # FOB world price of commodity k supplied from r to s #
pmsk(k,r,s) # domestic price for good k supplied from r to region s #
qxsk(k,r,s) # export sales of commodity k from r to region s #
pcifk(k,r,s) # CIF world price of commodity k supplied from r to s #
qok(k,r) # Domestic output of commodity k in region r, mkt prices #
pmk(k,r) # market price of commodity k in region r #
qdmk(k,r) # domestic usage of commodity k in region r, at mkt prices#
qdm(i,r) # domestic usage of composite i in region r, at mkt prices#
amsk(k,r,s) # import k from region r augmenting tech change in region s#
qimk(k,s) # aggregate imports of k in region s, market price weights #
pimk(k,r) # market price of composite import k in region r #
qdk(k,r) # aggregate demand of k in region r, at market prices #
pdk(k,r) #Domestic price of composite commodity k in region r #
pdmk(k,r) # price of domestic production of k in region r #
qd(i,r) # aggregate composite demand of i in region r at market prices #
pd(i,r) #Domestic price of composite commodity i in region r #
tmk(k,s) # source-generic change in tax on imports of k into s #
tmsk(k,r,s) # source-spec. change in tax on imports of k from r into s #
txk(k,s) # source-generic change in tax on imports of k into s #
txsk(k,r,s) # source-spec. change in tax on imports of k from r into s #
tradslackk(k,r) # slack variable in tradeables market clearing condition #
atallk(m,k,r,s) # tech change in m's shipping of k from region r to s #
atfk(k) # tech change shipping of k, worldwide #
ptransk(k,r,s) # cost index for international transport of k from r to s #
atmfsdk(m,k,r,s) # tech change in m's shipping of k from region r to s #
qtmfsdk(m,k,r,s) # international usage margin m on k from r to s #
CNTqxskrs(k,r,s) # cont. to EV of changes in exports of k from r to s #
CNTqxsslack(i,r,s) #Slack variable for CNTqxsirs to invoke PE part#
CNTqimksr(k,s,r) # cont. to EV of changes in imports of k from s to r #
CNTqimslack(i,s,r) #Slack variable for CNTqimisr to invoke PE part#
qxsslack(i,r,s) # Endogenous slack variable that invokes E_QXS (PE part)#
qimslack(i,r) #Endogenous Slack Variable that invokes E_QIM #
pmslack(i,r,s) #Endogenous Slack Variable to invoke E_PMS#
pimslack(i,r) #Endogenous Slack Variable to invoke E_PIM#
pfobslack(i,r,s) #Endogenous Slack Variable to invoke E_PFOB#
pcifslack(i,r,s) #Endogenous Slack Variable to invoke E_PCIF#
```

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[46] All variables listed herein are in percentage changes. This list includes merely the variables that have been added in the PE-GE model and it does not include the standard GTAP Model variables (See Hertel, 1997 for details on them)