INTEGRATING THE AIDADS

DEMAND SYSTEM INTO THE GTAP MODEL

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Abstract

The objective of this paper is to illustrate how the newly developed AIDADS demand system is estimated, calibrated and how the AIDADS system and its econometrically estimated income elasticities are incorporated into the standard GTAP model. A demand side experiment with the modified GTAP model is conducted using different demand specification (LES, CD and AIDADS) to illustrate where the AIDADS functional form makes a substantial difference, and where it does not. The simulation results show that for regions with rapid income growth, the LES over-predicts growth in private demand, import and output growth requirement for food products and under-predicts that for non-food products. On the other hand, for high-income regions with smaller income growth, model results based on the calibrated LES produces similar results to the model with AIDADS.

INTRODUCTION

Recently it has become more common to use the GTAP model (see Hertel 1997 for details on the database and model of the Global Trade Analysis Project) for making predictions of what the world economy might look like at some future point of time. In making such projections, the behavior of private consumption as income increases is a key feature of the model. This is nowhere so evident as in the world food market, where changing consumption patterns have led to an upgrading of household diets as incomes have risen. At the lower income levels, consumers have shifted away from grains toward livestock products and at higher income levels consumers have been seeking greater product variety and reduced food preparation requirements. As a consequence, there has been a major shift in the pattern of world food trade. Compared to the modest annual growth in aggregated food trade at 5.3 percent from 1980 to 1995, the relative changes at the disaggregated levels are more striking. For the four broadly defined food categories—bulk, livestock, horticulture, and other processed food, the annual growth rates are 2.1, 6.9, 6.6, and 8.3 percent, respectively. The share for bulk food declined from 50 percent to 32 percent during the same period. Another notable trend is the disparity of patterns of trade in countries at different income levels. Wealthy areas such as the US, the EU, import more processed, value-added food, while the developing countries import more bulk and intermediate products.

To what extent can an applied general equilibrium model such as GTAP track this historical behavior? Coyle et al. (1998) explore this issue using a preliminary version of a modified GTAP model which incorporated the newly developed AIDADS demand system (stands for "An Implicit Direct Additive Demand System") by Rimmer and Powell (1996). Cranfield et al. (1999) compare AIDADS with several other functional forms and their results show that the AIDADS system outperforms all the other functional forms in forecasting food demand. In their historical analysis of world trade patterns over 1980-1985-1990-1995 period, Coyle et al. are able to explain a significant share of the changes.

This paper focuses squarely on the challenges raised by incorporating AIDADS into GTAP and proposes an improved method for calibration of the demand system and associated margins. The improved model is then used to make demand-side projections to the year 2020. The results are compared to several simpler functional forms that are nested under AIDADS, including the Linear Demand System (LES) and the Cobb-Douglas (CD), These comparisons help to identify the extent to which incorporation of the richer AIDADS demand system might make a difference for such projection exercises. The first section of the paper introduces the general modeling approach of incorporating AIDADS into the standard GTAP model. The second section discusses the data, aggregation, and the estimation, calibration and implementation of the ADAIDS. The third section compares the results from a "demand side" experiment using models under alternative demand specifications and describes the results from the AIDADS model. Conclusion and discussion are included in the last section.

MODELING THE AIDADS DEMAND SYSTEM IN THE GTAP MODEL

The AIDADS Demand System

AIDADS starts from an implicit directly additive utility function defined by Hanoch (1975):

(1) $$\sum_{i=1}^{n} U_i(x_i, u) = 1 \quad (i = 1,2,\ldots,n)$$

where $\{x_1, x_2, \ldots, x_n\}$ is the consumption bundle, *u* is the utility level. *Ui* is a twice-differentiable monotonic functions satisfying appropriate concavity conditions and has the following form:

(2) $$U_i = \frac{[\alpha_i + \beta_i G(u)]}{[1 + G(u)]} \ln\left(\frac{x_i - \gamma_i}{Ae^u}\right)$$

where G(u) is a positive, monotonic twice-differentiable function, γ_i is the subsistence level of consumption, α_i, β_i and A are parameters. The following restrictions are imposed on the parameters:

(3) $$0 \le \alpha_i, \beta_i \le 1; \quad \sum_{i=1}^{n} \alpha_i = 1; \quad \sum_{i=1}^{n} \beta_i = 1.$$

The usual utility maximization yields:

(4) $$x_i = \frac{\phi_i (M - \gamma' \cdot P)}{P_i} + \gamma_i \quad for\ i = 1,2,..,n$$

where $\phi_i = \frac{\alpha_i + \beta_i e^{u_j}}{1 + e^{u_j}} \quad for\ i = 1,2,...,n$ and $\gamma' P = \sum_{i=1}^{n} p_i \gamma_i$.

Pick $G(u) = e^u$, we can derive income elasticities implied by the AIDADS demand system:

(5) $$\eta_i = \psi_i / w_i$$

where Ψ_i is the marginal budget share, w_j is the average budget share. If we set every α_i equal to the corresponding β_i, the AIDADS system collapses into the Linear Expenditure System (LES). The Cobb-Douglas function (CD) is also a special case for both the AIDADS and LES if we set the subsistence consumption level γ_i to zero. The richer Engel flexibility of the AIDADS system is gained by the additional *(n-1)* independent parameters α_i.

Demand Specifications in the Standard GTAP Model

In the standard GTAP model, the regional household receives all income that is generated in that economy. Regional income must be fully spent in three forms: private consumption, government consumption, and savings. Spending of regional income generates aggregate regional utility. The distribution of regional income into the three types of expenditure is governed by a per capita regional utility function, which is specified as a Cobb-Douglas function. This is illustrated at the top level of the “tree” in Figure 1. This per capita C-D utility function implies constant budget shares for the three types of expenditures with the standard closure. The middle level of the “tree” in Figure 1 shows how these three forms of demand are further distributed across individual products and services once the amount of expenditure for the three forms of demand is determined. Private demand is specified using the Constant Difference Elasticity (CDE) expenditure function. Government demands are specified with a Cobb-Douglas function. The next to bottom level of the "tree" in the Figure 1 shows how composite government and private demands are further decomposed into domestic and foreign products and services via the specification of the so-called "Armington" structure, which is specified as a CES function. The very bottom level of the "tree" in figure shows how private and government import demands are divided among exporters by means of another Armington structure.

The CDE function represents nonhomothetic preferences for private household demand and allows for marginal budget shares of individual goods to vary with income levels. In the standard GTAP model, parameters of the CDE function are calibrated to price and income elasticities taken from historical studies. Since the CDE function is not directly estimated, the overall behavior of the associated Engel relationships are not guaranteed to capture the desired effects. By contrast, the richer Engel effects of AIDADS have been econometrically estimated by Rimmer and Powell (1992), and Cranfield et al.(1998). Cranfield et al. show that in low per capita expenditure countries, grain budget shares were the highest among the food items, followed by livestock. As per capita expenditure rises, the position of grain relative to livestock switches, until eventually, livestock budget shares dominates the other food items, while grain has the smallest budget share of the food goods.

Incorporation of AIDADS into the GTAP Model

Integration of the AIDADS functional form for private household behavior replaces the CDE specification in the mid-level of the private expenditure "tree" in Figure 1. This modification is summarized in Figure 2. The demand equations for regional private household's consumption are now governed by the AIDADS. Then there are two transition matrices linking the private household consumption at consumers' prices and at producers' prices. These links are needed since the consumption concept in the AIDADS estimation is different from that in the rest of the GTAP model. The AIDADS estimation uses data from the International Comparison Project (See United Nations 1992 for details on the ICP data set). ICP data are evaluated at consumer prices, while GTAP data are collected at "basic" market, i.e. producer good prices. Also, there are some inconsistencies due to the classification of the GTAP and ICP data sets. These, too must be resolved via a transition matrix. These two transition matrices are modeled as two CD production nests. In the first CD nest, GTAP goods are treated as inputs to produce ICP goods. A cost share matrix is needed for this nest. The second nest deals with the margin problem—service margins and goods at the "farm gate" in the GTAP aggregation are blended together to produce goods that reach final consumers. This requires another cost share matrix. Through the link of the two CD nests, the private composite demand at producers' prices is derived, which is further divided into domestic produced and imported via the Armington specification (See the next-to bottom level in the "tree" in Figure 1). This completes the conceptual integration of the AIDADS system into the GTAP model.

DATA, ESTIMATION, CALIBRATION AND IMPLEMENTATION OF AIDADS

Data, Aggregation and Estimation of AIDADS

The 1985 ICP cross-country data set is used for the estimation of the AIDADS system. The ICP data set includes 113 commodities and covers 64 countries. This data set is based on a survey of national household consumption and is evaluated at common 1985 "international dollars" so that the values across countries are directly comparable. Cranfield et al. estimates AIDADS using a 7-good aggregation. In this study, a 9-good aggregation of the ICP data set is employed. This aggregation is focused on the food and agricultural goods (grains, livestock and meat products, horticulture and vegetable, fish, and other food). Other goods in the aggregation are textile and wearing apparel, resource intensive goods, manufacturing, and services.

For the GTAP database, the final release of Version 4.0 is used. The GTAP 4 database includes 45 region and 50 commodities. A 9-good GTAP aggregation similar to ICP-9 is used for this study. Although efforts are made to make sure those two aggregations match each other as closely as possible, there remain discrepancies due to differences in the original classifications. These differences are precisely the reason for developing the transition matrices proposed for the modified GTAP model. The 50 regions in the GTAP model are grouped into 13 regions (West Europe, Australia and New Zealand, U.S., Canada, Japan, ASEAN, Newly Industrialized Countries, China, Mexico, MERCOUSOR, Mid-East and North Africa, Economy in transition, and rest of the world). The regional aggregation based on GTAP 4 is listed in Table 2.

We use the Maximum Likelihood Estimation method developed by Cranfield et al. (2000). The objective function is minimized with respect to the unknown parameters of the AIDADS system, fitted budget shares, residuals, and the utility levels for each observation. This optimization problem is implemented subject to constraints defining the residual terms and subsistence consumption. The ICP data are used on a per capita basis. This study adopts that method to the case of the 9 good aggregation. Since the GTAP database has 1995 as its base year, the estimated AIDADS system needs to be updated from 1985 to 1995. This requires additional information on income and population growth during the period 1985-1995. Assuming constant prices, demand and utility levels can be updated to 1995 by a utility maximization problem in which the estimated parameters are used. The income elasticites implied by the estimated AIDADS system at 1985 as well as the income elasticities from the updated AIDADS system at 1995 are listed in Table 3. The Engel flexibility of AIDADS can be readily identified by comparing elasticities for grains in different years. Take AS6 (ASEAN) as an example, income elasticity for grains is 0.531(0.530 calibrated) at 1985, then decreases to 0.220(0.220) at 1995, finally it drops to 0.038 at 2020.

Assuming unchanging prices, and using predicted quantities at 1995, the predicted ICP budget shares for 1995 for each country can be obtained. Comparison between the GTAP budget shares for private consumption and AIDADS shares reveals substantial differences —in part due to the aggregation and margin problems. The next part discusses these inconsistencies and develops the transition/cost share structures to bridge them.

Retailing-Wholesaling Activities, Cost Share Matrices and The Calibration of AIDADS

Two transition matrices—cost share matrices—are constructed to solve the aggregation and margin problems. These matrices serve as the cost shares for the two Cobb-Douglas nests below AIDADS function in Figure 2. As mentioned earlier, each of the aggregated goods in the ICP aggregation may not have exactly the same "contents" as its counterpart in the GTAP aggregation. The first matrix is built to link the goods in the ICP-9 aggregation to goods in a hypothetical GTAP-9-margin-inclusive aggregation. This hypothetical GTAP-9-margin-inclusive aggregation will include the same goods as the GTAP-9-margin-exclusive aggregation (GTAP-9 or G-9 for short from now on), with each good having exactly the same "ingredients" as the corresponding GTAP-9 goods, except that the former includes the marketing margin. Thus, GTAP-9-margin-inclusive is evaluated at consumer's prices. The second matrix is used to link the GTAP-9 aggregation with GTAP-9-margin-inclusive aggregation by adding the service margins to each of the non-service goods in GTAP-9 to get the corresponding GTAP-9-margin-inclusive non-service goods. Service margins come from the service sector in the GTAP-9 aggregation, so that consumers' direct expenditure share on services is much lower when viewed at consumers' prices.

Implementing the two transition matrices based on the shares of the 1995 predicted demand at ICP-9 level from the estimated uniform AIDADS system and the shares of the GTAP-9 goods from the GTAP 4 database reveals some major problems, i.e. some of the margins are negative. This forces consideration of a calibration process. There are several possibilities. First, use of the same transition matrix derived from the 1985 ICP data set and applying it to 1995 predicted ICP shares could be problematic since the "input-output" relationship with respect to the two aggregations might have changed during that period. Second, uniform preferences are assumed for all the regions when using the estimated system to produce demand for the year 1995. It is very much debatable whether preferences across regions are uniform. Authors such as Clements and Chen (1996) support uniform or similar preferences across countries. They have identified some fundamental similarities in consumer behavior. Connor (1994) also argues for North America as a precursor of changes in Western European food purchase patterns. But instead of uniform preferences, international preference convergence is probably a more appropriate concept according to both authors. Under uniform preferences, deviations from the generic preferences due to regional characteristics are ignored. This may cause either over-prediction or under-prediction of the ICP shares of different goods. For example, fish consumption in Japan is under-predicted, whereas in the US it is over-predicted by the uniform AIDADS system.

In deference to the problem of region-specific preferences, we calibrate region-specific AIDADS demand systems. Based on the estimated AIDADS functional form (namely the αs, βs, and γs in equations 1-5) and the original 1985 ICP data, country-specific demand functions (and utility functions) can be calibrated by replacing the generic αs, βs, and γs with country-specific αs, βs, and γs. The objective is to minimize the difference between the income elasticities implied by the generic AIDADS system and the country specific systems. This objective is set so that the resulting income elasticities will not drift away from the econometrically estimated ones. In order to preserve the Engel relationships over the prediction period (1985-1995), both the estimated 1985 and predicted 1995 Engel elasticities are targeted in the calibration process. A time subscript *t* (t=1for 1985 and t=2 for 1995) is introduced. The country specific AIDADS functional forms are required to fit the 1985 data exactly. These systems will also predict a new set of 1995 demands and utility levels. This calibration process is formulated in (6)-(11). Note in the following formulae, the country subscripts are suppressed.

(6) $$\min_{\alpha,\beta,\gamma,x_{i2},u_2} \sum_{i=1}^{n} [(\eta_{it} - \hat{\eta}_{it})/\eta_{it}]^2 \quad \text{S.T.}$$

(7) $$x_{it} = \frac{\phi_{it}(M - \gamma' \cdot P)}{P_i} + \gamma_i \quad for\ i = 1,2,..,n \quad and\ t = 1,2$$

(8) $\sum_{i=1}^{n}\phi_{it}\ln\left(\frac{x_{it}-\gamma_i}{Ae^{u_t}}\right)=1 \quad for\ i=1,2,...,n\ and\ t=1,2$

(9) $\hat{\eta}_{it}=\psi_{it}/w_{it} \quad for\ i=1,2,...,n \quad and\ t=1,2$

(10) $\sum_{i=1}^{n}\hat{\eta}_{it}w_{it}=1 \quad or \quad \sum_{i=1}^{n}\psi_{it}=1 \quad for\ i=1,2,...,n\ \ and\ t=1,.2$

(11) $0\le\alpha_i,\beta_i\le1; \quad \sum_{i=1}^{n}\alpha_i=1; \quad \sum_{i=1}^{n}\beta_i=1; \quad \gamma_i\le x_{it} \quad \forall i,t$

In (6)-(11), η_{it} is the income elasticity from the original estimation, while $\hat{\eta}_{it}$ is the income elasticity using the calibrated country-specific parameters. η_{it} is used as a scaling factor in the objective function. The scaling is needed because many food products have smaller elasticities and without the scaling, the relative differences between the original and calibrated elasticities for these products will be substantial. Equation (7) contains the first order conditions for the utility maximization problem in both years. In these equations, x_{i1} are original ICP quantity data at 1985, while x_{i2} are demands for 1995 and are choice variables. Equation (8) contains the defining equations for the implicit directly additive utility functions for both years. Equation (9) contains the formulae for the income elasticities in both years. Equation (10) imposes the Engel Aggregation directly in the calibration process. Note if we can calibrate the system perfectly, i.e., the calibrated elasticities are exactly the same as the targeted ones for both years, we will have a zero value for the objective function. Since it is unlikely that we can solve the system exactly, the problem is formulated as a scaled, least squares problem. The final constraints are the regularity restrictions on the parameters.

The problem of (6)-(11) is a highly nonlinear programming problem. These results are reported in Table 3. It is very clear that income elasticities for both 1985 and 1995 are very close to the estimated ones. Also, the negative margins are mostly resolved. The remaining negative margins are remedied by making minimal adjustments to the first transition matrix using another optimization problem. At this point, all the necessary pieces are in place to conduct model simulations.

DEMAND SIDE EXPERIMENTS UNDER ALTERNATIVE FUNCTIONAL FORMS

The Experiments

Cranfield *et al.*(1999) compare the performance of four demand systems (LES, AIDS, AIDADS, and QUAIDS) in predicting demands based on estimation with cross sectional data spanning a range of countries with very different income levels. AIDADS has been shown to outperform all the other systems in the prediction of food demands. Most of the general equilibrium or partial equilibrium models for predicting world food demand use simpler functional forms such as LES, CD and CDE, or even simple translog specifications in which income elasticities are constant. Some examples are the International Food Policy Research Institute's global model on food products (Agcaoili and Rosegrant 1995), the World Bank's econometric model on global grain market (Mitchell et al. 1996), the FAO's world agricultural model (Alexandratos 1995), the ORANI model of the Australia economy (Dixon et al. 1982), and a GTAP study (Anderson et al. 1997). In this section, the comparison is extended in the context of this modified GTAP model using alternative demand specifications, ranging from the most naïve one (Cobb-Douglas), to the still popular Linear Expenditure System (LES), to the one used in this study, AIDADS. A "demand side" experiment is conducted to explore the impact of population and income growth on private household demand and aggregate regional demand, and on requirements of production and trade growth in 2020. In this experiment, endowments are allowed to adjust freely to match the increased demand caused by the population and real income growth. All the prices will remain constant in this demand side experiment.

The income and population growth data are drawn from the GTAP baseline projection (See Table 1, drawn from Walmsley and McDougall 2000). The developing economies will have the higher population growth rates, while in developed economies, the US, Canada and Australia will also see considerable increase. Since only population and aggregate real income are shocked, higher population growth merely means relatively less per capita real income growth. The highest population growth is in Mid-East and North Africa (MAN) and the Rest of the World (ROW). The AIDADS demand systems are defined on the per capita basis, so it would be interesting to look at the per capita real income growth by using the difference between real income growth and population growth as a rough measure. In the developing world, regions such as China, Newly Industrialized Countries (NIC) and ASEAN (AS6) have very high-income growth, compared to their population growth. As a result, these regions still maintain relative high per capita income growth. On the other hand, ROW and MAN will contribute much of the growth to catch population increase.

The CD and LES Demand Systems and Their Modeling in GTAP

For the C-D demand system, all income elasticities are 1 while uncompensated cross price elasticities of demand are 0 and own price elasticities are –1. In the GTAP model, these elasticites are directly assigned their corresponding values and are kept constant regardless of income changes, thereby preserving private expenditure shares over the course of the simulations.

The LES system is derived from Stone-Geary preferences:

(12) $$u = \sum_i \beta_i \ln(q_k - \gamma_k) \quad where \sum_i \beta_k = 1 .$$

The income elasticities implied by the LES are

(13) $$e_i = \frac{\beta_i}{w_i}$$

where w_i is the budget share for good i. With this specification, the Engel flexibility is severely restricted since the marginal budget share is just constant and equal to the parameter β_i, regardless of the income level. Since LES is a special case of AIDADS, the elasticity formulas can be easily implemented. However, a set of parameters β_i and γ_i are still needed to complete the system. In order to find a common basis for comparing LES and AIDADS, region-specific LES systems are calibrated so that their income elasticities in 1985 are the same as the ones from the calibrated AIDADS system. Also, the budget shares predicted by these calibrated LES systems at 1995 are required to be the same as the ones from the calibrated AIDADS systems in order to satisfy the other structures in the model such as the aggregation transition and margin activities. There are actually three steps in this calibration: first, the regional LES systems are calibrated to income elasticities predicted by AIDADS in 1985; second, these calibrated systems are updated to 1995 using data on real per capita income and constant prices; third, these LES systems are recalibrated to the predicted income elasticites from the previous step and the budget shares predicted by the calibrated AIDADS system at 1995. By updating these calibrated LES systems (called "LESa") to the years 1995 and 2020, one can observe the Engel behavior of these systems and see how they are different from the AIDADS systems.

Income Elasticities from Alternative Functional Forms

The income elasticities from these systems (AIDADS and LESa) and the updated elasticities for the year 2020 for selected countries are listed in Figure 4. In addition, purely for the purpose of comparison, the income elasticities for another set of LES systems, which is only calibrated to AIDADS income elasticities and demand at 1995 and denoted as LESb in the figure, are also included in Figure 4. For China, at 1995, LESb implies similar income elasticities as the AIDADS system since the objective of the calibration is to minimize the difference between the two sets of elasticities. However, income elasticities from LESa are much higher than that from either LESb or AIDADS, even though the 1985 income elasticities for LESa target that for AIDADS. The biggest differences are from the income elasticities in 2020 for the three systems. At 2020, LESa suggests income elasticities around 1 for all food products, as does LESb to a less extent. AIDADS at 2020 shows a decline of income elasticities in all foods, while among food products, livestock and other food have higher income elasticities. AS6 is projected to have significant income growth during the same period, although the growth is not expected as big as China. Consequently the AIDADS system for AS6 predicts decrease in income elasticities for grain and fish and slight increase in livestock and other food. LESb shows increase in all food products, while LESa shows that the income elasticities for all foods are close to 1. For the high income economy USA, the income growth during the period is projected to increase moderately. From the figure, it is clear that there are no dramatic changes in income elasticities for USA by all three systems.

In summary, compared to the AIDADS system, at 2020, the calibrated LES systems (LESa and LESb) tends to generate income elasticities that are similar to the C-D function even though initially the income elasticities are calibrated to those from AIDADS function. Furthermore, the LES systems calibrated at 1985 (LESa) tend to produce more biased elasticities than the LES systems calibrated only at 1995 (LESb), which suggests that calibration using only "older" information may cause more serious problem. The bias of the LES is more significant for the countries with bigger income growth (such as China) than for the countries with less income growth and high income level (such as the US). However, in terms of comparing the behavior of the demand systems, the LESa systems are more relevant since these systems are targeting the 1985 estimated income elasticities from estimated AIDADS, which resembles the common calibration practices of using often "old" estimated results from previous studies.

Demand Side Experiment under the AIDADS System

Figure 3a reports the percentage changes in private consumption at consumers' prices. Clearly, the regional demand pattern matches its profile of income elasticities and its growth in real income and population. Among food products, grain consumption changes little for the wealthy countries, while that for China, MAN and ROW increases a lot. This is evident in income elasticities for both years (see Table 3. Note that income elasticities for MAN and ROW remain relatively high in 2020 due to their relatively lower income levels). Livestock and other food have the highest increase in consumption for almost all regions while horticulture ranks third.

Figure 3a also displays regional population growth. Except for some developing countries such as MAN and ROW, where most of the increase in food consumption goes to keep up with population growth, there is considerable per capita consumption growth in non-grain food products. Figure 3b reports increases in regional private demand at producers' prices. The differences between Figure 3a and Figure 3b are due to the aggregation and margin activities that are modeled as C-D production functions in the model. The rankings of growth across regions and products are preserved at producers' prices.

Figure 3c show that in most regions, livestock production requirement increases the most and grain or fish production requirement increases the least. For the wealthy regions, however, the difference of growth requirement across products is relatively smaller than what is observed for private demand, as the "bandwidth"—differences between growth rates of different products—for these regions are really thin. There are also some ranking reversals in production requirement. For example, in Canada and the US, grain production requirement increases at much higher rate than that for private demand and has the most growth among food productions. Combining Figure 3b and Figure 3c, it is clear that for developing world the magnitude for required growth in food production is smaller than that for private food demand, while for the developed regions, required output growth for food is generally higher than private demand growth. These observation may suggest that either intermediate demand for food products in developed regions grows a lot, or export in these regions grows very fast, or a combination of both. Figure 3d shows the required regional import growth pattern for all food products. This pattern reinforces what is observed in Figure 3c: the disparity of required import growth across products is much smaller, especially for the wealthy regions.

To explore the difference between the required production growth pattern and the private demand growth pattern, a decomposition of domestic production into sales to private demand, export and intermediate demand is needed. Likewise, growth in regional import can also be decomposed into contributions from private import demand, government import demand, and industry import demand. These decompositions will offer more insights into the interactions between different activities and sectors. Table 4 reports the decomposition of total domestic sales for CHN, USA and AS6. For China, the total domestic sales increase 277% for grain, 356% for livestock, and 347% for other food. About 2/3, 1/3 and 1/3 of the increases in the three products are from total intermediate demand. For example, own use of grain contributes to about 48% of the 277% increase and demand by other food contributes about 46%. The strong own use is also evident in livestock, where 50% of the demand from own uses. The same story of intermediate uses applies to USA and AS6. Clearly, the fast growth in private demand for other food and livestock will also push up the production requirement for other food products, which is exactly the reason why the production requirement pattern is "smoother" than the private demand pattern. Similarly the decomposition of total imports by CHN, USA and AS6 can be conducted and are reported in Table 6. Take China as an example, 212% of the increases in grain imports is due to intermediate uses, which includes 34% by livestock, 91% by other food and 49% by textiles. Livestock imports by China are dominated by private consumption with more than 2/3 of the 355% total growth. For other food, private demand and intermediate uses contributes about equal to total import growth (158% vs. 170%).

Although wealthy countries have lesser, more balanced growth in food product imports, due to their dominant shares in world food trade, growth for these countries still dominates the world food market. The dynamic growth for the developing economies has not translated into dominant shares at world level. Table 5 decomposes regional contributions to world food imports. World imports of grain, livestock and other food are required to grow at the rates of 97%, 95% and 97%, respectively. The developing world contributes much more to grain imports (64% vs. 33% for the developed world) but less to livestock, horticulture and fish. Imports for other food are about equally distributed between developing and developed countries.

Comparison between Alternative functional forms

Two more experiments with the same income and population growth are conducted, one for the C-D model and the other for the LES model that is corresponding to the LESa case. Figure 5 and 6 show percentage changes in private demand, imports requirement and output requirement under the three demand specifications (CD, LES and AIDADS) in 2020 for China and USA, respectively.

China is expected to have the highest income growth during this 25-year period. As a result, the experiment with C-D demand function predicts more than 350% increases in private demand in China for all the products, while the experiment with AIDADS predicts less than 200% increase in grain, close to 300% for livestock and much higher growth in non-agricultural goods. The LES system predicts growth around the level of the C-D case, with growth for livestock, horticulture and fish as high as 400%. Overall, compared to AIDADS, LES significantly over-predicts growth in private consumption for food products than AIDADS and under-predicts non-food products, as does the C-D function. For China's imports growth requirement, both LES and C-D function would over-predict imports for all agricultural products. For example, LES over-predicts imports in grain, livestock and horticultural by 122%, 115% and 171%, respectively. Predictions for textiles are almost the same from the three experiments. LES under-predicts growth in resources, manufactures, and services by 33%, 30% and 80% respectively. The differences between the predictions for output growth requirements for China by the three functional forms are similar to that for import growth requirements. Again, output requirements are over-predicted by LES for food products (150% for grain, 120 for livestock, and 160% for horticulture), while it under-predicts output growth in nonfood products.

In contrast to China, the US has the highest income level but is expected to grow at much slower pace during the 25-year period with real GDP rises by 95%. From Figure 4 we can see that for the US the LES function would predict the similar income elasticities as AIDADS. Not surprisingly, C-D predicts the highest growth in private consumption of foods as the percentage changes exceed 80%. The only substantial difference between the predictions by LES and AIDADS is in horticulture (LES under-predicts by around 10%). These results suggest that the LES does provide similar results as long as the income growth is moderate and the income level is very high.

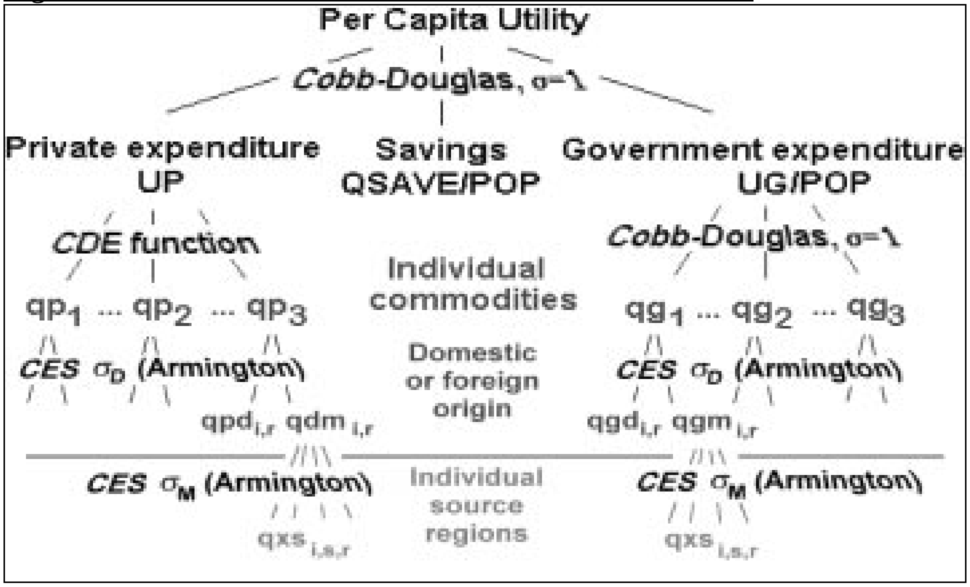
CONCLUSION AND DISCUSSION

The objectives of this paper is to document how to incorporate the econometrically estimated AIDADS demand system into the standard GTAP model and to show where AIDADS makes a difference, compared to other demand systems such as LES and CD, in projecting world food market in a general equilibrium context. This estimation and modeling exercise is useful in capturing the possible structure changes in the world food market due to income growth.

The newly developed AIDADS demand system is estimated using the 1985 ICP data set at the 9-goods level. This estimated demand system is updated to 1995 per capita expenditure at constant prices and then regional specific systems are calibrated through a very complicated calibration process. The demand specification in the standard GTAP model is modified in order to integrate these calibrated AIDADS systems and their econometrically estimated income elasticities into the model. Specifically, the CDE demand system is replaced by the AIDADS. In addition, two Cobb-Douglas production nests are included in the modified model in order to deal with the aggregation transition and margin activities.

In order to compare the performance of alternative demand systems within the GTAP and to show why AIDADS is important in projection the world food market, a demand side experiment with the modified GTAP model is conducted using different demand specification (LES, CD and AIDADS). The simulation results show that for regions with rapid income growth, the LES over-predicts growth in private demand, import and output growth requirement for food products and under-predicts that for non-food products. On the other hand, for very high-income regions with smaller income growth, model with the calibrated LES seems to products similar results as the model with AIDADS. This suggests that the popular LES system may overstate the widely projected "livestock revolution" and understate the production and trade in low value food such as grain. A future exercise will be to compare AIDADS with CDE. Furthermore, simulation with the preferred AIDADS specification shows that flexible Engel effects triggered by income growth would likely cause very disparate private demand pattern across products. However, the imports and output growth requirements growth is much more balanced across products than what is dispayed in private demand pattern. A decomposition analysis shows that intermediate uses play a key role in balancing these patterns.

Figure 1.Household behavior in the standard GTAP model



Source: GTAP short course notes

Figure 2. Modification to the Private Demand Structure

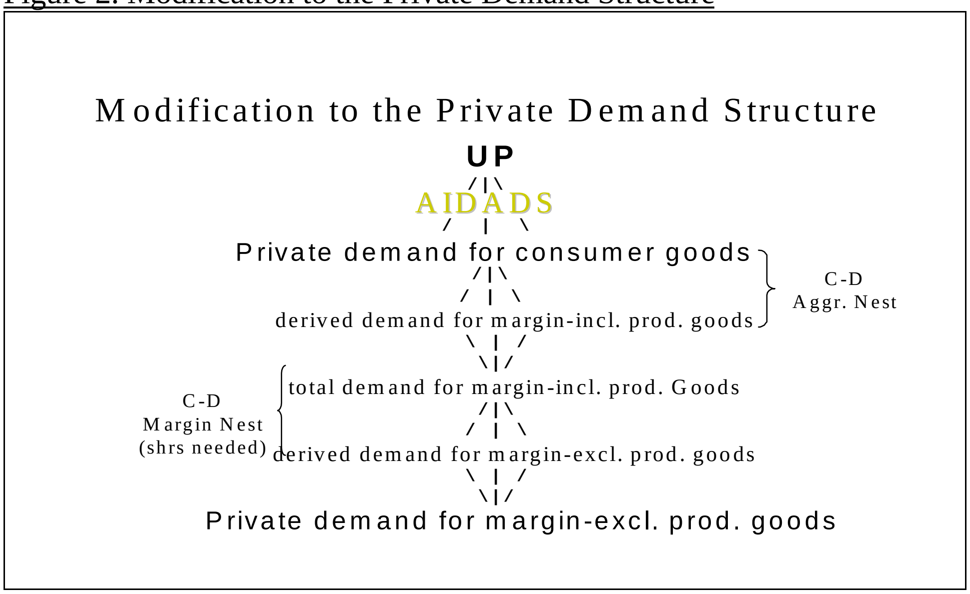


Table 1. Cumulative GDP and Population Growth (%): 1995-2020

	CHN	NIC	AS6	MEX	ROW	MER	EIT	MAN	AUS	USA	CAN	WEU	JPN
GDP	523.3	243.8	210.2	208.8	184.1	165.9	159.7	155.9	124.9	94.8	93.7	87.3	54.0
POP	53.7	19.5	32.6	23.3	68.6	26.9	20.0	92.9	23.6	22.6	22.7	1.8	3.9

Source: Walmsley and McDougall (2000).

Table 2. GTAP Regional aggregation

Aggregated Region	Description	Representing Country in ICP 1985 data set
AUS	Australia and New Zealand	Australia
JPN	Japan	Japan
NIC	Asia NIC (Korea, Taiwan, Hong kong…)	Korea
AS6	6 ASEAN countries	Thailand
CHN	China	Not included in ICP; the estimated system is used*
CAN	Canada	Canada
USA	United States of America	USA
MEX	Mexico	Not included in ICP; the estimated system is used*
MER	MERCOSUR (Argentina, Brazil, Chile…)	Not included in ICP; the estimated system is used*
WEU	West European	West Germany
EIT	Central European Associates and Russia	Poland
MAN	Middle East and North Africa	Turkey
ROW	Rest of World	India

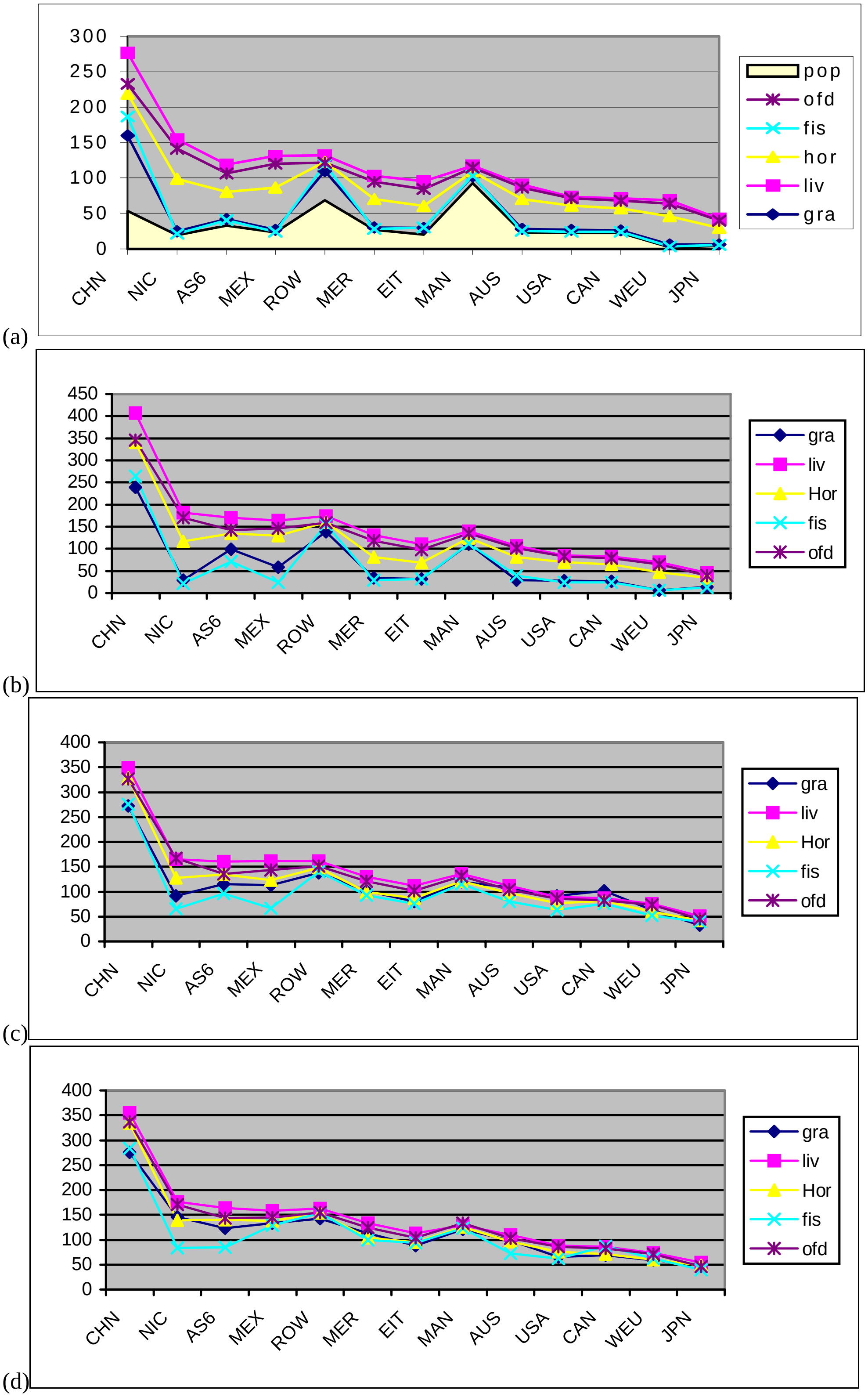
Source: Authors' aggregation based on GTAP 4 and ICP data set.
Note: ICP prices of India, Korea and Hungary are used for CHN, MER and MEX, respectively. These prices and expenditures are used to generate demand and elasticties for these regions via the estimated AIDADS system.

Table 3 Income Elasticities from the Estimated and Calibrated AIDADS systems

		85C	85O	95C	95O	2020			85C	85O	95C	95O	2020
WEU							MAN						
	GRA	0.090	0.090	0.074	0.074	0.064467		GRA	0.406	0.398	0.375	0.368	0.27175
	LIV	0.772	0.776	0.800	0.804	0.87193		LIV	0.806	0.753	0.793	0.743	0.765395
	HOR	0.506	0.507	0.543	0.544	0.666201		HOR	0.589	0.572	0.568	0.553	0.510179
	FIS	0.073	0.073	0.049	0.049	0.015209		FIS	0.422	0.421	0.389	0.388	0.278724
	OFD	0.716	0.720	0.748	0.753	0.835875		OFD	0.724	0.685	0.711	0.676	0.685235
AUS							NIC						
	GRA	0.083	0.083	0.070	0.070	0.081007		GRA	0.315	0.312	0.060	0.060	0.037391
	LIV	0.786	0.788	0.824	0.825	0.891056		LIV	0.730	0.722	0.731	0.729	0.780606
	HOR	0.523	0.523	0.577	0.577	0.701554		HOR	0.518	0.515	0.442	0.442	0.50382
	FIS	0.062	0.062	0.041	0.041	0.024983		FIS	0.336	0.336	0.046	0.046	0.010977
	OFD	0.728	0.732	0.773	0.776	0.856395		OFD	0.659	0.650	0.661	0.659	0.709783
JPN							AS6						
	GRA	0.061	0.061	0.043	0.043	0.09545		GRA	0.530	0.531	0.220	0.220	0.038
	LIV	0.757	0.757	0.798	0.798	0.85937		LIV	0.803	0.804	0.706	0.707	0.843
	HOR	0.474	0.474	0.528	0.528	0.637322		HOR	0.661	0.662	0.465	0.465	0.603
	FIS	0.044	0.044	0.017	0.017	0.061563		FIS	0.560	0.561	0.220	0.220	-0.003
	OFD	0.694	0.694	0.742	0.742	0.816698		OFD	0.704	0.706	0.621	0.621	0.787
CAN							ROW						
	GRA	0.056	0.056	0.057	0.057	0.081975		GRA	0.768	0.758	0.727	0.720	0.594813
	LIV	0.807	0.809	0.837	0.839	0.889559		LIV	1.079	1.067	1.007	0.998	0.870759
	HOR	0.549	0.549	0.598	0.598	0.699406		HOR	0.993	0.986	0.918	0.913	0.752902
	FIS	0.029	0.029	0.023	0.023	0.028969		FIS	0.988	0.987	0.896	0.895	0.686823
	OFD	0.752	0.755	0.789	0.791	0.854035		OFD	0.897	0.880	0.862	0.849	0.772482
USA							EIT						
	GRA	0.060	0.060	0.071	0.071	0.10239		GRA	0.255	0.255	0.219	0.217	0.057839
	LIV	0.839	0.841	0.869	0.871	0.912944		LIV	0.725	0.704	0.716	0.698	0.763146
	HOR	0.600	0.600	0.656	0.656	0.750548		HOR	0.477	0.474	0.457	0.455	0.46948
	FIS	0.026	0.026	0.027	0.027	0.03531		FIS	0.263	0.266	0.226	0.224	0.059551
	OFD	0.792	0.795	0.830	0.832	0.885046		OFD	0.642	0.621	0.632	0.615	0.687883

Note: 85, 95 and 2020 refer to years; C denotes calibrated elasticities while O denotes estimated elasticities.

Figure 3 Percentage changes in Private demand, import requirement and output requirement



Source: Simulation results.

Table 4 Decomposition of percentage changes in domestic food demand into changes in private, government and intermediate demand for selected regions

	Private	Gov't	GRA	LIV	HOR	FIS	OFD	TEX	RES	MAN	OSE	CGDS	tot inter.	Total domestic
							CHN							
GRA	92.658	0.491	47.512	41.761	5.4085	1.5067	46.074	16.724	0.6678	7.0872	16.688	0.0003	183.43	276.6
LIV	243.67	1.3015	0.4095	49.821	0.0032	0.0008	6.2564	29.139	0.0126	8.3542	14.268	2.6625	110.93	355.9
HOR	201.17	0.494	4.7798	26.511	17.587	0.419	55.44	0.5944	2.0929	16.163	8.0613	0.0001	131.65	333.3
FIS	168.42	0.0891	18.575	0.0068	0.0009	15.391	30.885	0.0141	0.0213	1.0536	47.843	0.0005	113.79	282.3
OFD	221.41	22.288	6.4413	21.823	0.7877	1.2903	23.956	0.5364	0.491	7.2154	41.064	0.0002	103.61	347.3
							USA							
GRA	2.3336	1.8052	6.8299	34.036	0.3202	4E-05	27.635	5.5166	0.1103	0.9318	4.2374	6E-05	79.617	83.76
LIV	30.35	2.0993	0.8416	40.424	0.017	3E-06	2.3457	0.587	0.0467	0.1732	11.542	0.0004	55.977	88.43
HOR	44.919	1.1046	0.0007	0.3962	0.9429	0	19.975	0.0004	0.0001	0.0557	8.8131	0.0001	30.184	76.21
FIS	10.005	0.2619	2E-05	0.0243	0	0.156	26.509	0	4E-05	0.0379	25.268	0	51.995	62.26
OFD	53.153	0.8522	0.0011	5.2103	4E-05	0.0131	12.66	0.0146	0.1235	0.6908	12.141	1E-06	30.854	84.86
							AS6							
GRA	37.652	0.1468	39.814	3.242	0.744	0.1408	18.97	0.7439	0.2511	7.4899	4.3436	1.7925	77.532	115.33
LIV	80.03	0.2588	0.3955	50.951	0.4249	0.0189	1.703	1.488	0.1925	1.1545	24.379	1.8715	82.579	162.87
HOR	93.913	0.1239	0.0433	1.1816	4.7121	0.0139	23.977	0.0313	0.2878	0.7081	9.6537	1.5961	42.205	136.24
FIS	46.699	0.0636	0.6421	11.516	0.0002	3.0982	14.166	0.0635	1.5038	0.7925	19.337	0.0003	51.12	97.882
OFD	91.89	0.0825	0.663	10.209	0.0152	0.7692	22.428	0.1482	0.2821	1.3951	15.27	0.1339	51.314	143.29

Source: Simulations results and authors' calculation. All numbers are in percentage.

Table 5 Regional Contributions to Percentage changes in World Food Import

	WEU	AUS	JPN	CAN	USA	MAN	NIC	AS6	ROW	EIT	CHN	MEX	MER	World	developed	developing
GR	21.131	0.552	4.971	0.936	5.135	11.054	9.453	8.066	11.394	3.297	14.738	2.627	3.226	96.581	32.726	63.856
LIV	40.233	0.461	5.865	1.106	4.660	7.676	9.634	5.196	7.452	5.368	3.068	1.933	2.019	94.670	52.324	42.346
HO	35.099	0.507	3.105	2.958	7.535	4.323	4.575	3.606	6.514	4.170	0.509	0.557	1.920	75.376	49.203	26.173
FIS	26.067	0.538	7.557	1.056	4.567	1.609	15.126	3.378	5.471	1.377	1.626	0.104	0.711	69.186	39.784	29.402
OFD	31.347	1.171	5.443	1.916	7.726	7.479	7.544	6.212	11.091	6.358	7.582	0.867	1.960	96.696	47.603	49.094

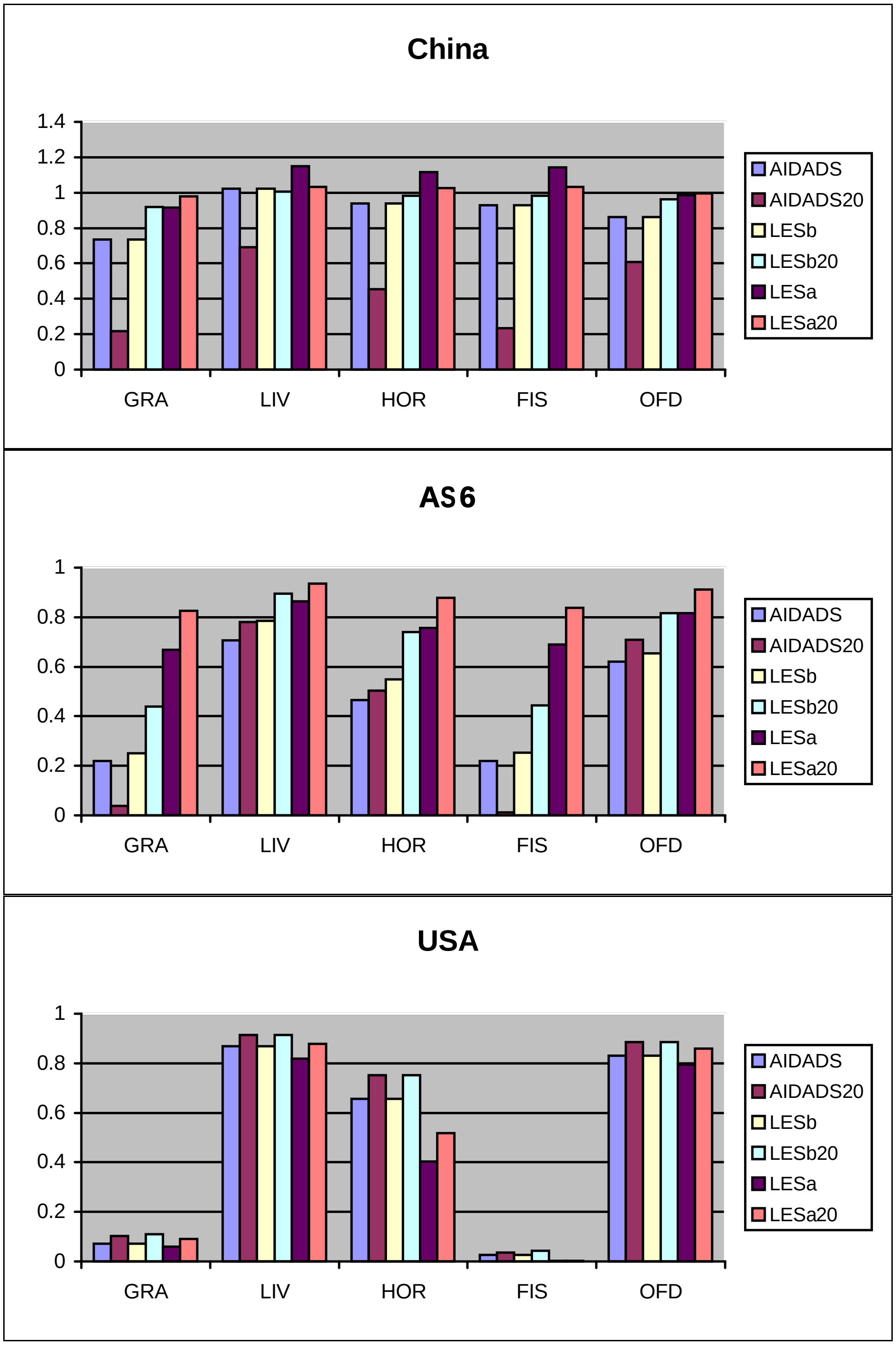
Source: Simulations results and authors' calculation. All numbers are in percentage.

Table 6 Decomposition of percentage changes in food imports into changes in private, government and intermediate demand for imported food for selected regions

	GRA	LIV	HOR	FIS	OFD	TEX	RES	MAN	OSE	CGDS	total intermediate	private shr	gov shr	total
							CHN							
GRA	21.726	33.827	4.350	1.137	90.838	48.820	0.645	3.737	6.484	0.015	211.579	62.459	1.600	275.638
LIV	1.737	36.352	0.040	0.046	6.345	33.390	0.765	7.261	26.584	1.698	114.217	236.275	4.304	354.797
HOR	7.444	37.392	16.391	0.688	58.823	0.429	0.563	6.116	6.487	0.005	134.340	200.202	0.364	334.906
FIS	17.845	1.734	0.236	14.668	30.327	1.453	5.455	4.905	48.013	0.123	124.759	158.199	0.586	283.545
OFD	16.234	32.615	1.243	5.528	45.063	1.466	1.034	6.254	60.918	0.005	170.360	158.700	7.366	336.426
							USA							
GRA	13.202	3.841	1.533	0.000	13.252	0.923	0.151	2.007	18.058	0.003	52.969	10.696	2.039	65.7039
LIV	2.091	33.303	0.110	0.000	4.364	0.852	0.169	0.207	12.816	0.021	53.933	32.268	2.120	88.3202
HOR	0.001	0.256	0.848	0.000	19.273	0.001	0.000	0.057	8.317	0.000	28.755	46.096	1.054	75.9056
FIS	0.000	0.023	0.000	0.156	26.509	0.000	0.000	0.038	25.269	0.000	51.995	10.004	0.266	62.2658
OFD	0.002	1.922	0.000	0.006	20.792	0.017	0.049	0.919	16.335	0.001	40.043	44.038	1.364	85.4447
							AS6							
GRA	5.463	2.768	0.231	0.046	41.378	11.811	0.647	13.305	9.619	5.765	91.032	31.527	0.084	122.643
LIV	0.397	29.929	0.013	0.009	7.894	0.326	0.916	0.461	25.412	1.285	66.642	96.831	0.148	163.621
HOR	0.073	0.159	1.190	0.000	33.111	0.090	0.544	6.985	33.437	2.657	78.247	61.491	0.002	139.74
FIS	0.217	3.223	0.004	2.344	4.676	0.030	0.405	1.624	13.174	0.002	25.699	59.069	0.004	84.7719
OFD	0.838	13.607	0.036	0.411	28.197	0.097	2.147	1.228	16.620	0.209	63.392	80.489	0.007	143.887

Source: Simulations results and authors' calculation. All numbers are in percentage.

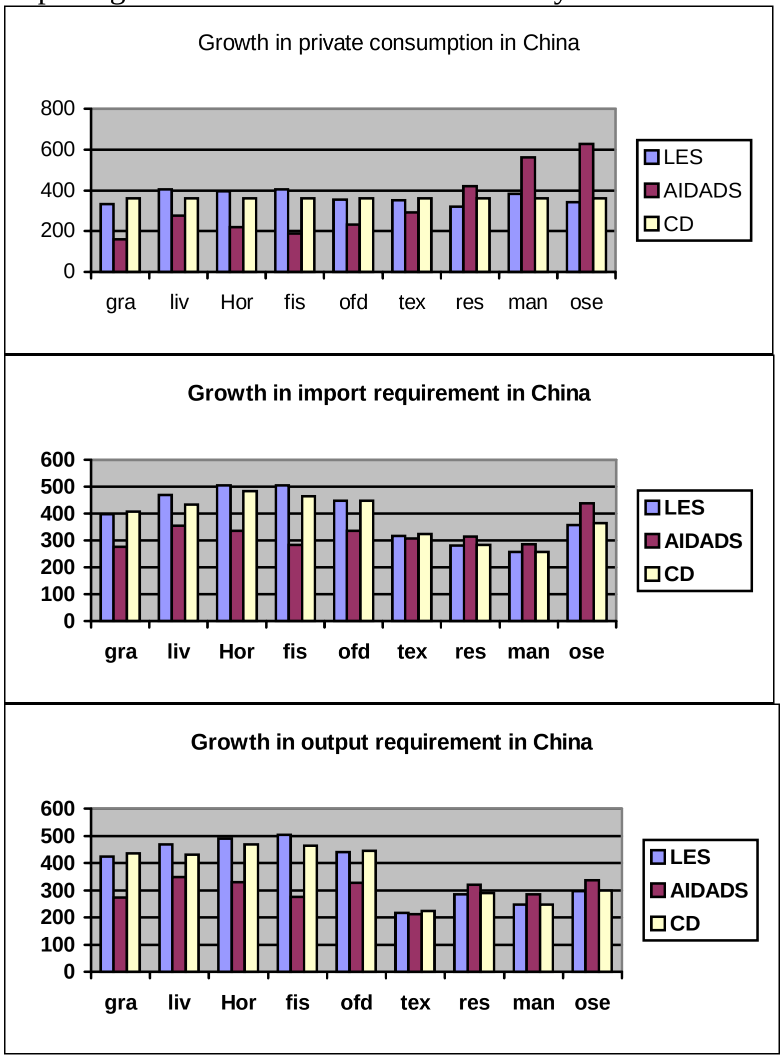
Figure 4. Income elasticities for selected regions under alternative demand specifications



Source: authors' calculation based on estimation and calibration.

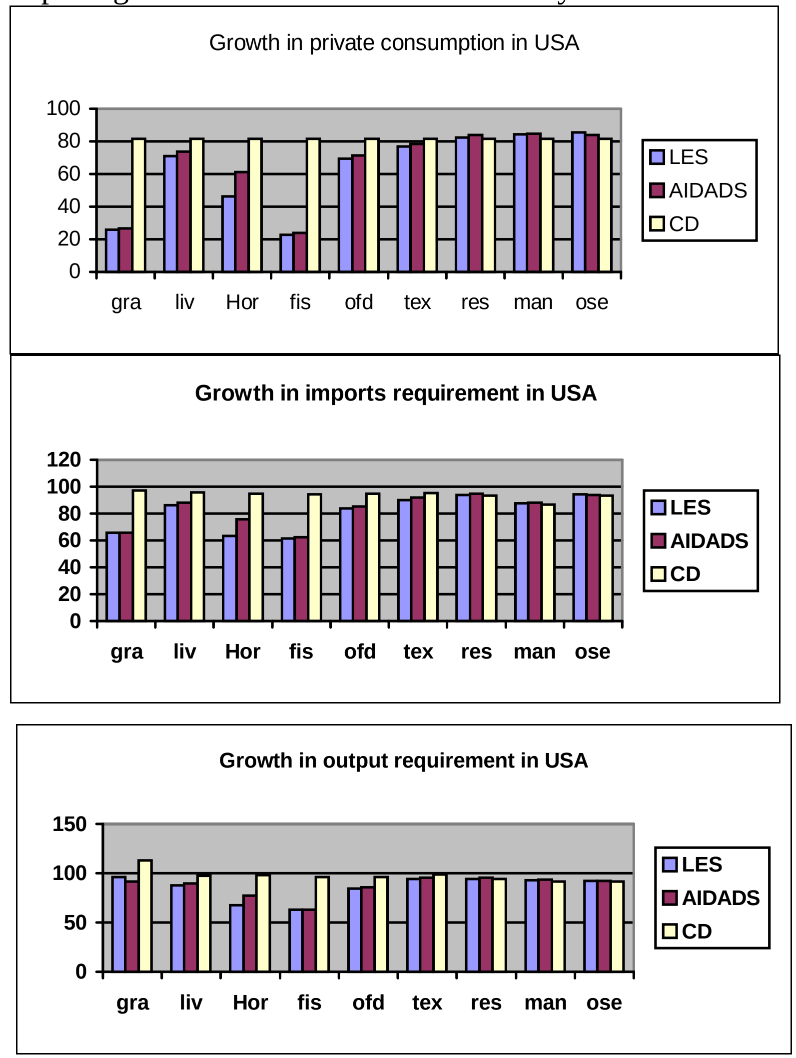
Note: LESb refers to the LES systems calibrated to the AIDADS demand and income elasticities at 1995. LESa refers to the LES systems calibrated first at 1985 AIDADS demand and income elasticities and then at 1995 AIDADS demand. LESb20, AIDADS20 and LESa20 refer to the updated systems using 2020 projected per capita real GDP data.

Figure 5. Regional private consumption, output and imports growth under alternative demand systems for China



Source: Simulation results. All numbers are in percentage.

Figure 6. Regional private consumption, output and imports growth under alternative demand systems for USA



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