Projecting World Food Demand:

A Comparison of Alternative Demand Systems

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Paper prepared for presentation at the Xth EAAE Congress
'Exploring Diversity in the European Agri-Food System',
Zaragoza (Spain), 28-31 August 2002

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January 22, 2002

Abstract

Projections of world food demands hinge critically on the underlying functional form used to predict future demands. Simple functional forms can lead to unrealistic projections by failing to capture changes in income elasticities of demand as consumer becomes wealthier. This paper compares several demand systems in the projection of disaggregated food demand across a wide range of countries with different income levels using a global general equilibrium model.

We find that the recently introduced AIDADS system represents a substantial improvement over existing demand systems currently in use in CGE modeling. In particular, our projection results show that for relatively poor regions experiencing rapid income growth, the widely used LES and CDE demand systems tend to over-predict growth in consumer demand, and hence import and output requirements for food products and under-predict that for non-food products, compared to the AIDADS system. On the other hand, for high-income regions with modest income growth, the choice of functional form is less critical.

Keywords: food demand, agricultural trade, functional form, demand system, CGE modeling

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Abstract

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Projecting World Food Demand under Alternative Demand Systems

1. Introduction

Income growth has led to changing world food consumption patterns over the last two decades. At lower levels of per capita income, consumers have shifted away from grains toward livestock and meat products and at higher income levels consumers have been sought greater product variety and reduced food preparation requirements. As a consequence, there has also been a major shift in the pattern of world food trade. During the period of 1980 to 1995, although aggregate food trade grew modestly with an annual growth rate of 5.3 percent, the relative changes at the disaggregated levels were significant. For example, the share for bulk food trade declined from 50 percent to 32 percent during the same period (Coyle *et al.* 1998).

To what extent can an empirical model track historical behavior and predict future changes? The answer hinges largely on the demand specification and parameter choice within the model. Engel properties and regularity of these demand systems are the two important considerations, with the latter ensuring that the extrapolating of these systems with large income shocks would not lead to negative budget shares. Virtually all the general equilibrium and partial equilibrium models in predicting world food demand use simple functional forms (such as the Linear Expenditure System (LES), the Constant Difference of Elasticities (CDE) Demand System, and the Cobb-Douglas System (CD)). Some partial equilibrium models even use a simple log-log specification in which income elasticities are constant. Examples of such global models include: 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), and the Global Trade Analysis Project (GTAP) model (Hertel 1997). The demand systems in these studies are all limited in their ability to capture changes in consumer demand across the global spectrum. Some are also not globally regular. In contrast, a recently developed demand system, AIDADS (An Implicitly Direct Additive Demand System) by Rimmer and Powell (1996) has proved well suited for this task. Cranfield *et al.* (2001) compared AIDADS with several other functional forms and show that the AIDADS system outperforms all the other functional forms in predicting aggregate food demand across a wide range of developing and developed countries.

The objective of this paper is to build upon the earlier work with AIDADS, showing how it can be effectively incorporated into a global CGE model. CGE models have been increasingly used to project global food demand (e.g. Coyle *et al.* 1998, and Anderson *et al.* 1997) due to the fact that they offer a comprehensive treatment of forward and backward linkages from agriculture, as well as inter-sectoral competition for resources and the tracking of bilateral trade flows for food and non-food commodities alike. In this context, we will compare the performance of AIDADS with the demand systems currently in use in global CGE analysis, focusing specifically on long run projections of the global trade and production consequences of income and population growth.

Section 2 of the paper begins with a general discussion of properties of demand systems and then briefly reviews demand systems in the context of projections over a long period of time when incomes change greatly. The AIDADS system is introduced and contrasted with the LES, CD and the CDE systems. Section 3 develops the methodology for comparing AIDADS with the three alternative systems in the projection of food demand. In Section 4, variations of the predicted income elasticities from the four demand systems as income grows are discussed. This highlights the different behavior of the alternative demand systems and helps to explain the subsequent differences in projection results. The last section offers some conclusions and suggestions.

2. Functional Form Choice and Long Run Projection of Food Demand

2.1 Regularity of demand systems

Demand systems consistent with economic theory should satisfy the usual theoretical restrictions, including: adding-up, symmetry, homogeneity, and negativity. These regularity requirements are related to the properties of the expenditure function. The non-negative requirement, coupled with the adding-up property requires that the budget share of any good should lie in the [0,1] interval. In long run projections with considerable changes in income/expenditure, this requirement is crucial in ensuring the demand system behaves in accordance with economic theory.

The LES, CD, CDE, Almost Ideal Demand System (AIDS), the Translog system, Working's model, and the Rotterdam model are the most popular demand systems in recent applied work. Unfortunately, global regularity requirements are not always satisfied by some of these systems. For example, budget shares of the AIDS system (Deaton and Muellbauer 1980) can fall outside the [0,1] interval. This is particularly likely to occur for staple food demands when income growth is very large. Working's (1943) model allows marginal budget shares to vary with income level, but with large income changes, the average budget shares may also easily stray outside of the [0,1] interval. The Translog demand system by Christensen, Jorgenson, and Lau (1975) meets all the theoretical restrictions except negativity. Once again, fitted budget shares may be negative.

2.2 Engel properties of demand systems

While regularity requirements ensure that a system is consistent with economic theory, the famous Engel's law, as supported by numerous empirical studies, require a demand system to generate declining budget shares for food as income rises. This implies an income elasticity of demand less than one. Econometric studies of income elasticities for countries at different stages of development often show that demand for food in low-income countries is relatively more elastic than that in wealthy countries. This suggests that when economic growth in poor countries raises consumer expenditure, the demand for food will become less elastic. The extent of Engel flexibility required for projection work is even greater when dealing with disaggregated food demand. For example, high-value, ready-to-eat food may be in high demand in rich countries, while staple foods are more essential for low-income people. This is reflected in Bennett's law that states that staple food's share in the total food budget declines as income rises.

Engel property of demand systems can be classified according to the concept of demand system rank. According to Lewbel (1991), only rank three demand systems give sufficiently flexible, non-linear Engel responses while rank one and two systems are more or less restricted in this regard. Most of the systems mentioned above fall into the category of either rank one or two and thus do not possess sufficient flexibility to capture these effects across the development spectrum. Even though some demand systems may be able to produce very sensible estimates around a certain data point, extrapolation of these systems with big income shocks often leads to unrealistic Engel responses at the new income level. The CD function or the log-log specification clearly gives no Engel flexibility as income elasticities are constant. Barten and Theil's Rotterdam demand system (1967) displays constancy in the marginal budget shares, which further implies very little Engel flexibility. As we will show below, the LES and CDE functions also display troublesome Engel properties.

2.3 The AIDADS system

These limitations on regularity and Engel properties led Rimmer and Powell (1996) to develop a new rank three demand system based on an implicitly direct additive preference, nicknamed AIDADS. AIDADS satisfies the regularity conditions over the price-expenditure space where consumers have strictly positive discretionary expenditure. McLaren, Powell and Rimmer (1998) showed that the AIDADS expenditure function is non-negative, continuous, homogenous of degree one in prices, non-decreasing in prices, and concave in prices. And the expenditure function is non-decreasing in utility under certain condition. The Engel elasticities will in general vary non-linearly with respect to income changes. Although as real income grows indefinitely all Engel elasticities will converge to unity, it should be noted that these asymptotes are not approached monotonically. This is a very important point that distinguishes AIDADS from the widely used LES. As we can see from below, as income grows, the income elasticities for necessities such as grains fall over the range of observed incomes.

Cranfield *et al.* (2002) compare the performance of LES and AIDS with three rank three systems (AIDADS, Quadratic AIDS—QUAIDS and the Quadratic Expenditure System—QES) in predicting food demands based on estimation with cross section data spanning a range of countries with very different income levels. They showed that the full rank QES, AIDADS and QUAIDS do indeed out-perform the LES and AIDS using both in-sample and out-sample criteria. A further comparison between the rank three systems suggest that AIDASD would be a more suitable demand system in projecting food demand when the projection covers a long period of time and involves a wide range of countries.

2.4 The Commonly used Demand Systems: CD, LES and CDE

The simplest functional form used in applied models is the Cobb-Douglas function (CD), which is homothetic and exhibits constant average budget shares. This type of preference clearly cannot describe the dynamic phenomena of changing consumption and trade patterns in the world food market and is in contradiction with Engel's law. However, this system is still used in applied models due to the simplicity in its calibration and hence is includes in our comparison to establish a "worst case" benchmark.

The Linear Expenditure System (LES), which is more general than CD but can be viewed as a special case of AIDADS[1], satisfies the theoretical restrictions of adding-up, homogeneity and symmetry. But with this specification, substitutability is severely restricted. The marginal budget shares are constant over all income levels (i.e. the fraction of an extra dollar spent on food is independent of per capita income). It further implies that as income increases without bound, average budget shares will converge to marginal budget shares and consequently, income elasticities converge monotonically to unity. Assuming food is initially a necessity, this implies that income elasticity for food will rise as incomes increase. This behavior of the LES clearly contradicts Engel's Law and wider empirical evidence.

The Constant Difference Elasticity function (CDE) was proposed by Hanoch (1975) and has been widely used in CGE models since the work of Hertel *et al.* (1991). This system has been shown to be robust and regular globally. However, this system also has some clear drawbacks. In particular, it can be shown that, while the marginal budget shares are non-constant in the CDE system, its structure prevents luxury goods from becoming necessities – even as income grows without limit. This means for developing countries, if meat is a luxury at very low-income levels, it will remain a luxury even as their per capita incomes grow several folds. This is clearly an undesirable feature. Another troublesome fact about the CDE is that the adjustment of the marginal budget shares as households become wealthier, while typically in the right direction, is modest, relative to the available econometric evidence.

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[1] AIDADS becomes LES when parameter α_i are equal to β_i, for all i. If all the subsistence parameters γ_i are zero, LES becomes CD. So both CD and LES are special cases of AIDADS.

3. Methodology for Comparing Alternative Demand Systems

While one could choose among demand systems for use in a CGE model based on purely theoretical considerations, most researchers find themselves weighing the benefits of incorporating more complex functional forms into their analysis against the higher costs of implementation. Therefore, it is important to work through a specific application in order to shed additional light upon the benefits and costs associated with these alternative demand systems. This section outlines our methodology for comparing the four systems.

We begin with estimation of the AIDADS system for disaggregated food products. Second, the LES and CDE systems are calibrated to the AIDADS estimates so that all three systems start with the same income elasticities of demand. (Note that this is not possible for the CD functional form for which these elasticities are always unitary.) We then systematically explore how these income elasticities evolve for countries with different income levels as the global economy grows. The third step involves individually building these different demand systems into a global CGE model. For this purpose, we have chosen the GTAP model, which is widely used to make projections of global trade in food and non-food products. Finally, a common long run demand-side growth experiment is carried out on all four "versions" of the CGE model and the results are compared to investigate the empirical significance of the differences in model performance. Throughout this analysis we adopt the econometrically estimated AIDADS model as the benchmark against which the others are compared. This is because it is a rank three demand system and has proven to out-perform competing models in out-of-sample predictions using international cross-section data (Cranfield *et al.* 2002). We are thereby able to establish the benefits of "going the extra mile" and incorporating this more sophisticated demand system in a CGE model.

3.1 Estimation of AIDADS

We adopt the Maximum Likelihood Estimation method developed by Cranfield *et al.* (2000) to estimate the AIDADS system. This is formulated as a constrained optimization program in which the objective function is minimized with respect to the unknown parameters of AIDADS, fitted budget shares, residuals and the utility levels. The latter are needed due to the implicit nature of the ADAIDS function. The constraints that define the residual terms, the demand systems and the utility levels are included in the program. The data used for the estimation is drawn from the International Comparison Project data set for 1985 (UN 1992). This data set is based on national household consumption surveys and is evaluated in 1985 "international dollars". While Cranfield *et al.* (2000) only studied the demand for aggregated food product, our study extends the estimation to disaggregated food products, which include grains (GRA), livestock and meat products (LIV), horticulture and vegetable products (HOR), fish (FIS), and other food (OFD). Also included in our study are textile and wearing apparel (TEX), resource intensive goods (RES), manufacturing (MAN), and services (SEV).

Estimation of AIDADS, using international, cross-section data, is based on the assumption that preferences are common across all countries. This produces a demand system for the world in 1985. Each country's demand structure differs due to its prices and per capita income level. To make computation manageable in the subsequent simulations of the global model, the world is aggregated into 13 regions[2] in this study. One advantage of having an econometrically estimated demand system is that it can be updated from the year of estimation (1985) to the benchmark year for the CGE

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[2]The thirteen aggregated regions are: Australia (AUS), Japan (JPN), Newly Industrialized Regions (NIC), ASEAN (AS6), China (CHN), Canada (CAN), USA, Mexico (MEX), MERCOSUR (MER), Western Europe (WEU), Economies in Transition (EIT), Mid East and North Africa (MAN) and the rest of the world (ROW). The demands for each of the 13 aggregated regions in this study are represented by those of a typical country in the ICP data set.

model (1995). This update is done by shocking per capita expenditure by observed growth in regional per capita incomes over this period (relative prices are assumed to remain unchanged).

Table 1. Regional aggregation, and GDP and population growth rates during 1995-2020

Aggregated Region	Description	GDP	Population	GDP per year	Population per year	Per capita GDP per year
CHN	China	523.3	53.7	7.6	1.7	5.8
NIC	Asia Newly Industrialized	243.8	19.5	5.1	0.7	4.3
AS6	ASEAN countries	210.2	32.6	4.6	1.1	3.5
MEX	Mexico	208.8	23.3	4.6	0.8	3.7
ROW	Rest of World	184.1	68.6	4.3	2.1	2.1
MER	MERCOSUR	165.9	26.9	4	1	3.0
EIT	C. Europe and Russia	159.7	20	3.9	0.7	3.1
MAN	Mid-East and North Africa	155.9	92.9	3.8	2.7	1.1
AUS	Australia and New Zealand	124.9	23.6	3.3	0.9	2.4
USA	United States of America	94.8	22.6	2.7	0.8	1.9
CAN	Canada	93.7	22.7	2.7	0.8	1.8
WEU	West European	87.3	1.8	2.5	0.1	2.5
JPN	Japan	54	3.9	1.7	0.2	1.6

Source: Authors' aggregation based on GTAP 4 database. GDP and population growth data are drawn from Walmsley and McDougall (2000). All numbers in the table are percentage growth rates.

3.2 Calibration of LES and CDE to AIDADS estimates

Instead of estimating the LES and CDE systems, we choose to calibrate them to the estimated AIDADS elasticities. This provides us with a common basis for comparison since the LES and CDE systems start at the same income elasticities in 1985 as ADAIDS. It is also consistent with the way in which CGE models are constructed, since the demand system is typically calibrated to externally estimated elasticities. Note that we calibrate these competing demand systems to the income elasticities in the year of estimation – since this is the norm for CGE analysis. Thus there are really two sources of approximation error. The first is the error associated with having out-of-date elasticities in the benchmark equilibrium, and the second is the error introduced when per capita incomes grow as part of the model simulation – in this case, long run growth projections to the year 2020.

The Linear Expenditure System (LES) is calibrated for each region in the CGE model to ensure that the 1985 AIDADS elasticities can be reproduced. The calibration process is formulated as the following optimization program:

(1) $$\underset{\beta,\gamma}{\text{Min}} \sum_i^n [(\frac{\beta_i}{w_i} - \overline{\eta}_i)/\overline{\eta}_i]^2$$

Subject to:

(2) $$p_i q_i = p_i \gamma_i + \beta_i (M - \sum_i^n p_i \gamma_i) \quad \forall i = 1,..,n-1$$

(3) $$\sum_i^n p_i (q_i - \gamma_i) = -M / \varsigma$$

(4) $$\sum_i^n \beta_i = 1 \quad \text{and } 0 < \gamma_i < q_i$$

where $\overline{\eta}_i$ are the targeted income elasticities from the AIDADS systems, β_i and γ_i are the LES substitution and subsistence parameters, respective. p_i, q_i, w_i, M and ς are the observed prices, quantities, budget shares, expenditures, and the Frisch parameter[3], respectively. The objective is to minimize the sum of the squares of the scaled deviation of the calibrated income elasticities from the targeted ones. The first constraints (eq. 1) are the *(n-1)* independent LES demand equations, which are derived from the utility maximization problem. Due to the adding-up property, one of the demand equations is dropped. The second constraint (eq. 2) is the Frisch equation, where the Frisch parameter is expressed as minus the ratio of total expenditure over supernumerary expenditure and its value is drawn from the AIDADS estimation. This equation is added into the program because the Frisch parameter helps to determine the subsistence budget shares, hence the subsistence parameters of the LES system. The last constraints (eq. 3) are the regularity requirements imposed on parameters β_i and γ_i. The optimization problem posed by (1)-(4) is solved 13 times to generate LES systems for each of the 13 regions in the study. These calibrated systems are then updated to 1995 using real, per capita income growth rates and assuming constant prices – as was done with AIDADS.[4].

The calibration of the CDE functional form involves choosing the parameters so that the pre-specified income and own price elasticities can be replicated. Similar to the calibration of the LES systems, the regional CDE systems are first calibrated to income elasticities predicted by AIDADS in 1985. The routine (eqs. 5-11) to calibrate the CDE, developed by Liu *et al.* (1998), is used here with some modifications. The objective of the program is to maximize the entropy to the two sets of parameters and to penalize the deviations from the targeted elasticities[5]:

(5) $$\max_{\alpha_i,\gamma_i} \; -(T_1 * \mathrm{P}_\gamma + T_2 * \mathrm{P}_\alpha) + \mathrm{E}_\gamma + \mathrm{E}_\alpha$$

Subject to:

(6) $$\mathrm{P}_\gamma = \sum_i^n w_i (\eta_i - \overline{\eta}_i)^2$$

(7) $$\mathrm{P}_\alpha = \sum_i^n w_i (\varepsilon_{ii} - \overline{\varepsilon}_{ii})^2$$

(8) $$\mathrm{E}_\gamma = -\sum_i^n w_i \gamma_i \ln \gamma_i$$

(9) $$\mathrm{E}_\alpha = -\sum_i^n w_i \left(\alpha_i \ln\left(\frac{\alpha_i}{\sum_k^n w_k \alpha_k}\right) + (1-\alpha_i) \ln\left(\frac{1-\alpha_i}{1-\sum_k^n w_k \alpha_k}\right)\right)$$

(10) $$\eta_i = [\sum_k^n w_k \gamma_k \alpha_k + \gamma_i (1-\alpha_i)] / \sum_k^n w_k \gamma_k + (\alpha_i - \sum_k^n w_k \alpha_k)$$

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[3] The Frisch parameter (Frisch 1959) is minus the reciprocal of the marginal utility of income.

[4] In order to fit the GTAP data point at 1995, budget shares for the LES and CDE systems had to be adjusted to fit the same data point as for the AIDADS system in that year. We preserve the 1995 income elasticities predicted by these functional forms in the previous step. This process is formulated as a optimization program, similar to (1)-(4).

[5] Note in this program, both income elasticities and own price elasticities are explicitly targeted, which is different from the calibration of the LES system. In the calibration of the LES, the price elasticities are implicitly targeted by imposing a constraint that defines the Frisch parameter.

$$\varepsilon_{ii} = -(1-w_i)\alpha_i - w_i\gamma_i + w_i(\alpha_i\gamma_i - \sum_{k}^{n} w_k\alpha_k\gamma_k) \quad (11)$$

where P_γ, P_α, E_γ, E_α are, respectively, the penalty related to the expansion parameters, the penalty related to the substitution parameters, the entropy of the expansion parameters, and the entropy of the substitution parameters. α_i and γ_i are CDE parameters. Symbols $w_i, \eta_i, \overline{\eta}_i, \varepsilon_{ii}, \overline{\varepsilon}_{ii}$ are, for good i, budget share, calibrated income elasticity, targeted income elasticity, calibrated uncompensated own price elasticity, uncompensated own price elasticity target, respectively. T_1 and T_2 are arbitrary scale parameters related to the penalty components in the objective function. In order to get a closer fit of the income elasticity targets, the penalty to the deviation from the AIDADS income elasticity targets is assigned a bigger weight than that to the deviation from the price elasticity targets. This program is solved individually for each of the 13 regions in the model. These calibrated CDE systems are updated to 1995 and adjusted to the GTAP data point in a similar procedure to the one used in the LES case.

3.3 Integration of the four systems into a CGE model

With calibrated parameters for these demand systems, the structure of the GTAP model can be modified to reflect each of these functional forms. Aggregate final demand in each region of the GTAP model is governed by a per capita aggregate utility function specified over private demand, government demand and savings. (see Chapter 2 in Hertel 1997). We do not alter this specification – which is Cobb Douglas in form and aims to hold each of these macro-economic aggregates fixed as a share of national income. The four different functional forms are applied at the next level – to represent private household demands for individual products and services. In the standard GTAP model, private demand is specified as a CDE function whose parameters are calibrated to price and income elasticities adopted from the literature. These individual demands (e.g., the demand for staple grains) are further divided into domestic and imported products and services through the so-called "Armington" specification (Armington 1969).

Integration of the AIDADS, LES and CD representations of consumer demand into the GTAP model requires replacement of the CDE with the alternative functional forms. Details of the modification are documented in Yu (2000).[6] These modifications result in four different GTAP models, which fit the same data point at 1995 and have otherwise identical modeling structure.

3.3 The Projections Scenario

The projections scenario used to compare these different functional forms is designed to allow direct comparison of their Engel flexibility (or inflexibility). Thus we project the global economy forward 25 years, to the year 2020. Normally such a projection would involve both price and income effects – which would greatly complicate our comparison – since the implied price elasticities of demand from these four demand systems differ – even in 1995. Therefore, we have chosen to conduct a more limited experiment. In this case, we formulate a purely "demand-side" experiment in which endowments are allowed to adjust freely to match the changes in demand induced by population and real income growth. Therefore, relative prices remain unchanged in this experiment – permitting us to focus our attention on the differences in predicted output and trade "requirements" under the four different functional forms.

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[6] This modification is quite straightforward, with the exception of the fact that the AIDADS demand system has been estimated at consumer prices. Therefore, we must introduce margins activities to bridge the difference between the producer prices, for which GTAP is normally solved, and these margin-inclusive, consumer prices. In order to retain comparability, the CDE, CD and LES demand systems are also implemented at consumer prices.

According to the projected income and population growth data from 1995 to 2020, as reported in Table 1, the regions with the highest population growth in Mid-East and North Africa (MAN) and the Rest of the World (ROW). Since only population and aggregate income are shocked, higher population growth means relatively less per capita real income growth. In the developing world, China, Newly Industrialized Countries (NIC) and ASEAN (AS6) show the highest rates of projected per capita income growth, whereas ROW and MAN show reasonably high aggregate growth, but low per capita income growth due to very high rates of population growth.

4. Does It Matter? Projecting World Food Market under Alternative Systems

4.1 Comparison of the income elasticities

It is useful to begin our analysis by simply comparing the predicted income elasticities of demand across the four models, over time. We begin with an examination of the predicted elasticities from the AIDADS model that we will use as the standard against which to compare the performance of the other functional forms. Table 2 reports AIDADS elasticities in 1985, 1995 and 2020. These estimates are quite consistent with other studies in which AIDADS has been estimated using international cross-section data (Rimmer and Powell, 1996; Cranfield *et al.* 2000, 2002), i.e., elasticities for food products are generally under unity, indicating that food is a necessity, while elasticities for industrial goods (resource-intensive, manufacturing and services) are generally above unity, suggesting these are luxuries.

One interesting thing about this study is the additional disaggregation of food products in the AIDADS system. Here, our results also show significant differences in income elasticities across products and regions. The estimated income elasticity for grains in ASEAN in 1985 is 0.53; then it decreases to 0.22 in 1995, finally dropping to 0.04 in 2020. This shows the Engel flexibility of the AIDADS model. ROW (the rest of the world), which represents the poorest economies in the world, is estimated to also see a decline in income elasticity of demand for grains from 0.76 in 1985 0.47 in 2020. At the other end of the income spectrum, however, we see that in the US, demands for food are relatively stable and income elasticity for grains remains under 0.1 over the entire period. Compared to the demand for grains, the elasticity for meats is relatively more elastic and remains in the 0.7 – 0.8 range for most of the regions (except for CHN and ROW where it is over 1 in 1985 but drops to the same range in 2020). Overall, we can see that, within the low-income regions such as CHN and ROW, income elasticities for all food products drop from 1985 to 2020, indicating that income growth in these countries causes significant changes in the marginal response of consumers to additional income growth. For the wealthy regions, however, the demand for food products remains quite stable.

Recall that the other three demand systems in our study are all calibrated to the same, *estimated* elasticities in 1985. They are then updated to 1995 based on observed per capita income growth over that period, so a comparison of the different starting values in the 1995 benchmark year is a relevant place to begin our analysis. We also compare them at the end of the projections period – in the year 2020 to obtain an initial understanding of the likely differences in output and trade requirements over this period across models. For this purpose, Table 3 reports these differences from the benchmark. (The CD differences are trivial since all of the income elasticities are unitary.)

Compared to the AIDADS system in 2020, the calibrated LES system generates income elasticities that converge to the CD ones (unitary income elasticities) despite the initial calibration to AIDADS. While both of these demand systems involve the use of subsistence quantities – and therefore must converge asymptotically to unitary income elasticities, the LES converges monotonically and much more quickly than AIDADS. The difference between the LES and the AIDADS is most significant for the countries with high income growth (such as China) than for the countries with less income growth and/or high-income level (such as the US). In fact, for China and most of the other developing regions, the 1995 income elasticities for food from LES are much higher than those from AIDADS, and the differences generally become greater in the year 2020. For example, the income elasticity of demand for grains in China drops from 0.74 in 1995 to 0.22 in 2020 according to the AIDADS, whereas the LES system predicts an increase from 0.92 to 0.98 during this period, causing a dramatic overstatement by the year 2020. On the other hand, for the USA and other developed economies, the LES system generally predicts insignificant increases in income elasticities for food products, due to the smaller income growth and high-income levels. This is comparable to the AIDADS system which also predicts little movement in these elasticities. As a result, the LES elasticities are not very much different from AIDADS in 2020 for the rich economies.

The CDE system implies small drops in income elasticities during 1985-2020 for all the food products across all the regions. This could be problematic where income growth is significant, but not so where income is high and/or income growth is low. More seriously, perhaps, is the observation that the CDE precludes the possibility of goods switching from luxury to necessity as income rises. This is particularly problematic for livestock products where income elasticities are typically above one for countries at very low-income levels, thereafter falling below one as these countries reach middle-income status. The fact that the AIDADS elasticities for food decline for low income countries with big income growth implies that there is a significant gap between CDE and AIDADS income elasticities for these countries and this gap becomes bigger in 2020. For example, in China, demands for livestock, horticulture and fish remain elastic (1.03 for livestock, 1.2 for horticulture and 1.3 for fish) in 2020 according to the CDE. Unlike the LES system, the CDE does not always predict higher food income elasticities. In fact, for NIC and MER, for some food products CDE income elasticities are actually lower than the AIDADS ones. For the developed economies, we observe that CDE income elasticities for food products are slightly smaller than the AIDADS ones, due to the fact that AIDADS elasticities are relatively stable in these regions while the CDE ones continue to decrease.

To summarize the differences between the calibrated LES and CDE systems and the AIDADS system, the root mean square percentage error (RMSPE[7]) index is computed (the bottom panel of Table 3) using AIDADS as the base. According to this index, we offer several general observations. First, the deviation from the AIDADS income elasticities under the LES and CDE systems increases from 1995 to 2020 for most regions. Second, the deviation is generally bigger in the developing regions than the developed ones, indicating potentially bigger difference in food demand projections for developing countries. Third, the LES performs more poorly than the CDE for most developing regions, while the CDE does not differentiate itself from the LES for the developed regions where income growth is rather slow.

4.2 Projection results using the AIDADS model

We now turn to the simulation of demand-side effects on production and trade of projected population and income growth over the period: 1995-2020. As noted above, this involves shocking the GTAP model with the projected growth rates for these variables, as reported in Table 1. Simulation results in percentage changes in consumer demand, output and import requirements,

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[7] This measure is defined as $\zeta = \left(\sum_i [(\eta_i - \eta_i^a)/\eta_i^a]^2 \right)^{1/2}$ where ζ is the error measure, η_i are the calibrated income elasticities for the LES and CDE systems, and η_i^a are the income elasticities for the AIDADS system.

relative to their levels in 1995 are presented in Table 4. Remember that these simulations abstract from the supply-side by fixing primary factor prices and freeing up endowments so that commodity prices remain unchanged over the projection period.

Begin with the results for China. Based on the first column in Table 4, per capita consumption of grain and associated products is projected to double over this period. This is a relatively modest change in light of the fact that per capita income is rising more than four-fold. This is reflective of the lower and declining income elasticity of demand for staple grains products (Table 2 – it falls to 0.2 by 2020). As we move down the column for China, we see larger increases for the other food products – particularly for livestock and meat products where per capita consumption is projected to increase by 223 per cent.

Due to the presence of intermediate input requirements and population growth, output typically must increase more than consumption. This is evidenced in the second panel of Table 4 where production of grains increases by 273%. Grains production requirements (bear in mind that we have relaxed any supply-side constraints in these simulations) must increase by more than consumption since some grains are used as an input into grains production (seed), as well as into other products such as livestock – the demand for which is rising more strongly. Since China imports some of the grains used for intermediate and final consumption, and since all supply side constraints are relaxed in this projections exercise, import requirements increase – at a similar rate to that observed for output.[8]

In contrast to food products, China's rate of increase in domestic consumption of manufactures far outstrips her increase in domestic production (509% vs. 284%). This is because China is very significant net exporter of manufactures. But import demand in her most important market (USA) is growing much more slowly – just 88%. A similar phenomenon – although less pronounced -- is observed for textiles and natural resources. In the case of services, the consumption category with the highest income elasticity of demand in 2020 (1.37 in 2020), the rate of consumption increase exceeds that of production since much of the services output is tied to the provision of wholesale/retail and transport margins for the merchandise goods. And demands for the latter are growing more slowly. The combination of all of these factors means that the differences in output expansion across sectors (213% - 349%) are far more muted than the differences in consumption (106% - 574%).

The entries in the column for USA provide a striking contrast to those for China. Consumer demands for grains and fish are virtually flat, with other per capita demands increasing at a rate between 39% (horticultural products) and 61-62% (resources, manufactures and services). However, the USA is an important exporter of grains, and so these products show one of the highest rates of increase in output requirements (92%) – slightly exceeding that for livestock products. In general, the USA has a very dense input-output matrix, and the high level of intermediate input demands tends to spread quite evenly the output increases across sectors.

4.3 Comparing projection results under alternative functional forms

To see the differences in projection results by the four demand systems, percentage differences of the predictions in consumer demand, output and import requirements by the CD, LES and CDE models from the AIDADS predictions for four representative regions (China, Newly industrialized, West Europe and USA) are presented in Table 5. The complete results for all the regions are in the appendix tables.

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[8] There are two reasons why the rates of increase in import requirements and output requirements differ. Firstly, the intensity of use of import and domestic goods differs across industries and intermediate uses. Secondly, where exports play a large role in driving output changes, we expect the two to diverge as well.

It is interesting to start with the CD functional form. Since it assumes homotheticity, this is trivial case, and a good benchmark against which to compare the performance of the other functional forms. If they do not offer a significant improvement over the CD functional form, then they should be called into question. Table 5 shows that the CD model over-predicts consumption in all food products and textile products and under-predicts manufacturing, resources and services for all the four regions. This is especially true for grains whose income elasticities are far below unity for the all these regions. For example, CD over-predicts grain demands in China and NIC by 97 and 173 percent, respectively. Even for West Europe and USA, the CD model over-predicts grain demands by 77 and 55 percent. For livestock products, the difference is less serious as the CD model over-predicts by less than 25 percent. This is because in year 2020, livestock demands in all these regions remain relative elastic and the difference between income elasticities of AIDADS and CD is relatively small.

The LES model produces projections similar to the CD model for developing countries (CHN and NIC), i.e., it over-predicts demand in food products and textiles and under-predicts demand in non-food products. This is due to the tendency of LES elasticities to converge to unity, whereas the AIDADS income elasticity for food goes down during the same period. On the other hand, for developed regions (WEU and USA), the LES model predicts similar results to the AIDADS model for all the products (except horticultural product). In fact, the LES model just slightly under-predicts food demand.

The deviations in predictions of the CDE model from AIDADS are not as clear-cut as for the LES. Although demands of nonfood products in CHN and NIC are under-predicted and demands for nonfood products in WEU and USA are close to those predicted by AIDADS, it is hard to draw a clear line as to where the CDE over-predicts and/or under-predicts demands for food products. In fact, the CDE model over-predicts demand for food in China but under-predicts demand for some food products in NIC. Dramatic income growth, coupled with low base period income in China, causes universal decline in food income elasticities under AIDADS, whereas the CDE model predicts very little adjustment in these elasticities. Therefore, it is not surprising that CDE over-predicts food demands in China. It should be noted that since the CDE system keeps income elasticities for luxury goods over unity (e.g. livestock), it actually produces worse predictions than the CD model. For example, the CD system only over-predicts demand for livestock by 25 percent, whereas the CDE over-predicts demand for the same product by over 100 percent. For the case of low–value food (e.g. grains) in NIC, where AIDADS income elasticities decrease and CDE income elasticities adjust slowly, the CDE model over-predicts, whereas for the case of high-value food (e.g. horticulture and livestock), where AIDADS income elasticities remain relative elastic and CDE income elasticities adjust slowly, the CDE model slightly under-predicts demand.

While the differences in projections of food demand by these systems are significant, especially for developing countries, the differences in output and import requirements are smaller, due to intermediate input and trade linkages. Take China as an example. Using AIDADS projections as the base, output requirements of grains are over-projected by only about 30-40% in China by the CD, LES and CDE systems, in contrast to the 42-97% over-prediction in grains demand by these systems. These differences are even smaller for the projections of import requirements (in the range of 24-35%). For the USA, the biggest difference in the projection of output and import requirements by the CD model comes from fish, around 20% of over-prediction, while the LES and CDE models predicts almost the same results.

Table 6 summarizes the differences in projections of demand, output and import requirements using Root Mean Square Percentage Errors (RMSPE) along both the regional (upper panel) and commodity (lower panel) dimensions, using the AIDADS projections as the base. First we look at this index for demand. From the regional dimension, the CD model performs the worst for all the regions except China (where the CDE model performs the worst). The LES and CDE models do not distinguish each other as each of them produces larger RMSPE for about half of the regions. From the commodity dimension, CD performs the worst for all food products except livestock, for which the CDE model performs the worst (due to the problem in China again). Compared to the LES system, CDE performs better in grains and other food products.

Moving down in Table 6, we can see that the RMPSE measure for production or import requirements is universally smaller than its counterpart for demand. For example, these measures for demand in China are 1.535, 1.644 and 2.548 for the CD, LES and CDE models, respectively, while these for production requirements are 0.825, 0.916 and 1.487 and the numbers for import requirements are even smaller. Similarly, the RMSPE for the commodity dimension also shows smaller deviation from AIDADS in the projection of output and import requirements. Again, the relative performance of the CDE and LES systems are not substantially different in terms of their projections of output and import requirements.

5. Conclusion and Discussions

This paper focuses on the issue of choice of functional form in projecting food demand, output and trade for a wide range of countries in the income spectrum. The objective is to assess the relative value of the newly developed AIDADS system, compared to those demand systems (LES, CDE and CD) currently in use in global CGE models. For this purpose, a method of comparing these systems in projection food market in an applied global CGE model is proposed, which begins with estimation of the AIDADS system for disaggregated food demands; then proceeds to calibration of the CDE and LES systems to AIDADS estimates. These competing demand systems are then built into a common CGE model which permits us to conduct a common projection experiment to 2020.

Simulation with the AIDADS model shows that its flexible Engel effects effectively capture very different consumer demand patterns across disaggregated food products and regions. The evolution of these Engel effects over time are quite severely restricted under the alternative systems, and are subsequently very different from that of the AIDADS systems. These differences can give rise to unrealistic projections of demand, and to a lesser extent of production and trade in 2020. Compared to the AIDADS results, for regions with rapid income growth, the CD, CDE, and LES systems over-predict growth in consumer demand, as well as import and output requirements for food products and under-predicts that for non-food products. This could have serious consequences for studies of future food supply and demand. For example, use of the simpler functional forms in projecting future livestock demand could dramatically overstate the extent of the "livestock revolution" foreseen by some authors (e.g. Dalgado *et al.* 1999). The choice of functional form for such modeling efforts can indeed be an important decision. Therefore, when conducting a projection, one has to give serious consideration to the Engel property of a demand system.

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Table 2. Income elasticities from AIDADS system at year 1985, 1995 and 2020 expenditure levels

	China			Newly Industrialized			ASEAN			Mexico			Rest of world			MERCUSOR			Econ. in Transition		
GRA	0.81	0.74	0.22	0.31	0.06	0.05	0.53	0.22	0.04	0.06	0.06	0.03	0.76	0.72	0.47	0.12	0.09	0.03	0.26	0.22	0.02
LIV	1.46	1.02	0.69	0.72	0.73	0.86	0.80	0.71	0.84	0.73	0.73	0.83	1.07	1.00	0.79	0.70	0.71	0.82	0.70	0.70	0.87
HOR	1.33	0.94	0.46	0.52	0.44	0.63	0.66	0.47	0.60	0.45	0.44	0.57	0.99	0.91	0.64	0.43	0.43	0.57	0.47	0.46	0.64
FIS	1.43	0.93	0.23	0.34	0.05	0.01	0.56	0.22	0.00	0.04	0.05	0.00	0.99	0.90	0.53	0.12	0.08	0.00	0.27	0.22	0.02
OFD	0.96	0.86	0.61	0.65	0.66	0.81	0.71	0.62	0.79	0.66	0.66	0.77	0.88	0.85	0.71	0.63	0.64	0.77	0.62	0.62	0.82
TEX	0.94	0.91	0.84	0.87	0.89	0.95	0.89	0.86	0.94	0.88	0.88	0.93	0.92	0.91	0.87	0.87	0.88	0.94	0.85	0.85	0.95
RES	0.72	0.97	1.17	1.17	1.11	1.05	1.11	1.14	1.05	1.12	1.12	1.06	0.94	0.99	1.14	1.14	1.13	1.06	1.21	1.20	1.05
MAN	1.20	1.25	1.28	1.28	1.17	1.07	1.30	1.24	1.07	1.16	1.16	1.08	1.24	1.26	1.29	1.21	1.19	1.09	1.26	1.25	1.07
SEV	0.86	1.24	1.37	1.34	1.21	1.10	1.35	1.30	1.09	1.20	1.21	1.10	1.19	1.26	1.39	1.26	1.23	1.11	1.34	1.33	1.10
	Mideast & N Africa			Australia&NZealand			USA			Canada			W Europe			Japan					
GRA	0.40	0.37	0.21	0.08	0.07	0.07	0.06	0.07	0.10	0.06	0.06	0.07	0.09	0.07	0.06	0.06	0.04	0.13			
LIV	0.75	0.74	0.76	0.79	0.83	0.87	0.84	0.87	0.91	0.81	0.84	0.88	0.78	0.80	0.86	0.76	0.80	0.88			
HOR	0.57	0.55	0.49	0.52	0.58	0.65	0.60	0.66	0.74	0.55	0.60	0.68	0.51	0.54	0.65	0.47	0.53	0.68			
FIS	0.42	0.39	0.21	0.06	0.04	0.03	0.03	0.03	0.03	0.03	0.02	0.03	0.07	0.05	0.02	0.04	0.02	0.09			
OFD	0.69	0.68	0.69	0.73	0.78	0.82	0.79	0.83	0.88	0.76	0.79	0.84	0.72	0.75	0.83	0.69	0.74	0.84			
TEX	0.87	0.87	0.95	0.92	0.93	0.95	0.94	0.95	0.97	0.93	0.94	0.96	0.91	0.93	0.95	0.90	0.92	0.96			
RES	1.16	1.16	1.20	1.09	1.07	1.05	1.06	1.05	1.03	1.08	1.06	1.04	1.09	1.07	1.04	1.10	1.08	1.04			
MAN	1.27	1.26	1.33	1.12	1.09	1.06	1.08	1.06	1.03	1.10	1.08	1.05	1.13	1.10	1.05	1.14	1.11	1.06			
SEV	1.32	1.32	1.38	1.14	1.10	1.05	1.09	1.07	1.03	1.12	1.09	1.04	1.15	1.12	1.04	1.17	1.13	1.07			

Note: The three columns (from left to right) under each region contain the income elasticities for the years 1985,1995 and 2020, respectively. GRA, LIV, HOR, FIS, HOR, FIS, OFD, TEX, RES, MAN and SEV stand for, respectively, grains, livestock and meat, horticulture and vegetable, fish, other food, textiles, resource intensive goods, manufacturing and services. These abbreviations are used throughout the tables below.
Source: Author’s calculation.

Table 3. Differences between calibrated LES and CDE income elasticities and AIDADS income elasticities in 1995 and 2020

		CHN	NIC	AS6	MEX	ROW	MER	EIT	MAF	AUS	USA	CAN	WEU	JPN
LES95*	GRA	18	44	45	-1	8	5	11	10	2	-1	-1	0	4
	LIV	13	12	16	0	6	2	4	3	-3	-5	-5	-6	1
	HOR	18	26	29	0	9	3	12	10	-10	-25	-16	-24	2
	FIS	22	46	47	0	20	6	33	70	-4	-2	-2	-5	4
	OFD	13	14	20	0	5	2	3	5	-1	-4	-3	-4	1
	TEX	6	5	7	0	3	1	5	-3	-3	-3	-5	-4	1
	RES	-11	-4	-12	0	-2	-1	16	5	-5	-3	-4	-5	0
	MAN	-18	-6	-13	0	-6	-1	-3	-10	-1	-1	-1	0	0
	SEV	-30	-13	-16	0	-14	-1	-11	-10	2	2	3	4	-1
LES20*	GRA	76	68	79	8	28	22	45	27	7	-1	0	6	2
	LIV	34	7	16	1	17	3	11	9	-1	-4	-4	-3	1
	HOR	57	20	38	2	25	8	28	22	-7	-23	-15	-22	1
	FIS	80	74	83	10	37	25	67	79	-2	-3	-3	-1	2
	OFD	39	9	20	1	17	4	12	12	0	-2	-2	-2	0
	TEX	16	2	6	0	8	1	6	0	-2	-2	-3	-2	0
	RES	-20	-1	-7	0	-11	-1	3	-2	-3	-2	-3	-3	0
	MAN	-26	-2	-7	0	-18	-1	-5	-15	-1	0	0	0	0
	SEV	-38	-4	-9	0	-31	-1	-10	-17	1	1	2	2	0
CDE95*	GRA	6	18	23	0	4	2	8	10	-1	-3	-3	-3	0
	LIV	41	-9	2	1	7	-3	3	4	-7	-6	-6	-7	-6
	HOR	36	0	12	1	8	-2	6	8	-8	-8	-8	-8	-7
	FIS	47	21	26	0	10	3	8	11	0	-1	-1	-2	1
	OFD	8	-9	1	1	3	-3	3	5	-7	-6	-7	-8	-7
	TEX	0	-10	-5	0	1	-2	2	-1	-5	-4	-4	-5	-4
	RES	-28	-3	-11	0	-5	0	3	0	-1	-1	-1	-2	0
	MAN	-7	3	-2	0	-2	1	-2	-8	1	0	0	0	1
	SEV	-40	0	-2	0	-10	1	-7	-9	3	2	3	4	2
CDE20*	GRA	53	16	39	0	17	7	22	19	-3	-7	-6	-2	-6
	LIV	61	-29	-9	-17	19	-17	-7	5	-15	-11	-12	-16	-14
	HOR	74	-27	5	-22	23	-17	1	13	-22	-18	-19	-21	-20
	FIS	104	23	45	3	30	10	23	21	1	-2	-2	1	-4
	OFD	27	-31	-11	-19	11	-19	-7	6	-17	-12	-14	-17	-16
	TEX	2	-23	-15	-11	3	-12	-7	-2	-9	-6	-7	-10	-9
	RES	-51	-5	-10	1	-16	-1	4	-1	0	0	-1	-1	0
	MAN	-19	3	2	3	-7	3	4	-7	2	1	1	2	2
	SEV	-58	6	5	5	-22	5	4	-8	4	3	3	4	3
RMPSE*	LES95	0.53	12.37	3.05	0.13	0.31	1	1.57	1.83	1	1.01	0.96	1.06	2.55
	LES20	5.13	106.24	78.18	15.98	0.89	83.2	13.64	3.03	1.21	0.96	0.92	1.22	0.4
	CDE95	0.88	5.53	1.63	0.1	0.19	0.48	0.55	0.44	0.3	0.72	0.78	0.57	0.68
	CDE20	5.47	32.93	42.14	5.68	0.69	32.53	5.38	1.07	0.63	1.02	1.08	0.96	0.95

* This difference is calculated by subtracting AIDADS elasticity from the LES/CDE one. For presentation purpose, these numbers are multiplied by 100.

** Root mean square percentage errors using the AIDADS income elasticities as the base.

Table 4. Percentage changes in private demand, import and output requirements in 2020, relative to the base data, from the AIDADS model

	CHN	NIC	AS6	MEX	ROW	MER	EIT	MAF	AUS	USA	CAN	WEU	JPN
						per capita consumer consumption							
GRA	106	5	9	4	41	3	10	10	4	4	3	4	3
LIV	223	135	86	108	63	76	75	25	67	51	48	67	39
HOR	165	79	48	63	55	43	41	16	47	39	34	44	26
FIS	133	2	8	1	51	2	10	10	2	1	1	2	1
OFD	179	122	74	97	53	68	64	22	63	49	46	62	36
TEX	239	167	112	132	60	96	97	31	76	56	54	77	45
RES	368	211	157	169	73	124	146	42	87	61	61	90	52
MAN	509	222	172	176	96	131	160	49	89	62	62	91	53
SEV	574	239	182	183	103	137	182	51	88	61	61	90	54
						total production							
GRA	273	91	115	113	138	102	80	119	108	92	101	64	33
LIV	349	165	160	161	162	130	111	136	112	89	87	76	50
HOR	328	128	135	123	148	100	87	121	97	77	81	59	42
FIS	276	65	97	66	140	93	76	115	81	63	75	52	40
OFD	327	167	136	144	151	121	102	132	104	86	82	73	45
TEX	213	178	132	160	145	151	123	127	131	95	93	89	63
RES	321	190	160	155	150	153	139	127	117	95	94	89	67
MAN	284	158	135	133	144	146	125	125	108	93	92	86	77
SEV	337	200	162	188	160	151	140	127	115	92	90	86	63
						total import							
GRA	276	146	123	134	143	113	88	120	99	66	69	59	49
LIV	355	177	164	158	163	133	113	128	110	88	86	74	54
HOR	335	139	140	138	154	105	95	125	96	76	71	60	49
FIS	284	84	85	129	153	99	93	123	72	62	87	62	40
OFD	336	170	144	145	154	124	104	133	103	85	82	72	47
TEX	308	200	152	173	157	150	132	135	119	92	90	82	54
RES	314	188	172	149	159	150	136	129	116	95	93	88	73
MAN	286	162	144	135	153	127	130	103	99	88	89	80	70
SEV	438	216	205	170	180	159	143	136	118	94	92	86	63

Source: Simulation results.

Table 5. Percentage changes in private demand, output and import requirements (base= projection from the AIDADS model) for selected regions

		China			Newly Industrialized			W Europe			USA		
		CD	LES	CDE	CD	LES	CDE	CD	LES	CDE	CD	LES	CDE
	GRA	97	84	42	173	84	21	77	2	-1	53	-1	-2
	LIV	25	39	110	22	11	-19	10	-3	-7	5	-2	-4
	HOR	53	66	115	61	29	-13	27	-13	-9	15	-11	-6
Demand	FIS	74	93	178	182	91	27	81	-2	0	57	-1	-1
	OFD	45	44	28	30	13	-20	13	-2	-7	7	-1	-4
	TEX	20	18	2	8	4	-17	4	-2	-5	2	-1	-2
	RES	-13	-22	-45	-7	-3	-4	-3	-2	-1	-2	-1	0
	MAN	-33	-30	-20	-11	-4	3	-4	0	1	-2	0	0
	SEV	-40	-43	-54	-15	-8	5	-3	2	2	-2	1	1
	GRA	44	40	30	72	35	1	19	1	-3	11	2	-1
	LIV	18	27	71	21	10	-14	8	-2	-5	4	-1	-2
	HOR	33	37	56	47	22	-12	19	-7	-6	12	-6	-4
	FIS	50	61	111	99	49	8	24	0	-1	21	0	-1
Output	OFD	28	27	18	22	10	-12	10	-1	-5	6	-1	-3
	TEX	3	1	-7	4	1	-8	3	-1	-3	2	-1	-2
	RES	-7	-9	-13	-3	-2	-1	-1	-1	0	-1	-1	0
	MAN	-9	-9	-10	-3	-2	-1	-1	0	0	-1	0	0
	SEV	-9	-9	-13	-5	-3	1	-1	0	0	0	0	0
	GRA	35	33	24	28	13	-7	20	0	-3	19	0	-2
	LIV	17	25	67	12	5	-11	8	-2	-5	4	-1	-3
	HOR	34	39	59	37	17	-9	18	-7	-6	11	-7	-5
	FIS	47	57	105	79	39	8	16	-1	-3	20	-1	-1
Import	OFD	26	25	21	22	10	-12	10	-1	-5	5	-1	-3
	TEX	4	2	-7	5	2	-11	3	-1	-4	2	-1	-2
	RES	-7	-8	-11	-3	-2	-1	-1	-1	0	-1	0	0
	MAN	-8	-8	-9	-4	-2	0	-1	0	0	-1	0	0
	SEV	-14	-15	-20	-6	-3	2	-1	0	0	0	0	0

Table 6. Difference between projection results by region and commodity (RMSPE measure, base=projection from AIDADS model)

Summary by Region

		CHN	NIC	AS6	MEX	ROW	MER	EIT	MAN	AUS	USA	CAN	WEU	JPN
Demand	CD	1.535	2.624	1.806	2.152	0.347	1.592	1.560	0.389	1.120	0.794	0.799	1.162	0.678
	LES	1.644	1.285	1.175	0.078	0.268	0.188	0.614	0.254	0.065	0.112	0.077	0.140	0.021
	CDE	2.548	0.491	0.532	1.073	1.026	0.154	0.209	0.081	0.136	0.090	0.094	0.143	0.086
Production	CD	0.825	1.354	0.689	0.978	0.232	0.538	0.750	0.268	0.368	0.272	0.255	0.387	0.256
	LES	0.916	0.658	0.436	0.037	0.181	0.083	0.258	0.174	0.070	0.061	0.074	0.076	0.012
	CDE	1.487	0.248	0.181	0.109	0.131	0.085	0.063	0.053	0.084	0.065	0.068	0.105	0.058
Import	CD	0.764	0.951	0.750	0.535	0.193	0.482	0.610	0.217	0.371	0.303	0.229	0.338	0.173
	LES	0.868	0.463	0.491	0.019	0.164	0.060	0.192	0.102	0.024	0.073	0.052	0.078	0.008
	CDE	1.438	0.243	0.231	0.120	0.122	0.080	0.038	0.043	0.102	0.068	0.069	0.112	0.055

Summary by commodity

		GRA	LIV	HOR	FIS	OFD	TEX	RES	MAN	SEV
Demand	CD	3.351	0.592	1.424	3.417	0.847	0.290	0.250	0.472	0.581
	LES	1.431	0.452	0.860	1.628	0.512	0.200	0.247	0.321	0.471
	CDE	0.780	1.149	1.174	1.990	0.459	0.524	0.825	0.569	0.772
Production	CD	0.793	0.375	0.773	1.295	0.572	0.166	0.104	0.116	0.171
	LES	0.397	0.278	0.475	0.835	0.310	0.067	0.092	0.086	0.159
	CDE	0.268	0.690	0.613	1.081	0.270	0.167	0.120	0.090	0.203
Import	CD	1.153	0.432	0.880	1.643	0.600	0.143	0.101	0.129	0.130
	LES	0.587	0.303	0.496	0.896	0.321	0.045	0.095	0.101	0.105
	CDE	0.312	0.732	0.587	1.127	0.251	0.140	0.137	0.105	0.129

Note: The difference is defined as $\left(\sum_i ((x_i - \bar{x}_i)/\bar{x}_i)^2\right)^{1/2}$, where x_i is the projection for country (commodity) i by the alternative system and $\bar{x}_i$ is the one by the AIDADS system