Item #7

Report on the use of an Almost Ideal Demand System

Draft summary of Almost Ideal Demand System method, and summary of several papers on the effects of a sugar tax, prepared for internal use only, 19 February 2016

Report on an almost ideal demand system (AIDS)

1. Purpose

This report provides you with information on AIDS method. It includes the definition, advantages and limitations of the model. The report also provides comments on recent publication on the impact of sugar tax.

2. Definition

1.1 The AIDS model

An almost ideal demand system was introduced by Angus Deaton and John Muellbauer[1] in 1980. This paper has been cited 4503 times (as of 16 February 2016). It has been widely used to study consumer behaviour.

Verbeke and Ward (2001) provided a clear explanation for the AIDS model[2]. The AIDS model estimates the market demand if consumers are rational. Consumers minimise their expenditure/cost to attain a specific utility level at given prices. The original AIDS demand functions in budget share form is

$$w_i = \alpha_i + \sum_j \gamma_{ij} \log p_j + \beta_i \log\{x/P\}$$

Where

w is the budget share of the ith commodity, $w = \frac{p*q}{x}$, p_i is the price and q_i is the quantity of the commodity i

x is the total expenditure

p_j is the price of commodity j

α, β, γ are the parameters and

P is a price index defined by

$$\log P = \alpha_0 + \sum_k \alpha_k \log p_k + \frac{1}{2} \sum_j \sum_k \gamma_{kj} \log p_k \log p_j$$

γ_{ij} represents the change in the commodity i's budget share with respect to a change in the commodity j's price while real expenditure is held constant. The β_{ij} coefficient represents the commodity i's budget share corresponding to a change in real expenditure while prices are held constant.

The restrictions on the parameters are

[1] https://www.aeaweb.org/aer/top20/70.3.312-326.pdf

[2] Verbeke W., & Ward RW. 2001. A fresh meat almost ideal demand system incorporating negative TV press and advertising impact. Agricultural Economics 25, 359-374.

$$\sum_{i=1}^{n} \alpha_i = 1 \quad \sum_{i=1}^{n} \gamma_{ij} = 0 \quad \sum_{i=1}^{n} \beta_i = 0$$

$$\sum_{j} \gamma_{ij} = 0$$

$$\gamma_{ij} = \gamma_{ji}$$

The above restrictions are necessary so that sum of budget share is equal to zero and the demand are homogeneous of degree zero in prices.

2.2 The linear approximate almost ideal demand system (LA/ AIDS)

Using the price index, P, may make the estimate of the AIDS difficult. Thus, many papers have used Stone's price index (P*) rather than P. The Stone's price index is

$$\ln P_t^* = \sum_{k=1}^{n} w_{kt} \ln p_{kt}.$$

The result is a LA/ AIDS model.

The uncompensated own (i= j) and cross- (i≠ j) elasticities are:

$$e_{ij}^{LA/AIDS} = -\delta_{ij} + \left(\frac{1}{w_i}\right)\left(\frac{\partial w_i}{\partial \ln(p_j)}\right)$$

$$= -\delta_{ij} + \left(\frac{\gamma_{ij}}{\overline{w}_i}\right) - \left(\frac{\beta_i}{\overline{w}_i}\right)\overline{w}_j \qquad \forall i, j = 1, \ldots, n.$$

Where δ= 1 when i= j and δ= 0 otherwise.

The LA/ AIDS is easier to estimate. Additionally, it is a good approximation to the true AIDS[3]. Alston, Forster and Green (1994) found that the quality of the approximation is high if either the elasticity expression assumes that budget shares are endogerous on the right hand side of the demand equations or it assumes that they are constant. The estimates are poor when multicollinearity among prices is high.

3. Advantages and limitations of the model

Reasons for the popularity of the AIDS[4]:

- It is as flexible as other locally flexible functional forms but it has the added advantage of being compatible with aggregation over consumers. It is thus can be interpreted in terms of economic models of consumer behaviour when estimated with aggregated or disaggregated (household survey) data.

[3] Alston J., Foster K., & Green R. 1994. Estimating elasticities with the linear approximate almost ideal demand system: some Monte Carlo results. The Review of Economics and Statistics Vol 76, No2, 351-356.

[4] Taljaard P.R., Alemu A.G., Schalkwyk H.D. 2003. A Linearised Almost Demand System (LA/AIDS) Estimation of the Demand for Meat in South Africa. 41st Annual Conference of the Agricultural Economics Association of South Africa, CSIR conference centre, Pretoria, 2 October 2003

- It is derived from a specific cost function and thus corresponds with a well-defined preference structure, which is convenient for welfare analysis.
- Homogeneity and symmetry restrictions depend only on the estimated parameters and are therefore easily tested and/or imposed.
- The Linear Approximate version of the AIDS is relatively easy to estimate and interpret.
- The AIDS gives an arbitrary first-order approximation to any demand system
- It satisfies the axioms of choice
- It aggregates perfectly across consumers without invoking parallel linear Engel curves
- It has a functional form which is consistent with known household-budget data

The AIDS model is useful to for estimating a demand system with many desirable properties. The AIDS satisfies the aggregation restriction, and with simple parametric restrictions, homogeneity and symmetry can be imposed (Moschini, 1998). However, the AIDS model is difficult to estimate because the price index is not linear in terms of parameter estimated (Chern et al, 2003). Thus, most of papers have used the linear approximateOther limitations are mostly because of data limitation.

- Sharma et al (2014) indicated the possibility of endogeneity of expenditure because total expenditure on beverages is the sum of expenditures on individual beverages. They removed the possible endogeneity of total expenditure by predicting total expenditure through a regression wherein the natural log of real price of all non-alcohol beverages, and the natural log of real per capita income, and household characteristics.
- Zhen et al (2014)[5] mentioned endogeneity problems such as prices can be endogenous. Price endogeneity can arise because of supply-demand simultaneity, omitted variables and measurement errors. Supply-demand simultaneity may not a concern because in micro level, household purchasing levels do not have significant impact on the equilibrium price. Omitted variables happen if households with a stronger preference may be better than other at finding lower prices for identical products. Another example is household preferences. They can prefer quantity to quality. Thus, they buy cheap products rather than expensive one. This is analogous to the bias from using unit values as prices in consumer demand models. Another the omitted variable bias is caused by unobserved household heterogeneity. Additionally, the data have a degree of measurement error. The difference between the survey results and sales data. Thus, Zhen et al (2014) proposed to use instrumental variables to account for the omitted variable bias and measurement errors.
- Sharma et al (2014) also took into account the price endogeneity problem of prices. Household preferences can be different (omitted variable bias). For example, households might choose a cheaper brand to get more quantity. Thus, higher unit values may indicate a better quality, reflecting household preferences for quality. This trade-off can potentially cause endogeneity bias in prices (unit value) (Sharma et al, 2014). Sharma et al (2014) followed a similar method in Deaton (1988) and Zhen et al (2014). They used a price index calculated based on brand level prices and quantities instead of the unit values to reduce this bias. The authors found that ignoring endogeneity in prices overestimates elasticity and corresponding changes in body weight. Zhen et al (2014) found a similar result.

[5] Zhen C., A.Finkelstein E., M.Nonnemaker J., A.Karns S., & E.Todd J. 2013. Predicting the effects of sugar-sweetened beverage taxes on food and beverage demand in a large demand system. American Journal of Agricultural Economics. 1-25.

- Another problem is censored data. For example, due to health conditions or health attitudes some people can consume zero sugary drinks. Ignoring censoring and dropping observations with zero purchases could lead to a non-random sample and selection bias. One solution is to use a Heckman-type two step method where in the first stage we model the binary decision to purchase a particular beverage as a function of detailed household characteristics with a probit model. Inverse Mill's ratios are derived from these models and are subsequently used as an additional regressor in the second stage simultaneous equation demand system (Sharma et al, 2014).
- Most of papers have used data from survey. However, the consumption/purchase reported can be underestimated. If we can compare the average per capita in the survey and that in the sales data, it will be useful. One reason can be the head of the household may not remember to include consumption of other household members. This can lead to a bias result.
- Most papers have investigated the beverage consumption at home. However, they have not take into account consumption at bars or restaurants.
- Results can vary considerably, even within one study, depending on model choice and subgroups analysed (Sharma et al, 2014).

4. Papers

4.1 Briggs Adam D M, et al. (2013). "Overall and income specific effect on prevalence of overweight and obesity of 20% sugar sweetened drink tax in UK: econometric and comparative risk assessment modelling study." BMJ **347**.

The paper used 2 sources of data, the Living Costs and Food Survey (prices and purchasing of drinks and foods) and the National Diet and Nutrition Survey (NDNS) (consumption data). The first one was used to estimate the change in drink purchases as a result of a sugar tax. The second one was used to estimate the effect of changes in drink purchased on energy intake. They assumed that the change in drink consumption will be the same as the change in drink purchases. They separated the NDNS sample to thirds of equivalised (adjusted for household size and composition) income. They also broke these estimate down by age.

In order to estimate the effects of sugar tax on drink purchase, they used a Bayesian approach to estimate an almost ideal demand system. They also used a modified approach to allow for the possibility that within 2 week survey observed purchases may different from actual demand as stocks are either built up or run down, by treating quantity demanded as a latent variable. Model estimation was carried out with a Markov Chain Monte Carlo algorithm. The authors calculated unconditional elasticities because they allow expenditure on "a group to change in response to a price change within that group".

Due to limited explanation in the report, it is hard to investigate the method the authors used. However, one of my concerns is that the model does not include the heterogeneity of household behaviour in the model (i.e household characteristics). Additionally, the model may have price endogeneity. Price per unit value are estimated from quantity and expenditure in the Living Costs and Food Survey. It is suggested to use a Fishcher ideal price index instead of the unit values to reduce this bias (Sharma el al, 2014)

The paper produced the cross elasticities for all food categories. However, the authors only reported change in consumption of drinks as result of 20% tax. I believe it makes more sense to compare the change in consumption of all food. However, I have checked and found that the cross price elasticity of SSBs and other food is insignificant.

As seen in table 1, there are differences in our calculation and their results. This is because they also take into account the insignificant coefficients. I let these insignificant values equal to 0.

Table 1 Change in consumption of drinks of people with the lowest income as result of 20% tax. Values are percentage

	Our calculation	The paper results
Dairy &eggs	0.0	
Meat & fish	0.0	
Fats & starches	0.0	
Fruits & nuts	0.0	
Veg	0.0	
SSBs (concentrated)	-15.9	-15.9
SSBs (non-concentrated)	**-15.7**	**-15.2**
Milk	4.3	4.3
Fruit juice	3.5	3.5
Diet soft drinks (concentrated)	**0.0**	**11.8**
Diet soft drinks (non-concentrated)	**4.5**	**5.4**
Tea and coffee	4.1	4.1
Other beverages	2.8	2.8
Beer	0.0	0
Wine	0.0	0
Other alcohol	0.0	0
Water	**0.2**	**1.1**

I haven't checked the impact on consumption for other groups (people with moderate and high income). But I expect that they did a similar method.

4.2 Ni Mhurchu C, E. H., Schilling C, Yang Q, Kaye-Blake W, et al. (2013). "Food Prices and Consumer Demand: Differences across Income Levels and Ethnic Groups." PLoS ONE 8(10): e75934 **8**(10).

This paper used data from the household economic surveys and the food price index. The survey included data on expenditure over the previous 12 month period and the demographic information. And the food prices were from the food price index. They were prices faced by households across New Zealand over time.

The paper did not describe the methodology in details. For example, they did not provide a regression function and how they dealt with endogeneity problems. Based on their description, the model included demographic variables such as household type and size dummies, ethnicity, regional, month dummies and income. In addition, they used a Heckman-type two-stage analysis to deal with censored data (zero expenditure). This is sensible because prior researches have showed that ignoring censoring and dropping observations with zero purchases could lead to a non-random sample and selection bias.

For the income differences in own- PE, I do not understand their methodology. They "ran an inverse-variance weighted ordinary least squares regression of the five quintile own-PEs (dependent variable) by the income quintiles' relative position on a continuous scale (0 for highest income quintile, 0.25 for second quintile,.., and 1.0 for lowest income quintile)". The method in most researches is that the authors split the sample into sub-samples based on

household income quintile. Then they compared the differences across income groups and test whether the differences are significant.

For ethnicity, the model included a household ethnicity dummies based on ethnicity of household head, which I guess it indicates whether a person is Maori or non-Maori. But in the results, they had 3 categories, Maori, non-Maori, non-Maori non Pacific, which is hard to understand.

I found unusual things in the results table. In table 6, text is in bold if the 95% CI excludes the null. But this condition is not strong enough because these results also include confidents with high standard errors. For example in table 6, the cross price elasticity of cake and biscuits and poultry is 0.11 and the standard error is 0.09. It is not significant. And the cross price elasticity of carbonate soft drink is 0.21 with the standard error is 0.03. It is significantly different from zero, but the text is not bold.

It is also hard to interpret the tables when they did not state whether the changes in prices happen in variables in column or row.

In the strengths and limitations part, the author admitted that the absence of food price and quantity in the survey, the small population sample and short measurement period lead to some unreliable PE values.

What I found interesting in this paper is 1% increase in price of carbonated soft drink will lead to 0.21% increase in demand of chocolate, confectionary and snacks.

4.3 Tiffin, R., et al. (2015). "The Effects of A Soft Drink Tax in the UK." Health Economics **24**(5): 583-600.

The paper used data from the 2010 Living Costs and Food Survey and KANTAR WorldPannel. Different from Briggs et al (2013), the authors dealt with the problem of price endogeneity by using an EKS quantity index. I am not familiar with this approach but happy that they took into account price endogeneity problem.

I am not sure their criteria for high, moderate and low consumers. High consumers have more than seven portions of soft drink per week. Moderate consumers have between 3 to 7 portions and the low consumer have less than 3 portions. I wonder whether they should base on the consumption distribution to categorise the groups of consumers.

Compared with the paper of Briggs et al (2013), the drink categories in this paper did not include coffee and tea. According to Briggs et al (2013), an average of tea and coffee consumption is quite large. A person in 20s consumes an average of 131 ml of milk, 719 ml of tea and coffee and only 300 ml sugar sweetened drinks. In addition, milk is included in dairy and eggs (food categories). This miscategorisation can have an impact on the results.

The authors claimed that their data showed that sugar-sweetened soft drinks contribute on average 0.334% of total energy intake (MJ). However, they did not provide any data/evidence supported this argument. This is also not sensible when they used the average reduction in consumption of soft drinks and cola in all 4 scenarios. This weakens their conclusion that a sugar tax will reduce energy intake by 0.02% (A1), 0.008% (A2), 0.014% (B1), 0.005% (B2). The following table illustrates the different scenarios.

Table 2 Policy scenarios

Scenario	Policy
A1	regular and diet soft drinks and juice drinks with sweetener are taxed £0.06/ litre
A2	regular and diet soft drinks and juice drinks with sweetener are taxed £0.02/ litre
A3	regular soft drinks and juice drinks with sweetener are taxed £0.06/ litre
A4	regular soft drinks and juice drinks with sweetener are taxed £0.02/ litre

The authors provided no further information on average price of soft drinks and juice drinks so that we can find the magnitude of the tax.

The paper compared the financial impact on household by looking broadly at description of the income distribution and share and total expenditure on drink of high and low consumers. And they gave a general statement that "the effect of the sugar tax is amplified in the case of a soft drink tax because low income households tend to consume more soft drinks and they spend a larger share of their food expenditure in the taxed drink". Actually, they can test this statement by separating the sample into sub sample and test the impact of tax on different household group.

Again, the paper only concentrated on drink consumption rather than total food consumption. The authors assumed that food and drinks are separable thus they focus on drinks.

I don't think that the authors took into account the heterogeneity of household preference by including household characteristics in the model.

The authors admitted some limitations of the study. First, it is the assumption that the full burden of tax is passed on to the consumer. Additionally, the consumers can purchase large volume or discount products, which weakening the impact of the tax. Producers can also react to the tax by increasing prices in both taxed and untaxed beverages.

I feel that the authors can do more with results. For example, they can study the impact of the tax to the energy intake and weight or prevalence of overweight. Their result implications are not great. They conclude that "the overall impact of a soft drink tax on calorie consumption is likely to be small". The research was funded by the Union of European Soft Drinks Associations. Thus I wonder whether there is any conflict of interest.

5. Conclusion

AIDS is a widely popular model. The AIDS model is useful to for estimating a demand system with many desirable properties. The AIDS satisfies the aggregation restriction, and with simple parametric restrictions, homogeneity and symmetry can be imposed. Additionally the Linear Approximate version of the AIDS is relatively easy to estimate and interpret.

The model has sound root. The limitations are mostly because of data limitation. For example, price endogeneity arises because of supply-demand simultaneity, omitted variables and measurement errors. Additionally, it is possible for expenditure endogeneity based on the way calculated total expenditure. It is because total expenditure on beverages is the sum of expenditures on individual beverages. By using appropriate approaches, we can limit these endogeneity problem.

References:

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