Testing Aggregation Without Separability in Meat Demand:

An Investigation of the Generalized Composite Commodity Theorem

George C. Davis

May 28, 1998

---

*Assistant Professor, Department of Agricultural Economics, Texas A&M University.

Appreciation is extended to Jug Capps and Rudy Nayga for the data and comments on an earlier version of the paper. Richard Shumway is also thanked for providing comments on an earlier draft of this paper. Appreciation is also expressed to David Bessler for allowing me to access his expansive knowledge of seminal articles in economics.

For contact: George C. Davis, 306 Blocker Building, Texas A&M University, College Station, TX 77843-2124. PH:409.845.3788 e-mail:gdavis@tamu.edu.

Testing Aggregation Without Separability in Meat Demand:

An Investigation of the Generalized Composite Commodity Theorem

Abstract

In the estimation of aggregate meat demand systems, weak separability is often a maintained assumption. However, only a few studies have tested and failed to reject this assumption. Recently, Lewbel (1996) developed a generalized composite commodity theorem (GCCT) that is less restrictive than weak separability. In this study, a data set in which the weak separability conditions for aggregation have been rejected is reconsidered to determine if aggregation can be based on the GCCT. Some subtleties of Lewbel's testing procedure that are not discussed by Lewbel are considered, and the fundamental problem of formulating aggregates prior to conducting tests for aggregation is addressed.

Key Words: aggregation, demand, weak separability, generalized composite commodity theorem.

***Note to Discussant*:** The companion paper from which this paper was carved is about twice as long as this paper. The companion paper describes in more detail the theory and testing procedures and presents more of the empirical results in the body of the paper. Because of space restrictions, this meeting version emphasizes the problem statement and final results without going into minor details regarding the theory, testing procedures, and empirical results. However, for your convenience, we have provided a discussant's appendix with the empirical results from which the conclusions were drawn.

Testing Aggregation Without Separability in Meat Demand:
An Investigation of the Generalized Composite Commodity Theorem

Over the past two decades an extensive literature has accumulated in which aggregate meat demand systems have been estimated and analyzed (e.g., Brester and Schroeder; Eales and Unnevehr; Kinnucan et al.). To justify such aggregate analysis, it is commonly maintained that meat commodities are weakly separable from all other goods. However, we are aware of only three published articles that have actually tested for weak separability in meat demand in the United States: Eales and Unnevehr; Moschini, Moro, and Green; Nayga and Capps. The articles by Eales and Unnevehr, and Moschini, Moro, and Green both failed to reject weak separability, whereas Nayga and Capps rejected weak separability. Yet, Eales and Unnevehr did not test the sufficient conditions for weak separability (Moschini, Moro, and Green pp. 61-2) so their results are contestable.

If weak separability is not satisfied and commodities can not be aggregated, this creates a dilemma for two reasons. First, it would imply that many other issues of interest in meat demand, such as health information (Kinnucan et al.) or advertising and promotion effects (Brester and Shroeder) can not be accurately analyzed within aggregate demand systems. Second, disaggregate demand systems have their own difficulties, such as high collection costs and limited degrees of freedom. This dilemma exists because there has been no viable alternative to the weak separability conditions for aggregation.

Recently, Lewbel (1996) has proposed a Generalized Composite Commodity Theorem (GCCT) with conditions for commodity aggregation that are weaker and less restrictive than separability. The importance of the GCCT is that even if commodity aggregation is not justified by separability, it may be justified by the GCCT. In this paper two issues are explored. First, the inability to aggregate based on the rejection of weak separability found in Nayga and Capps is reconsidered to determine if aggregation in their data set can be based on Lewbel's GCCT. Second, a fundamental assumption underlying all forms of aggregation, and the resulting tests for aggregation, is that the intuitive partition identified by the researcher is the only possible partition that may satisfy the aggregation conditions. Consequently, aggregation may be rejected simply because the researcher is unsuccessful in identifying the appropriate partition(s). Therefore, a relevant question becomes: If aggregation based on intuition is rejected, is there another way to identify theoretically consistent aggregates? This issue is also investigated.

In the next section, an overview of Lewbel's testing procedure is given followed by a test of the GCCT for the Nayga and Capp's intuitive partitions. Following Lewbel's suggestion, and Nicol, cluster analysis is used to identify three alternative partitions to see if they partitions satisfy the GCCT. The paper closes with conclusions and caveats.

Testing Overview

Following Lewbel, let p_i be prices of individual commodities i = 1,2,…,n. Dropping the i subscript gives the corresponding vector $\boldsymbol{p}$. Let $\boldsymbol{P}$ be vectors of group price indices P_I, where I indexes groups of commodities. Define $r_i = \ln(p_i)$, $R_I = \ln(P_I)$, $\rho_i = \ln(p_i / P_I) = r_i - R_I$, and let $\boldsymbol{r}$, $\boldsymbol{\rho}$, and $\boldsymbol{R}$ be the vectors with elements r_i, ρ_i, and R_I, respectively. Furthermore, define $g_i(\boldsymbol{r})$ and $G_I(\boldsymbol{R})$ to be the disaggregate and aggregate expenditure share demand functions, respectively.

Lewbel proves that if (i) the expenditure share functions $g_i(\boldsymbol{r})$ for all i are rational, and (ii) the distribution of the vector of relative prices $\boldsymbol{\rho}$ is independent of $\boldsymbol{R}$, then the disaggregate commodities can be consistently aggregated (i.e., $G_I(\boldsymbol{R})$ satisfies all the normal properties). The first assumption is equivalent to utility maximization. The second assumption is the crucial assumption to be tested.

Lewbel's approach to testing assumption two is to test if $\boldsymbol{\rho}$ and $\boldsymbol{R}$ are independent. If the variables are stationary, then a correlation test for independence is appropriate. However, as Lewbel discusses, if the variables are nonstationary, a cointegration test is needed. Therefore, the stationarity of the $\boldsymbol{\rho}$'s and $\boldsymbol{R}$'s must first be tested. Following Lewbel, two stationarity tests are conducted on these variables: the Dickey-Fuller test with a null of nonstationarity and the Kwiatkowski et al. test with a null of stationarity. However, having two tests introduces the possibility of conflicting results.

Let I(0) be the null of a stationary process and I(1) the null of a nonstationary process. There are then three possible tests conclusions: (i) stationarity is rejected if I(0) is rejected but I(1) is not rejected; (ii) stationarity is not rejected if I(0) is not rejected but I(1) is rejected; (iii) the results are indeterminate if both I(1) and I(0) are rejected or not rejected. Because there are three possible tests conclusions and the tests are applied to two variables (ρ_i and R_I), there are nine possible conclusions.

Table 1 summarizes the appropriate test for independence based on the conclusions from the stationarity/nonstationarity tests. Lewbel discusses the first two rows. The third row is a direct result of the algebra of cointegration, which says that two series cannot be cointegrated if one is stationary and the other is nonstationary. No cointegration is interpreted here as in Lewbel as suggesting the series are independent. The fourth row follows from the algebra of cointegration. If the indeterminate series is nonstationary, then the stationary series cannot be cointegrated with the nonstationary series. However, if the indeterminate series is stationary, then the correlation test is appropriate. The fifth row result is due to similar logic to the fourth row: if either ρ_i or R_I is nonstationary and the other is indeterminate, the appropriate test is a cointegration test. Finally, row six shows that if both ρ_i and R_I are indeterminate, then both a correlation test and a cointegration test must be conducted. This result combines the logic rows four and five.

Intuitive Partitions: Data and Results

The data set used in this study is the same data as used by Nayga and Capps in their tests for weak separability. The data consists of weekly retail price and quantity data for a food firm in Houston, Texas from September 1986 to November 1988. There are 115 observations of 21 cuts of meat from six animal types and all prices are reported in cents per pound. The details of the data are given in Nayga and Capps. Prior to the results, there may be some concern about the span versus the frequency of the data. The work of Perron (1991) is often used to claim that there must be at least 30 years of data for unit root testing. However, Pierse and Snell (1995) have shown for a model based on some basic unit, say weeks, that is aggregated up to say a monthly model, then the power of the test for unit roots in the monthly model will be less than the power of the test in the weekly model, unless more observations are added to the monthly model, i.e. the span is increased. Thus the real issues is determining the correct unit of measurement for transactions. For retail cuts of meat, in which prices usually are changed weekly, a weekly data set is more appropriate than a monthly or annual data set.

Table 2 recreates Nayga and Capps' table 3. Table 2 identifies the 21 cuts of meat by animal type and the four intuitive partitions considered by Nayga and Capps. The common letters in each column indicate which meats are hypothesized to be grouped together for each partition. As in Lewbel, the analysis is done using nominal prices and real prices. The R_I is the log of the Tornqvist price index calculated over the commodities in the I^{th} group. To obtain deflated, or real prices, all nominal prices were deflated by a Tornqvist price index over all meats.

Table 3 gives a summary of the results of the test of the GCCT for the nominal data for the four intuitive partitions considered by Capps and Nayga. The results are ominous for consistent aggregation as they indicate the conditions for aggregation based on Lewbel's GCCT are not satisfied. The results for the deflated data were similar. The third partition based on quality comes close for the nominal relative prices, given there are only two relative prices that do not satisfy the conditions. However, the only real conclusion that can be drawn from this analysis and that of Nayga and Capps is that there is no support for estimating aggregate demand systems based on these four intuitive partitions.

Partitions Based on Cluster Analysis: Empirics and Results

The intuitive partitions are just four partitions among an extremely large number of possible partitions. The difficulty of course is that it is impractical to attempt to consider all possible partitions. However, as Lewbel has suggested and Nicol has shown, a pragmatic way to proceed is to use cluster analysis to help identify likely partitions that may satisfy the conditions for the GCCT.

Similar to Nicol, a hierarchical clustering procedure is used in this study based on the covariance matrix of the log of the individual prices. In hierarchical cluster analysis, clusters are organized to allow one cluster to be a proper subset of another cluster. The procedure begins with a single cluster containing all variables and then uses an iterative algorithm to find cluster components that maximize the variance across all variables. Variables in one cluster at one stage of the algorithm can be reassigned to different clusters at higher stages in the algorithm. The algorithm stops when either the number of clusters specified is reached or the variation in the cluster explained by the cluster component is at least 75 percent. The hierarchical cluster procedure in version 6 of the STAT software from the SAS Institute was used in this analysis to identify the clusters.

The cluster partitions are reported in table 4 in the same format as the intuitive partitions were reported in table 2. For comparative purposes, three cluster partitions are considered: A cluster partition with four groups (there are two intuitive partitions in table 2 with four groups), a second cluster partition with six groups, and a third cluster partition with ten groups. In comparing the partitions in table 4 with those in table 2, the only common pattern appears to be that many of the cuts of pork remain in the same partition.

Table 5 gives a summary of the results of the test of the GCCT for the nominal data for the cluster partitions. Unfortunately, the results again indicate that the conditions for aggregation based on Lewbel's GCCT are not satisfied. The results for the deflated data were again similar.

In comparing the results between the intuitive partitions (table 3) and the cluster partitions (table 5), the results are mixed as to which performs better at identifying partitions that are more likely to satisfy the aggregation conditions. The first intuitive partition of four groups had nine nominal violations of the independence assumption compared with seven nominal violations for the cluster partition with four groups. The second intuitive partition of four groups had two nominal violations of the independence assumption compared again with seven nominal violations for the cluster partition with four groups. The intuitive partition of six groups had nine nominal violations of the independence assumption compared with ten nominal violations for the cluster partition with four groups. The intuitive partition of ten groups had ten nominal violations of the independence assumption compared with eight nominal violations for the cluster partition with four groups. On average then there is little difference in the number of violations for the nominal measures between the intuitive partitions and the cluster partitions (i.e., both are about eight). When it is all said and done, the conclusion is sadly the same as that of Nayga and Capp. There is no apparent empirical justification for the aggregation of the meats in this data set and therefore no empirical support for the estimation of an aggregate meat demand system.

Conclusions and Caveats

In this article the rejection of weak separability and therefore consistent aggregation found by Nayga and Capps is reconsidered to determine if aggregation in their data set can be based on Lewbel's weaker Generalized Composite Commodity Theorem (GCCT). Unfortunately, neither intuitive based partitions or cluster analysis based partitions are consistent with the GCCT. Thus, there is no apparent empirical justification for the aggregation of the meats for this data set based on weak separability (Nayga and Capps) or the GCCT. Consequently, there is no apparent justification for the estimation of an aggregate meat demand system for this data set.

Though the results from this study are discouraging they do not necessarily carry over to other data sets. Presently, only Lewbel and Nicol have used the presented approach with other data sets. Lewbel found the conditions for the GCCT were easily satisfied and Nicol found that cluster analysis worked well in identifying theoretically consistent aggregates. The only obvious difference between this study and the studies by Lewbel and Nicol is that Lewbel and Nicol were analyzing commodities that were already highly aggregated over space, time, and form.

So even with Lewbel's recent contribution to the aggregation literature, the early insights by Griliches are still correct (p. 737): "[T]here are different 'truths' at different levels of aggregation.…I think when we come to know more, we shall find that good monthly and annual models do not really look alike, and there is rhyme and reason for this difference." The differences have been observed, but the rhymes and reasons are still elusive and require more work.

REFERENCES

Brester, G.W. and Schroeder, T.C. (1995). The Impacts of Brand and Generic Advertising on Meat Demand. American Journal of Agricultural Economics 77(November):969-979.

Dickey, D. and Fuller, W. (1979). Distribution of the Estimators for Autoregressive Time Series with a Unit Root. Journal of the American Statistical Association 74:427-431.

Eales, J. S. and Unnevehr, L. J. (1988). Demand for beef and chicken products: separability and structural change. American Journal of Agricultural Economics 70(August):521-532.

Griliches, A. (1972). The effects of aggregation over time: Discussion. In R. Engle and T. Liu, Econometric Models of Cyclical Behavior. Vol. II. B. Hickman (ed.). National Bureau of Economic Research. New York: Columbia University Press.

Kinnucan, H.W., Xiao, H., Hsia, C. and Jackson, J. (1997). Effects of health information and generic advertising on U.S. meat demand. American Journal of Agricultural Economics 79(1):13-23.

Kwiatkowski, D., Phillips, P.C.B., Schmidt, P. and Shin, Y. (1992). Testing the null hypothesis of stationary against the alternative of a unit root. Journal of Econometrics 54:159-178.

Lewbel, A. (1996). Aggregation without separability: A generalized composite commodity theorem. American Economic Review 86(3):524-543.

Moschini, G., Moro, D. and Green, R. (1994). Maintaining and testing separability in demand systems. American Journal of Agricultural Economics 76(February):61-73.

Nayga, R.M., Jr. and Capps, O., Jr. (1994) Tests of weak separability in disaggregated meat products. American Journal of Agricultural Economics 76(November):800-808.

Nicol, C.J. (1991). The effects of expenditure aggregation on hypothesis tests in consumer demand systems. International Economic Review 32(2):405-416.

Perron, P. (1991). Test consistency with varying sample frequency. Econometric Theory. 7:341-368.

Pierse, R. G. and Snell, A. J. (1995). Temporal aggregation and the power of tests for unit root. Journal of Econometrics 65:333-345.

Table 1. Appropriate Test for Independence

Stationary / Nonstationary Results	Test
ρ_i and R_I are both stationary	Correlation
ρ_i and R_I are both nonstationary	Cointegration
ρ_i or R_I is stationary and the other is nonstationary	None
ρ_i or R_I is stationary and the other is indeterminate	Correlation
ρ_i or R_I is nonstationary and the other is indeterminate	Cointegration
ρ_i and R_I are both indeterminate	Correlation & Cointegration

Table 2. Intuitive Partitions from Nayga and Capps

COMMODITY PRODUCTS	NUMBER	CUT	PARTITION			
			1	2	3	4
Beef	1	brisket	A	A	B	B
	2	loin	A	A	A	A
	3	rib	A	A	A	A
	4	all other beef	A	A	B	B
	5	round	A	A	B	B
	6	ground	A	A	B	B
	7	chuck	A	A	B	B
Pork	1	chops	B	B	A	C
	2	ham	B	B	A	C
	3	spare ribs	B	B	A	C
	4	roast	B	B	A	C
	5	loin	B	B	A	C
	6	other pork	B	B	B	D
Chicken	1	breast	C	C	A	E
	2	parts	C	C	B	F
	3	other	C	C	B	F
Turkey	1	breast	D	C	A	G
	2	parts	D	C	B	H
	3	other	D	C	B	H
Lamb			E	D	C	I
Veal			F	D	D	J
Number of Commodity Groups			6	4	4	10

Note: In each partition, all commodities with the same letter belong to the same group. Commodities with different letters are in different groups.

Table 3. Summary of Intuitive Nominal Partition Results

		Number of Components	Violations of GCCT
Partition 1	Animal Origin I		
	Beef (A)	7	4
	Pork (B)	6	3
	Chicken (C)	3	1
	Turkey (D)	3	1
	Lamb (E)	1	NA
	Veal (F)	1	NA
Partition 2	Animal Origin II		
	Beef (A)	7	4
	Pork (B)	6	3
	Chicken-Turkey (C)	6	2
	Lamb-Veal (D)	2	0
Partition 3	Quality		
	High Quality (A)	9	1
	Low Quality (B)	10	1
	Lamb (C)	1	NA
	Veal (D)	1	NA
Partition 4	Quality / Animal Origin		
	High-Quality Beef (A)	2	2
	Low-Quality Beef (B)	5	3
	High-Quality Pork (C)	5	3
	Low-Quality Pork (D)	1	NA
	High Quality Chicken (E)	1	NA
	Low Quality Chicken (F)	2	1
	High Quality Turkey (G)	1	NA
	Low Quality Turkey (H)	2	1
	Lamb (I)	1	NA
	Veal (J)	1	NA

Table 4. Cluster Partitions

COMMODITY PRODUCTS	NUMBER	CUT	PARTITION 1	PARTITION 2	PARTITION 3
Beef	1	brisket	A	E	E
	2	loin	D	F	F
	3	rib	A	E	H
	4	all other beef	B	B	B
	5	round	D	F	F
	6	ground	A	E	H
	7	chuck	B	B	B
Pork	1	chops	D	D	D
	2	ham	C	C	G
	3	spare ribs	D	D	D
	4	roast	D	D	D
	5	loin	D	D	D
	6	other pork	D	D	D
Chicken	1	breast	D	D	I
	2	parts	C	C	C
	3	other	A	A	A
Turkey	1	breast	C	C	G
	2	parts	A	E	H
	3	other	C	C	J
Lamb			C	C	G
Veal			D	D	D
Number of Commodity Groups			4	6	10

Note: In each partition, all commodities with the same letter belong to the same group. Commodities with different letters are in different groups.

Table 5. Summary of Cluster Analysis Nominal Partition Results

		Number of Components	Violations of GCCT
Partition 1	Four Groups		
	A	5	2
	B	2	1
	C	5	1
	D	9	3
Partition 2	Six Groups		
	A	1	NA
	B	2	1
	C	5	1
	D	7	5
	E	4	3
	F	2	0
Partition 3	Ten Groups		
	A	1	NA
	B	2	1
	C	1	NA
	D	6	4
	E	1	NA
	F	2	0
	G	3	0
	H	3	3
	I	1	NA
	J	1	NA