Identifying and Understanding the Structural Break in Meat Demand in the U.S.

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Introduction

- Policy makers, consumers, and producers need to know the response of the market to particular events which might change the market structure.
- For demand systems, structural break is a change in the parameters of the representative consumer's unobservable utility function.
- Structural break may lead to permanent changes in consumer preferences.
- In empirical demand analysis, identification and understanding of structural breaks are serious challenges.
    - Identification is crucial since assuming a stable utility function in the presence of a structural break might lead to false inference and misguided policy recommendations.
    - Understanding means that the researcher should also examine the possible sources of structural break such as commodity prices or expenditures.

Introduction

- Several studies indicate that the structure of meat preferences shifted in the late 1970s.
  - A decline in the demand for beef and pork
  - An increase in poultry and seafood
- Some factors that contributed to a change in consumer preferences and spending habits in the U.S. meat demand; and thus, a change in the meat demand structure.
  - Medical evidence linking red meat consumption to high blood cholesterol levels (Dahlgran, 1988)
  - Seafood is found to be particularly healthy due to its Omega-3 fatty acids.
  - New popularity of chicken in restaurants (Thurman, 1987)
  - Social and economic changes (Rickertsen, 1996)

Purpose

- Examining whether the change in consumer preferences and spending habits for different type of meats have caused structural break in the U.S. meat demand.
- Identifying the structural break and understanding its source can help producers to reduce risks by taking positions in advance and prevent misguided policy recommendations.
- The change in meat demand structure is investigated by allowing one structural break.
  - Data segments determined by Chow test.
  - Linear Approximation of Almost Ideal Demand System (LA/AIDS) model in the first–differenced form
  - Source of the structural break is revealed using dummy variable approach.
  - Change in consumer preferences and spending habits are unveiled comparing Marshallian, Hicksian, and Morishima elasticities before and after structural break.

Literature Review

- Although, there is a general agreement that structural break in the U.S meat demand did occur in the late 1970s in previous literature, there are also some studies which provide contradictory evidence.
- Table 1 summarizes all of these studies and their associated results.

Table 1. A Summary of Previous Studies on Structural Break in Meat Demand

Research	*Data*	*Meat Types*	*Result*
Haidacher et al. (1983)	1950-1977	Beef, veal, pork and chicken	No Structural Break for any of the meats
Nyankori and Miller (1982)	1965-1979	Beef and chicken	Structural Break
		Turkey and pork	No Structural Break
Chavas (1983)	1950-1979	Poultry and Beef	Structural Break
		Pork	No Structural Break
Braschler (1983)	1950-1982	Beef and Pork	Structural Break
Moschini and Meilke (1989)	1966-1981	Beef	No Structural Break
Wohlgenant (1985)	1947-1983	Beef	No Structural Break

*Source: Dahlgran (1988).

Data Descriptions

- A yearly dataset
  - Collected and distributed by United States Department of Agriculture (USDA).
  - Covers from 1970 to 2010.
  - Consisted of per capita retail quantity in pounds, consumer price index, and per capita expenditure in dollars for beef, veal, pork, poultry, and fish.
  - With a base year of 1982-1984.
- Beef and veal categories are aggregated into a single “beef and veal” category, called “beef”, to identify the aggregated red meat other than pork.
- Consumption patterns for meat products have changed considerably over the periods 1970-2010 in the U.S.
  - Decline in per capita consumption of beef and pork, 32% and 15% respectively
  - Increase in per capita consumption of poultry and fish, 106% and 35% respectively
  - Decrease in budget shares for beef and pork, 22% for both
  - Rise in budget shares for poultry and fish, 74% and 130% respectively

See the Figures

LA/AIDS Model in the First–Differenced Form

- The LA/AIDS model in first–differenced form is employed as the main model.

$$\Delta w_{it} = \theta_i + \beta_i \left[\Delta \log x_i - \sum_j w_{jt} \Delta \log p_{jt} \right] + \sum_k \gamma_{ik} \Delta \log p_{kt} + \varepsilon_{it} \qquad (1)$$

where i and k indexes the meats; $t = 1, \ldots, T$ indexes time; p_i denotes the consumer price index for i^{th} meat; x denotes the total expenditure on all type of meats; w_i represents the budget share of i^{th} meat; ε is the error term; and θ, β, and γ are the parameters.

- To be consistent with the fundamental assumptions of the demand theory, the following restrictions must hold.

$$\sum_i \theta_i = 1, \quad \sum_i \beta_i = 0, \quad \sum_i \gamma_{ik} = 0 \qquad \text{(Adding–up Restrictions)}$$

$$\sum_j \gamma_{ik} = 0 \qquad \text{(Homogeneity Restriction)}$$

$$\gamma_{ik} = \gamma_{ki} \qquad \text{(Symmetry Restriction)}$$

LA/AIDS Model in the First–Differenced Form

- Marshallian price elasticity, income elasticity, and Morishima elasticity of meats are

$$\eta_i = \frac{\beta_i}{w_i} + 1 \qquad \text{(Income Elasticity of the } i_{th} \text{ meat)}$$

$$\epsilon_{ik} = \frac{\gamma_{ik} - \beta_i w_k}{w_i} \qquad \text{(Cross Price Elasticity between the } i_{th} \text{ and } k_{th} \text{ meat)}$$

$$\epsilon_{ii} = \frac{\gamma_{ii}}{w_i} - \beta_i - 1 \qquad \text{(Own Price Elasticity of the } i_{th} \text{ meat)}$$

$$\sigma_{ik} = \epsilon^*_{ki} - \epsilon^*_{ii} \qquad \text{(Morishima Elasticity between the } i_{th} \text{ and } k_{th} \text{ meat)}$$

where ϵ^* denotes the Hicksian price elasticities and w_i indicates the mean budget share of the i_{th} meat.

Procedure in Structural Break Testing

- Before performing Chow test in the first–differenced LA/AIDS model as presented in Eq. 1, homogeneity and symmetry restrictions are tested.
- If these restrictions hold, then the Chow test is performed by jointly imposing homogeneity and symmetry restrictions.
- Although the Chow test detects the presence and location of the structural break, it does not provide any information about the source.
  - Dummy variable approach is employed.
  - "Pure structural break" in which the entire parmeter vector is subject to change (i.e., intercept, expenditure, and consumer price index parameters)
  - "Partial structural break" in which only a component of the parmeter vector is subject to change.
  - In each case homogeneity and symmetry restrictions should hold.

Structural Break Results - Chow Test

- In first–differenced LA/AIDS model as presented in Eq. 1, homogeneity and symmetry restrictions hold jointly.
  - LR test statistic is 4.6 and the associated p-value is 0.059.
  - The null hypothesis which jointly holds homogeneity and symmetry restrictions cannot be rejected at the 5% significance level.
- The Chow test is performed by jointly imposing homogeneity and symmetry restrictions.
  - In the 41 data points, the null hypothesis of no structural break is rejected in 5% significance level only for the year 1976 (the associated p-value is 0.0465).
  - The year 1976 is chosen as the structural break date.
  - Data are separated into two periods.
  - Before and after the structural break period, which are 1970-1975 (period 1) and 1976-2010 (period 2) respectively

Structural Break Results - Dummy Variable Approach

- The combination of dummy parameters for intercept and expenditure terms is the only specification which holds homogeneity and symmetry restrictions jointly.
- The Eq. 2 presents the modified first–differenced LA/AIDS model for the case of partial structural break.

$$\Delta w_{it} = \theta_i + \delta_i \Delta D_t + \beta_i \left[\Delta \log x_i - \sum_j w_{jt} \Delta \log p_{jt} \right] + \psi_i \Delta \left[D_t \left(\log x_i - \sum_j w_{jt} \Delta \log p_{jt} \right) \right] + \sum_k \gamma_{ik} \Delta \log p_{kt} + \varepsilon_{it} \quad (2)$$

where D is the dummy variable which is 0 for 1970-1975 and 1 for 1976-2010, and δ and ψ are the structural break parameters for the intercept and expenditure respectively.

- Modified restrictions are

$$\sum_i \theta_i = 1, \quad \sum_i \beta_i = 0, \quad \sum_i \gamma_{ik} = 0, \quad \sum_i \delta_i = 0, \quad \sum_i \psi_i = 1 \qquad \text{(Adding–up Restrictions)}$$

$$\sum_j \gamma_{ik} = 0 \qquad \text{(Homogeneity Restriction)}$$

$$\gamma_{ik} = \gamma_{ki} \qquad \text{(Symmetry Restriction)}$$

Structural Break Results - Source

- To gain some insight into the nature of structural break, the dummy parameters for intercept and expenditure terms are tested jointly and separately while the homogeneity and symmetry conditions are imposed.
  - The main source of the structural break is the meat expenditures.
  - Consumer behavior in the meat market has changed not through the meat prices but through the meat expenditures.
- Although, the intercept term is found to exhibit no structural break (i.e., dummy parameters for intercept are zero), it does not alter any of the elasticity calculations.
- The modified versions of elasticities related to Eq. 2 after structural break period are

$$\eta_i^a = \frac{\beta_i + \psi_i}{w_i^a} + 1 \qquad \text{(Income Elasticity of the } i_{th} \text{ meat)}$$

$$\epsilon_{ik}^a = \frac{\gamma_{ik} - (\beta_i + \psi_i)\, w_k^a}{w_i^a} \qquad \text{(Cross Price Elasticity between the } i_{th} \text{ and } k_{th} \text{ meat)}$$

$$\epsilon_{ii}^a = \frac{\gamma_{ii}}{w_i^a} - (\beta_i + \psi_i) - 1 \qquad \text{(Own Price Elasticity of the } i_{th} \text{ meat)}$$

$$\sigma_{ik}^a = \epsilon_{ki}^{*a} - \epsilon_{ii}^{*a} \qquad \text{(Morishima Elasticity between the } i_{th} \text{ and } k_{th} \text{ meat)}$$

where ϵ^* denotes the Hicksian price elasticities; w_i^a indicates the mean budget share of the i_{th} meat after the structural break; and superscript a denotes the after structural break.

Estimated Marshallian Elasticities

Table 3. Estimated Marshallian Elasticities at the Sample Mean

	Beef	*Pork*	*Poultry*	*Fish*	*Expenditure*
			Before Structural Break		
Beef	-1.10485***	-0.07306*	-0.1118***	-0.10849***	1.3982***
	(<.0001)	(0.0831)	(0.0002)	(0.0003)	(<.0001)
Pork	0.040366	-0.95637***	-0.08633*	-0.03821	1.040541***
	(0.8205)	(<.0001)	(0.0753)	(0.4505)	(0.0006)
Poultry	-0.01438	-0.04813	-0.2265**	-0.26887**	0.557882
	(0.9600)	(0.6818)	(0.0234)	(0.0165)	(0.2060)
Fish	0.691805	0.495164**	-0.23978	0.478692*	-1.42589*
	(0.1833)	(0.0194)	(0.1192)	(0.0625)	(0.0969)
			After Structural Break		
Beef	-0.90178***	0.016902	-0.08636*	-0.10605***	1.077296***
	(<.0001)	(0.7447)	(0.0664)	(0.0083)	(<.0001)
Pork	0.079982	-0.93503***	-0.08211	-0.03454	0.971689***
	(0.5282)	(<.0001)	(0.2171)	(0.5513)	(0.0004)
Poultry	-0.06724	-0.05519	-0.44672***	-0.18154**	0.750687***
	(0.5568)	(0.4295)	(<.0001)	(0.0158)	(0.0027)
Fish	-0.41458**	-0.10623	-0.33602***	-0.2803**	1.137121***
	(0.0217)	(0.3265)	(0.0082)	(0.0451)	(0.0028)

***, **, ** denotes significance at 1%, 5%, and 10% level respectively.

Estimated Hicksian Elasticities

Table 4. Estimated Hicksian Elasticities at the Sample Mean

	Beef	*Pork*	*Poultry*	*Fish*
		Before Structural Break		
Beef	-0.34535***	0.287462***	0.068541***	-0.01066
	(<.0001)	(<.0001)	(0.0063)	(0.6527)
Pork	0.605593***	-0.68807***	0.047881	0.034598
	(<.0001)	(<.0001)	(0.2084)	(0.3993)
Poultry	0.288661***	0.09572	-0.15455	-0.22983**
	(0.0063)	(0.2084)	(0.1737)	(0.0137)
Fish	-0.08274	0.127503	-0.42369**	0.378927*
	(0.6527)	(0.3993)	(0.0137)	(0.0827)
		After Structural Break		
Beef	-0.41258***	0.275076***	0.109643***	0.027863***
	(<.0001)	(<.0001)	(0.0004)	(0.3280)
Pork	0.521225***	-0.70216***	0.094685**	0.086253*
	(<.0001)	(<.0001)	(0.0243)	(0.0561)
Poultry	0.27365***	0.124717**	-0.31014***	-0.08822
	(0.0004)	(0.0243)	(0.0004)	(0.1683)
Fish	0.101784	0.166285*	-0.12913	-0.13894
	(0.3280)	(0.0561)	(0.1683)	(0.2523)

***, **, ** denotes significance at 1%, 5%, and 10% level respectively.

Estimated Morishima Elasticities

Table 5. Estimated Morishima Elasticities at the Sample Mean

	Beef	*Pork*	*Poultry*	*Fish*
		Before Structural Break		
Beef		0.260247^{***}	-0.05669	-0.42809^{**}
		(<.0001)	(0.4700)	(0.0122)
Pork	-0.40061^{***}		-0.59235^{***}	-0.56057^{***}
	(<.0001)		(<.0001)	(0.0002)
Poultry	-0.08601	-0.10667		-0.57823^{***}
	(0.3927)	(0.3273)		(0.0009)
Fish	0.368269^{*}	0.413525^{**}	0.149092	
	(0.0777)	(0.0416)	(0.4600)	
		After Structural Break		
Beef		0.108643^{*}	-0.13893^{**}	-0.3108^{***}
		0.0536)	(0.0136)	(0.0009)
Pork	-0.42709^{***}		-0.57745^{***}	-0.53588^{***}
	(<.0001)		(<.0001)	(<.0001)
Poultry	-0.2005^{***}	-0.21546^{***}		-0.43927^{***}
	(0.0048)	0.0094)		(<.0001)
Fish	-0.11108	0.166285	-0.22717^{*}	
	(0.3176)	(0.6190)	(0.0544)	

***, **, ** denotes significance at 1%, 5% and 10% level respectively.

Conclusion

- The meat expenditure exhibited the most significant effect in the U.S. meat demand.
- The estimated Marshallian, Hicksian, and Morishima elasticities indicated that the structure of beef, pork, poultry, and fish demand have changed significantly.
- After the structural break,
  - fish turns out to be a normal good.
  - the income elasticities of beef and pork have decreased while the income elasticities of poultry and fish have increased.

  - the cross price elasticity of pork and beef, and poultry and beef have decreased.
  - except fish the own price elasticities of all other meats has increased.

  - the degree of substitutability between beef and pork has decreased.
  - the degree of substitutability between fish and other meats has increased.

Thank You!

Questions?

Additional Figure

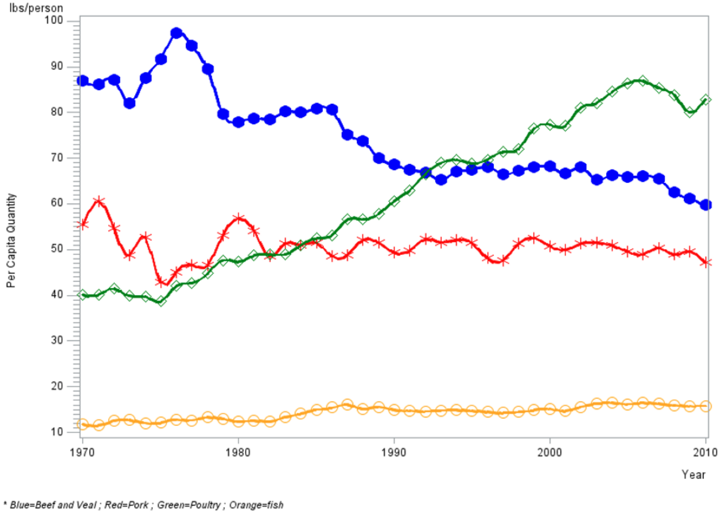

Figure 1: Per Capita Retail Quantity of Meats Between 1970-2010

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Additional Figure

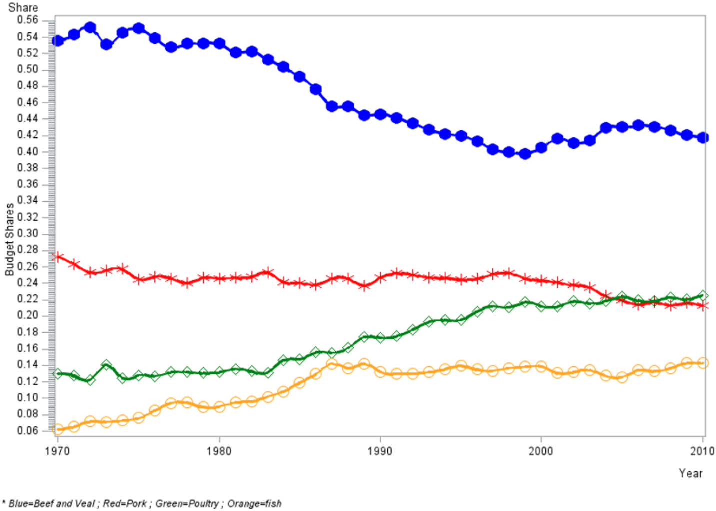

Figure 2: Budget Shares of Meats Between 1970-2010

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