Estimation of a Censored Demand System in Stratified Sampling:

An Analysis of Mexican Meat Demand at the Table Cut Level

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Outline

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1. Motivation
   - Mexico's Importance
   - Previous Studies
2. Data
   - ENIGH
   - Data Considerations
3. Theoretical Framework
4. Empirical Results
   - Estimates
   - Elasticities
5. Conclusion

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Mexico is an important market for meat exporters

- It is among the largest meat importers
- It has a relatively high preference for meat offal
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- It is among the largest meat importers
  - According to USDA, PSD Online Database (computed by authors), from 1997 to 2006,
    - Mexico imported 8% of the total world meat imports of 13,195,000 MT
    - Mexican meat imports more than doubled (increased by 147%)
    - They went from 568,000 MT to 1,405,000 MT
    - They experienced the fastest growth among the leading importing countries
- It has a relatively high preference for meat offal
- It has a relatively low per capita meat consumption

Mexico's Importance (Continued)

High Preference for Meat Offal

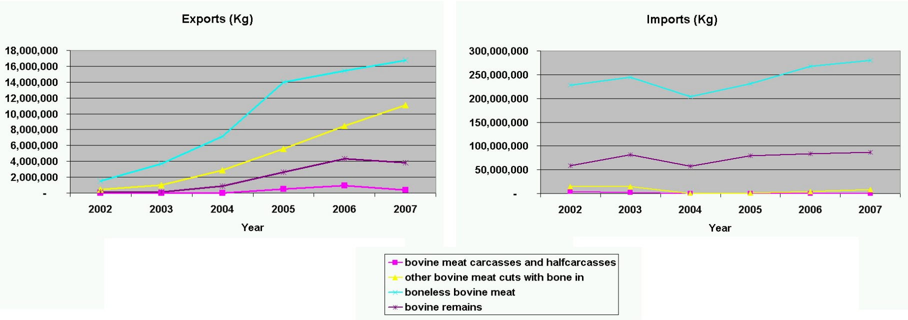

Figure 1. Mexican Exports and Imports of Bovine Meat

Source: Mexican Ministry of Economy, SIAVI Database, computed by authors.

Mexico’s Importance (Continued)

High Preference for Meat Offal

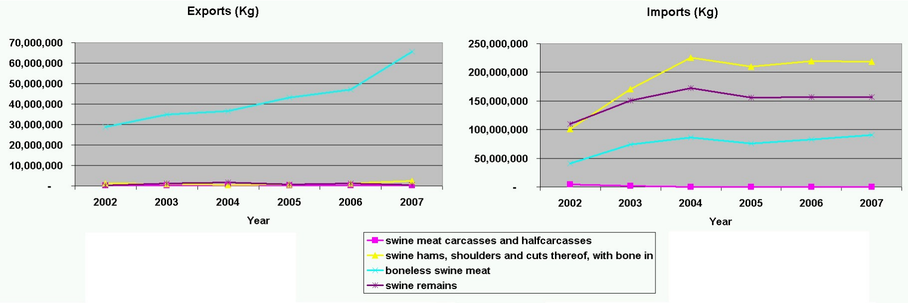

Figure 2. Mexican Exports and Imports of Swine Meat

Source: Mexican Ministry of Economy, SIAVI Database, computed by authors.

Mexico's Importance (Continued)

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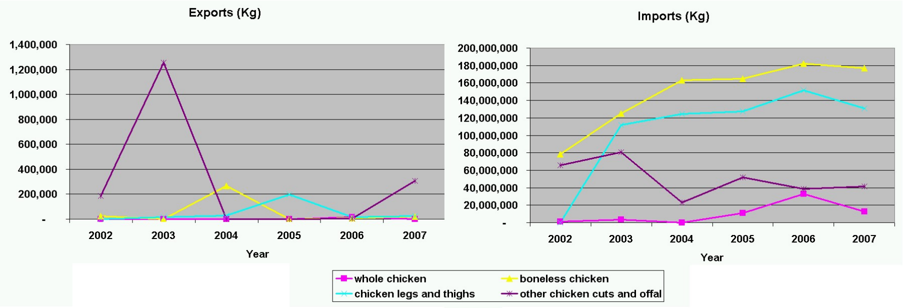

Figure 3. Mexican Exports and Imports of Chicken

Source: Mexican Ministry of Economy, SIAVI Database, computed by authors.

Mexico's Importance (Continued)

Low Per Capita Meat Consumption

Per capita meat consumption still remains low compared to the United States and Canada.

- According to USDA, PSD Online Database (computed by authors), from 1997 to 2006,
  - Mexico averaged 60.78 kg per capita
  - The Unites States and Canada averaged 121.61 and 98.38 kg per capita respectively
- Mexican per capita meat consumption could continue growing
- Mexico could still remain an important market for years to come

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Previous Studies

- Erdil (2006), Malaga et al. (2006), Dong et al. (2004), Golan et al. (2001), Dong and Gould (2000), Garcia Vega and Garcia (2000), and Heien et al. (1989)
  - They have all aggregated Mexican meat into broad categories or analyzed meat as one product within a more general demand system (i.e., including cereals, meat, dairy, fats, fruit, vegetables, etc.)
  - This is not appropriate when consumer tastes and preferences vary across meat cuts.
- Malaga et al. (2006), Dong et al. (2004), Gould-Villarreal (2002), Golan et al. (2001), Sabates et al. (2001), Garcia Vega Garcia (2000), Heien et al. (1989),
  - They use the same data source (ENIGH) used in this study
  - They have not taken into account the fact that the sample is stratified

This Study

- Estimates demand elasticities at the table cut level (i.e., beefsteak; ground beef; pork steak; ground pork; chicken legs, thighs and breast; fish, etc.)
    - Expenditure, Marshallian and Hicksian price elasticities
        - Currently not available for Mexico
    - Censored demand system estimated in two steps

Outline

Data
ENIGH

- National Survey of Household Income and Expenditures
  - *Encuesta Nacional de Ingresos y Gastos de los Hogares (ENIGH)*
- ENIGH is published since 1977 by
  - The National Institute of Statistics, Geography and Information Technology
  - *Instituto Nacional de Estadística Geografía e Informática (INEGI)*
  - Mexican governmental institution
- Extensive Mexican household survey containing information about
  - House infrastructure, appliances and services
  - Household member demographic and sociodemographic characteristics
  - Occupational activities

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Data

ENIGH 2006

- ENIGH's sampling methods are stratified
  - The target population is divided into subgroups (strata) with similar characteristics
    - Stratum 1: hh within a pop. of 100,000 people or more
    - Stratum 2: hh within a pop. between 15,000 and 99,999 people
    - Stratum 3: hh within a pop. between 2,500 and 14,999 people
    - Stratum 4: hh within a pop. of less than 2,500 people
  - A simple random sample is taken from each stratum
  - A weight is assigned to each sampling unit
    - Weight: number of households that the interviewed household represents nationally
- ENIGH performs direct interviews to households during one week
- Data on food, drinks, cigarettes and public transportation is recorded only when the household makes a purchase

Data

ENIGH 2006 (Continued)

Table 1. Number of Observations, Sum of Weights and Average Household Size Per Stratum

Strata	No. of Obs.	Sum of Weights	Avg. hhsize
Str1	7,285	11,473,327	3.99
Str2	3,942	3,241,161	4.13
Str3	1,574	2,837,679	4.52
Str4	4,108	4,554,086	4.28
Total	16,909	22,106,253	4.14

Source: ENIGH 2006 Database, computed by authors.

Data

ENIGH 2006 (Continued)

- Not incorporating from ENIGH 2006 the weight variable into the analysis is equivalent to assigning a constant weight of 1,307.37 (i.e., 22,106,253/16,909) to each observation
  - Malaga et al. (2006), Dong et al. (2004), Gould and Villarreal (2002), Golan et al. (2001), Sabates et al. (2001), Garcia Vega Garcia (2000), Heien et al. (1989)
- Taking a random sample of 1,000 households and not incorporating the weight variable will only produce a sample that is representative of the 16,909 households assuming a constant weight
  - Golan et al. (2001)
- Restricting the analysis to only strata 1 and 2 (i.e., households that live in cities or towns with a population of 15,000 or more), in ENIGH 2006, is equivalent to excluding 7,391,765 households
  - Malaga et al. (2006) and Dong et al. (2004)

Data

ENIGH 2006 (Continued)

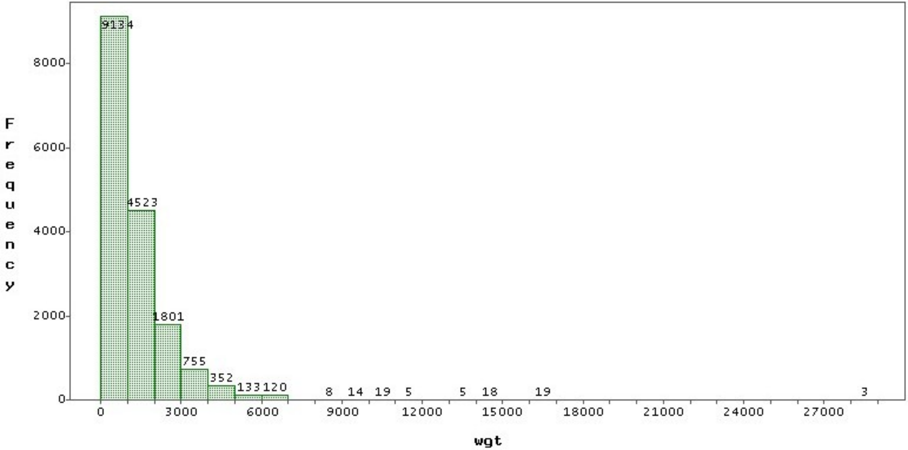

Figure 4. Histogram of the Weight Variable in ENIGH 2006

Source: ENIGH 2006 Database, computed by authors.

Outline

Data Considerations

- Stratified sample
  - Need to incorporate stratification variables (weight and strata)
  - Weighted least squares estimation is consistent (Wooldrigde, 2001; Lohr 1999)
  - However, the standard errors obtained from weighted least squares estimation are incorrect and should be ignored (Lohr 1999)
  - Consequently, standard errors were estimated by bootstrap
- During one week of the interview, not all households reported consumption of all meat cuts (Censoring Problem)
  - Missing observations for some price and quantities
    - To solve the problem of missing prices, a regression imputation approach was adopted for each of the eighteen meat cuts considered in this study
    - Non-missing prices of each meat cut was regressed as function of total income, education level of the household decision maker, regional dummy variables, stratum dummy variables, the number of adult equivalents, a dummy variable for car, and a dummy variable for refrigerator

Data Considerations (Continued)

- Variables such as price, quantity, and expenditure are reported at the household level regardless of the household size
  - Households are not comparable
  - Not adjusting is equivalent to assuming a constant household size
  - Compute the number of adult equivalents
    - National Research Council's recommendations of the different food energy allowances for males and/or females during the life cycle as reported by Tedford et al. (1986)
  - Compute per capita meat consumption (i.e., per adult-equivalent consumption)
  - Other studies have ignored (Malaga et al., 2006) or used a simple count or proportion (Dong et al., 2004; Golan et al., 2001) of household members.

Censored Demand System

- This study uses the two-step estimation of a censored demand system proposed by Shonkwiler and Yen (1999), but incorporates stratification variables into the estimation procedure
- The censored system of equations can be written as

$$y_i = \Phi(\mathbf{z}_i'\boldsymbol{\alpha}_i)\mathbf{x}_i'\boldsymbol{\beta}_i + \delta_i\phi(\mathbf{z}_i'\boldsymbol{\alpha}_i) + \xi_i, \quad i = 1, \ldots, M$$

- Where:
  - y_i is a (1×1) observed dependent variable
  - $\Phi(\mathbf{z}_i'\boldsymbol{\alpha}_i) =$ standard normal cumulative distribution function (cdf) evaluated at $\mathbf{z}_i'\boldsymbol{\alpha}_i$
  - $\phi(\mathbf{z}_i'\boldsymbol{\alpha}_i) =$ standard normal probability density function (pdf) evaluated at $\mathbf{z}_i'\boldsymbol{\alpha}_i$
  - $\mathbf{z}_i' = \begin{pmatrix} 1 & z_{i2} & \ldots & z_{iK_1} \end{pmatrix}$ is $(1 \times K_1)$ vector of explanatory variables
  - $\mathbf{x}_i' = \begin{pmatrix} 1 & x_{i2} & \ldots & x_{iK_2} \end{pmatrix}$ is $(1 \times K_2)$ vector of explanatory variables
  - $\boldsymbol{\alpha}_i = \begin{pmatrix} \alpha_{i1} & \alpha_{i2} & \ldots & \alpha_{iK_1} \end{pmatrix}'$ is a $(K_1 \times 1)$ vector of parameters
  - $\boldsymbol{\beta}_i = \begin{pmatrix} \beta_{i1} & \beta_{i2} & \ldots & \beta_{iK_2} \end{pmatrix}'$ is a $(K_2 \times 1)$ vector of parameters
  - ξ_i is a (1×1) random error

Two-Step Estimation

1. Obtain maximum-likelihood probit estimates $\hat{\boldsymbol{\alpha}}_i$ of $\boldsymbol{\alpha}_i$ for $i = 1, 2, \ldots, M$ using the binary dependent variable $d_i = 1$ if $y_i > 0$ and $d_i = 0$ otherwise

$$P(d_i = 1|\mathbf{z}_i) = \Phi(\alpha_{i1} + \alpha_{i2}z_{i2} + \ldots + \alpha_{iK_1}z_{iK_1}) = \Phi(\mathbf{z}_i'\boldsymbol{\alpha}_i)$$

   - Multiply the contribution of each observation to the likelihood function by the value of the weight variable

2. Calculate $\Phi(\mathbf{z}_i'\hat{\boldsymbol{\alpha}}_i)$ and $\phi(\mathbf{z}_i'\hat{\boldsymbol{\alpha}}_i)$ and estimate $\boldsymbol{\beta}_1$, $\boldsymbol{\beta}_2$, ..., $\boldsymbol{\beta}_M$, δ_1, δ_2, ..., δ_M in the system

$$y_i = \Phi(\mathbf{z}_i'\hat{\boldsymbol{\alpha}}_i)\mathbf{x}_i'\boldsymbol{\beta}_i + \delta_i\phi(\mathbf{z}_i'\hat{\boldsymbol{\alpha}}_i) + \xi_i, \quad i = 1, \ldots, M,$$

   by seemingly unrelated regression (SUR) procedure
   - Weight all observations by the weight variable prior to estimation

Outline

Eighteen Table Cuts of Meat

1. beefsteak
2. ground beef
3. other beef cuts
4. beef offal
5. pork steak
6. pork leg & shoulder
7. ground pork
8. other pork
9. chorizo
10. ham, bacon & similar products from beef & pork
11. beef & pork sausages
12. other processed beef & pork
13. chicken legs, thighs and breasts
14. whole chicken
15. chicken offal
16. chicken ham & similar
17. fish
18. shellfish

Table 4. SUR Parameter Estimates from System of Equations (Step 2)

Variable	Beefsteak ($i=1$)		Ground Beef ($i=2$)		Other Beef ($i=3$)		Beef Offal ($i=4$)		Pork Steak ($i=5$)	
	Param. Est.	Bootstr. Std. Err.	Param. Est.	Bootstr. Std. Err.	Param. Est.	Bootstr. Std. Err.	Param. Est.	Bootstr. Std. Err.	Param. Est.	Bootstr. Std. Err.
$\Phi(z_i'\hat{\alpha}_i)$	1.6951*	0.3939	0.6607	0.4387	2.0916*	0.7051	13.0161	16.0844	1.5472†	0.8903
$\Phi(z_i'\hat{\alpha}_i)\ p_1$	-0.0038*	0.0015	-0.0002	0.0007	-0.0038*	0.0022	-0.0057	0.0080	0.0051†	0.0040
$\Phi(z_i'\hat{\alpha}_i)\ p_2$	0.0000	0.0008	-0.0130*	0.0046	0.0053*	0.0031	0.0176	0.0230	0.0022	0.0069
$\Phi(z_i'\hat{\alpha}_i)\ p_3$	-0.0016*	0.0007	-0.0005	0.0006	-0.0109*	0.0040	0.0035	0.0090	-0.0019	0.0028
$\Phi(z_i'\hat{\alpha}_i)\ p_4$	0.0008	0.0013	0.0006	0.0016	-0.0019	0.0026	-0.0497*	0.0168	0.0075	0.0115
$\Phi(z_i'\hat{\alpha}_i)\ p_5$	-0.0067*	0.0024	0.0022†	0.0023	0.0044†	0.0050	0.0504	0.0884	-0.0235*	0.0105
$\Phi(z_i'\hat{\alpha}_i)\ p_6$	0.0050*	0.0021	0.0030‡	0.0016	0.0009	0.0044	-0.0061	0.0183	0.0027	0.0108
$\Phi(z_i'\hat{\alpha}_i)\ p_7$	-0.0072*	0.0021	-0.0011	0.0027	-0.0236*	0.0080	-0.0320	0.0333	-0.0017	0.0090
$\Phi(z_i'\hat{\alpha}_i)\ p_8$	-0.0020*	0.0007	0.0014	0.0011	-0.0036	0.0034	-0.0006	0.0036	0.0045‡	0.0025
$\Phi(z_i'\hat{\alpha}_i)\ p_9$	-0.0007*	0.0003	-0.0002	0.0002	0.0021	0.0022	0.0528	0.0738	-0.0024‡	0.0014
$\Phi(z_i'\hat{\alpha}_i)\ p_{10}$	-0.0009‡	0.0004	-0.0003	0.0004	-0.0003	0.0009	0.0035	0.0077	0.0062	0.0115
$\Phi(z_i'\hat{\alpha}_i)\ p_{11}$	-0.0007	0.0007	-0.0009	0.0007	0.0070*	0.0030	0.0208	0.0238	-0.0035	0.0055
$\Phi(z_i'\hat{\alpha}_i)\ p_{12}$	0.0005	0.0004	0.0007	0.0006	-0.0008†	0.0007	0.0192	0.0345	0.0028	0.0043
$\Phi(z_i'\hat{\alpha}_i)\ p_{13}$	-0.0014*	0.0008	0.0009	0.0011	-0.0025‡	0.0017	-0.0097†	0.0069	0.0052	0.0080
$\Phi(z_i'\hat{\alpha}_i)\ p_{14}$	-0.0002	0.0005	0.0017	0.0022	-0.0008	0.0011	0.0085	0.0202	0.0021	0.0087
$\Phi(z_i'\hat{\alpha}_i)\ p_{15}$	-0.0018†	0.0010	-0.0011	0.0009	-0.0006	0.0027	-0.0026	0.0171	-0.0043	0.0071
$\Phi(z_i'\hat{\alpha}_i)\ p_{16}$	0.0032*	0.0011	0.0014	0.0011	0.0019†	0.0014	-0.0053	0.0066	0.0090	0.0069
$\Phi(z_i'\hat{\alpha}_i)\ p_{17}$	-0.0002	0.0007	-0.0007‡	0.0004	-0.0016†	0.0010	0.0206	0.0455	-0.0009	0.0013
$\Phi(z_i'\hat{\alpha}_i)\ p_{18}$	0.0049*	0.0016	0.0021	0.0017	0.0014	0.0021	0.0162	0.0179	0.0058	0.0103
$\Phi(z_i'\hat{\alpha}_i)\ m$	-0.0003	0.0018	0.0005	0.0009	0.0010	0.0020	-0.0215	0.0410	-0.0033	0.0072
$\Phi(z_i'\hat{\alpha}_i)\ NE$	0.1933*	0.0552	0.1172*	0.0624	0.1733‡	0.1201	-0.2618	0.4762	0.9236	1.9232
$\Phi(z_i'\hat{\alpha}_i)\ NW$	0.0432	0.0487	-0.0280	0.1539	-0.0402	0.1721	-1.1865*	0.4623	1.4056	2.2352
$\Phi(z_i'\hat{\alpha}_i)\ CW$	-0.0888	0.0734	-0.0384	0.0437	-0.0149	0.0911	2.0145	4.2729	0.5291	0.7748
$\Phi(z_i'\hat{\alpha}_i)\ C$	-0.0698	0.0504	0.0683†	0.0541	0.1229	0.1251	-0.9158	0.7403	0.1874	0.3540
$\Phi(z_i'\hat{\alpha}_i)\ urban$	-0.2890*	0.0938	-0.1448†	0.0895	-0.0609	0.0614	-1.4360	2.2463	-0.2713	0.5124
$\phi(z_i'\hat{\alpha}_i)$	-0.8134*	0.2837	-0.1105	0.1768	-0.3410	0.3433	-8.2907	13.4497	-1.1200	1.9879

Note: Number of bootstrap resamples = 1,000. Bootstrap significance levels of 0.05, 0.10 and 0.20 are indicated by asterisks (*), double daggers (‡) and daggers (†) respectively.

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Table 6. Hicksian Price Elasticities

Table entries are e_{ij}^{c}.

i\j	1	2	3	4	5	6	7	8	9
1	-0.8317	0.3678	-0.2734	-0.0541	0.3180	-0.1536	-0.0051	0.1874	0.1820
2	0.4311	-3.4253	-0.0851	-0.0850	0.4725	0.4208	0.4099	0.1832	0.0076
3	-1.1835	0.2814	-1.6797	0.2860	1.2986	-0.4435	-3.3377	-0.9642	0.2537
4	1.7919	0.5057	-0.3286	-4.8079	-1.3690	0.8257	-1.5365	-0.2055	0.6261
5	0.7945	-0.7222	0.0787	-0.2241	-4.4646	-1.1003	-1.6600	0.7306	-0.4366
6	-1.1882	-0.5048	0.0307	0.4996	-0.7791	-4.8218	0.9328	0.3310	-0.1576
7	-2.4891	-0.5648	0.2494	0.1262	-1.9000	-0.8219	-15.9417	-0.2934	0.1776
8	-0.0883	0.5327	0.3558	0.4122	1.4607	1.7303	-1.9368	-8.2689	0.6582
9	0.1971	-0.0665	0.1340	-0.0162	1.0014	-0.3696	0.0384	-0.1072	-1.2050
10	0.2692	-0.7360	0.4478	-0.2419	0.1828	0.1929	-1.3145	0.1293	0.0724
11	-0.3748	0.1515	0.2016	0.5597	1.0545	-0.8204	0.4742	0.6804	0.0897
12	0.1686	-0.7457	0.0838	-1.2107	-2.2195	0.0135	0.5745	-0.3542	0.1133
13	-0.1127	0.1549	0.1689	-0.3130	0.4281	0.4449	0.8049	0.0697	0.1989
14	0.5599	-0.1846	-0.0963	-0.0479	0.1029	0.2012	-0.0899	0.1640	0.0569
15	0.0311	0.2473	0.0718	0.3439	0.7394	0.4791	-1.7064	0.1615	-2.0445
16	-0.0401	0.2427	0.0707	0.1473	2.1236	0.2343	-1.7173	0.7102	0.0693
17	0.0549	-0.0310	0.1395	-0.0846	0.9832	-0.5326	-1.5399	0.2237	0.0037
18	-1.0640	0.5979	-0.6511	0.1449	0.8916	0.3099	0.2186	-0.5414	0.0341

Note: $i, j = 1, 2, \ldots, 18$, where 1 = Beefsteak, 2 = Ground Beef, 3 = Other Beef, 4 = Beef Offal, 5 = Pork Steak, 6 = Pork Leg & Shoulder, 7 = Ground Pork, 8 = Other Pork, 9 = Chorizo, 10 = Ham, Bacon & Similar Product from Beef & Pork, 11 = Beef & Pork Sausages, 12 = Other Processed Beef & Pork, 13 = Chicken Legs, Thighs & Breasts, 14 = Whole Chicken, 15 = Chicken Offal, 16 = Chicken Ham & Similar, 17 = Fish, 18 = Shellfish.

Table 6. Hicksian Price Elasticities (Continued)

Table entries are e^c_{ij}.

i\j	10	11	12	13	14	15	16	17	18
1	0.1535	0.0823	0.2024	-0.1665	0.0541	0.1123	-0.0188	0.1143	-0.3558
2	0.0915	-0.0725	0.0367	0.0242	0.2416	0.1215	-0.1014	-0.0659	-0.9194
3	0.1229	0.2569	-0.0550	-0.2668	0.0516	0.3020	0.1749	-0.1149	-0.5811
4	-0.2234	0.5134	-0.7042	-0.6453	-0.4149	0.5072	-0.1950	-1.3816	1.2042
5	-0.5771	0.0937	-0.1240	-0.1378	-0.5374	0.2170	0.8374	0.0209	-0.9032
6	-0.3008	0.0597	0.6082	0.1203	-0.4490	0.0177	0.2078	0.1676	0.3965
7	-0.0666	0.6998	-1.4879	-0.2325	-0.5563	-0.3206	-0.6385	-0.4841	-0.6676
8	0.1075	0.5695	-0.3557	-0.1954	-0.3366	0.0705	-0.8324	-0.1837	0.5525
9	-0.5937	-0.0795	-0.3450	-0.1471	-0.2112	-0.2961	-0.3764	-0.0301	0.0917
10	-0.7598	0.2870	0.2510	0.1160	0.1440	-0.4645	0.2370	0.1074	0.5302
11	0.0014	-1.8339	-0.1129	0.0061	-0.1040	-0.2718	0.3132	0.2447	0.6681
12	-0.5934	0.0882	-3.0977	0.6030	-0.0168	-0.6071	0.2902	0.0446	0.3286
13	0.3139	0.0799	0.3123	-1.1904	-0.0795	0.0305	0.3111	0.1846	0.2972
14	-0.0916	-0.0134	0.2387	0.1261	-1.1853	0.2465	0.1169	-0.5672	0.2371
15	-2.6553	1.0175	0.2776	-0.1625	-0.1907	-9.1617	1.1371	-0.4551	-0.0436
16	0.1486	0.2656	0.0679	0.2184	0.0453	0.1317	-1.2569	0.0553	0.2014
17	0.3093	0.1588	0.1544	-0.0014	0.1785	0.2664	0.2060	-0.9119	0.7942
18	0.2128	0.4503	0.0898	-0.1533	-0.0231	0.1873	1.1430	0.0079	-7.5851

Note: $i, j = 1, 2, \ldots, 18$, where 1 = Beefsteak, 2 = Ground Beef, 3 = Other Beef, 4 = Beef Offal, 5 = Pork Steak, 6 = Pork Leg & Shoulder, 7 = Ground Pork, 8 = Other Pork, 9 = Chorizo, 10 = Ham, Bacon & Similar Product from Beef & Pork, 11 = Beef & Pork Sausages, 12 = Other Processed Beef & Pork, 13 = Chicken Legs, Thighs & Breasts, 14 = Whole Chicken, 15 = Chicken Offal, 16 = Chicken Ham & Similar, 17 = Fish, 18 = Shellfish.

Table 7. Expenditure Elasticities

i	e_i
Beefsteak	0.9733
Ground Beef	0.5228
Other Beef	0.7260
Beef Offal	0.6413
Pork Steak	0.3904
Pork Leg & Shoulder	0.5141
Ground Pork	0.1846
Other Pork	0.5776
Chorizo	0.6190
Ham, Bacon & Similar	0.4547
Beef & Pork Sausages	0.2728
Other Processed Beef & Pork	0.3570
Chicken Legs, Thighs & Breasts	0.6142
Whole Chicken	0.6761
Chicken Offal	0.6112
Chicken Ham & Similar	0.3354
Fish	0.6970
Shellfish	0.4361

Conclusion

- Mexico is an important market for meat exporters
- Results indicate that consumption on all meat cuts is expected to increase as the economy grows
- All meat cuts are considered necessary commodities but pork appeared to have the most inelastic expenditure elasticities (except for processed meat)
- Several cases of substitutability and complementarity were identified based on elasticity values
- Data issues were incorporated into the analysis
  - Deals with censored observations
  - Computes per adult-equivalent consumption
- The study outlines how to estimate a censored demand system in stratified sampling
  - Uses a consistent two-step estimation procedure
  - Incorporates stratification variables (strata and weight)
  - Estimates standard errors of parameter estimates by using bootstrap

The End

Thank You.