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ESTIMATION OF SCALE ELASTICITIES AND PRICE FLEXIBILITIES OF MEAT AND FISH IN SAUDI ARABIA

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ABSTRACT

This paper applied the synthetic inverse demand model to estimate scale and price flexibilities of lamb, beef, chicken, and fish in Saudi Arabia. Model selection tests showed that the differential inverse AIDS model and the inverse CBS model provided the best fit for the data. The estimated own-price flexibilities for both models were negative and consistent with theory. Furthermore, the results revealed that a 1% increase in aggregate quantity of meat and fish decreased the normalized prices of fish and chicken by approximately 0.7% and 1.1%, respectively.

Keywords: Inverse Demand, Price Flexibility, Scale Elasticity, Meat, Fish.

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INTRODUCTION

Inverse demand systems have been widely applied to study agricultural and food products. The main reasons for using inverse demand systems in lieu of direct demand systems are mainly attributed to perishability and production lags. As indicated by Ferris (2005), the inverse demand is suitable for livestock and perishable crops because quantity produced is predetermined and must be consumed within a specific period. The induction of the synthetic inverse demand system in the economic literature was revealed by Brown, Lee, and Seale (1995). Their synthetic inverse demand model was primarily derived from Barten's (1993) direct synthetic demand system. Holt (2002) applies a hybrid inverse demand system to estimate price and scale flexibilities of demand for beef, pork, and chicken in the United States. Lee and Kennedy (2010) use an inverse synthetic demand system to estimate quantity elasticity and scale elasticity of catfish, trout, tuna, tilapia, salmon, and shrimp in the United States. Model selection tests showed that the synthetic model fits the data better than the other nested models (differential inverse Rotterdam, differential inverse CBS, differential inverse AIDS, and differential inverse NBR). The synthetic inverse demand system was also used in another study by Lee and Kennedy (2008) to estimate price and scale flexibilities of crawfish tail meat in Louisiana, United States. This study used annual observations from 1989 to 2005. The results showed that the differential inverse NBR model fits the data better than the other competing models. The estimated own-price flexibilities were all negative in sign. Demand for wholesale fish grades was estimated in Greece using the synthetic inverse demand system (Fousekis and Karagiannis, 2001). Results showed that the inverse CBS model is the optimal model for the Greek fish grades data, and the scale effect is negative for all fish grades. Eales, Durham, and Wessells (1997) conclude that the forecasting performance of a synthetic inverse demand model is better than the synthetic direct demand systems. Therefore, the purpose of this paper is to estimate the scale and price flexibilities of meat and fish demand in Saudi Arabia. Beef, lamb, chicken, and fish were chosen as products in this paper because they are perishable items and their production is predetermined due to biological factors.

Meat and fish demand in Saudi Arabia were analyzed by Selvanathan *et al*. (2016) using the direct Rotterdam demand model. The results showed that the demand for beef, lamb, and fish is income elastic, and the demand for chicken is income inelastic. Furthermore, the estimated own-price elasticities for meat and fish were inelastic. However, no study in economic literature has applied the inverse demand model to analyze Saudi Arabia's meat and fish consumption. Thus, this paper fills the gap in economic literature by revealing the best demand model that fits Saudi Arabia meat and fish data.

Data and Methodology: This paper uses the same data used by Albalawi (2015) and Selvanathan *et al*. (2016). The data is annual data from 1985 to 2010. The data consists of the price in Saudi Riyal and quantity consumed of beef, lamb, chicken, and fish measured in kilograms per capita.

The synthetic inverse demand model of Brown, Lee, and Seale (1995) that nests the Rotterdam inverse demand model, CBS inverse demand model (ICBS), NBR inverse demand mode, and differential inverse AIDS (DIAIDS) model can be expressed as:

$$w_i d \quad \pi_i = (e_i - d_1 w_i) d \quad Q + \sum_i \left(e_i - d_2 w_i(\delta_i - w_j)\right) d \quad q_j \quad (1)$$

Where $w_i = \frac{p_i q_i}{\sum p_i q_i} = \frac{p_i q_i}{X}$ is the budget share, $\pi_i = \frac{p_i}{X}$ is the normalized price, q and p are the quantity and price for the fish, lamb, chicken, and beef. Also, $d \quad Q = \sum_i w_i d \quad q_i$ is the Divisia volume index, and δ_i is the kroneker delta that equals 1 if i=j and zero otherwise. e_i a e_i are parameters to be estimated that are used to calculate scale and price flexibilities, respectively. d_1 a d_2 are additional parameters that help us to select the model that best describes the data among the other competing models. The likelihood ratio test is used to select the best model using the following guidelines:

a) When $d_1 = 0$ a $d_2 = 0$, then the synthetic demand system becomes the Rotterdam inverse demand model.

b) When $d_1 = 1$ a $d_2 = 0$, then the synthetic demand system becomes the ICBS demand system.

c) When $d_1 = 0$ a $d_2 = 1$, then the synthetic demand system becomes to the inverse NBR demand system.

d) When $d_1 = 1$ a $d_2 = 1$, then the synthetic demand system becomes the DIAIDS.

To make the synthetic inverse demand model (1) consistent with microeconomic theory, the following parametric restrictions are imposed:

1- Homogeneity implies $\sum_i e_i = 0$ and $\sum_j e_i = 0$.

2- Symmetry implies $e_i = e_j$.

3- Adding-up implies $\sum_i e_i = -1 + d_1$

Brown, Lee, and Seale (1995) showed that the scale elasticity for the synthetic inverse model (1) is calculated as follows: $f_i = \frac{e_i}{w} - d_1$ (2)

The compensated price flexibilities are calculated as follows:

$$f_i^* = \frac{e_i}{w} - d_2(d_i - w_j) \qquad (3)$$

Furthermore, the uncompensated price flexibilities are computed as below:

$$f_i = \frac{e_i}{w} - d_2(d_i - w_j) + w_j(\frac{e_i}{w} - d_1) \qquad (4)$$

RESULTS AND DISCUSSION

The first step is to estimate the synthetic inverse demand model (1). The synthetic model (1) was estimated using the full information maximum likelihood method (FIML) since it is insensitive to the deleted equation from the system (Barten, 1969; Brown, Lee, and Seale, 1995). Table 1 shows model selection based on the likelihood ratio test.

Table 1. Inverse Demand Models Test.

Model	LRT
Rotterdam inverse demand model	39.30***
Inverse CBS demand model (ICBS)	4.87
Inverse NBR demand model	38.89***
Differential inverse almost ideal demand model (DIAID)	3.37

*** denote significance level at the 1% level.

The results of the likelihood ratio test reject the inverse Rotterdam demand model and the inverse NBR demand model at the one percent level. The ICBS model is rejected at the ten percent level. However, we fail to reject the DIAIDS model. Therefore, we only report the results of the ICBS and the DIAIDS. Table 2 shows the estimated parameters for the ICBS DIAIDS models.

Table 2. Parameter Estimates for the Inverse CBS Model and the Differential Inverse AIDS Models.

Parameter	Inverse CBS	DIAIDS	Parameter	Inverse CBS	DIAIDS
e_f	-0.00441	0.078551***	e_p	-0.03914*	0.169581***
	(0.00720)	(0.00729)		(0.0217)	(0.0227)
e_f	-0.00917*	-0.05809***	e_p	0.0043	-0.02396**
	(0.00507)	(0.00499)		(0.00886)	(0.00858)
e_f	0.009878	-0.01852**	e_b	-0.00283	0.085918***
	(0.00801)	(0.00809)		(0.00745)	(0.00710)
e_f	0.003698	-0.00194	e_f	0.036074***	0.029746***
	(0.00350)	(0.00351)		(0.0106)	(0.0105)
e_l	-0.01062	0.245207***	e_l	-0.00066	0.001697
	(0.0205)	(0.0210)		(0.0372)	(0.0382)
e_l	0.024958	-0.1271***	e_p	-0.03542	-0.03144
	(0.0186)	(0.0196)		(0.0367)	(0.0389)
e_l	-0.00517	-0.06001***	e_b	0.00006	-0.00006
	(0.00878)	(0.00851)		(0.0202)	(0.0178)

***, **, and * denote significance level at the 1%, 5% percent, and 10% respectively. f=fish, l=lamb,p= poultry, b=beef.

The results in Table 2 show that most of the estimated parameters for the DIAIDS model are significant. Conversely, there are only a few parameters that are significant in the ICBS model. The single R^2 for the DIAIDS model is 0.76, 0.90, and 0.74 for fish, lamb, and chicken equations, respectively. Moreover, the single R^2 for the ICBS model is 0.75, 0.90, and 0.76 for fish, lamb, and chicken equation, respectively. However, Bewley, Young, and Colman (1987) indicate that the single R^2 is inappropriate for the case of system of equations; further, they suggest an equation that provides the required R^2.

$$R_L^2 = 1 - \frac{1}{1+L\ /[T(n-1)]} \qquad (5)$$

Where R_L^2 is the alternative R^2 that is suggested for the case of systems of equation, LR is twice the difference between the log-likelihood of the model and the log-likelihood of the dependent variables on the constant term. This equation has been applied to measure R^2 for the synthetic demand model by Brown, Lee, and Seale (1994). The calculated R_L^2 in this paper is almost 0.63 for both the DIAIDS and the ICBS models. It is clearly obvious that the R_L^2 is smaller than the smallest value of the single R^2.

Tables 3 and 5 show the estimated scale and compensated price flexibilities for the DIAIDS model and the ICBS model, respectively. All the estimated scale elasticities for the DIAIDS and the ICBS models are negative and significant at the one percent level. The scale elasticity of lamb and beef in both models equal unity in absolute value, which indicates homothetic preferences (Lee and Kennedy, 2008). On the other hand, the scale elasticity for fish and chicken shows that a one percent increase in aggregate quantity of meat and fish decreases the normalized prices of fish and chicken by approximately 0.7 percent and 1.1 percent, respectively.

The estimated compensated own-price flexibilities are all negative for both models, showing consistency with the theory. The compensated own-price flexibilities for both models are inelastic. However, the ICBS model's flexibilities are all significant at the one percent level and larger in magnitude compared to the DIAIDS model. Moreover, the uncompensated own-price flexibilities, as shown in Tables 4 and 6, for both models, also differ in magnitude. The compensated own-price flexibilities are inelastic as shown by the DIAIDS model, while the ICBS model shows that the own-price flexibilities are elastic. The uncompensated own-price flexibility of lamb, as shown by the DIAIDS model, reveals that a one percent increase in the quantity of lamb decreases the normalized price of lamb by 0.5 percent. In addition, the uncompensated own-price flexibility of chicken, as illustrated by the ICBS model, indicates that a one percent increase in the quantity of chicken reduces the normalized price of chicken by 1.17 percent. This shows that a 1% increase in chicken consumption leads to more than 1% percent decrease in the marginal value of chicken (normalized price) in consumption (Eales and Unnevehr, 1991). Thus, the demand for chicken is flexible.

The uncompensated cross-price flexibilities for the DIAIDS model show that fish and chicken are gross-substitutes for lamb. The compensated cross-price flexibilities for the DIAIDS model imply that beef and fish are net-complements. Furthermore, the ICBS model shows that lamb, chicken, and beef are all complements for fish.

Table 3. Scale and Compensated Price Flexibilities for the DIAIDS Model.

Item	Fish	Lamb	Chicken	Beef	Scale
Fish	-0.144* (0.0697)	-0.065 (0.0478)	0.405 (0.0774)	0.086** (0.0336)	-0.716*** (0.1003)
Lamb	-0.014 (0.0102)	-0.010 (0.0427)	0.042 (0.0400)	-0.018 (0.0173)	-0.997*** (0.0778)
Chicken	0.043 (0.0269)	0.068 (0.0652)	-0.135* (0.0753)	0.024 (0.0285)	-1.105*** (0.1294)
Beef	0.086** (0.0337)	-0.089 (0.0817)	0.071 (0.0824)	-0.071 (0.0682)	-1.000*** (0.2043)

***, **, and * denote significance level at the 1%, 5% percent, and 10% respectively.

Table 4. Uncompensated Price Flexibilities for the DIAIDS Model.

Item	Fish	Lamb	Chicken	Beef
Fish	-0.219***	-0.416***	0.190	0.011
	(0.0661)	(0.0577)	(0.0974)	(0.0351)
Lamb	-0.118***	-0.498***	-0.258***	-0.122***
	(0.0128)	(0.0471)	(0.0535)	(0.0187)
Chicken	-0.073**	-0.474***	-0.467***	-0.091***
	(0.0281)	(0.0712)	(0.0982)	(0.0308)
Beef	-0.019	-0.576***	-0.230**	-0.175**
	(0.0337)	(0.0817)	(0.0824)	(0.0682)

***, **, and * denote significance level at the 1%, 5% percent, and 10% respectively.

Table 5. Scale and Compensated Price Flexibilities for the Inverse CBS.

Item	Fish	Lamb	Chicken	Beef	Scale
Fish	-0.938***	0.403***	0.377***	0.140***	-0.655***
	(0.0689)	(0.0485)	(0.0766)	(0.0334)	(0.1014)
Lamb	0.086***	-0.531***	0.352***	0.097***	-1.001***
	(0.0103)	(0.0418)	(0.0379)	(0.0179)	(0.0757)
Chicken	0.137***	0.574***	-0.829***	0.118***	-1.118***
	(0.0266)	(0.0618)	(0.0723)	(0.0294)	(0.1219)
Beef	0.140***	0.441***	0.342***	-0.923***	-1.000***
	(0.0336)	(0.0843)	(0.0850)	(0.0715)	(0.2244)

***, **, and * denote significance level at the 1%, 5% percent, and 10% respectively.

Table 6. Uncompensated Price Flexibilities for the Inverse CBS.

Item	Fish	Lamb	Chicken	Beef
Fish	-1.006***	0.0815	0.180*	0.071*
	(0.0654)	(0.0588)	(0.0967)	(0.0350)
Lamb	-0.019	-1.022***	0.050	-0.011
	(0.0130)	(0.0465)	(0.0511)	(0.0190)
Chicken	0.021	0.025	-1.166***	0.002
	(0.0278)	(0.0676)	(0.0935)	(0.0312)
Beef	0.036	-0.050	0.041	-1.027***
	(0.0336)	(0.0843)	(0.0850)	(0.0715)

***, **,and * denote significance level at the 1%, 5% percent, and 10% respectively.

Morishima elasticities have been used in inverse demand by Park, Thurman, and Easley (2004). The Morishima elasticities of complementarity are calculated as below:

$$\sigma_i = f_i^* - f_{ii}^* \quad (6)$$

The Morishima elasticities of complementarity for beef, lamb, chicken, and fish in Saudi Arabia are reported in Tables 7 and 8. All the Morishima elasticities of the ICBS model and most of Morishima elasticities of DIAIDS model are positive, showing the dominance of complementary relationship. These results are consistent with the results obtained by Park *et al*. (2004). They attributed the dominance of complementary relationship to the negative own-price flexibility and the inclination toward complementarity in consumption. Furthermore, the dominance of complementary relationship in Morishima elasticity for the case of inverse demand can be attributed to the fact that the value of own price-flexibility is larger in absolute value than the cross-price flexibilities.

Table 7. Morishima Price Flexibilities for the IDAIDS.

Item	Fish	Lamb	Chicken	Beef
Fish	0	0.079	0.549*	0.230**
		(0.0846)	(0.1384)	(0.0860)
Lamb	-0.004	0	0.051	-0.009
	(0.0446)		(0.0805)	(0.0516)
Chicken	0.178*	0.203	0	0.160*
	(0.0892)	(0.1358)		(0.0882)
Beef	0.157*	-0.014	0.142	0
	(0.0813)	(0.1266)	(0.1233)	

***, **, and * denote significance level at the 1%, 5% percent, and 10% respectively.

Table 8. Morishima Price Flexibilities for the Inverse CBS.

Item	Fish	Lamb	Chicken	Beef
Fish	0	1.340***	1.315***	1.077***
		(0.0856)	(0.1365)	(0.0843)
Lamb	0.617***	0	0.883***	0.625***
	(0.0454)		(0.0770)	(0.0511)
Chicken	0.967***	1.403***	0	0.948***
	(0.0853)	(0.1286)		(0.0877)
Beef	1.063***	1.364***	1.265***	0
	(0.0802)	(0.1316)	(0.1316)	

***, **, and * denote significance level at the 1%, 5% percent, and 10% respectively.

Conclusion: Due to the fact that meat and fish are perishable commodities and require a certain production lag before reaching the market, this paper examined the demand of meat and fish in Saudi Arabia using inverse demand models. The study had adopted the synthetic inverse demand model since it allowed selection of the best fitting model for the Saudi meat and fish data among other competing demand systems. The results showed that the inverse CBS demand model and the differential inverse AIDS demand model fit the Saudi's meat and fish consumption data better than the inverse Rotterdam demand model and the inverse NBR demand model. Furthermore, the scale elasticities for both models were negative, and the scale elasticities of lamb and beef equal unity. The results of cross-price flexibilities of the differential inverse AIDS model and the inverse CBS model show some disagreement in classifying the relationship among beef, lamb, chicken, and fish. The results of the Morishima elasticities for both models show that the relationship among beef, chicken, lamb, and fish are biased toward complementarity. The policy implication of this paper can be drawn by focusing on the uncompensated own-price flexibilities. The uncompensated own-price flexibilities of the inverse CBS model showed that the own-price flexibilities of fish, lamb, chicken, and beef are elastic. Thus, public policy that intends to lower the price of fish, lamb, chicken, and beef should strive to increase the available quantity for consumption, which can be accomplished by increasing meat import or supporting domestic meat producers. The beneficiary in this case are consumers since they will be able to purchase meat at lower prices. However, the estimated uncompensated own-price flexibilities of the inverse AIDS model were inelastic. As a result, the beneficiary from increasing the available meat quantity for consumption will be meat producers because they will sell more meat while ensuring modest price decrease, which will eventually increase their revenues.

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