Dynamics Almost Ideal: Demand System Application of Kalman Filter

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Abstract

The demand elasticity for a product is the basis of its price determination. The ratio in which a product demand will fall with the rise in its price and, vice versa, can be known as demand elasticity. With increasing population and increasing demand for meat, it is important to accurately estimate price and income demand elasticities. This paper used almost ideal demand systems (AIDS) with log linear analogue of the Paasche price index, referred to as the corrected Stone index to model consumer demand system. The study employs the Kalman filter estimation strategy, which is based on state-space models that are applied to linear regressions with stochastically time-varying parameters, to determine the evolution of price and income elasticities of red meat and fish demand for monthly data 1997–2017. Variables stationary is tested with Hegy test. Results show that Price elasticity for fish is elastic. Elasticity results indicate that the two products are strong substitutes. Income elasticity indicated that fish considered to be luxury good.

Keywords	***JEL code***
AIDS model, fish, red meat, Kalman Filter	*C22, Q11*

INTRODUCTION

Total of 68 300 tons of red meat were produced in Iran during the first quarter of the current fiscal year 2019 (March 21–June 21) to register a 29% decline compared with the similar period of the year before. The Statistical Center of Iran's latest report shows beef accounted for 37 000 tons or 54.2% of the overall production, indicating a decrease of 31% year-on-year. The production of lamb reached 25 100 tons (down 27% YOY), goat meat 4 700 tons (down 28% YOY) and meat of other types of livestock amounted to 1 500 tons during the three-month period, accounting for 36.7%, 6.8% and 2.3% of the total output, respectively, SCI reported on its website. The Iranians consume around 920 000 tons of red meat per year, 90% of which are supplied from local sources. Imports are made from CIS countries as well as from Brazil and Australia. With rapid population growth and improved per capita income and lifestyle changes resulting from urbanization, it is predicted that there will be further increases in demand

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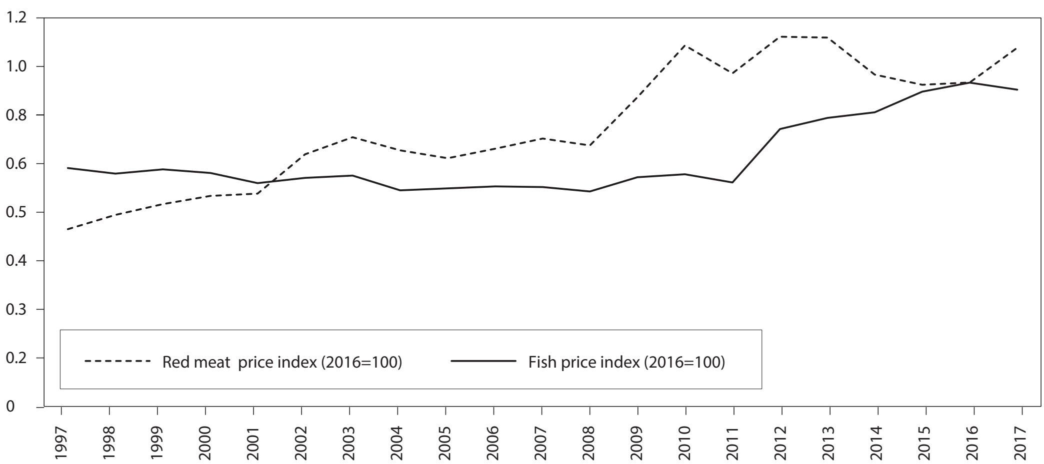
for meat products in the country. Average capital consumption of red meat in developed countries is 27 kg per year while it is about 11 kg in Iran. Average capital consumption of fish in developed countries is 21.6 kg per year while it is about 10 kg in Iran in 2016. According to FAO estimates in 2015, the average per capita consumption of meat in the world was 41.3 kg which is estimated to reach 45.3 kg by 2030 as the world's population grows. Currently in Iran the average per capita consumption of meat is 35.5 kg comprising of 12.5 kg of red meat and 23 kg of poultry meat (faostat.org). High level retail price of these two kinds of products with also low purchase power, are most important causes for low capital consumption and demand. The self-sufficiency level for meat has been declining over the years. Efforts have been made to increase meat production; nevertheless the progress has been slow. Currently, Iran imports about 10–15% of its red meat requirement from various countries to meet local beef demand. Hence, knowing the demand for meat products is thus an important concern for policymakers due to its impact on self-sufficiency, changing food prices, and the nation's trade balance. Therefore, understanding meat demand and its characteristics is important in order to give a more accurate evaluation of the factors that govern consumers' behavior for meat products. Meats are important component of Iranian diet.

Figure 1 shows the increasing but fluctuation trend in the price index of red meat and fish at the retail level in Iran from 1997 to 2017. Red meat price index starts from about 0.6 in 1997 and during the time passes it increased smoothly till 2012. In 2012 red meat price index reached its maximum amount 1.2. In 2015 both red meat and fish price indexes are equal and 0.97 and after that red meat price index again increased but fish price decrease. It is concluded that during the whole period fish price index is lower than red meat price index. Main reasons for high red meat price index are: high cost of animal food and rising cost of inputs, importing live sheets to neighbor's country, some companies which are allocated dollars to import meat, put these dollars in their pockets instead of importing red meats.

Figure 1 Annual price index of red meat and fish in Iran during 1997–2017



Source: Central Bank of Iran (CBI)

This study determined consumer demand for red meat and fish. The growing population and consequent rise in demand for meat has increased the importance of estimating the demand function and significant factors affecting demand. It is crucial to estimate the demand function to identify consumer preferences, develop coherent policies for consumption, and to forecast and plan for future consumer needs.

The results may help policymakers to predict demand and control the prices of these two important products.

However a number of studies have used the dynamic AIDS specification, including Thamae et al. (2015); Nzuma and Sarker (2010); Iootty et al. (2009); Basmann et al. (2009); Barnett and Serlertis (2008); Barnett and Seck (2008); Li et al. (2006); Taljaard et al. (2006); Eakins and Gallagher (2003); Katranidis and Velentzas (2000); Poray et al. (2000); Kremers, Ericsson, Dolado (1992); Goddard and Akiyama (1989); Banerjee et al. (1986); Anderson and Blundell (1983, 1984); and Blancifiorti and Green (1983). Barnett and Kanyama (2013), assesses the ability of the Rotterdam model and of three versions of the almost ideal demand system (AIDS) to recover the time-varying elasticities of a true demand system and to satisfy theoretical regularity. They find that the Rotterdam model performs better than the linear-approximate AIDs at recovering the signs of all the time-varying elasticities. Motallebi and Pendell (2013) present a dynamic form of the almost ideal demand system (AIDS). The static AIDS model was employed to determine the long-run equilibrium model and represents the short-run dynamics by an error correction mechanism. This estimation procedure is applied to estimate three kinds of popular meats (red meat, chicken and fish) demand function in Iran. The estimated elasticities of red meat and chicken are found to be price elastic in the long run. While fish is price inelastic in the long run. Iranian government will remove all indirect and direct goods subsidies. It is suggested that government should be careful about chicken and red meat pricing policy to decreasing malnutrition after subsidy removal. Kilungu et al. (2012), estimate a dynamic version of an almost ideal demand system (AIDS) model for U.S.A. imports of fresh tropical fruits: bananas, pineapples, avocadoes, papayas, mangoes/guavas, grapes and other fresh fruit imports. Estimated income elasticities show that fresh grapes and other fresh fruit imports appear to be considered luxury commodities. All own-price elasticities were negative and significant. While imported bananas, pineapples, U.S.A. grapes and other fresh fruit were quite inelastic, demand for papayas and mangoes/guavas were elastic. Carew et al. (2005) employ a source differentiated almost ideal demand system (AIDS) model with time-varying parameters to estimate the demand for premium quality wines using scanner sales data from the British Columbia wine market. The empirical findings reveal that consumers' response to foreign-produced wines differs from that of wine produced locally. It is evident that the expenditure elasticities for British Columbia, European and Rest-of-the-World white wines are bigger than those for red wines. The high expenditure elasticities associated with British Columbia white wines may suggest that these wines are associated with higher quality. We reject the hypotheses of block separability and product aggregation. There is no evidence of structural change from the tests employed in this paper. Mario Mazzocchi (2003) provides a generalisation of the structural time series version of the Almost Ideal Demand System (AIDS) that allows for time-varying coefficients (TVC/AIDS) in the presence of cross-equation constraints. An empirical appraisal of the TVC/AIDS is made using a dynamic AIDS with trending intercept as the baseline model with a data set from the Italian Household Budget Survey (1986–2001). The assessment is based on four criteria: adherence to theoretical constraints, statistical diagnostics on residuals, forecasting performance and economic meaningfulness. No clear evidence is found for superior performance of the TVC/AIDS, apart from improved short-term forecasts.

1 OBJECTIVE OF THE STUDY

Due to changes in prices of agricultural products, the consumers behave differently against price changes over time so this study focuses on:

- estimation time varying price elasticities of red meat and fish,
- estimation time varying income elasticities of red meat and fish,
- comparison between averages of time varying elasticities with their fixed ones.

1.1 Data

Data on red meat and fish expenditure in Iran were provided by monthly Data from 1997–2017. All of the following data is from the statistical office of the Central Bank of Iran:

- red meat expenditure in Rials using a constant price of 2016 = 100,
- fish expenditure in Rials using a constant price of 2016 = 100,
- red meat and fish price indexes using a constant price of 2016 = 100.

1.2 The full AIDS model

The AIDS model in budget shares is:

$$W_i = \alpha_i + \sum y_{ij} \log P_j + \beta_i \log \left(\frac{X}{P^*}\right), \tag{1}$$

in which, W_i is share of budget that allocate to commodity i from total budget, P_j is the price of commodity j, X is total expenditure and *P** is the price index or price deflator. The loglinear analogue of the Paasche price index, referred to as the corrected stone index, is written as:

$$\log P_t^* = \sum_{i=1}^{n} W_{it} \log \frac{P_{it}}{P_i^0}. \tag{2}$$

In applications, the nonlinearity of the AIDS model is usually viewed as a technical problem to be circumvented by a linearizing approximation to income's price deflator. Deaton and Muellbauer (1980a, 1980b) suggest Stone's price index. The restrictions on the demand functions are deduced from the cost function, using Shephard's duality lemma. The following are the resulting conditions imposed during estimation of the constrained model:

$\sum_{i=1}^{n} \alpha_i = 1$ for adding up, $\sum_{i=1}^{n} y_{ij} = 0$ and $\sum_{i=1}^{n} \beta_i = 0$ for linear Homogeneity, $y_{ij} = y_{ji}$ for symmetry.

1.3 Kalman Filter estimation strategy

The study employs the Kalman (1960, 1963) filter estimation strategy, which is based on state-space models that are applied to linear regressions with stochastically time-varying parameters, to determine the evolution of price and income elasticities of red meat and fish demand. The use of this technique compared to other conventional econometric methods is based on the following advantages. First, this approach is considered an ideal model for estimating regressions with variables whose impact changes over time (Slade, 1989). Second, the Kalman filter is believed to be superior to the least squares models, especially in the presence of parameter instability (Morisson and Pike, 1977). Third, this procedure can be used with non-stationarity data and it is predictive and adaptive (Inglesi-Lotz, 2011). The formal representation of this dynamic model (assuming its parameters are functions of time) is given by the following observation and state equations, respectively:

$$\begin{aligned} x_t &= \alpha(z_t) + [\beta(z_t)]' \varepsilon_t + w_t, \\ \varepsilon_{t+1} &= H(z_t)\varepsilon_t + v_{t+1}, \end{aligned} \tag{3}$$

where α is a constant parameter, β and H are matrices of parameters, x_t is a vector of observations and z_t is a vector of exogenous variables. Furthermore, $\alpha(z_t)$ and $\beta(z_t)$ are vector and matrix valued functions, respectively, and $H(z_t)$ is a matrix with elements that are functions of x_t. A vector of unobserved variables is then given by ε_t while w_t and v_t are the disturbance vectors that are assumed to be independent and white noise. The estimating equations which allow for stochastically time varying parameters:

$$W_{it} = \alpha_i + \sum y_{ijt} \log P_{jt} + \beta_{it} \log \left(\frac{X}{P^*}\right). \tag{4}$$

Above equation is then specified below as a state-space model following the Eviews software notation in order allow for time-varying coefficients:

$$
\begin{aligned}
&@\,signal \quad w_{it} = sv_1 \log P_{it} + sv_2 \log P_{jt} + sv_3 \log(x/p) + [\mathrm{var} = \exp c(1)]\\
&@\,state \quad sv_1 = sv_1(-1)\\
&@\,state \quad sv_2 = sv_2(-1)\\
&@\,state \quad sv_3 = sv_3(-1),\\
&\\
&@\,signal \quad w_{jt} = sv_4 \log P_{it} + sv_5 \log P_{jt} + sv_6 \log(x/p) + [\mathrm{var} = \exp c\,(3)]\\
&@\,state \quad sv_4 = sv_4\,(-1)\\
&@\,state \quad sv_5 = sv_5\,(-1)\\
&@\,state \quad sv_6 = sv_6\,(-1),
\end{aligned}
\tag{5}
$$

where sv_1 $i = 1, ..., 6$ are, the final estimates for price and income elasticity. c_i are the constant parameters of estimation. The evolution of price and income elasticities over time is therefore shown to follow a random walk process. After finding time varying parameters of AIDS system with Kalman state space model, time varying elasticities are calculated using below formulas:

Marshallian price elasticity $\varepsilon_i^M = \dfrac{y_{ij}}{w_i} - \beta_i\,(\dfrac{w_j}{w_i}) - \delta_{ij}$,

where δ_{ij} is the Kronecker delta, defined as: $\delta_{ij} = 1$ if i=j, $\delta_{ij} = 0$ otherwise (Buse, 1996; Barnett and Ousmane, 2007).

Hicks price elasticity $E_{ij} = -\,\delta_{ij} + \dfrac{y_{ij}}{w_i} + w_j$,

Income elasticity $\eta_i = 1 + \dfrac{\beta_i}{w_i}$.

2 ESTIMATION RESULTS

All variables used in this study were time series; so the augmented Dickey-Fuller (ADF) test was used to test the stationarity of variables (Table 1). The ADF unit root test results allowed for acceptance of the null hypothesis of non-stationarity of the red meat price index (p red meat) and the fish price index

Table 1 Result of unit root test (ADF test) for variables

Variable		ADF at level	ADF with one difference
(p red meat)		0.7	–3.1*
(P fish)		–0.6	–3.7*
(x red meat)		–5.4	
(x fish)		–1.6	–3.7*
X/P		–1.3	–10
	1%	–3.6	–4.3
Critical value	5%	–2.9	–3.7
	10%	–2.6	–3.2

Note: * indicate significance at the 5% level.
Source: Research finding

Table 2 Result of Hegy unit root test for variables

Variable	Null hyphotesis	Test statistic	Simulated P-value
LOG(PR)	Non seasonal unit root (zero frequency)	−0.659314	0.882998
	Seasonal unit root (2 months per cycle)	−2.773849	0.111750
	Seasonal unit root (4 months per cycle)	15.25249	0.000000
	Seasonal unit root (2.4 months per cycle)	12.16319	0.000000
	Seasonal unit root (12 months per cycle)	11.52706	0.000000
	Seasonal unit root (3 months per cycle)	8.850001	0.000000
	Seasonal unit root (6 months per cycle)	12.07574	0.000000
LOG(PF)	Non seasonal unit root (zero frequency)	−2.035364	0.541567
	Seasonal unit root (2 months per cycle)	−3.415713	0.054486
	Seasonal unit root (4 months per cycle)	12.14653	0.000000
	Seasonal unit root (2.4 months per cycle)	16.78231	0.000000
	Seasonal unit root (12 months per cycle)	10.78571	0.000000
	Seasonal unit root (3 months per cycle)	17.17169	0.000000
	Seasonal unit root (6 months per cycle)	13.90648	0.000000
LOG(WR)	Non seasonal unit root (zero frequency)	−3.311438	0.162262
	Seasonal unit root (2 months per cycle)	−4.668780	0.054486
	Seasonal unit root (4 months per cycle)	30.03822	0.000000
	Seasonal unit root (2.4 months per cycle)	24.70168	0.000000
	Seasonal unit root (12 months per cycle)	26.59229	0.000000
	Seasonal unit root (3 months per cycle)	32.25468	0.000000
	Seasonal unit root (6 months per cycle)	26.77380	0.000000
LOG(WF)	Non seasonal unit root (zero frequency)	−3.039070	0.209804
	Seasonal unit root (2 months per cycle)	−6.821745	0.054486
	Seasonal unit root (4 months per cycle)	46.13639	0.000000
	Seasonal unit root (2.4 months per cycle)	46.00186	0.000000
	Seasonal unit root (12 months per cycle)	46.82536	0.000000
	Seasonal unit root (3 months per cycle)	46.04062	0.000000
	Seasonal unit root (6 months per cycle)	46.36882	0.000000
LOG(WP)	Non seasonal unit root (zero frequency)	1.437834	1.000000
	Seasonal unit root (2 months per cycle)	−0.971411	0.789852
	Seasonal unit root (4 months per cycle)	4.457963	0.077572
	Seasonal unit root (2.4 months per cycle)	30.70673	0.000000
	Seasonal unit root (12 months per cycle)	6.421286	0.021544
	Seasonal unit root (3 months per cycle)	12.15545	0.000000
	Seasonal unit root (6 months per cycle)	4.341545	0.069994

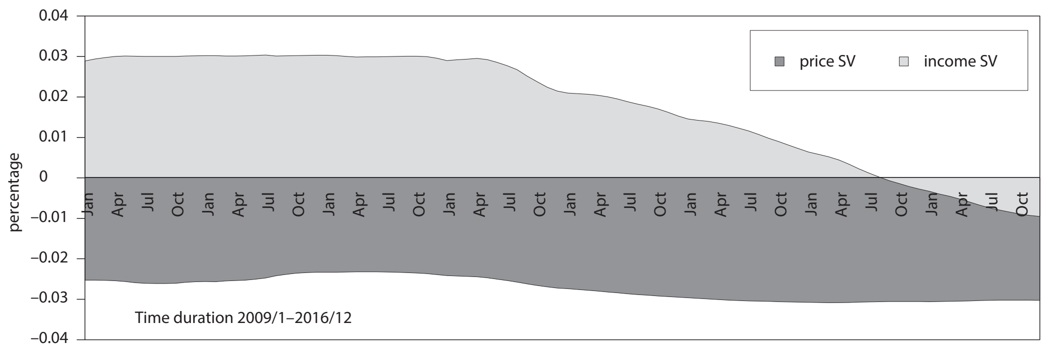
Source: Research finding

Table 3 Kalman state space model

Intercept	Estimated coefficient	Prob statistic
C(1)	0.06	00
C(2)	–147	00
Red meat share expenditure equation	Final state	P value
Sv1(red meat price coefficient)	–0.03*	00
Sv2(fish price coefficient)	–0.001	00
Sv3(income coefficient)	0.001*	00
Fish share expenditure equation	Final state	P value
Sv4(fish price coefficient)	0.00006	00
Sv5(red meat price coefficient)	–0.00002	00
Sv6(income coefficient)	0.000007*	00

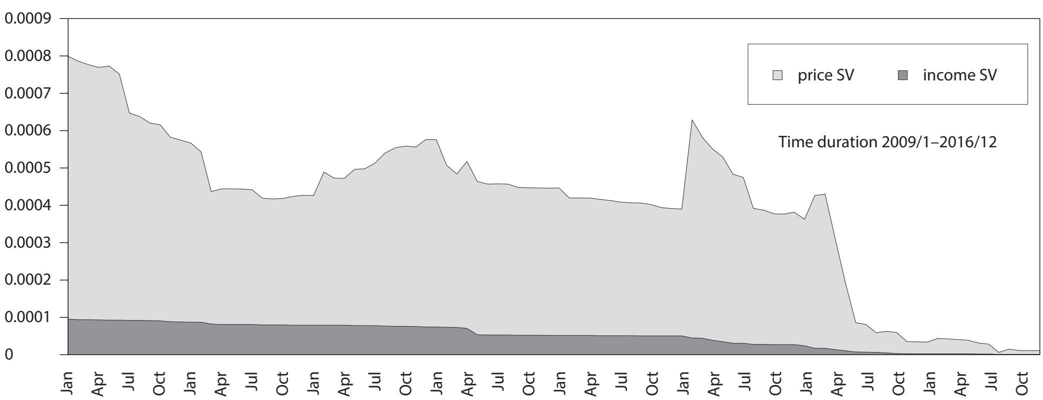
Note: * indicate significance at the 5% level.
Source: Research finding

Figure 2 Trends of red meat price and income states



Source: Research findings

Figure 3 Trends of fish price and income states



Source: Research findings

Table 4 Marshalian price elasticity and income elasticity

Income elasticity	Fish	Red meat	Product
Red meat	–0.03* (–0.9*)	0.01 (0.13*)	–0.017*
Fish	1.12* (1.15*)	–2.51* (-0.3*)	1.34*

Notes: Compensated elasticities in parenthesis (). * indicate significance at the 1% level.
Source: Research finding

(p fish). The two indexes were non-stationary at level, but they were stationary after the first difference. Red meat expenditure (x red meat) was stationary at level. Results of Hegy test also show that all variables in logarithm form are stationary.

For linearized AIDS model, Paasche, price index was used. Table 3 displays the results from the Kalman filter estimation technique. Table 4 shows the final (average) estimates for price and income elasticities being significant and having the values of –0.113 (–0.155) and 1.009 (1.797), respectively. These show that, on average, increases (decreases) in real red meat prices have resulted in less than proportionate fall (rise) in red meat consumption, implying that the demand is price inelastic (in agreement with Zeranezhad and Saadatmehr, 2007 results). However, if the real red meat prices become too high over time, consumers might change their behavior and sensitivity to price and hence, policymakers will need to reconsider their impact in the long-run. The increase in the coefficient of disposable income in the red meat equation (budget coefficient or X/P) increased red meat share expenditure. In both budget share equations, red meat and fish were regarded as substitutes, as indicated by the positive cross-price coefficients. The cross-price coefficient of red meat equation was positive and significant; a 1% increase in the fish price index increased the red meat budget share 0.02%. A negative and significant own-price coefficient was found for red meat and fish in AIDS, which satisfies the law of demand. Since the income elasticity of fish was more than unity, fish is considered a luxury and elastic good.

DISCUSSION AND CONCLUSION

The aim of this paper was to evaluate the ability of the AIDS to recover time varying elasticities. A structural time series model was specified for red meat and fish demand specification and the time varying elasticities estimated using Kalman filter. Results of Hegy unit root test shows that, logarithm of all variables include price indexes and expenditures for both red meat and fish are stationary. Results also show that state space coefficient in both red meat and fish equations are significant and in accordance with theory. Red meat price elasticity is –0.03 and significant. Negative price elasticities of these two products indicate, as their prices increased, expenditure on them decreased. Since fish is elastic, an increase in price led to a larger-than-proportional decrease in value demanded and a decrease in sales revenue. A decrease in income does not result in uniform changes in expenditure for all goods. Expenditure on fish decreased in a proportionately larger amount than any other demand; this may have been the result of fish being considered a luxury good. An increase in the price of fish, increased the consumption of red meat because they were substitutes for one another.

Successive drought, conflicting trade policies, the absence of subsidies for inputs, and lack of government support for producers has raised the price of inputs. This has led to increases in the price of products. Red meat and fish prices have grown sharply, which has decreased per capita consumption of these products. This has led to insufficient consumption of protein to maintain nutritional health. Also, the increase in population and subsequent rise in demand for meat has emphasized the importance of estimating the demand function and significant factors affecting demand. Demand function identifies consumer preferences and helps to develop coherent policies on consumption, forecast future consumer needs, and plan for the future.

Since red meat and fish are elastic goods, to modify consumption patterns, the price tool can be recommended as effective. In addition, government policies such as decreasing subsidies should be carefully considered because it has resulted in unacceptably high prices for red meat and fish. The results of this study may help policymakers to predict demand and to control the prices of these two important products.

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