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PCAIDS and Growth Index Demand Modelling for Imported Cod Products in Portugal

'Special Issue – Fisheries and Aquaculture'

Frank Asche
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'Special Issue – Fisheries and Aquaculture'

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Abstract

The demand function represents the fundamental building block in economics and provides important information for investment and policy purposes. The aim of this paper is to characterize and measure the demand structure for imported cod products to Portugal. A PCAIDS model is used to identify and measure own- and cross-price elasticities of demand for frozen, salted and salted & dried cod products. The calculated elasticities of demand are then used in combination with a demand growth index model to measure shifts in demand impacting price of product. Controlling for supply shocks the growth index shows over the period a positive growth in demand for frozen product but a negative change in demand growth for salted, and to a lesser degree, for salted & dried products. The results are used in simulating alternative price demand scenarios.

Key words
Imported Cod Products, Demand Characteristics, PCAIDS, Market Growth, Portugal

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Introduction

The purpose of this paper is to identify and measure demand characteristics for imported cod products in Portugal. Portugal has a long history of fishing cod, primarily as a distant-water fishing nation. However, the introduction in 1977 of the exclusive economic zone (EEZ) imposed by many coastal states reduced drastically the cod harvest by the Portuguese fleet and increased Portuguese imports of cod products (Bjørndal *et al.* 2015a). Portugal imports cod from many countries primarily in three forms; frozen, salted and salted & dried (klippfisk) but consumption of cod is primarily as a salted & dried product (bacalhau) (Asche *et al.* 2007).

Norway is the major producer and exporter of salted & dried cod, but Portugal also produces of its own salted & dried cod based on imported frozen or salted cod.[1] The Portuguese industry has developed a number of new sources of raw material since its distant water fishing operations for cod were terminated. It started by importing (wet) salted cod for drying in Portugal, but has increasingly turned to frozen cod and also expanded the sourcing from Atlantic cod to also include Pacific cod, and also re-exports from China.

In this paper, the interest is twofold; first, in measuring demand characteristics (own elasticities and cross price elasticities) for imported frozen, salted and salted & dried cod and, second in measuring shifts or growth in demand for imported product. The price elasticity of demand will provide a measure of how sensitive import demand is to changes in own-price, whereas the cross-price elasticity of demand will allow a measure of how sensitive import demand is to changes in price of other imported cod products and as such, how the expanded sourcing increase Portuguese flexibility in obtaining salted and dried cod. Once price and income changes are accounted for, additional movements or shifts in the demand function are a measure of the growth in market demand for imported cod products. This growth has been

[1] See Bjørndal *et al.* 2015b for a descriptive study of the Portuguese fish processing industry.

shown to be very strong in the farmed salmon market (Asche *et al*. 2011, Brækkan and Tyholdt 2014, and Brækkan 2014) and Tveteras *et al.* (2012) show that prices for wild seafood have been increasing relative to prices for farmed seafood. In a world with stagnating catches and rapid product development it is of interest to investigate to what extent demand growth is present in a strong traditional market like that for salted and dried cod in Portugal.

It is common in economics to measure elasticities based on the Almost Ideal Demand System (AIDS) modelling framework[2] of Deaton and Muellbauer (1980). The AIDS model can incorporate the theoretical properties of the demand structure within the estimated model. To estimate a full and exhaustive AIDS model requires information on quantity, price and expenditure on all products within the market structure of interest. The data available here for analysis provides information only on quantity and price of codfish products exported to Portugal. For this paper, a version of the Proportionally Calibrated Almost Ideal Demand System (PCAIDS) model as developed by Epstein and Rubinfeld (2002, 2004) is used. The PCAIDS model maintains much of the economic structure of the AIDS model and is designed and developed as a calibrated simulated model used to recover demand elasticities. Coloma (2006) shows regression procedures using incomplete data to provide initial estimates for calibration of the PCAIDS model. We follow the Coloma procedure in this paper.

Marsh (2003) shows a straightforward technique for measuring growth in market demand using an index approach. The technique is a decomposition of a change in quantity demanded between the percentage change accounted by a price change along (i.e., a movement allow the demand curve) and the percentage change accounted by a shift in the demand curve. Asche *et al.* (2011), Brækkan (2014) and Brækkan and Tyholdt (2014) provide applications of the technique for demand growth for Atlantic salmon.

[2] See Sjöberg (2015), Huang (2015), Xie *et al.* 2008, Wellman (1992) for examples of demand modelling in the fishery.

The paper is organized as follows. The next section describes the data available for analysis and reports summary statistics to identify and characterize the Portuguese market for imported cod. This is followed by a brief description of the PCAIDS and market demand index models used to measure elasticities and import demand growth. Empirical results are also reported. The final section offers discussion.

Data and Summary Statistics

The data available for investigation are obtained from Eurostat and provided by the Norwegian Seafood Council[3] and covers all countries' monthly exports of frozen, salted & dried and salted cod to Portugal for the period 1990-2013. For summary presentation the data are presented annually. Cod is harvested and processed in only a few countries, but cod products can pass through many countries on the way to Portugal. The transportation and transaction for cod products depends on costs, taxes and European export/import regulations. To show how the assigned country of origin has changed over the period of analysis, Table 1 reports the country of origin share for cod product exports to Portugal for major suppliers, select years 1990-2013. For frozen cod, tremendous changes and variation are observed over time. The most remarkable change is the Netherlands with a market share of 0.0 in 2000 and 0.494 in 2013. This is due to the role of the Netherlands as a hub in international cod trade: cod from many countries in the North Atlantic and North Pacific is shipped to the Netherlands for further distribution to other markets. For salted & dried cod, the reduced market share in recent years for Norway is striking. This is due to the fact that substantial amounts of product are shipped to Sweden, an EU member, so as to reduce duty (Bjørndal and Ellingsen 2015). A similar development can be observed for salted cod.

[3] We thank Kristin Lien for providing data.

Table 1: Assigned Country of Origin; Share of Cod Products

	1990	1995	2000	2005	2010	2013
			Frozen			
Netherlands	0.0	0.008	0.0	0.015	0.224	0.494
Russia	0.0	0.526	0.511	0.408	0.135	0.075
Spain	0.149	0.101	0.02	0.115	0.188	0.208
US	0.414	0.044	0.22	0.287	0.322	0.101
			Salted & Dried			
Denmark	0.217	0.388	0.075	0.155	0.021	0.149
Norway	0.427	0.432	0.662	0.218	0.017	0.012
Spain	0.232	0.108	0.171	0.072	0.041	0.081
Sweden	0.0	0.0	0.01	0.379	0.792	0.623
			Salted			
Iceland	0.231	0.130	0.482	0.172	0.069	0.048
Netherlands	0.041	0.005	0.008	0.134	0.224	0.262
Norway	0.159	0.626	0.195	0.051	0.001	0.003
Sweden	0.0	0.0	0.0	0.085	0.449	0.471

Figure 1 shows annual quantity (tonnes) imports of frozen, salted & dried and salted cod.[4] The figure shows different patterns of development for each of the three products. On the one hand, both frozen and salted & dried show a general increase over the period but frozen product shows considerable variation over time starting from a very low level of only 7,000 tonnes in 1990 to a high of 55,000 tonnes in 2006, then dropping to under 40,000 tonnes in 2011 to increase again to about 50,000 tonnes in 2013. Salted & dried cod shows a very stable import path from 1990 to the mid-2000s, however, for the period 2006-08 imports fall by about 9,000 tonnes to rise again to over 30,000 tonnes by 2013. On the other hand, salted product shows a serious and steady decline in imports from a high of 66,000 tonnes in 1996 to less than half this quantity (24,000 (t)) in 2013.

[4] Portugal also imports other cod products (fresh fillet, fresh whole, frozen fillet, frozen fish meat) that accounts for about a 3% share of the total imported cod market.

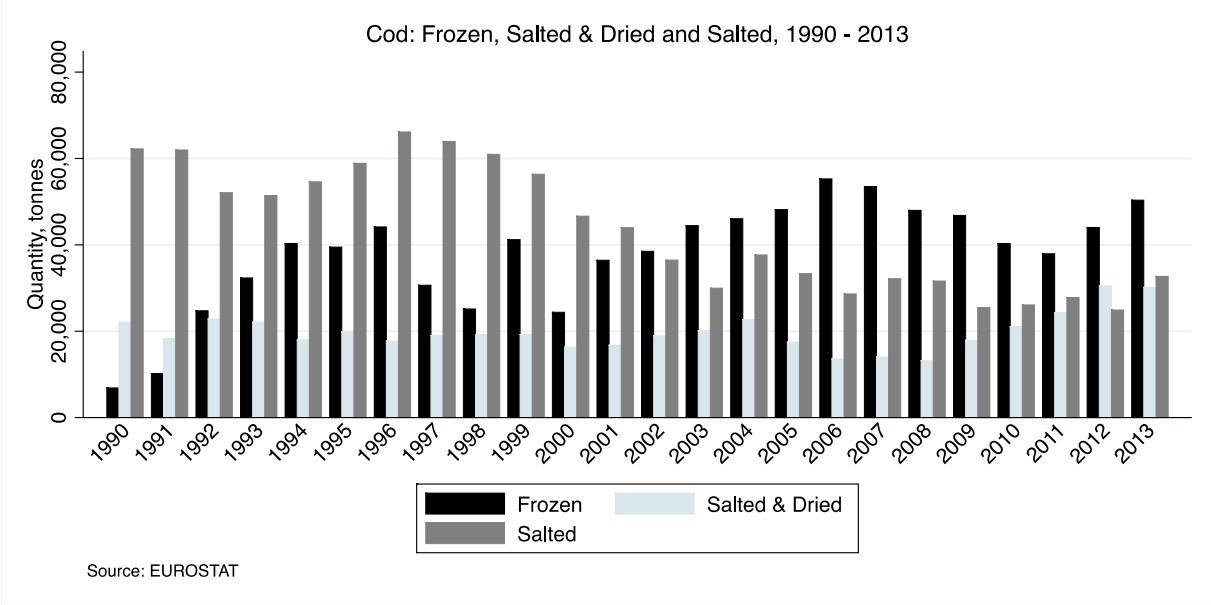

Figure 1: Total Imports of Cod Products Portugal: 1990-2013

Figure 2 reports real revenue[5] received by export suppliers for frozen, salted & dried and salted cod product, respectively over the reporting period. Revenue from frozen product does not follow the upward trend of frozen cod import. We do observe revenue increasing up to the end of the 2008, reaching a high of 195 million € in 2007 but thereafter a drastic fall in revenue for the period 2009-13 that averages only 100 million € per year. Real revenue value for salted & dried product actually fell in the early 1990s from over 200 million € in 1990 to just over 100 million € in 1997. As observed for the rest of the period through to 2013, there is some variation in revenue averaging somewhat less than 150 million €, particularly 2006-2009. The real revenue value of salted cod has declined over the period in line with the downward trend in imported salted cod. We observe a high of over 430 million € in 1991 to just over 100 million € in 2009. The reduction in 2009 can be attributed to the financial crisis that had a major impact on the Portuguese economy (Bjørndal *et al.* 2015). Of course, the link

[5] Prior to 1999 Eurostat uses a normalization or conversation ratio for Portuguese Escudo/Euro to define a virtual Euro.

between quantity and revenue is price and we now move on to represent the real price of cod imports.

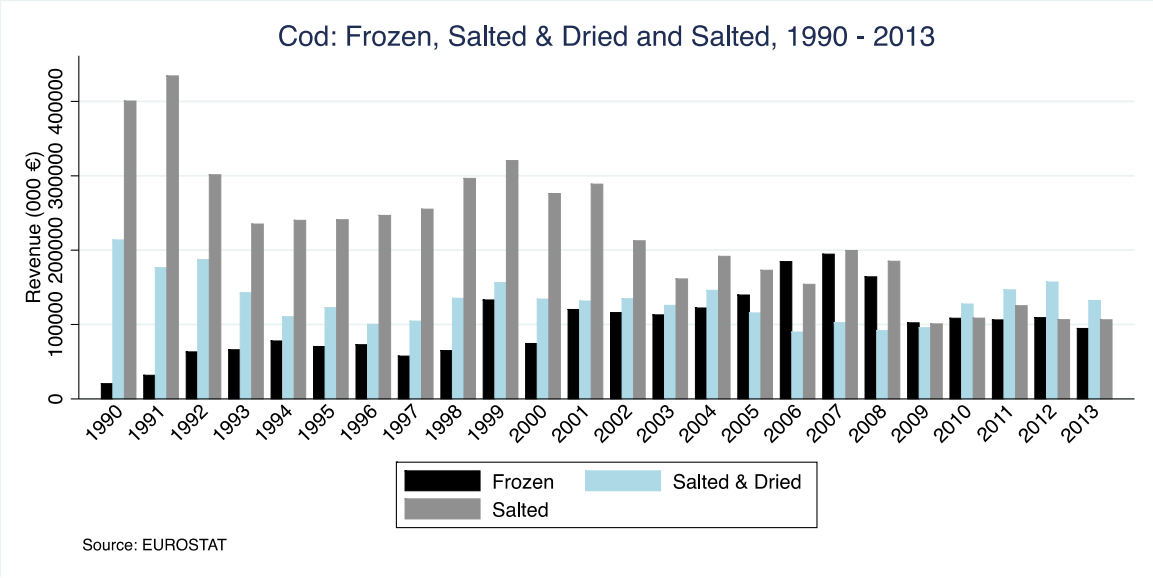

Figure 2: Real Value (000 €) Cod Product Portugal: 1990-2013

Figure 3 graphs the real price for frozen, salted & dried and salted imported cod. Over the period salted & dried receives the highest price per kg with salted receiving a premium over the low-priced frozen product. As shown by Asche, Menezes and Dias (2007) this is primarily due to differences in water content of the three product forms (and, of course, processing costs). Over the period 1990 to 2013 the import prices trend togther very closely with an average price difference of 1.7 € per kg for salted & dried and salted product and 2.5 € per kg for salted and frozen product. Notice the sharp drop in all prices in 2008 due to the recession.[6] Keep in mind that salted & dried is a final product whereas frozen and salted must be processed before final sale. The figure compares prices at different levels in the market demand structure and thus the differences in prices also reflect the degree of processing. Nevertheless, the price realizations show that the markets for these three products are closely linked.

[6] See Verick and Islam 2010.

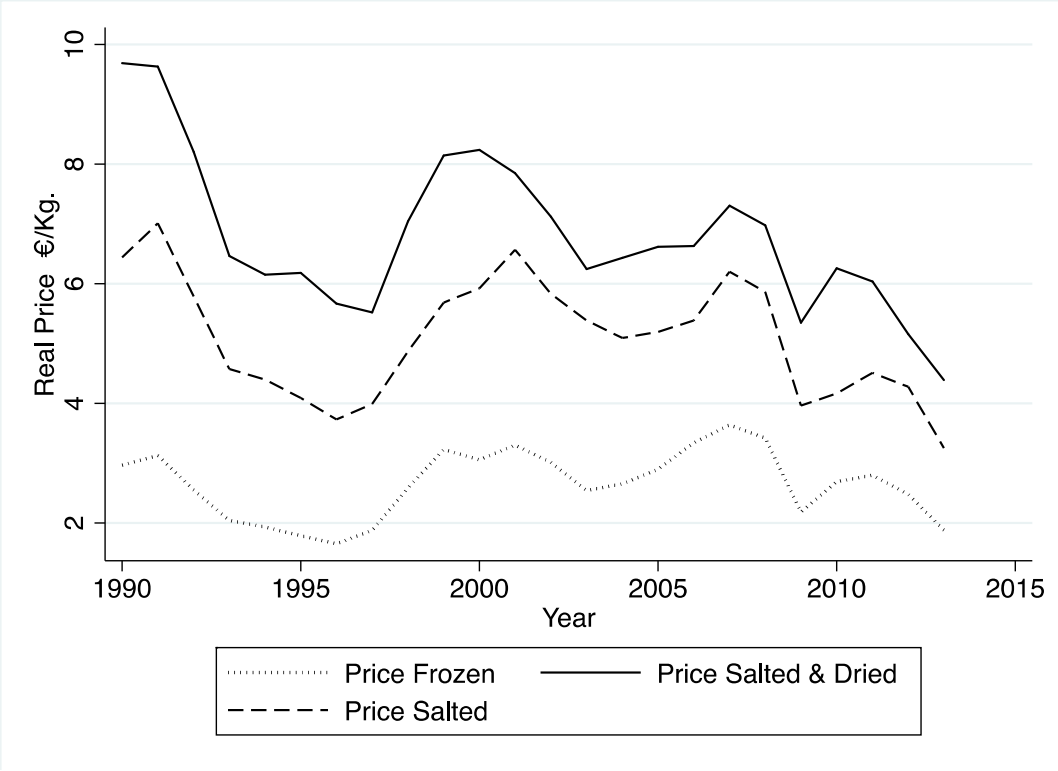

Figure 3: Average Annual Real Price: Frozen, Salted & Dried, Salted Cod Imports Portugal

It is worthwhile to look more closely at China and the development of the Chinese export trade in frozen, salted & dried and salted cod product to Portugal.[7] China did not enter the Portuguese cod market until the mid 1990s and even then it was a sporadic participant up to the mid 2000s. Table 2 reports for selected years the quantity and real value share of Chinese exports of frozen, salted & dried and salted cod to Portugal. Notice that in 2005 China was a very minor player in all three product forms but by 2013 China had captured over 10% of the salted market and over 1% of the salted & dried market. In terms of quantity supplied, in 2013 China was exporting 82 tonnes of frozen product, 326 tonnes salted & dried product and 3,092 tonnes salted product to Portugal. The market share for frozen is

[7] China has shown similar developments in white fish markets (Asche and Zang 2013).

negligible.[8] This makes sense, as China does not have its own cod fishery so that any export would be transshipments from the North Atlantic or North Pacific.

Table 2: Chinese Quantity and Value Share for Salted & Dried and Salted Cod Imports to Portugal: Selected Years. Percentage of Market

Cod Product		2005	2010	2013
Salted & dried	Quantity	2.43	3.78	1.08
	Value	1.50	2.17	0.97
Salted	Quantity	1.83	5.69	9.45
	Value	1.54	5.21	10.60

a) Quantity share of Portuguese market
b) Value share of Portuguese market

For estimation data are available monthly from January 1990 to December 2013, for a total of 288 observations. All prices are in real 2010 Euros. Real GDP[9] is collected from OECD Quarterly National Accounts (expenditure approach) and used to proxy aggregate income. GDP is available quarterly[10] and a cubic spline function[11] is used to interpolate to a monthly frequency (Gordon 2016). Finally, and in anticipation of the aggregate demand equation, an aggregate quantity (Q_t) and price index (P_{avg}) of the three cod products are calculated monthly using a Cobb-Douglas aggregator function with volume shares as weights.

PCAIDS Model

In this section, the goal is to statistically characterize the import demand structure for cod in Portugal. A popular empirical procedure for evaluating demand possibilities and calculating elasticities is the AIDS model introduced by Deaton and Muellbauer (1980). The AIDS model

[8] China has made gains in both the salted & dried and salted Portuguese market but the data does not allow us to identify whom if any supplier has lost market share.
[9] GDP in 2010 US dollars.
[10] https://stats.oecd.org/index.aspx?queryid=350
[11] Cubic splines are piecewise continuous, and first and second derivatives are continuous at the nodes.

is a flexible procedure that satisfies a number of theoretical properties in conventional demand analysis. Consider an AIDS representation of a market characterized by *n* products written as a linear approximation:

$$S_f = a_{f0} + a_{ff} \cdot lnP_f + a_{fk} \cdot lnP_k + a_{fs} \cdot lnP_s + \cdots + \alpha_{fn} \cdot lnP_n + a_{fE}\ln(E/P)$$

$$S_k = a_{k0} + a_{kf} \cdot lnP_f + a_{kk} \cdot lnP_k + a_{ks} \cdot lnP_s + \cdots + \alpha_{kn} \cdot lnP_n + a_{kE}\ln(E/P) \qquad (1)$$

$$S_s = a_{s0} + a_{sf} \cdot lnP_f + a_{sk} \cdot lnP_k + a_{ss} \cdot lnP_s + \cdots + \alpha_{sn} \cdot lnP_n + \alpha_{sE}\ln(E/P)$$

$$S_n = a_{n0} + a_{nf} \cdot lnP_f + a_{nk} \cdot lnP_k + a_{ns} \cdot lnP_s + \cdots + \alpha_{nn} \cdot lnP_n + \alpha_{nE}\ln(E/P)$$

where S_i represents the share of the i^{th} product in total market expenditures over all *n* products, P_i represents the i^{th} price assumed exogenous to the model, *E* represents expenditure and *P* is an aggregate price index[12]. For estimation additive error terms are appended to each equation and *n*-1 equations are estimated due to the singular nature of the system.[13]

To maintain theoretical consistency, the system of equations must satisfy a number of regularity conditions: Adding up, homogeneity and Slutsky symmetry.[14] With these conditions satisfied the system of equations represents the economic structure of the complete product market. Moreover, what is important for demand analysis is that the estimated a_{ij} coefficients in the system (call it the 'AIDS A' matrix) have a correspondence to the demand elasticities that characterize the market structure. Coloma (2006) writes this correspondence as,

$$\eta_{ii} = -1 + \frac{a_{ii}}{S_i} + S_i \cdot (\eta + 1) \qquad (2)$$

$$\eta_{ij} = \frac{a_{ij}}{S_i} + S_j \cdot (\eta + 1)$$

[12] Deaton and Muellbauer 1980 write the price index as $lnP = \alpha_o + \sum \alpha_k lnP_k + \frac{1}{2}\sum_k \sum_l \gamma_{kl} lnP_k lnP_l$.

[13] The estimated parameters are invariant to the equation deleted and the parameters in the deleted equation are recovered using the Adding-up condition.

[14] Deaton and Muellbauer 1980, pp.75-78.

Here η_{ii} is the own-demand elasticity for each product, η is the aggregate demand elasticity for the product market and η_{ij} is the cross-price elasticity.

If data are available then the consistent and efficient procedure for empirical work is to characterize the structure of demand by estimating the full system of equations defined by equation (1). However, as is often the case, the data for a complete description of the market is not available. In cases with limited data or data for only a subset of the total product market, Epstein and Rubinfeld (2002 and 2004) suggest a simulation approach based on the assumption of 'proportionally consistent market shares' or PCAIDS model. What this means is that under a price change for one product, demand shifts towards other products in the defined sub-market according to relative market shares. Epstein and Rubinfeld (2002) prove that based on the proportionally consistent market shares assumption the PCAIDS model has many of the ideal theoretical properties of the full AIDS model and what is most important the following conditions hold,

$$a_{jj} = \frac{S_j \cdot (1 - S_j)}{S_i \cdot (1 - S_i)} \cdot a_{ii} \qquad (3)$$

$$a_{ij} = \frac{-S_i}{1 - S_j} \cdot a_{jj}$$

In words, if we are able to obtain an estimate of a_{ii} (call it the PCAIDS prime coefficient) then based on equation (3) the complete 'AIDS A' matrix can be recovered using only the one initial value of a_{ii}. In addition, if an estimate of the aggregate market demand elasticity, η, is available then using equation (2) a full elasticity description of the market can be calculated.[15]

In order to apply the PCAIDS model two conditions are required; first, is the assumption of proportionally consistent market shares, and second, the availability of initial estimates of both the prime coefficient a_{ii} and aggregate demand elasticity η. For the former, Epstein and Rubinfeld (2002) suggest that the PCAIDS assumption is robust to some

[15] Epstein and Rubinfeld (2002) use estimates of a_{ii} and η obtained from the published demand literature.

variation in the proportionally consistent assumption and for empirical work here we maintain this assumption. For the latter, Coloma (2006) shows a regression procedure based on data for only a sub-component of the market to obtain initial estimates of the prime parameter. For the case at hand, we do have data information for the import cod market (frozen whole, dried & salted, and salted cod imports), so the system of equations available can be written as:

$$\begin{aligned} S_f &= a_{f0} + a_{ff} \cdot lnP_f + a_{fk} \cdot lnP_k + a_{fs} \cdot lnP_s + a_{fI} I \\ S_k &= a_{k0} + a_{kf} \cdot lnP_f + a_{kk} \cdot lnP_k + a_{ks} \cdot lnP_s + a_{kI} I \\ S_s &= a_{s0} + a_{sf} \cdot lnP_f + a_{sk} \cdot lnP_k + a_{ss} \cdot lnP_s + a_{sI} I \end{aligned} \qquad (4)$$

where subscript *i* defines *f*-frozen, *k*-salted & dried, *s*-salted, and *I* is defined by real GDP. Note that for the sub-component PCAIDS model the shares S_i are defined to sum to one for the three products considered.[16] In estimation, a homogeneity assumption is imposed on the cross-price and own-price coefficients as suggested by Coloma (2006) or $a_{ii} = -\sum_{i \neq j} a_{ij}$. The PCAIDS 'A matrix' coefficients that we want to recover using equation (3) are defined in Table 3. Notice that each coefficient in the PCAIDS 'A matrix" is a function of market share and the prime coefficient a_{ff}.

Table 3: Coefficients for PCAIDS 'A Matrix'

	Frozen	Salted & Dried	Salted
Frozen	a_{ff}	$\frac{-S_k}{1-S_f} \cdot a_{ff}$	$\frac{-S_s}{1-S_f} \cdot a_{ff}$
Salted & dried	$\frac{-S_k}{1-S_f} \cdot a_{ff}$	$\frac{S_k \cdot (1-S_k)}{S_f \cdot (1-S_f)} \cdot a_{ff}$	$\frac{-S_k \cdot S_s}{S_f \cdot (1-S_f)} \cdot a_{ff}$
Salted	$\frac{-S_s}{1-S_f} \cdot a_{ff}$	$\frac{-S_s \cdot S_k}{S_f \cdot (1-S_f)} \cdot a_{ff}$	$\frac{S_s \cdot (1-S_s)}{S_f \cdot (1-S_f)} \cdot a_{ff}$

[16] On average for 1990-2013 market share is frozen (24%), salted & dried (31%), and salted (45%).

Coloma (2006) shows that given market share and prices for a subcomponent of the market an estimate of the prime coefficient, a_{ff} can be obtained using a transformation of market share, the log of each price relative to a reference price and a measure of income as:

$$\frac{S_f \cdot (1-S_f)}{S_s} = c_f + a_{ff} \cdot ln\left\{\frac{P_f}{P_s}\right\} + c_{fI} \cdot \ln(I) + \varepsilon_f$$

$$\frac{S_k \cdot (1-S_k)}{S_s} = c_k + a_{ff} \cdot ln\left\{\frac{P_k}{P_s}\right\} + c_{fI} \cdot \ln(I) + \varepsilon_k \qquad (5)$$

where ε_j are additive error terms. The price and share of salted imported cod product is defined as the reference product. The equations are estimated as a system with cross equation constraints on a_{ff}. A consistent estimate of a_{ff} is achieved if $E(\varepsilon_j | \ln\left\{\frac{P_j}{P_s}\right\}, \ln(I)) = 0$, or, in other words, the right-hand-side variables must not be correlated with the error term. This seems reasonable, as cod is part of a well-integrated international white fish market with Portugal a price taker in this market, and imported cod a small component of total GDP (Gordon and Hannesson 1996, and Asche *et al.* 2002).

The market demand function in log form is defined over aggregate quantity (Q_t), price (P_{avg}) and income (I) written in standard form as:

$$\ln Q_t = a + \eta \cdot \ln P_{avg} + c_I \ln I + \varepsilon_Q \qquad (6)$$

Equations (5) and (6) are estimated as a system using the non-linear seemingly unrelated regression (nlsur)[17] routine in Stata (12).[18] Econometrically the sample regression equations are specified directly from the underlying theoretical model but, nevertheless, a number of robustness checks are carried out to observe parameter stability.[19] In general, the data fit the models reasonably well and coefficients are robust to alternative model specifications. Table 4

[17] The nlsur routine is used because of ease of imposing cross-equation constraints and obtaining maximum likelihood parameter estimates.

[18] Quarterly dummy variables are used in estimation to account for seasonality and EU import regulations that are enforced over the course of the year. This addition had no practical impact on the value of the primary coefficient but does improve efficiency.

[19] Appendix A1 reports alternative elasticity results under different estimation routines and robustness checks using alternative values of the aggregate demand parameter.

reports the final estimated results for the PCAIDS prime coefficient, a_{ff} and aggregate demand elasticity[20], η. Both coefficients are estimated to be statistically valid and have the expected signs and magnitudes. Based on these estimates and using equation (2) the PCAIDS full set of own- and cross-price elasticities are reported in Table 5.

Table 4: PCAIDS prime coefficient and Aggregate Demand elasticity

	Coefficient	Std. Err.	p-value
a_{ff}	-0.134	0.041	0.001
η	-0.273	0.080	0.001
Obs.	288		

Table 5: Elasticities based on PCAIDS and Aggregate Demand Models

	Frozen	Salted & Dried	Salted
Frozen	-1.387[a)]	0.356	0.515
	(0.173)[b)]	(0.039)	(0.058)
Salted & Dried	0.356	-1.283	0.515
	(0.039)	(0.157)	(0.058)
Salted	0.515	0.515	-1.079
	(0.058)	(0.058)	(0.125)

[a)] Calculated at Mean
[b)] Standard Error

Individual own-price elasticities reported on the diagonal of Table 5 show an elastic response to own-price change for all three import commodities.[21] For example and to be clear on interpretation a 1% change in the price of salted & dried product cause a 1.3% decrease in own-demand but a 0.36% and a 0.52% increase in the demand for frozen and salted product, respectively. Recall that the elasticities reflect the main assumption of the PCAIDS model that change is proportional to relative market share. The cross-price elasticities are statistically important and show substantial flexibility across the different product forms. Based on these

[20] Bjørndal *et al*. (2015) provide a descriptive analysis of Portuguese economic development and particularly the importance of the fishery sector. This work provides antidotal support for the estimated inelastic aggregate demand elasticity for imported cod products reported here.
[21] Table 5 reports average elasticity measures over the period but the associated standard error offers a range of possible values of this important parameter.

elasticity estimates the next section will investigate the growth in demand for the three main cod import product forms.

Demand Growth Index

Marsh (2003) outlines a technique for building a retail demand index for a food (beef) commodity. The index is a measure of the shift in demand caused by changes in income, price of substitutes, preferences, etc. The index does not identify or measure individual shift factors but rather the index can be viewed as a measure of gross change in demand controlling for supply side price effects. To be clear, the index allows for shifts in supply and demand, and compares actual price to the counterfactual price from a change in supply alone holding all other demand factors constant, i.e. the price change from a movement along the demand curve. Asche *et al.* (2011) argue that this gross measure of growth in demand provides very useful industry information for planning and investment purposes. Asche *et al.* (2011), Brækkan (2014) and Brækkan and Tyholdt (2014) provide applications of the technique for Atlantic salmon and show demand growth to be substantial. In this section, we will apply the index to the demand for imported frozen, salted & dried and salted cod to Portugal. This is of interest in learning more about demand and growth development of a traditional seafood product particularly given that aggregate seafood trade is rapidly increasing (Asche *et al.* 2015) and aquaculture is becoming increasingly more important (Smith *et al.* 2010).

The index is straightforward in that it measures the difference between what the product price would be in the absence of any shift in demand (i.e., the counterfactual price allowing for only the supply shock) and the actual reported price. The difference in these prices represents the growth index. The index will measure demand shifts from one period to the next and adding the index to a base period over time will provide a time series measure of growth in import demand relative to the base period.

There are four steps to building the index[22]; first, calculate the percentage change in quantity from one period to the next or;

$$\%\Delta Q_i = \frac{Q_{it} - Q_{it-1}}{Q_{it-1}} \quad (7)$$

Second, calculate the percentage change in price from one period to the next holding demand constant at the own-price elasticity for the product η_{ii} i.e. a change in price along the demand curve or:

$$\%\Delta P_i = \frac{\%\Delta Q_i}{\eta_{ii}} \quad (8)$$

Third, calculate the counterfactual price not allowing a shift in demand (the change in quantity is entirely a supply side effect) or;

$$P_i^{CF} = P_{it-1} + P_{it-1} \cdot \%\Delta P_i \quad (9)$$

Finally, calculate the demand index as the percent difference between actual price and the counterfactual price or:

$$\frac{P_{it} - P_i^{cf}}{P_i^{cf}} = \text{Change in Demand Index} \quad (10)$$

This value will represent the change in the index over time. A trend measure of demand growth relative to the base period represents the demand index overtime. For evaluation purposes the growth index is normalized to 100 for the base period.[23]

Figure 4 graphs out the demand growth index annually for the three cod products of interest. Frozen product shows a two and half fold increase in trend index up to 2007 and declining thereafter but nevertheless records a positive trend shift in demand over the entire period. Salted product shows quite the opposite with strong demand growth for 1990 and 1991 but a serious negative growth trend throughout the remainder of the period. In 2013 the

[22] See Marsh (2003) for full details on the index.

[23]It is important to note that the demand index is valid only for positive values in Euclidian space, i.e. the counterfactual price is not allowed to be negative, which can occur with very large supply shocks. For the case at the hand, the base period is set to 100 in year 2000 and this problem does not occur in the data.

index is recorded at less than half the value of the 2000 base year. The increase in demand for frozen product is the result of increased production in Portugal of salted & dried product and a shift or substitution away from salted product, which implies a shift away from processed imported (salted) fish, further increasing processing in Portugal. Salted & dried cod also records a negative growth over the period albeit modest compared to salted product. This represents the increased competition from Portuguese own production of salted & dried product.

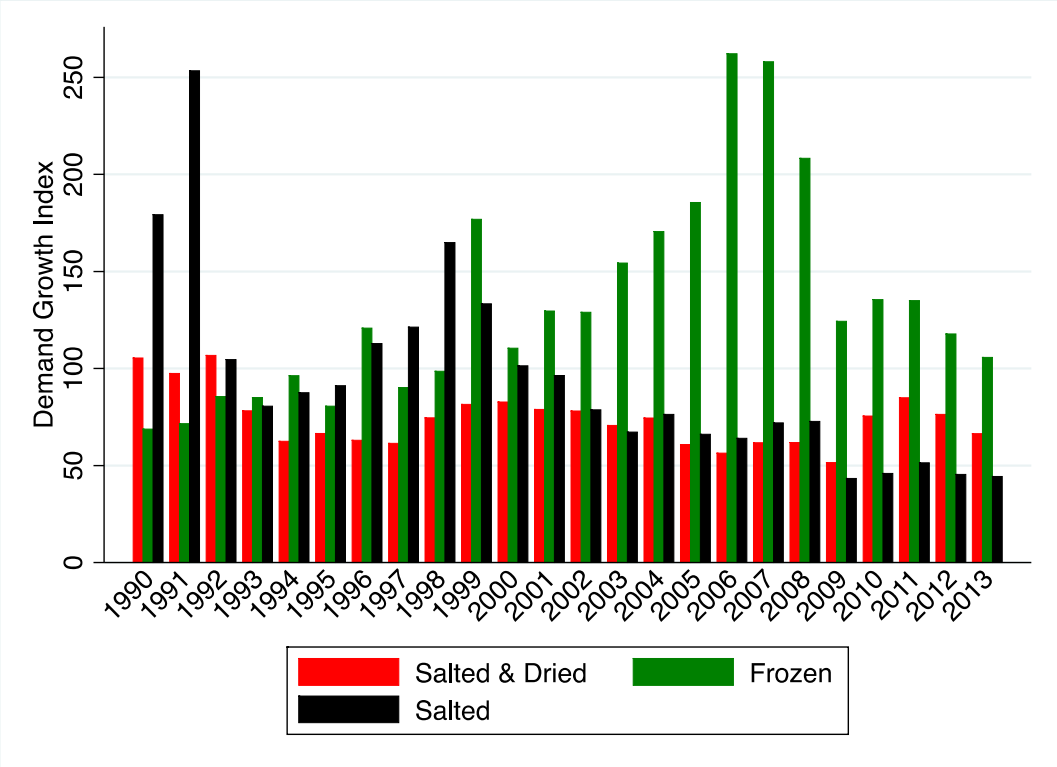

Figure 4: Demand Growth Index Annually: Frozen, Salted & Dried and Salted Cod Imports

Table 6 shows a summary of the demand growth index for select periods. Notice the strong positive growth in demand for frozen product after 2000 and for salted product prior to 1999. Just as noticeable is the negative growth trend in salted product after 2000. Salted & dried product shows a negative trend throughout the entire period but recovers somewhat after 2010.

Table 6: Summary Demand Growth Index, Select Periods

	Growth Index[a)]			
	1990-1999	2000-2009	2010-2013	1990-2013
Frozen	97.7	173.2	123.5	135
Salted	132.5	73.8	46.7	93.6
Salted & Dried	79.5	67.7	75.8	73.9

[a)] Base period 2000

Figure 5 shows the demand index monthly for the period 2011-2013 for the three cod products of interest. The purpose of this figure is to emphasize the seasonality in monthly variation in the demand growth index. Frozen and salted product show substantial positive growth in the months of May and June, whereas, and in addition to this, salted & dried product show large positive variation in demand growth in November and December. It is also worth pointing out that all three products show relatively stable trends over the last three years of the data period.

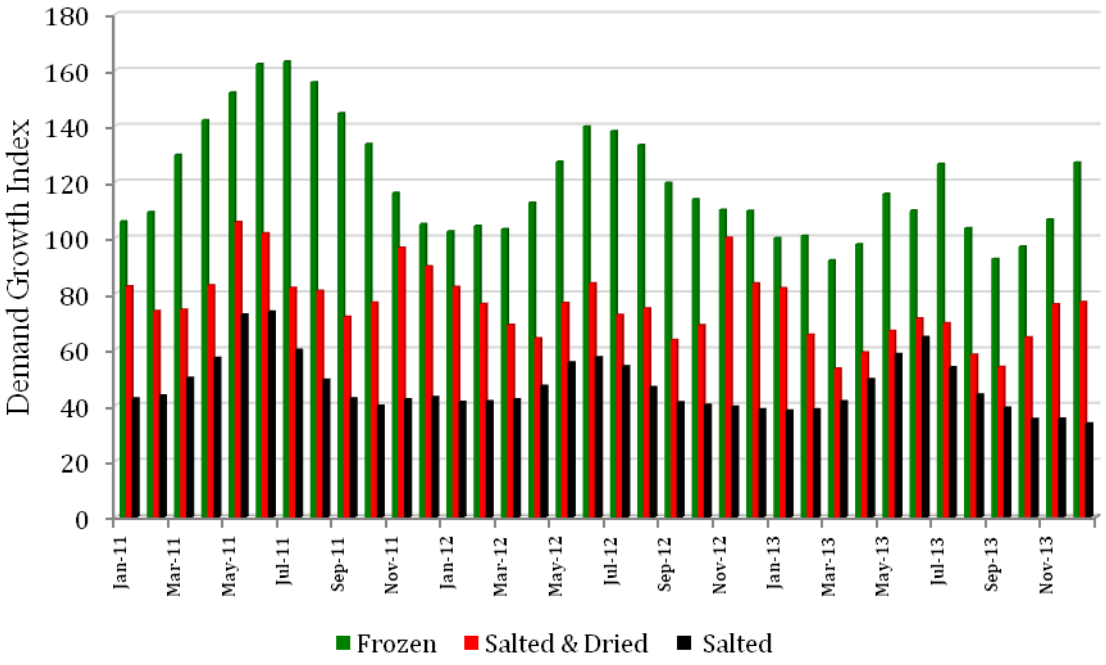

Figure 5: Demand Growth Index Monthly: Frozen, Salted & Dried and Salted Cod Imports

The growth index model offers the possibility of simulating what price or demand index would be under different scenarios. Of course, the models used here are certainly not forecasting models but do offer some evaluation of 'what if' policy scenarios.[24] Figure 6 graphs out one price scenario where the 2013 monthly supply values are interpolated to represent the 2014 monthly values and this is combined with a 2014 import demand index that reflects the average monthly value over the last three years. The simulated price is calculated using equation (10). In Figure 6 the actual price is represented for 2013 while the simulated price is reported for 2014. Under this scenario we observe that the simulated price of salted & dried cod shows an increase in monthly variation and a somewhat positive increase in price value compared to 2013. On the other hand, the simulated price of salted product basically replicates 2013 values showing a simulated 2014 price comparable in monthly variation and trend to actual 2013 price. Finally, under a combination of increased quantity supplied and a positive shift in the demand index, simulated frozen price shows increased monthly variation and an overall negative trend for 2014.

[24] Recall the data used in estimation covers the period monthly from 1990 to 2013.

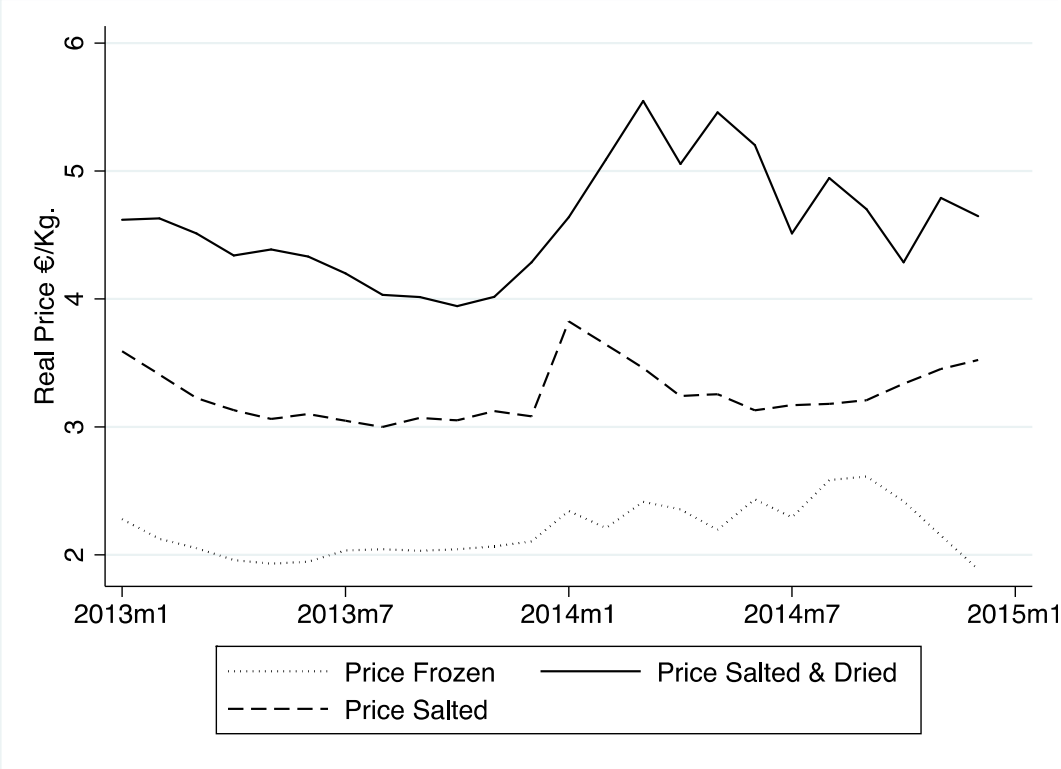

Figure 6: Simulated Monthly Price 2014

Figure 7 graphs out an alternative price scenario where we measure for each cod product the necessary shift in import demand to maintain an average real price equivalent to the actual average real price for the two-year period 2012-13. For frozen product the average price is set at 2.40 € per kg and represents a 17% price increase over the average 2013 value. We measure that a fairly substantial increase in import demand of some 15% on average would be necessary to maintain this average real price. For salted & dried product average price is set at 4.67 € per kg and represents a 9% price increase over the average 2013 value. For this product only a 9.5% increase on average in the monthly index is required to maintain average real price. Finally, for salted product an average price is set at 3.44 € per kg and represents an 8% price increase over the average 2013 value. This product requires an 8.8% increase on average in the monthly index to maintain average real price.

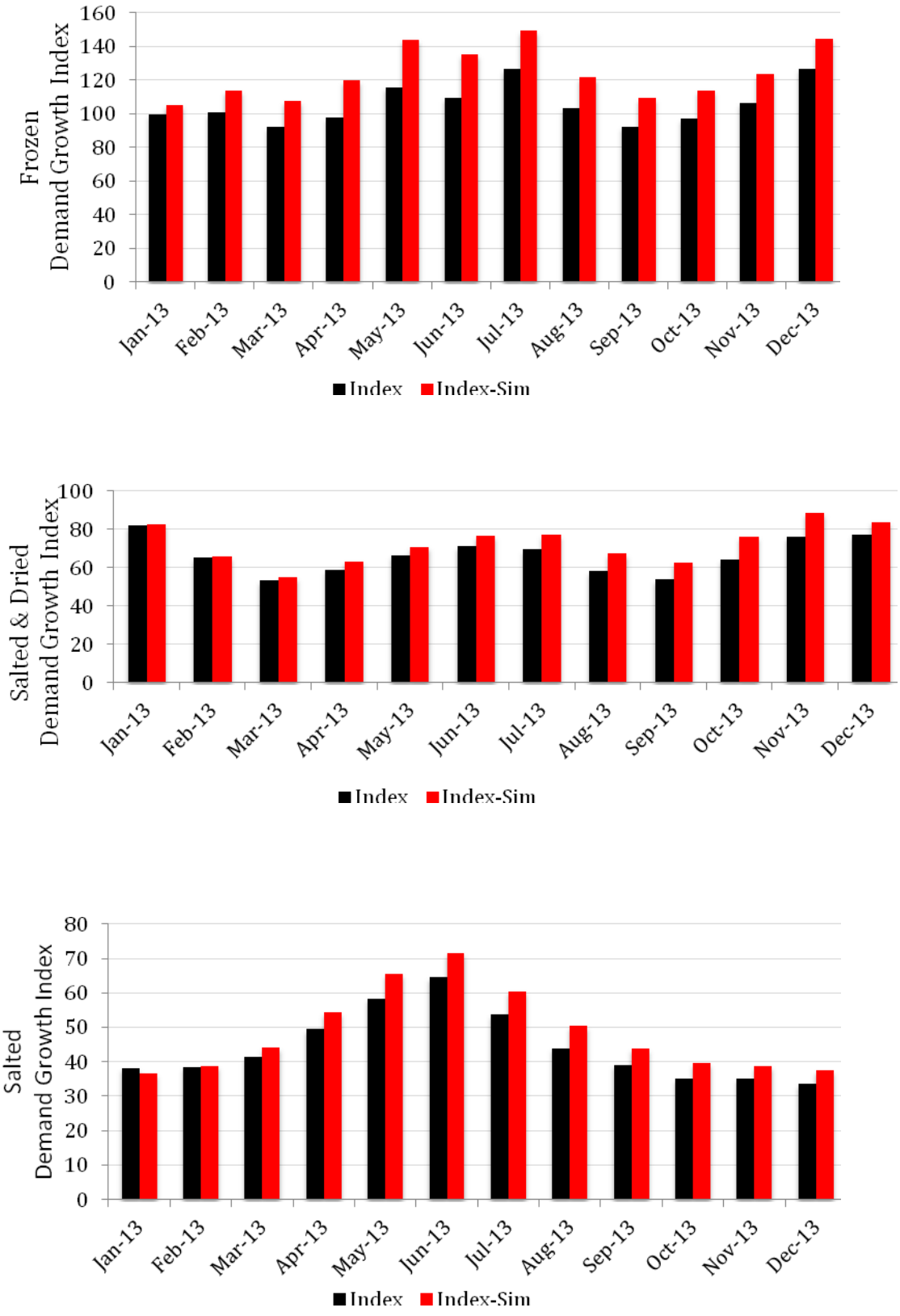

Figure 7: Simulated Demand Index for 2013: Average Real Price

Of course, to force an increase in real price we would expect positive shifts in import demand as we see but the point here is that fish suppliers have some opportunities in manipulating or reinforcing demand characteristics to enhance and improve price and revenue conditions. As such, although the long-term demand trends are currently against salted and salted & dried imports, fish suppliers of cod products are not without some recourse to limit the consequence.

Comments

The Portuguese import cod market has over the period 1990-2013 experienced a number of changes in the structure of both supply and demand conditions resulting in wide swings in both quantity and price. The PCAIDS model of Epstein and Rubinfeld (2002, 2004) offers the ability to measure own- and cross-price elasticities for a restricted group of products yet maintain many of the theoretical benefits of a full AIDs model. The elasticity results combined with a growth index model (Marsh 2003) provide useful information on changes in the structure of demand over time. The results show that for salted product the measured demand index declines, shifts inward, overtime to such an extent that both quantity of supply and real price of product are substantially less in 2013 compared to 1990. The demand structure for salted & dried product fares much better but still shows long term negative trend. On the other hand, the demand growth index for frozen product has been positive. Price simulations indicate that under reasonable quantity and demand conditions real price should be stable for salted & dried and salted product but suggests continuing decline in the real price of frozen product.

On the supply side, we observe a substantial increase in the quantity of frozen cod, a modest increase in salted & dried product and an overwhelming decline in the quantity of salted cod product entering the market. All three product forms report declines in real price with salted & dried and salted product showing prices declining by as much as 50% over the

period. However, frozen cod does show an increase in real revenue over the period. However, overall, total real revenue for this industry has declined by about 48% over the period of study.

On the demand side we observe Portuguese fish importers substituting away from salted towards frozen product and a negative growth over time in demand for imported salted & dried cod. Both of these factors are manifestations of increased codfish processing in Portugal at the expense of major suppliers such as Norway. Overall, codfish suppliers face a particular challenge in trying to maintain and develop the market for processed or semi-processed cod products.

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Appendix A

Two share equations and one aggregate demand curve are used in estimation.

$$\frac{S_f \cdot (1-S_f)}{S_s} = c_f + a_{ff} \cdot ln\left\{\frac{P_f}{P_s}\right\} + c_{fI} \cdot \ln(I) + \varepsilon_f \qquad (1a)$$

$$\frac{S_k \cdot (1-S_k)}{S_s} = c_k + a_{ff} \cdot ln\left\{\frac{P_k}{P_s}\right\} + c_{fI} \cdot \ln(I) + \varepsilon_k \qquad (2a)$$

$$\ln Q_t = a + \eta \cdot \ln P_{avg} + c_I \ln I + \varepsilon_Q \qquad (3a)$$

The equations are estimated as a system with cross equation constraints imposed with robust standard errors using the non-linear seemingly unrelated program in Stata 12. To check robustness, elasticities are calculated under three estimation routines; routine 1, estimation using all three equations, routine 2, estimation of only equations 1a and 3a and finally, routine 3, all equations but using both total quantity (Q_t) and GDP (I) in per capita terms. The elasticity results for all three procedures are reported in Table A1.

Table A1: Own-price and Cross-price Elasticities;
Share and Aggregate Demand Equations

Routine 1			
Own-price elasticities		Cross-price Elasticities	
η_{ff} [a)]	-1.387[b)]	η_{fs} [c)]	0.514
η_{kk}	-1.283	η_{fk}	0.356
η_{ss}	-1.079	η_{ks}	0.515
Routine 2			
Own-price elasticities		Cross-price Elasticities	
η_{ff}	-1.681	η_{fs}	0.524
η_{kk}	-1.565	η_{fk}	0.362
η_{ss}	-1.339	η_{ks}	0.524
Routine 3			
Own-price elasticities		Cross-price Elasticities	
η_{ff}	-1.471	η_{fs}	0.521
η_{kk}	-1.362	η_{fk}	0.361
η_{ss}	-1.151	η_{ks}	0.521

[a)] Own-price elasticities where η_{ff} frozen, η_{kk} salted & dried and η_{ss} salted

[b)] For all elasticity estimates the p-values were recorded as 0.000

[c)] Cross-price elasticities where η_{fs} frozen/salted, η_{fk} frozen/salted & dried and η_{ks} salted & dried/salted

In addition, as robustness checks the elasticities are re-calculated under two alternative values for the aggregate demand elasticity η; $\pm$ two standard errors on the estimated value of the aggregate demand elasticity using estimation routine 1. The elasticity values are reported in Table A2.

Table A2: Own-price and Cross-price Elasticities;
Two alternative values for Aggregate Demand Elasticity

Plus two standard deviations			
Own-price elasticities		Cross-price Elasticities	
η_{ff} [a)]	-1.349[b)]	η_{fs} [c)]	0.587
η_{kk}	-1.233	η_{fk}	0.406
η_{ss}	-1.007	η_{ks}	0.587
Minus two standard deviations			
Own-price elasticities		Cross-price Elasticities	
η_{ff}	-1.426	η_{fs}	0.443
η_{kk}	-1.332	η_{fk}	0.306
η_{ss}	-1.151	η_{ks}	0.443

[a)] Own-price elasticities where η_{ff} frozen, η_{kk} salted & dried and η_{ss} salted
[b)] For all elasticity estimates the p-values were recorded as 0.000
[c)] Cross-price elasticities where η_{fs} frozen/salted, η_{fk} frozen/salted & dried and η_{ks} salted & dried/salted

The elasticity estimates are robust across estimation routines and alternative values for the aggregate demand elasticity. Elasticity results reported for routine 1 are used in calculating the Growth Demand Index reported in text.

The demand function represents the fundamental building block in economics and provides important information for investment and policy purposes. The aim of this paper is to characterize and measure the demand structure for imported cod products to Portugal. A PCAIDS model is used to identify and measure own- and cross-price elasticities of demand for frozen, salted and salted & dried cod products. The calculated elasticities of demand are then used in combination with a demand growth index model to measure shifts in demand impacting price of product. Controlling for supply shocks the growth index shows over the period a positive growth in demand for frozen product but a negative change in demand growth for salted, and to a lesser degree, for salted & dried products. The results are used in simulating alternative price demand scenarios.

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