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Using a Heterogeneous Estimator for Panel Data

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Abstract: Increased livestock and aquaculture production can put pressure on the fishmeal market, and thus industrial fisheries stocks, since both of these sectors use fishmeal in their feeds. Data indicate that fishmeal supply has reached a production limit due to limited marine resources. Meanwhile there has been an explosive growth in global aquaculture production in the last couple of decades while traditional livestock production continues to grow at a steady rate. This paper examines the impact this may have on the global fishmeal market and industrial fisheries using a derived demand analysis of fishmeal. Inelastic demand for fishmeal implies that prices are bound to increase strongly, which, furthermore, can limit growth of global aquaculture. We estimate a panel data model of fishmeal demand using a shrinkage estimator that allows heterogeneous estimators for individual countries. This is important for assessing the impact these two sectors will have on the fishmeal market. Our results show that the precision of predictions is substantially higher for a shrinkage estimator than for the OLS estimator and standard panel data estimators. Furthermore, econometric models estimated by OLS produce implausible elasticities for some countries. According to the empirical results from the shrinkage model total fishmeal demand is generally inelastic in own price. However, the own price elasticity has increased in absolute terms as salmon aquaculture production has increased relative to pig and poultry production. This implies that there is scope for reduced fishmeal consumption in the salmon industry when prices increase.

Keywords: Fishmeal, demand, livestock and aquaculture feeds, shrinkage estimator, bootstrap.

1. INTRODUCTION

Few degrees of freedom is a recurrent problem in demand analysis, a problem closely related to the debate of whether or not to pool data (see e.g. Maddala, 1991; Baltagi and Griffin, 1997). While retaining more degrees of freedom pooling leads to a loss of information by imposing homogeneity across individuals. This is the crux of the discussion, which, with the danger of oversimplification, can be stated as whether to sacrifice information for firmer statistical support. With the use of a shrinkage estimator we show that even with a small panel it is possible to obtain sensible estimates that retain heterogeneity across individuals while still using information from the entire panel. This is done in the context of a demand model for fishmeal. We bootstrap the results to provide statistical foundation for inference, which would otherwise have been problematic due to the small panel and properties of the shrinkage estimator. ((Monte carlo estimations are used to assure that the bootstrap produce reasonable confidence intervals)).

Livestock and aquaculture production is expected to increase due to growing global demand for animal proteins (Delgado, Crosson, and Courbois 1997). A main objective of this paper is to examine whether increased livestock and aquaculture production will put pressure on the fishmeal market. This is interesting due to the current dependency on marine proteins in aquaculture feeds. Global aquaculture production is consuming an increasing share of the worldwide fishmeal production, and this development has been accompanied by rising fishmeal prices. This raises important issues for the growth of global intensive aquaculture industry. Amongst other whether there are available raw materials for further global expansion of farmed seafood production since fishmeal supply have reached a limit due to biological limitations for the industrial fisheries. Sustainability of the aforementioned industrial fisheries is another prevalent issue under the current market pressure. In order to address these issues we need to look at market structures.

Earlier studies have indicated that marine proteins are part of the larger oilmeal market for high protein inputs like soybean meal and other vegetable meals, since all of these products are mainly used as protein sources in animal and aquaculture feeds (e.g., Vukina and Anderson 1993; Asche and Tveterås 2000). This means that the fishmeal price is first and foremost commanded by the price of substitutes like soybean meal, and only indirectly by the size of livestock and aquaculture production. However, the special qualities of fishmeal suggest that this is only partly true. In particular, the nutritional structure of marine proteins mirror what nature intended for carnivore farmed fish species, and thus it is likely that the aquaculture sector has a more inelastic demand for fishmeal than other sectors might have. This could explain the seemingly decoupling of the fishmeal price from the soybean meal price.

Developments in the fishmeal market depend mostly on demand since supply can be viewed as given in the long run. With this in mind, we examine the above issues along the lines of derived demand for fishmeal from two intensive food producing sectors, the salmon farming industry, on the one hand, and the pig and poultry industries on the other. Demand elasticities reflect the dependency of fishmeal as an input in animal and seafood production and thus indicate the impact of increased meat and aquaculture production. In order to distinguish between the meat- and fish-producing sectors we focus on five countries where both sectors are present: Canada, Chile, Ireland, Norway and the UK. Even if most raw material markets for feed inputs are globally integrated with similar prices, local policies and other factors can lead to some heterogeneity in price movements. This study use a shrinkage estimator for panel data, which takes into account the heterogeneity between countries, created by differences in production technology and raw material prices.

Shrinkage estimators shrink individual OLS parameter estimates toward a common probability distribution, but differences between the individual estimates remain after shrinkage unless the initial OLS estimates are very similar. With a small number of observations earlier studies have shown that the shrinkage estimator can produce more reasonable estimates than individual OLS on each country. Shrinkage estimators have been applied in demand analysis to the US energy market in studies by Maddala et al. (1997) and Garcia-Cerutti (1998).

Shrinkage estimators are super efficient, but in order to make inference about the parameters bootstrapping is necessary. These estimators are only important in finite samples where the actual sampling distribution is more tightly concentrated than for least squares and therefore standard asymptotic approximation is not useful for inference or constructing confidence regions (Kazimi and Brownstone, 1999).

In the next section, we will give some background information on the fishmeal market and the use of fishmeal livestock and aquaculture feeds, continued by a presentation of the data set in section three. The econometric model will be presented in section four, followed by the empirical results in section five. Finally, in section six, the discussion will be summarised and concluded.

2. THE FISHMEAL MARKET AND THE GROWTH OF AQUACULTURE

The global fishmeal production is concentrated among a handful of countries where Peru and Chile account for over 50 % of global output. As expected, the largest reduction fisheries are located in coastal areas on the Pacific side of South America. The second most important producers are the group of Scandinavian countries, Iceland, Norway and Denmark. Global production had an average around 6.5 million metric tonnes in the 1990s, but with a considerable year-to-year variation in output due to natural variations in the fish stocks, El Niño and fisheries regulations. In Figure 1 we see the impact El Niño had on output in 1998. It is not likely that there will be any significant increase in global output since most of the reduction fisheries are characterized as fully exploited by the FAO.

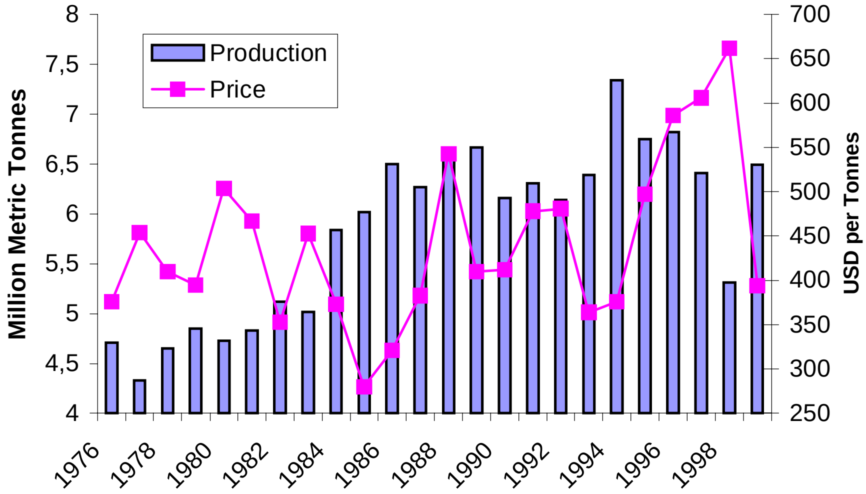

Figure 1. Global Fishmeal Production and Price (*Source: FAO*)

A shift towards producing more high-quality fishmeals is probably one of the most important changes that have taken place in the industry during the last two decades. This change is mostly due to increased use of marine proteins in compound fish feeds where high-protein meals are preferred because of their higher nutritional value. Unsurprisingly, this has increased the average price for fishmeal, which, in turn, has led many pig and poultry producers to use alternative high-protein products like soybean meal. El Niño in 1997/1998 accelerated the structural change in consumption of marine proteins due to unusually high fishmeal prices. While poultry, pig and aquaculture producing sectors consumed 56%, 20% and 17 % respectively of the global fishmeal production in 1996 there have been radical changes during the next four years, as shown in Figure 2. In 2000, a year with similar fishmeal production level as 1996, the poultry sector's consumption of fishmeal was more than halved compared to 1996, while the pig sector, somewhat surprisingly, had increased its share to 29%. For aquaculture this four-year period entailed a doubling of its consumption of fishmeal with a 35% consumption share of global fishmeal production.

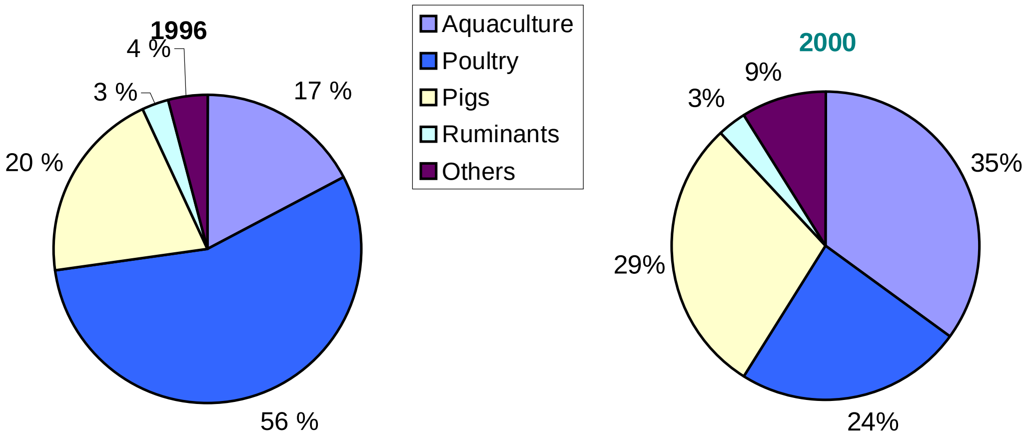

Figure 2. Share of fishmeal used in different livestock and aquaculture feeds 1996 and 2000

(Source: IFFO)

In aquaculture, farmed salmon and shrimp are the largest consumers of fishmeal with 45 % and 35 % feed inclusion rates respectively (Naylor *et al*., 2000).[1] In contrast, the inclusion rates for fishmeal in pigs and poultry feeds are much lower with a variation between 0-10 percent. Livestock feeds still use a large share of the available resources of marine proteins since the production of pigs and poultry is many times larger than intensive aquaculture production. The fact that marine proteins still are used extensively in pig and poultry feeds despite increased fishmeal prices indicates that the derived demand for fishmeal in livestock feeds is not altogether elastic.

3. DATA

Since we are going to estimate the structure of fishmeal demand we need data on fishmeal consumption, fishmeal prices, prices on substitutes and complements, and production of salmon, pig and poultry. Here we use annual FAO and IIFO data from 1975 to 1999 from five of the largest salmon (and sea trout) aquaculture producing countries.[2] Sorted by the size of their salmon production these are Norway, Chile, UK, Canada and Ireland. All of the aforementioned countries also have industrialized pig and poultry production, which makes them suitable candidates for this study.

For a study of the structure of fishmeal demand in salmon aquaculture and pig and poultry production we would ideally like to have separate fishmeal consumption figures for each of these

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[1] These figures are from 1997 and should be interpreted as approximate. Most likely average inclusion rates are lower today because of higher fishmeal prices and more flexible feed technology (Tveterås, 2002).

[2] FAO – Food and Agricultural Organization. IFFO – International Fishmeal and Fish oil Organization.

sectors. Unfortunately, such figures are not available to us, and we are therefore forced to use country aggregates on fishmeal consumption.

Fishmeal consumption in each country is defined as domestic production plus imports minus exports plus change in stock. We believe that there is some measurement errors associated with our fishmeal consumption construct. This is particularly the case for Chile, and will be dealt with in the econometric estimation. Further, we have to use trade data to estimate the value of fishmeal production that is consumed domestically because local prices are not available. The estimated value of consumption form the basis of calculating fishmeal prices.

Given the large number of ingredients used in salmon, pig and poultry feeds, a certain level of aggregation is inevitable. The list of feed is very long and inclusion of all of them is not feasible in our empirical framework. Thus, in order to avoid the problem of collinearity and retain sufficient number of degrees of freedom, aggregates for substitutes/complements to fishmeal were constructed. The studies of Peeters and Surry (1993) and Peeters (1995) have provided us with a proper level of aggregation in demand for feed ingredients. These studies and our own considerations, give us three aggregates: cereals (maize, barley, sorghum, wheat and other cereals), cereal substitutes (groundnut oil, palm oil, rapeseed oil, soybean oil, sunflower seed oil), and high-protein feeds (cottonseed meal, rapeseed meal, soybean meal, sunflower seed meal and gluten feed and meal). Cereals and cereal substitutes are first and foremost used as an energy source in feeds.

4. ECONOMETRIC SPECIFICATION AND ESTIMATION OF FISHMEAL DEMAND

This section presents the econometric models of fishmeal demand to be estimated, and the competing estimators that will be employed.

4.1. Econometric model specification

The general specification of the fishmeal demand model is:

$$X_{FM} = (W_{FM}, W_C, W_{CS}, W_{OS}, Y_{PP}, Y_S, T) \tag{1}$$

where X is quantity demanded, W denotes prices, Y is sectoral production, T is a time trend variable representing technical change, and subscripts FM = fishmeal, C = cereals, CS = cereal substitutes, OS = oil seed meals, PP = pig and poultry, and S = salmon. It should be noted that this model specification implies that we are estimating the aggregate demand of a cost-minimizing multi-output sector producing pig and poultry and salmon. Hence, there are potential aggregation problems associated with the model. As noted in the previous section, the aggregation of fishmeal demand over these sectors is due to data availability.

The initial econometric specification of the model of aggregate fishmeal demand is given by the following log-log model:

$$\begin{aligned} \ln X_{FM,i,t} = {} & \alpha_{0,i} + \alpha_{X,i}\ln X_{FM,i,t-1} + \alpha_{FM,i}\ln W_{FM,i,t} + \alpha_{C,i}\ln W_{C,i,t} + \alpha_{CS,i}\ln W_{CS,i,t} \\ & + \alpha_{OS,i}\ln W_{OS,i,t} + \alpha_{YPP,i}\ln Y_{PP,i,t} + \alpha_{YS,i}\ln Y_{S,i,t} + \alpha_{T,i}t, \end{aligned} \tag{2}$$

where subscripts t (= 1977, 1978, . . . , 1999) denotes time, and i (={Canada, Chile, Ireland, Norway, UK}) denotes country. Note that the parameter vector α_i is allowed to be country-specific, as implied by the subscript i. The own-price elasticity of fishmeal demand in country i is $e_{FM,i} = \partial \ln X_{FM,i,t} / \partial \ln W_{FM,i,t} = \alpha_{FM,i}$ in the short run and $e_{FM,i} = \alpha_{FM,i}/(1 - \alpha_{X,i})$ in theshort and longrun, run.

If demand elasticities are different between the pig and poultry and salmon sectors sectors, the estimated country-specific elasticities will be influenced by the relative size of pig and poultry production to salmon production. For example, if the own price elasticity of fishmeal demand is lower in the salmon sector than in the pig and poultry sector, then the ‘average’ elasticity will decline as salmon production increases relative to pig and poultry. This implies that there are several problems associated with the above econometric specification. In model (2) the elasticities of fishmeal demand with respect to own price and price of substitutes/complements are independent of the composition of pig and poultry and salmon production. If different countries had different ratios of pig and poultry to salmon production, and these ratios were relatively constant over time, then the country-specific parameters could capture this. However, the ratio of pig and poultry to salmon production decreases over time for all the countries in the data set, since salmon output increases at a faster rate. Consequently, we need a model that can account for the effect of changes in the output composition.

A more general econometric specification, which has model (2) as a special nested case, is:

$$\begin{aligned} \ln X_{FM,i,t} = {} & \alpha_{0,i} + \alpha_{X,i}\ln X_{FM,i,t\text{-}1} + \alpha_{FM,i}\ln W_{FM,i,t} + \alpha_{C,i}\ln W_{C,i,t} + \alpha_{CS,i}\ln W_{CS,i,t} \\ & + \alpha_{OS,i}\ln W_{OS,i,t} + \alpha_{YPP,i}\ln Y_{PP,i,t} + \alpha_{YS,i}\ln Y_{S,i,t} + \alpha_{T,i}t \\ & + \alpha_{FM,Y,i}\ln W_{FM,i,t}(\ln Y_{S,i,t} - \ln Y_{PP,i,t}) + \alpha_{C,Y,i}\ln W_{C,i,t}(\ln Y_{S,i,t} - \ln Y_{PP,i,t}) \\ & + \alpha_{CS,Y,i}\ln W_{CS,i,t}(\ln Y_{S,i,t} - \ln Y_{PP,i,t}) + \alpha_{OS,Y,i}\ln W_{OS,i,t}(\ln Y_{S,i,t} - \ln Y_{PP,i,t}), \end{aligned} \tag{3}$$

where the last four interaction terms between meal prices and the logarithmic difference between salmon and pig and poultry output capture the effect of changes in output composition on fishmeal demand. The own-price elasticity of fishmeal demand in country *i* is $e_{FM,i} = \partial\ln X_{FM,i,t}/\partial\ln W_{FM,i,t} = \alpha_{FM,i} + \alpha_{FM,Y,i}(\ln Y_{S,i,t} - \ln Y_{PP,i,t})$ in the short run and $e_{FM,i} = \{\alpha_{FM,I} + \alpha_{FM,Y,i}(\ln Y_{S,i,t} - \ln Y_{PP,,t})\}/(1 - \alpha_{X,i})$ in the long run. If the parameter $\alpha_{FM,Y,i}$ is negative and the percentage growth in salmon production over time is higher than for pig and poultry production, fishmeal demand becomes more elastic in own price over time.

Of course, one could also estimate a more general specification with multiplicative interactions between each of the four meal prices and both output levels. However, this model specification would have a large number of parameters (17) compared to the number of data observations on each country (23).

4.2. Estimators for fishmeal demand

Several competing estimators are employed in the estimation of fishmeal demand in this paper. The fact that we have 23 annual observations of fishmeal demand, prices and output in fishmeal consuming production sectors from five countries means that 115 observations are available for estimation in a pooled data set. Estimation of separate demand models for each country gives the greatest degree of flexibility with respect to elasticity estimates. However, earlier studies have demonstrated that such regression models often provide implausible elasticity estimates, for example, positive own-price elasticities (Atkinson & Manning, 1995). Here, we will compare four different estimators: (i) OLS on pooled data set, (ii) fixed effects (FE) on pooled data set, (iii) separate OLS on each country, (iv) "shrinkage" estimation, which will be presented below. The estimator (i) restricts all coefficients to be equal across countries, estimator (ii) restricts the slope coefficients to be equal across countries, while estimators (iii) and (iv) provide country-specific slope coefficient estimates.

Although the "shrinkage" estimator allows for slope coefficient heterogeneity, it imposes some additional structure on the generation of the true coefficient values compared to separate OLS regressions on each country (Maddala *et al.*, 1997). This additional structure is the assumption of a common probability distribution from which the true parameter values of the demand models are drawn for each country. The coefficients estimated by the shrinkage method will be a weighted average of the overall pooled estimate and separate estimates from each country.[3]

In its most general form the linear demand model is specified as

$$(4) \qquad y_i = X_i \beta_i + u_i, \qquad i = 1, 2, \ldots, N,$$

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[3] The "shrinkage" estimator shrinks estimates from separate regression models towards a population average.

where y_i is a $T\times 1$ vector, X_i is a $T\times k$ matrix of observations on the k explanatory variables, β_i is a $k\times 1$ vector of parameters, and u_i is a $T\times 1$ vector of random errors which is distributed as $u_i \sim N(0, \sigma_i^2 I)$.

We assume that

$$(5) \qquad \beta_i \sim IN(\mu,\Sigma),$$

or equivalently that

$$(6) \qquad \beta_i = \mu + v_i,$$

where $v_i \sim N(0,\Sigma)$. Equation (5) specifies the prior distribution of β_i in the Bayesian framework. The posterior distribution of β_i depends on μ and Σ. If μ and Σ are not known, priors must be specified. When μ, σ_i^2 and Σ are known, the posterior distribution of β_i is normal with mean and variance given by

$$(7) \qquad \beta_i^* = \left(\frac{1}{\sigma_i^2} X_i^{'} X_i + \Sigma^{-1}\right)\left(\frac{1}{\sigma_i^2} X_i^{'} X_i \hat{\beta}_i + \Sigma^{-1}\mu\right),$$

and,

$$(8) \qquad V\left(\beta_i^*\right) = \left(\frac{1}{\sigma_i^2} X_i^{'} X_i + \Sigma^{-1}\right)^{-1},$$

respectively. $\hat{\beta}_i$ is the OLS estimate of β_i.

If the matrix X_i include lagged values of y_i the normality of the posterior distribution of β_i^* holds only asymptotically and under the usual regularity conditions assumed in dynamic regression models.

In the empirical Bayes approach that we employ, we use the following sample-based estimates of μ, σ_i^2 and Σ in equation (7):

(9a) $$\mu^* = \frac{1}{N}\sum_{i=1}^{N}\beta_i^*$$

(9b) $$\hat{\sigma}_i^2 = \frac{1}{T-k}\left(y_i - X_i\beta_i^*\right)'\left(y_i - X_i\beta_i^*\right)$$

(9c) $$\hat{\Sigma} = \frac{1}{N-1}\sum_{i=1}^{N}\left(\beta_i^* - \mu\right)\left(\beta_i^* - \mu\right)' .$$

We see that the prior mean μ^* is an average of the β_i^*, the estimate of the prior variance Σ* is obtained from deviations of β_i^* from their average μ^*, and the estimate of σ_i^2 is obtained from the residual sum of squares using β_i^*, not the OLS estimator $\hat{\beta}_i$.

The equations (9) are estimated iteratively. In the initial iteration the OLS estimator $\hat{\beta}_i$ is used to compute μ^*, σ_i^2 and Σ*. To improve convergence and to allow for adjustment of the weight of the individual units i in the estimation, (9c) is modified as

(9c') $$\hat{\Sigma} = \frac{1}{N-1}\left[R + \sum_{i=1}^{N} w_i\left(\beta_i^* - \mu\right)\left(\beta_i^* - \mu\right)'\right],$$

where R is a diagonal $k\times k$ matrix with small values along the diagonal (e.g. 0.001), and w_i is a weight which determines the influence of unit i in the estimation of $\hat{\Sigma}$ ($\Sigma_i w_i = N$) According to a Monte-Carlo study by Hu and Maddala (1994), the iterative procedure gives better estimates in the mean squared sense for both the overall mean μ and the heterogeneity matrix Σ than two-step procedures.

5. EMPIRICAL RESULTS

This section presents the econometric estimates of the parameters of the fishmeal demand models. Table 1 shows the parameter estimates of model (2), which also can be interpreted as short run elasticities for the price and output parameters. The OLS parameter estimates on pooled data are with one exception (lagged fishmeal demand) not significantly different from zero at conventional confidence levels. Hence, there is no statistical support for predicting the effect of changes in prices or output levels on fishmeal demand. In the case of the FE estimator, five of the nine parameters are statistically significant at the 10% level.[4] However, the short run own price elasticity is close to zero and insignificant, and the elasticity of fishmeal demand with respect to output of pig and poultry is negative. When model (2) is estimated separately on each country by OLS we find that parameters generally are statistically insignificant, as indicated by the averages

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[4] We also estimated a random effects (RE)panel data model, but the variance of the country-specific effect was zero, leading to parameter estimates identical to the OLS estimates. However, for the fixed effects model we could not reject heterogeneity of the country-specific effects when we tested using F-tests of the null hypothesis $\alpha_{0,1} = \alpha_{0,2} = \alpha_{0,3} = \alpha_{0,4} = \alpha_{0,5}$. The discrepancy between the RE and FE model with respect to country heterogeneity is probably due to correlation between the country-specific effects and regressors.

reported in Table 1. We will examine further the OLS estimates in Table 2. We see in the last column of Table 1 that the shrinkage estimates on average are highly significant, implying that one can make predictions with small statistical confidence bands. The shrinkage model was estimated with a slightly smaller weight on Chile, due to the quality of Chilean fishmeal consumption data.[5]

Table 1. Competing Econometric Parameter Estimates Model (2)

Variable	OLS on pooled data		FE on pooled data		OLS average		Shrinkage average	
	Coef.	T-val.	Coef.	T-val.	Coef.	T-val.	Coef.	T-val.
$\ln X_{FM,i,t\text{-}1}$	0.838	16.680	0.419	4.780	0.307	0.913	0.487	26.362
$\ln W_{FM,i,t}$	-0.150	-0.690	-0.096	-0.430	-0.329	-0.745	-0.342	-22.718
$\ln W_{OS,i,t}$	0.381	1.260	0.723	2.340	0.237	0.950	0.608	33.611
$\ln W_{C,i,t}$	-0.268	-0.750	-0.268	-0.790	0.438	0.241	-0.195	-7.661
$\ln W_{CS,i,t}$	0.168	1.430	0.281	1.350	0.355	1.202	0.269	17.278
$\ln Y_{PP,i,t}$	0.016	0.390	-0.528	-1.890	-0.020	0.178	0.125	12.929
$\ln Y_{S,i,t}$	0.031	1.030	0.088	1.500	0.169	1.666	0.138	13.344
T	0.007	0.560	0.048	3.070	0.026	1.996	0.004	0.912
Constant	0.521	0.270	8.381	2.660	2.242	8.587	1.071	49.929

Next, we examine the estimated long run elasticities from Model (2). Table 2 shows a large variation in elasticity estimates between countries. The estimate of the own price elasticity of fishmeal (ε_{WFM}) for Ireland is as high as -2.073, while the figure for Canada is only -0.035. For the elasticities of substitutes and complements we see that the signs differ across countries. Most disturbing is, however, the negative output elasticity with respect to pig and poultry production (ε_{YPP}) associated with Ireland (-9.912) and the UK (-0.021). The output elasticity with respect to salmon output (ε_{YS}) also exhibits unreasonably large variations across countries.

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[5] The weight w_i of Chile is 0.96 while it is 1.01 for the other four countries.

Table 2. OLS Estimates of Long Run Elasticities Model (2)

	ε_{WFM}	ε_{WOS}	ε_{WC}	ε_{WCS}	ε_{YPP}	ε_{YS}
Canada	-0.035	0.552	0.264	0.347	1.093	0.202
Chile	-0.180	-0.473	1.890	0.633	0.033	0.072
Ireland	-2.973	-0.073	0.224	3.834	-8.912	1.130
Norway	-0.428	0.733	-0.425	-0.627	0.200	0.487
UK	-1.774	2.396	-1.274	1.086	-0.021	0.256

According to Table 3 the shrinkage estimates of the long run elasticities all have the same sign and are much closer in value between the countries than the OLS estimates. We see that the own price elasticity of fishmeal is inelastic in all countries, with values in the range -0.62 (Chile) to -0.71 (Norway). Not surprisingly, oil seed meals are the strongest substitute of fishmeal, with a cross-price elasticity (ε_{WOS}) above one for all countries. Unlike the OLS estimates there are no longer any negative output elasticity estimates with respect to pig&poultry production (ε_{YPP}) – they all lie in the range of 0.22 to 0.28. The salmon output elasticity range from 0.24 to 0.30.

Table 3. Shrinkage Estimates of Long Run Elasticities Model (2)

	ε_{WFM}	ε_{WOS}	ε_{WC}	ε_{WCS}	ε_{YPP}	ε_{YS}
Canada	-0.668	1.178	-0.406	0.503	0.222	0.262
Chile	-0.623	1.121	-0.210	0.578	0.281	0.243
Ireland	-0.696	1.222	-0.491	0.486	0.216	0.280
Norway	-0.705	1.250	-0.519	0.485	0.225	0.298
UK	-0.647	1.165	-0.286	0.563	0.278	0.261

As discussed in section 4 we also estimate a more general model (3), which allows the price elasticities to vary in the relative output of pig and poultry and salmon. Due to space considerations we do not present the parameter estimates here. However, we found similar patterns for model (3) as presented in Table 1 for model (2), with generally insignificant coefficients for the pooled estimators and the OLS estimated separately on each country, but highly significant coefficients for the shrinkage model. Below, we compare the OLS and shrinkage estimates of the long run elasticity elasticities. Table 4 presents the derived long run elasticities based on the OLS estimates of model (3). We see that several of the estimates are implausible, e.g. the positive own price elasticity for Canada and the negative pig and poultry output elasticities for Chile and Ireland.

Table 4. OLS Estimates of Long Run Elasticities Model (3)*

	ε_{WFM}	ε_{WOS}	ε_{WC}	ε_{WCS}	ε_{YPP}	ε_{YS}
Canada	0.134	0.421	0.397	0.693	0.725	0.178
Chile	-0.061	-0.710	2.420	0.125	-0.794	0.078
Ireland	-0.605	-1.795	2.602	0.544	-2.745	0.495
Norway	-0.151	0.524	-0.532	-0.405	0.140	0.024
UK	-1.240	1.648	-0.902	0.976	1.726	1.099

* Evaluated in the country sample mean values of the variables.

Table 5. Shrinkage Estimates of Long Run Elasticities Model (3)*

	ε_{WFM}	ε_{WOS}	ε_{WC}	ε_{WCS}	ε_{YPP}	ε_{YS}
Canada	-0.317	0.972	-0.116	0.841	0.600	0.469
Chile	-0.446	1.080	-0.020	0.511	0.954	0.157
Ireland	-0.436	1.035	-0.070	0.567	0.481	0.616
Norway	-1.004	1.131	0.109	-0.594	0.441	0.682
UK	-0.404	1.046	-0.092	0.632	0.655	0.452

* Evaluated in the country sample mean values of the variables.

The shrinkage estimates of the long run elasticities, presented in Table 5, generally seem much more reasonable than the OLS estimates. For all countries the own-price elasticity is now negative, with a range of -0.31 (Canada) to -1.00. Oil seed meal is as strong substitute for all countries, with a cross-price elasticity around 1. For cereals and cereal substitutes the picture is more mixed, where cereal is slightly complimentary in four countries and cereal substitutes is a substitute in four countries. The output elasticity with respect to pig and poultry is positive in all countries, with values in the range of 0.44 (Norway) to 0.95 (Chile). The salmon output elasticity varies from 0.16 (Chile) to 0.68 (Norway). When we compare the shrinkage estimates of model (2) and (3) we find that there generally is a larger cross-country variation in long run elasticities from the latter model. This can partly be attributed to fewer degrees of freedom in Model B, which leads to a larger variation in the initial OLS starting values.

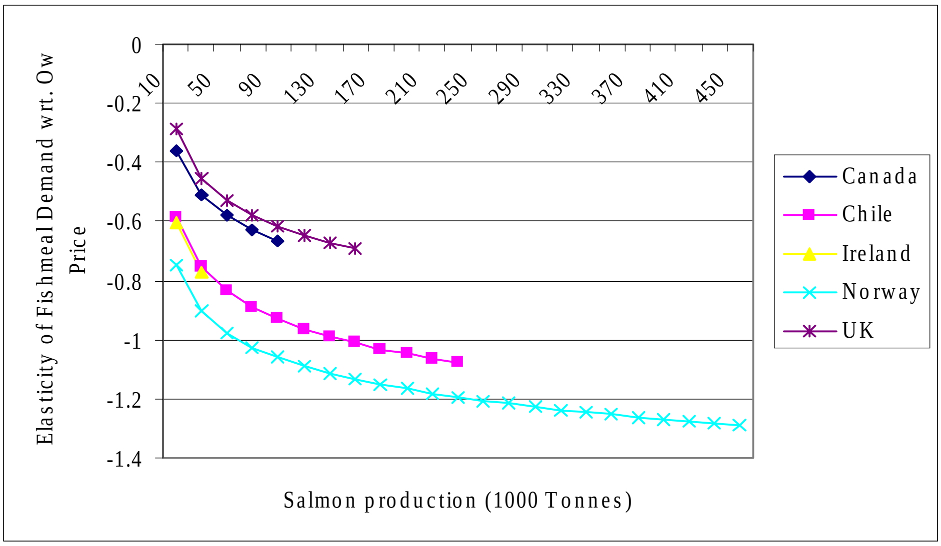

Figure 3. Own-price elasticity of fishmeal demand as a function of salmon output

Next, we examine how changes in the output composition influence the own price responsiveness of fishmeal demand. Figure 3 shows the own-price elasticity of fishmeal demand changes as salmon production increases when the output of pig and poultry is held fixed at the country sample mean level. We plot the elasticity over the range of salmon production levels observed for each country during the data period. For all countries the own-price elasticity increases in absolute terms as salmon output increases relative to pig and poultry output. For Norway and Chile fishmeal demand even becomes elastic at the high salmon production levels realized in the 1990s. Since production increased over time our results may reflect technological changes in salmon feeds which allowed for higher vegetable protein meal inclusion rates, and thus less dependence on fishmeal. A standard approach to capture the effects of technological changes on fishmeal own-price elasticity would be to include an interaction term between the time trend variable and the fishmeal price (i.e., $t \cdot \ln W_{FM}$). However, this is not possible with our data since we do not have separate figures on the fishmeal demand from the salmon aquaculture sector.

6. SUMMARY AND CONCLUSIONS

Insufficient number of data observations is usually a problem when one wishes to estimate structural differences over different individuals. Single equation OLS estimates often suffer from unreasonable parameter due to the lack of degrees of freedom. Pooled estimators like fixed effects and random effects estimators benefit from using all the information in panel data, but with the cost of imposing homogeneity across the individuals except for the slope coefficients. With the shrinkage estimator one can retain structural differences over the individuals while at the same time use all available information in the data set if one are willing to impose some common structure on the individuals.

We have estimated fishmeal demand models for a panel of five countries using a shrinkage estimator. We also estimated the models by OLS separately for each country, and by OLS and within (fixed effects) on the pooled data set. The individual country OLS estimates have problems with “wrong” signs on the parameters and also insignificant parameters. The pooled estimates have more reasonable signs, but parameters are still insignificant. In comparison the shrinkage estimator gave more reasonable and highly significant results.

The results from our two derived demand models using a shrinkage estimator indicate that demand for fishmeal is slightly inelastic with respect to own price. This implies that, ceteris paribus, increased salmon production will pressure fishmeal prices further upwards. It also put constraints on the expansion of salmon aquaculture because increased fishmeal prices increases salmon feed costs, which is the largest cost component in salmon farming. However, the results from most general econometric model indicate that fishmeal demand from the salmon sector has become more elastic relative to demand from the pig and poultry sector. This makes sense since the growth of salmon aquaculture has led to technological changes that allow for higher degree of substitution between fishmeal and alternative protein inputs. Considering that the share of fishmeal consumed by the pig and poultry sector has been reduced it is not unlikely that the remaining demand is more inelastic.

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