CONSUMER AND MARKET DEMAND

AGRICULTURAL POLICY RESEARCH NETWORK

Buyer and Seller Response to an Adverse Food Safety Event: The Case of Frozen Salmon in Alberta

Leigh Maynard, Sayed Saghaian and Megan Nickoloff
Department of Agricultural Economics
University of Kentucky

Research Project Number CMD-07-05

PROJECT REPORT

November 2007

Department of Rural Economy
Faculty of Agriculture & Forestry,
and Home Economics
University of Alberta
Edmonton, Canada

Buyer and Seller Response to an Adverse Food Safety Event: The Case of Frozen Salmon in Alberta

Leigh Maynard, Sayed Saghaian and Megan Nickoloff
Department of Agricultural Economics
University of Kentucky

Acknowledgements: Agriculture and Agri-Food Canada Consumer and Market Demand Agriculture Policy Research Network.

Buyer and Seller Response to an Adverse Food Safety Event: The Case of Frozen Salmon in Alberta

Fish is a low-fat protein source high in omega-3 fatty acids, but in 2004 consumers also heard that farmed salmon had high levels of *polychlorinated biphenyl* (PCBs). This research evaluated how Canadian consumers and processors reacted to the conflicting health messages. Demand estimates and time-series analysis of 2001-2006 frozen meat scanner data in Alberta, Canada show a significant drop in salmon expenditure share following the PCB finding. The industry responded by launching low-priced wild salmon products, which contributed to significant demand expansion. The analysis illustrates how a food safety threat was averted and even served as a catalyst for growth.

Keywords: Salmon, Scanner data, Food Safety, Demand, Directed acyclic graphs

JEL Classification: D12, L15, Q11

Objectives and Background

When a January, 2004 article by Hites et al. in *Science* reported dramatically higher levels of PCBs in farmed salmon versus wild-caught salmon, the Canadian salmon farming industry braced for a sharp downturn in sales (Simpson, 2004). The industry mounted a strong counter-attack on the methods and conclusions of Hites et al., and eventually introduced new wild salmon products to win back consumers.

The purpose of this study is to test the extent to which the health scare impacted supermarket sales of frozen salmon in Alberta, Canada, and to examine the strategic response of salmon processors. The quantitative analysis consists of demand system estimation, directed acyclic graphs and historical decomposition analysis. Alberta was chosen as the least geographically aggregated region for which product-level scanner data were available, because its residents consume salmon at a rate similar to the Canadian average, and because it is not itself a salmon producing region. The interaction of conflicting health and environmental issues on seafood demand is fascinating, yet we are not aware of any previous studies performed on retail-level seafood scanner data, especially at the level of product disaggregation emphasized in this study.

Medical experts encourage people to eat fish because it tends to be low in saturated fat, high in protein, and high in omega-3 fatty acids. Salmon is of special interest because it follows shrimp and canned tuna as the third most popular seafood in the U.S. (Knapp, Roheim, and Anderson, 2007), it leads seafood consumption in Canada (Statistics Canada, 2003), and only sardines and herring have comparable omega-3 content (Kris-Etherton et al., 2002).

Consumers also hear negative messages about fish consumption. In 2002 and 2004, respectively, health agencies in Canada and the United States advised consumers to limit consumption of seafood species found to be high in mercury, most notably tuna. The NPD Group (2006) found that 67% of U.S. consumers surveyed were concerned about mercury in seafood, although many intended to increase consumption in light of its dietary benefits. Examples of other negative issues that might reduce seafood demand include widespread environmental destruction attributable to shrimp farming (Naylor et al., 1998), transmission of parasites from escaped farmed salmon to vulnerable wild salmon stocks (Krkošek, Lewis, and Volpe, 2005), and trends toward collapse of major ocean fisheries (Worm et al., 2006).

In this study we focus on the demand impact and industry adaptation stemming from a particular negative message: the Hites et al. (2004) findings of high PCB levels in farmed salmon. Farmed salmon from Scotland and the Faroe Islands had the highest PCB levels, followed by Norway, East Canada, West Canada, Washington State, and Chile. Even the least contaminated Chilean farmed salmon contained significantly higher PCB levels than wild salmon. Judged by U.S. Environmental Protection Agency thresholds for safe fish consumption, the results suggested that consumers should eat no more than one meal per month of farmed salmon.

As with previous allegations of high PCBs in farmed salmon, salmon farming industry representatives immediately criticized the study as flawed, alarmist, reckless in its disregard for salmon-dependent local economies, damaging to consumers' health by discouraging salmon consumption, and even elitist in recommending consumption of higher-priced wild salmon (see, e.g., Salmon of the Americas, 2004). Common themes in rebuttals of the study were that farmed salmon PCB levels were lower than Food and Drug Administration standards, avoiding salmon would sacrifice other important health benefits, PCBs were not conclusively shown to be a human cancer agent and that cooking the fish with the skin removed would eliminate most of the contaminants. The motives of the Pew Charitable Trusts, sponsors of the Hites et al. study, were criticized by industry supporters on both sides of the Atlantic.

In February, 2004, The Nielsen Company survey data showed that about a third of respondents planned to avoid farmed salmon due to cancer concerns, almost half believed moderate consumption was warranted, and 13% felt the PCB claims lacked credibility (Lempert, 2004). Almost half of the respondents said they asked if salmon was wild or farmed when buying in the supermarket, and over a third said they asked when buying salmon in a restaurant. Industry fears of reduced salmon demand seemed justified.

Using data from dietary questionnaires, Oken et al. (2003) showed that pregnant women reduced intake of finfish by about 20% after the release of a 2001 federal mercury advisory. The results were interpreted as evidence that consumers responded to health advisories with a clear message, but noted that recent media coverage of dietary benefits from fish was making the health messages more complex. Roosen et al. (2006) found that French consumers' memory of high-mercury fish species was flawed, and that mercury warnings led to weak reductions in total fish consumption, but not in the high-risk species. Consumers reacted more strongly to information about health risks than health benefits. The public health message was deemed ineffective due to its complexity.

Food marketers and public health agencies routinely use complex health messages, and evaluations of consumer reaction are both business- and policy-relevant. The analysis presented here relies on revealed preferences from supermarket food purchases, providing an alternative to the choice experiments and self-reported behavior analyzed in the previous literature.

The Empirical Models and Data

The Data

The analysis was performed on The Nielsen Company scanner data for frozen boxed meat sales in Alberta, Canada. The data represent 4-weekly periods from December, 2000 to September, 2006, and reflect sales at supermarkets with more than $2 million in annual revenues. The frozen boxed meat category, which contains seafood and chicken products, but not red meat products, is part of a meat scanner data purchase by the Consumer and Market Demand Network based at the University of Alberta. Sadly, The Nielsen Company advises us that it does not collect any data on refrigerated seafood sold at the fresh meat counter, and details are not available on individual private label products. Conclusions should thus be tempered with the knowledge that we only observe a portion of supermarket seafood sales.

The raw data are highly disaggregated at the product level, with price and quantity information on 1,561 branded products. Prices and expenditures are denominated in Canadian dollars. Based on keyword searches of product names, products were aggregated into four categories expected to be substitutes: (1) salmon, (2) finfish other than salmon, (3) shrimp, and (4) chicken products. Up to 26 products in each 4-week period did not fit into these four categories, but were too diverse and comprised too small a share of expenditures to justify including in the analysis.

Table 1 shows descriptive statistics of the prices, quantities, and expenditure shares of each product category. Finfish and shrimp had average expenditure shares exceeding 30%, followed closely by chicken products, with salmon having by far the lowest share at 8%. Average price per pound ranged from $3.24 for chicken products to $9.90 for shrimp. Coefficients of variation showed that variability in prices, quantities, and expenditure shares was high compared to many retail food products. For example, scanner data on U.S. frozen dairy products (Maynard and Veeramani, 2003) suggested price coefficients of variation of only 3%-6%, and prices in Vickner and Davies' (1999) analysis of spaghetti sauce scanner data had coefficients of variation of 4%-11%, compared to values of 7%-25% shown in Table 1. High variability in prices is often beneficial for explanatory power in demand estimation.

Quantity graphs revealed spikes in shrimp sales during the holiday period at the end of each year. Frozen salmon and other finfish sales, however, often increased dramatically in the early months of the year (contributing factors may include New Year's resolutions and Lent), with a slump in late summer when the fresh salmon season peaks and the grilling season is still active. Figure 1 shows nonlinear trends in the expenditure shares of all four product categories. Salmon's share was stable during the early years of the study period, but then trended upward. Shrimp grew strongly but tailed off later in the study period, and finfish and chicken products lost expenditure share.

The Empirical Models

Demand System

A demand system consisting of four equations was estimated, with dependent variables representing frozen salmon products, other frozen finfish products, frozen shrimp, and frozen chicken products. Following Lee, Brown, and Seale (1994), a synthetic demand system nesting four alternative specifications was first estimated, with the results suggesting that the data were most consistent with an Almost Ideal Demand System (AIDS). A systemwide Durbin-Wu-Hausman test (McGuirk et al., 1995) failed to reject exogeneity of prices, supporting the use of a quantity-dependent demand system.

A linear approximate AIDS model (Deaton and Muellbauer, 1980) was subsequently estimated, using a Paasche index in place of the Stone Price Index

(Moschini, 1995) and lagged expenditure shares to avoid simultaneity (Eales and Unnevehr, 1988). Dummy variables representing four-week periods of the year were included as regressors to capture seasonal fluctuations in demand.

Additional regressors consisted of linear and quadratic trend terms, and a PCB dummy variable equal to one during the 12 weeks following publication of Hites et al. (2004). Compared to alternative PCB dummy variable specifications, the 12-week period offered slightly higher explanatory power, and encompassed over half of the post-2003 newspaper articles associated with the keywords "salmon" and "PCB" in the two major Alberta dailies, the *Edmonton Journal* and the *Calgary Herald*.

The estimated demand system was thus:

$$w_i = \alpha_i + \sum_j \gamma_{ij} \ln p_j + \beta_i \ln (x/P) + \sum_{k=1}^{12} \lambda_{ik} \ (4 - week\ dummy)_k$$
$$+ \tau_i\ trend + \delta_i\ trend^2 + \phi_i\ (PCB\ dummy) + \varepsilon_i ,$$

where w_i denotes expenditure share of the i^{th} product category, p_j denotes price of the j^{th} product category, x denotes total expenditure on the four product categories, $\ln P_t = \sum_j w_{j,t-1} \ln \left(\frac{p_{j,t}}{p_j^0} \right)$, p^0_j denotes the mean price of the j^{th} product category, the 13$^{\text{th}}$ 4-week period of the year serves as the basis of comparison for the remaining 12 periodic dummy variables, and the *PCB dummy* variable equals one during the first 12 weeks of 2004.

The same regressors appeared in each of the four equations, implying that the system added up by construction, and requiring that one equation (chicken) be omitted for the system to be identified. The theoretical restrictions of homogeneity and symmetry were tested and not rejected at the .05 level, and were thus imposed on the system to save degrees of freedom. Theoretical restrictions of the model were as follows:

adding-up:

$$\sum_i \beta_i = 0, \sum_i \alpha_i = 1, \sum_i \gamma_{ij} = 0 \ \forall\ j, \sum_i \lambda_{ik} = 0 \ \forall\ k, \sum_i \tau_i = 0 , \sum_i \delta_i = 0, \sum_i \phi_i = 0,$$

homogeneity: $\sum_j \gamma_{ij} = 0 \ \forall \ i$

symmetry: $\gamma_{ij} = \gamma_{ji} \ \forall \ i \neq j$.

After correcting for autocorrelation in the finfish equation, the systemwide joint conditional means test [F = 0.10 vs. $F^c_{.10}(54,102)$ = 1.34] and the joint conditional variance test [F = 0.09 vs. $F^c_{.10}(21,196)$ = 1.45] suggested by McGuirk et al. (1995) were not rejected at the .10 level, implying the absence of severe econometric violations relating to parameter stability at the first and second moments, autocorrelation, a RESET test of functional form, static heteroskedasticity, and autoregressive conditional heteroskedasticity.

The results of primary interest are those concerning the statistical and economic significance of the *PCB* dummy variables, the signs and significance of the time trend variables, the significance of the price parameters, and the compensated price elasticity matrix, each element of which is calculated as $\varepsilon^h_{ij} = -\delta_{ij} + \frac{\gamma_{ij}}{w_i} + w_j$, where $\delta_{ij} = 1$ if i=j and 0 otherwise.

Directed Acyclic Graphs and Historical Decomposition

While traditional demand models are commonly used to investigate the impact of food safety incidents, dynamic techniques are required to reveal the more complex interrelated effects among the variables under study. For this purpose, we utilize a co-integrated vector error correction (VEC) model, directed acyclic graphs and historical decomposition analysis. Directed graphs, in particular, allow the errors among the endogenous variables to be incorporated into the forecasted effects of PCB market shocks over time, and will complement the demand analysis with information about changes in dynamic causal relationships when the negative health information emerged. We trace the dynamic effects of the PCB event on retail-level series over time to see if these changes are consistent with the results of our demand system estimations.

The first step is to test if the series are stationary by using the Augmented Dickey-Fuller (ADF) test. Johansen's co-integration test is performed to determine whether the series are co-integrated (Holden and Perman, 1994). If the series are integrated and co-integrated, then a VEC Model is appropriate to characterize the multivariate relationships among the variables (Engle and Granger, 1987; Enders, 1995). The VEC model uses both short-term dynamics as well as long-term information; it has a co-integrating equation which captures the long-run relationship among the variables due to the presence of co-integration.

The covariance matrix of the VEC model is then used to investigate the causal relationship among the variables using directed acyclic graphs as in Bessler and Akleman (1998). Finally, historical decompositions break down the series into historical shocks in each series to determine their responses in a neighborhood (time interval) of the PCB event (Chopra and Bessler, 2005).

The Results

Table 2 contains the LA/AIDS parameter estimates. Explanatory power was indicated by respective adjusted R^2 values of 0.77, 0.87, and 0.90 in the salmon, finfish, and shrimp equations. Most parameters were statistically significant at the .05 level, with a noteworthy exception being the finfish own price coefficient (note that an own-price parameter of zero implies an own-price elasticity of -1). The only parameters with unexpected signs were the shrimp/finfish and shrimp/chicken cross-price terms. The signs of the linear and quadratic trend parameters were consistent with Figure 1, and all but one trend parameter was statistically significant. Parameters for the chicken equation were calculated from the adding-up restrictions.

Compensated own-price elasticities, presented in Table 3, ranged from an extremely insensitive value of -0.01 for shrimp to -0.63 for finfish to a highly elastic value of -2.15 for salmon. Shrimp cross-price elasticities were economically insignificant, suggesting that consumers do not view shrimp as having close substitutes in the freezer section. Salmon and other finfish were economically and statistically significant substitutes, as expected.

Of special interest was the statistically significant parameter on the *PCB dummy* variable in the salmon equation, which shows a 2% loss of salmon expenditure share attributable to the three-month period following publication of Hites et al. (2004) and subsequent media coverage. Given that salmon's expenditure share in surrounding months was only 5%-9%, a 2% decline is economically significant. The impact is visible in Figure 1 as an uncharacteristic break in the seasonal pattern of expenditure share growth early in the year. Table 2 shows the characteristic pattern as positive and statistically significant seasonal parameters for the first 12 weeks of the year, relative to the final 4 weeks. Only in 2004 was there a drop in expenditure share between late December and mid-March, the period corresponding to the heaviest media coverage of elevated PCB levels in farmed salmon.

The OLS unit-root test results for the quantity series of salmon, finfish, shrimp, and chicken appear in Table 4. The second column shows failure to reject the null hypothesis of zero first-order autocorrelation using the Durbin-Watson bounds test for salmon and shrimp series, given the MacKinnon critical value. The right-most column shows ADF results when the series are first differenced. The null hypotheses are rejected at the 1% significance level for all variables after first differencing.

Table 5 contains the co-integration test results for the quantity series. The null hypotheses of co-integrating ranks $r = 0$, $r \leq 1$, and $r \leq 2$ are rejected at the 5% level of significance, indicating that the co-integrating rank of the system is at most 3. Long-term relationships therefore exist among the variables, which supports use of the VEC model in determining the directed graphs and causal patterns for quantities.

Contemporaneous innovations are reflected by the VEC model's residual correlation matrix. The innovations are orthogonalized using TETRAD IV software to obtain historical decomposition functions from the endogenous variables in the system, indicating the causal patterns of the quantity series on innovations (Spirtes et al., 1999; Spirtes et al., 2000). Figure 4 shows the directed acyclic graphs of these causal structures. Only edges that are significantly different from zero at the 5% significance level are included. The results show that innovations in salmon, shrimp and chicken variables directly affect residuals in finfish, and the residual relationship among salmon, shrimp and chicken quantities is indirect through the finfish.

Figure 5 shows the historical decomposition results for the endogenous variables from the PCB report over a five-month horizon, chosen to explore the immediate postevent dynamics before the accumulation of other events obscures their impacts. The PCB historical decomposition graphs showed a negative impact on the consumption of frozen salmon beginning with February 2004, consistent with the results of the demand system, and concurrently, the consumption of chicken began to rise. Seemingly, consumers reacted negatively to the PCB news and substituted chicken for salmon.

Among the four products under study, salmon took the largest hit with the PCB event and reached its lowest point by April 2004. Figure 5 shows pre-shock estimates for the product quantities (the dashed line) with projections associated with the PCB shock. It is estimated that salmon consumption dropped some 10% from its forecasted values due to the adverse food safety report by April. In contrast, the positive impact on chicken consumption above its forecasted values was estimated to be about 8% by April, and for shrimp consumption was close to 5%. On average, the PCB had little impact on finfish consumption. In contrast to the Roosen et al. (2006) results showing haphazard consumer responses to a complicated health recommendation, these results show the expected response when the health message is less complicated. Alberta consumers reacted positively toward chicken and shrimp and less negatively against finfish. Purchases of frozen salmon, finfish, and shrimp rose soon after April, consistent with previous research indicating declining concern over time, though some anxiety may endure (Mazzocchi, 2005).

Discussion

Vehement industry criticism of Hites et al. (2004) suggested that salmon producers and processors expected a strong negative consumer reaction to the PCB issue, and the results of our analysis support that expectation, at least in the short-run. The industry's strategic response and subsequent consumer behavior, however, produced a much different outcome.

About five months after Hites et al. (2004) was published, a prominent seafood processor referred to here as "Brand 1" introduced a "Wild Salmon Chum Fillet" product with potential to ease consumers' fears of PCBs in farmed products. Chum and pink salmon are generally viewed as low-cost, low-quality species compared to chinook, coho, and sockeye salmon (Franz, 2006). As shown in Figures 2 and 3, the frozen wild product was introduced at a much lower price ($4.34/lb.) than the pre-existing, presumably farmed salmon products, and the initial quantity demanded exceeded that of all other salmon products combined.

Faced with the tremendous success of the product in its first month, Brand 1 raised the wild product's price to as high as $7.43/lb. during the next 16 weeks. In September, 2004, however, a dominant competitor referred to here as "Brand 2" introduced its own "Wild Pacific Salmon" product at a very low price of $4.87/lb. Brand 1 immediately retreated until it undercut Brand 2's price in the following month. Brand 1 made one effort to raise price again (to $6.06/lb.) in November, 2004, but Brand 2 did not follow the price increase. Brand 1 then reverted to a low-price strategy, and maintained a lower unit price than Brand 2 for the duration of the study period. Both wild products were consistently priced $2-$3/lb. lower than the pre-existing farmed salmon products.

In retail fish markets, wild salmon commands a price premium not only because of perceived health benefits, but because of perceived superior flavor. The persistently low prices of the processed frozen wild salmon products analyzed in this study were therefore puzzling. Knapp (2007) suggested that these wild frozen products are likely to be lower-value chum and/or pink salmon (Brand 1's product is labeled as chum). An especially low-cost marketing channel involves exporting chum and pink salmon to China for processing, then re-importing the value-added product.

As shown in Figure 2, the quantity demanded of the low-priced wild products quickly outstripped that of the pre-existing farmed salmon products, and remained on an upward trajectory through the end of the study period. The farmed products were often flavored or breaded, and one brand's products accounted for almost 91% of the farmed salmon quantity sold. Overall salmon expenditures and expenditure share grew during the study period, with the fastest growth occurring after the industry introduced the wild salmon products in response to the PCB scare.

The popularity of wild salmon, combined with the visual similarity of wild and farmed salmon (farmed salmon are fed dyes to achieve the pink color associated with wild salmon), led to incentives for unethical business practices. Burros (2005) reported test results showing that salmon being sold at a premium as "wild" by six of eight New

York City retailers were in fact farmed. When confronted with the results, some managers suspended supplier relationships, increased source verification requirements, and implemented spot tests to regain consumer trust.

By actively influencing the information reaching consumers, and by adapting the product mix to changing preferences, the salmon industry appears to have transformed a food safety threat into a growth opportunity with respect to the products evaluated in this study. Technological efforts to eliminate the source of higher PCB levels in farmed salmon are ongoing and, if achieved, will be a final beneficial outcome stemming from the alarm sounded by Hites et al. (2004).

References

Bessler, D.A. and D.G. Akleman. 1998. Farm prices, retail prices and directed graphs: Results for pork and beef. *American Journal of Agricultural Economics* 80:1144-1149.

Burros, M. 2005. Stores say wild salmon, but tests say farm bred." *The New York Times*, April 10. pp. 1,36.

Chopra, A. and D.A. Bessler. 2005. Impact of BSE and FMD on beef industry in U.K. Paper presented at the NCR-134 Conference on Applied Commodity Price Analysis, Forecasting, and Market Risk Management, St. Louis, Missouri.

Deaton, A. and J. Muellbauer. 1980. An almost ideal demand system. *American Economic Review* 70: 312-326.

Eales, J.S. and L.J. Unnevehr. 1988. Demand for beef and chicken products: Separability and structural change. *American Journal of Agricultural Economics* 70: 521-532.

Enders, W. 1995. *Applied Econometric Time Series*. New York: John Wiley & Sons, Inc.

Engle, R.E. and C.W.J. Granger. 1987. Cointegration and error correction: Representation, estimation, and testing. *Econometrica* 55:251-276.

Franz, N. 2006. Salmon – December 2006. FAO GLOBEFISH Market Reports, Food and Agriculture Organization Fisheries Department, Rome, Italy.

Hites, R.A., J.A. Foran, D.O. Carpenter, M.C. Hamilton, B.A. Knuth, and S.J. Schwager. 2004. Global assessment of organic contaminants in farmed salmon. *Science* 303 (January 9):226-229.

Holden, D. and R. Perman. 1994. Unit root and cointegration for the economist. In *Cointegration for the Applied Economist*, ed. B. Bhaskara Rao. New York: St. Martin's Press.

Knapp, G. 2007. personal communication, University of Alaska at Anchorage, May 17.

Knapp, G., C.A. Roheim, and J.L. Anderson. 2007. *The Great Salmon Run: Competition Between Wild and Farmed Salmon*. Washington, DC: TRAFFIC North America, World Wildlife Fund.

Kris-Etherton, P.M., W.S. Harris, and L.J. Appel. 2002. Fish consumption, fish oil, omega-3 fatty acids, and cardiovascular disease. *Circulation* 106: 2747-2757.

Krkošek, M., M.A. Lewis, and J.P. Volpe. 2005. Transmission dynamics of parasitic sea lice from farm to wild salmon. *Proceedings of the Royal Society B* 272(1564): 689-696.

Lee, J.-Y., M.G. Brown, and J.L. Seale, Jr. 1994. Model choice in consumer analysis: Taiwan, 1970-89. *American Journal of Agricultural Economics* 76: 504-512.

Lempert, P. 2004. Big trouble in the fish case? *Facts, Figures, and the Future*, AC Nielsen, Food Marketing Institute, and the Lempert Report, February. www.factsfiguresfuture.com/archive/february_2004.htm

Maynard, L.J. and V.N. Veeramani. 2003. Price sensitivities for U.S. frozen dairy products. *Journal of Agricultural and Applied Economics* 35(3):599-609.

Mazzocchi, M. 2005. Modeling consumer reaction to multiple food scares. Department of Agricultural and Food Economics Research Paper. The University of Reading.

McGuirk, A., P. Driscoll, J. Alwang, and H. Huang. 1995. System misspecification testing and structural change in the demand for meats. *Journal of Agricultural and Resource Economics* 20: 1-21.

Moschini, G. 1995. "Units of Measurement and the Stone Index in Demand System Estimation." *American Journal of Agricultural Economics* 77: 63-68.

Naylor, R.L., R.J. Goldburg, H. Mooney, M. Beveridge, J. Clay, C. Folke, N. Kautsky, J. Lubchenco, J. Primavera, and M. Williams. 1998. Nature's subsidies to shrimp and salmon farming. *Science* 282(5390): 883-884.

NPD Group, Inc. 2006. Americans eat fish despite mixed messages about health effects. press release, Port Washington, NY, March 9.

Oken, E., K.P. Kleinman, W.E. Berland, S.R. Simon, J.W. Rich-Edwards, and M.W Gillman. 2003. Decline in fish consumption among pregnant women after a National Mercury Advisory. *Obstetrics and Gynecology* 102: 346-351.

Roosen, J., S. Marette, S. Blanchemanche, and P. Verger. 2006. Does health information matter for modifying consumption? A field experiment measuring the impact of risk information on fish consumption. Center for Agricultural and Rural Development, Iowa State University, Ames, IA, Working Paper 06-WP 434.

Salmon of the Americas. 2004. Salmon of the Americas statement about the Hites et al. study. www.salmonoftheamericas.com/ topic_01_04_science.html.

Simpson, S. 2004. Study raises alarm over toxins in farmed fish. *Times-Colonist*. Victoria, B.C., January 8, p. A1.

Spirtes, P., Scheines, R., Meek, C., Richardson, T., Glymour, C., Boomsam, A., and Hoijtink, H. 1999. *TETRAD II-Version 3.1 Tools for causal modeling*. Pittsburgh PA: Carnegie Mellon University.

Spirtes, P., Glymour, C. and Scheines, R. 2000. *Causation, prediction, and search*. New York: Springer-Verlag.

Statistics Canada. 2003. Food expenditure in Canada, 2001. Income Statistics Division, Catalogue no. 62-554-XIE, Ottawa, Ontario.

Vickner, S.J. and S.P. Davies. 1999. Estimating market power and pricing conduct in a product-differentiated oligopoly: The case of the domestic spaghetti sauce industry." *Journal of Agricultural and Applied Economics* 31(1):1-13.

Worm, B., E.B. Barbier, N. Beaumont, J.E. Duffy, C. Folke, B.S. Halpern, J.B.C. Jackson, H.K. Lotze, F. Micheli, S.R. Palumbi, E. Sala, K.A. Selkoe, J.J. Stachowicz, and R. Watson. 2006. Impacts of biodiversity loss on ocean ecosystem services. *Science* 314 (5800): 787-790.

Table 1. Descriptive Statistics, Frozen Meat Products, Dec. 2000 – Sept. 2006.

		Mean	Std. Dev.	Coeff. of Variation	Min.	Max.
Expenditure Shares	Salmon	8%	3%	39%	2%	16%
	Finfish	37%	9%	25%	20%	58%
	Shrimp	31%	12%	40%	2%	54%
	Chicken	25%	5%	21%	17%	41%
Prices ($/lb)	Salmon	$6.68	$0.94	14%	$4.68	$8.37
	Finfish	$4.35	$0.29	7%	$3.65	$4.81
	Shrimp	$9.90	$2.49	25%	$6.28	$15.53
	Chicken	$3.24	$0.51	16%	$2.18	$4.02
Quantities (lb)	Salmon	32,292	23,117	72%	3,206	91,136
	Finfish	193,565	41,198	21%	108,087	309,334
	Shrimp	94,340	61,359	65%	2,494	190,733
	Chicken	175,687	27,931	16%	114,655	269,255

Table 2. LA/AIDS Parameter Estimates.

	Equation						
	Salmon		Finfish		Shrimp		Chicken[a]
Intercept	0.71277	***[b]	2.30814	***	-3.93973	***	1.91882
	(0.21550)[c]		(0.50420)		(0.55870)		
ln(P salmon)	-0.09297	***	0.11505	***	-0.01215		-0.00993
	(0.02560)		(0.03040)		(0.01310)		
ln(P finfish)	0.11505	***	0.03625		-0.12970	***	-0.02161
	(0.03040)		(0.06830)		(0.03160)		
ln(P shrimp)	-0.01215		-0.12970	***	0.21265	***	-0.07080
	(0.01310)		(0.03160)		(0.03230)		
ln(P chicken)	-0.00993		-0.02160		-0.07080	***	0.10233
	(0.02200)		(0.04540)		(0.02210)		
ln (real expenditure)	-0.04200	***	-0.12292	***	0.26897	***	-0.10405
	(0.01490)		(0.03530)		(0.03890)		
weeks 1-4	0.03466	***	0.04999	**	-0.12145	***	0.03681
	(0.00932)		(0.02000)		(0.02470)		
weeks 5-8	0.02546	**	0.06377	***	-0.12391	***	0.03469
	(0.00973)		(0.02220)		(0.02580)		
weeks 9-12	0.02803	***	0.08225	***	-0.11473	***	0.00445
	(0.00910)		(0.02100)		(0.02410)		
weeks 13-16	0.01843	**	0.04772	**	-0.07140	***	0.00525
	(0.00906)		(0.02090)		(0.02390)		
weeks 17-20	0.02656	***	0.03537	*	-0.10103	***	0.03910
	(0.00892)		(0.02060)		(0.02370)		
weeks 21-24	0.01933	**	0.01560		-0.06274	**	0.02781
	(0.00888)		(0.02050)		(0.02360)		
weeks 25-28	0.00461		-0.03676	*	0.00774		0.02441
	(0.00908)		(0.02110)		(0.02410)		
weeks 29-32	-0.00330		-0.02601		0.00541		0.02390
	(0.00924)		(0.02160)		(0.02450)		
weeks 33-36	-0.00268		-0.03176		0.02004		0.01440
	(0.00925)		(0.02160)		(0.02430)		
weeks 37-40	0.01186		0.04164	**	-0.05593	**	0.00243
	(0.00891)		(0.02050)		(0.02350)		
weeks 41-44	0.01065		0.03602	*	-0.03925		-0.00743
	(0.00937)		(0.02130)		(0.02460)		
weeks 45-48	0.01558	*	0.06050	***	-0.09392	***	0.01784
	(0.00926)		(0.01950)		(0.02420)		
trend	-0.00044		-0.00554	***	0.00916	***	-0.00318
	(0.00053)		(0.00123)		(0.00122)		
trend squared	0.00002	***	0.00005	***	-0.00009	***	0.00002
	(0.00000)		(0.00001)		(0.00001)		
PCB (Jan-Mar, 2004)	-0.02066	**	-0.00862		0.02074		0.00854
	(0.01000)		(0.02470)		(0.02590)		
Adjusted R^2	0.77		0.87		0.90		

[a] Parameter estimates in the chicken equation obtained from adding-up restrictions
[b] *, **, and *** denote statistical significance at the .10, .05, and .01 levels, respectively
[c] Standard errors in parentheses

Table 3. Compensated Price Elasticity Estimates.

		Equation			
		Salmon	Finfish	Shrimp	Chicken
Price	Salmon	**-2.15**	0.39	0.04	0.04
	Finfish	1.88	**-0.53**	-0.05	0.28
	Shrimp	0.15	-0.04	**-0.01**	0.02
	Chicken	0.12	0.19	0.02	**-0.51**

Table 4. Augmented Dickey-Fuller (ADF)[a] Test Results.

Quantity Variables	Test Results for Variables in Levels	Test Results for Variables after First-Differencing
Salmon	2.34	7.65*
Finfish	3.94*	9.28*
Shrimp	1.29	14.51*
Chicken	5.61*	10.38*

Note: * 1% significance level.
[a] Test statistics are in absolute value and compared to MacKinnon (1996) one-sided p-value.

Table 5. Johansen Cointegration Test Results for the Quantity Variables.

Null Hypothesis[a]	Trace Statistics	5% Critical Value	Eigenvalue
$r = 0$ *	66.17	47.86	0.37
$r \leq 1$ *	33.42	29.80	0.19
$r \leq 2$ *	18.05	15.50	0.17
$r \leq 3$	3.84	4.46	0.06

[a] r is the cointegrating rank, MacKinnon-Haug-Michelis (1999) p-value.
* 5% significance level.

Figure 1. Frozen Shrimp and Salmon Expenditure Shares Grew in Alberta, while Other Finfish and Chicken Shares Fell.

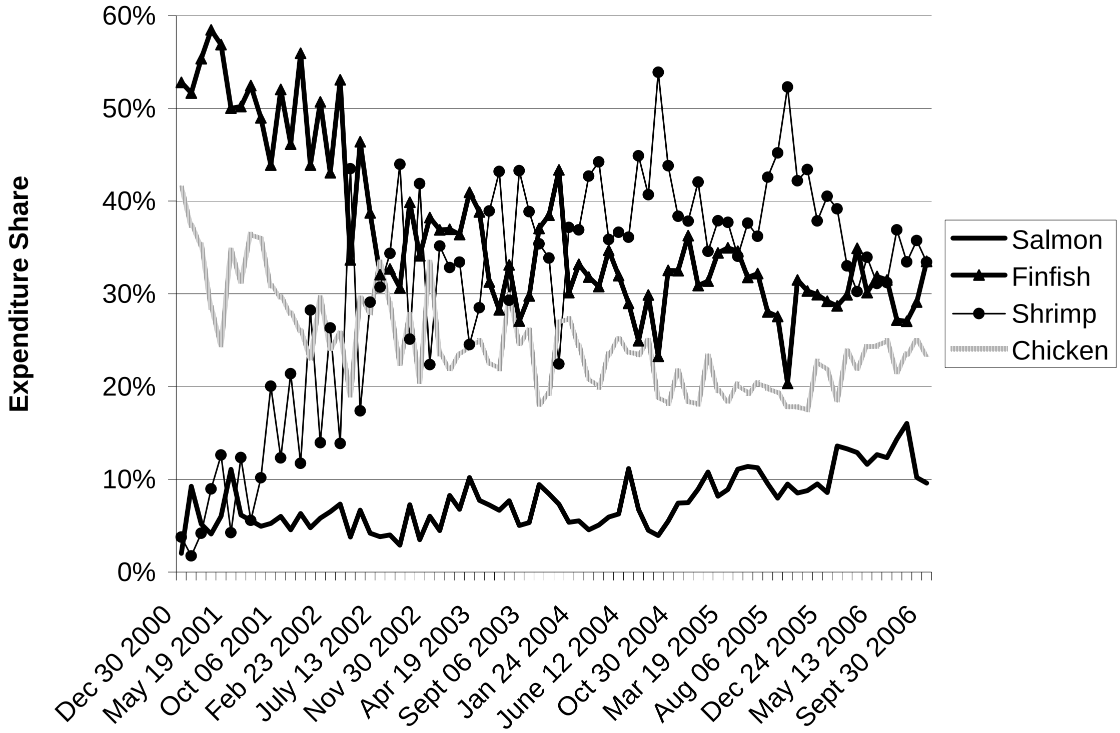


Figure 2. Wild Salmon Quantity Demanded Soon Overtook Non-Wild Salmon.

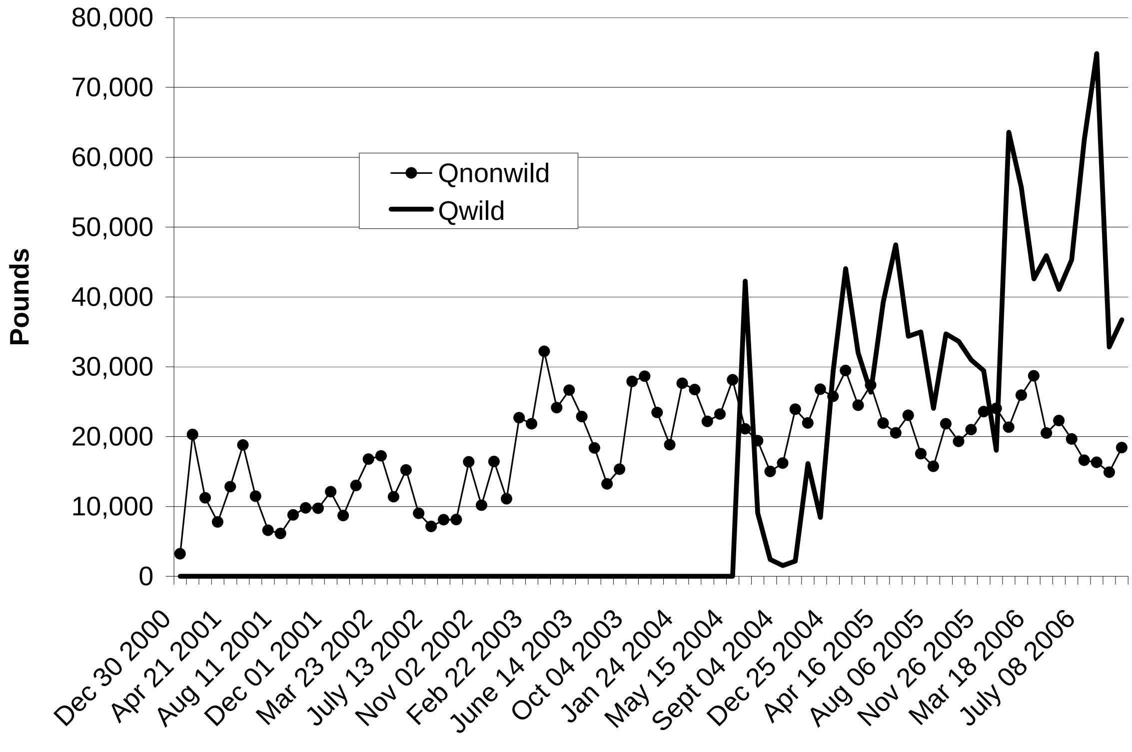


Figure 3. Strategic Price Interaction between the Two Main Wild Salmon Brands.

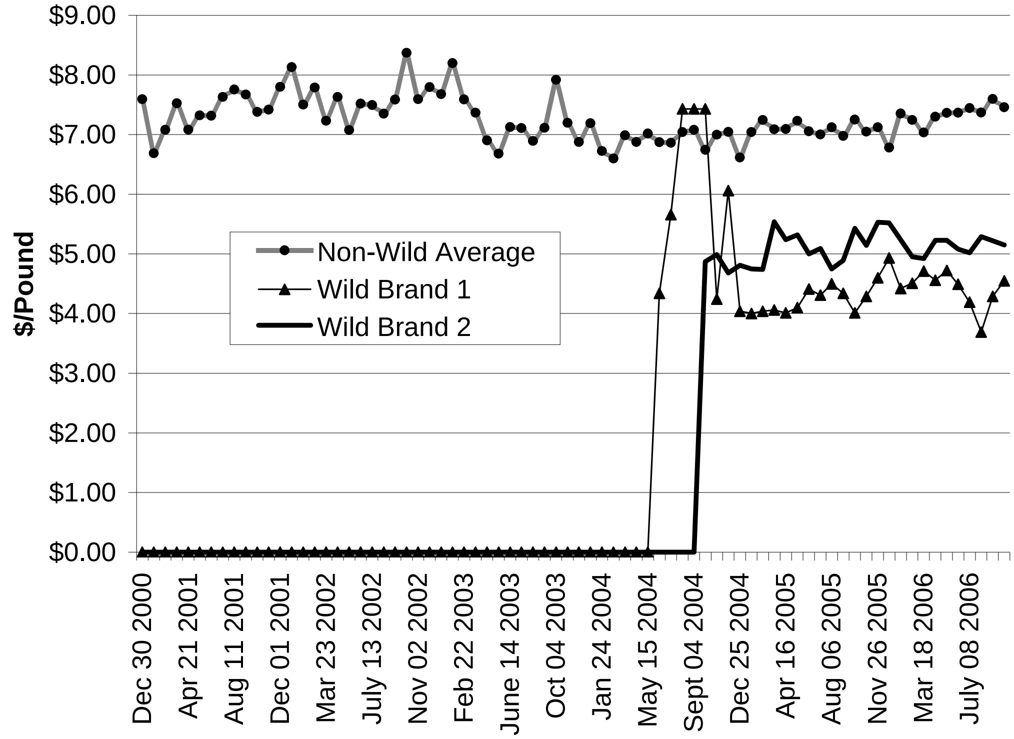


Figure 4. Directed Graph on Innovations from the Quantity Series.

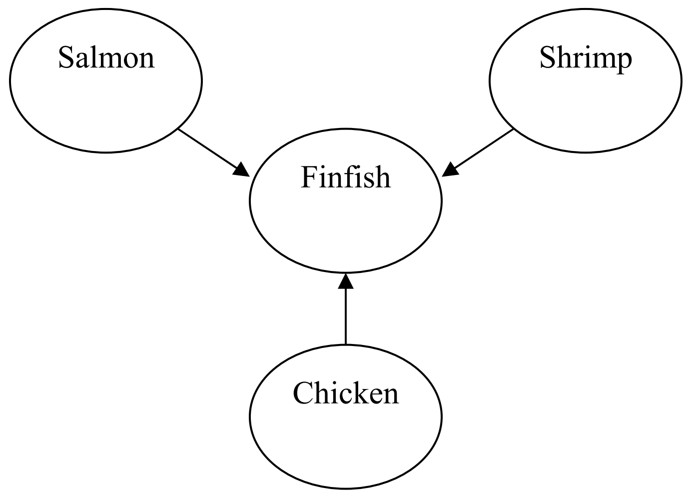
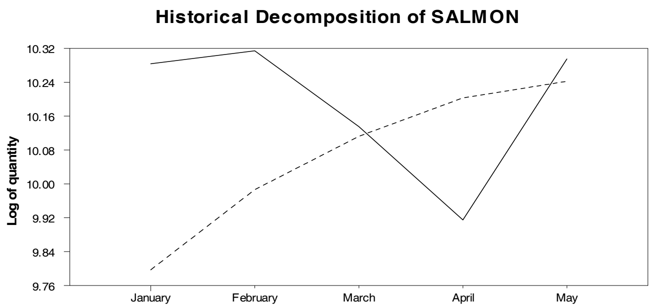
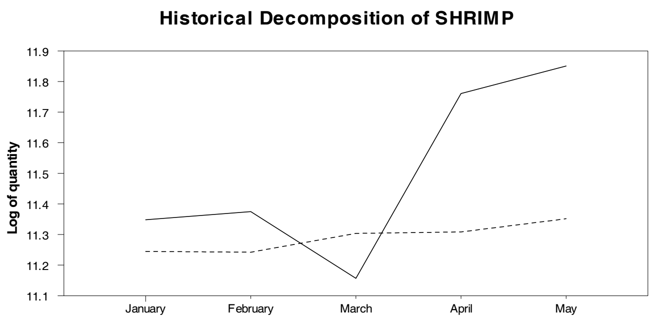
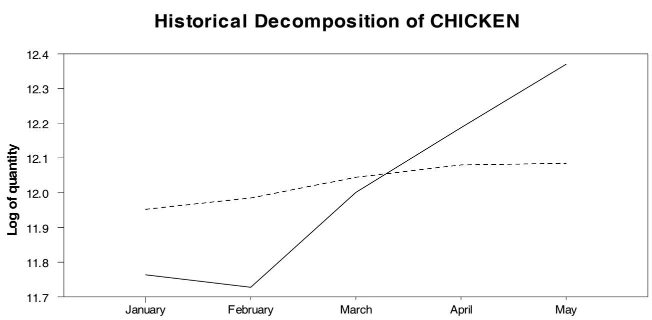
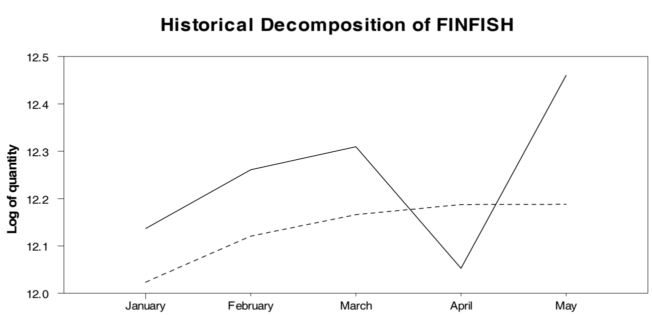


Figure 5: The PCB impact on the Quantity Series (pounds in log-form).









Actual Price: ________________

Forecasted price before the event: ---------------------