A Comparison of Annual, Quarterly and Monthly Turkey Export Models

Dale Colyer
West Virginia University

Abstract: Structural time series models of turkey exports were estimated using monthly, quarterly and annual data. The trend is statistically significant in all three models, seasonals are significant in the quarterly and monthly models. Exchange rates, lagged prices, and lagged production were explanatory factors in the monthly model; exchange rates and prices in the quarterly model; but only the exchange rates in the annual model.

Keywords: Turkey exports, international trade, structural time series

Paper for the Southern Agricultural Economics Annual Meeting, Lexington, KY, January 29-February 2, 2000. This material is based upon work supported by the National Research Initiative of the Cooperative State Research, Education, and Extension Service, U.S. Department of Agriculture under Agreement No. 96-35400-3748.

Address:
West Virginia University
P.O. Box 6108
Morgantown, WV 26506-6108
Phone: 304-293-4832 ext. 4472
FAX: 304-293-3740
email: dcolyer@wvu.edu

A Comparison of Annual, Quarterly and Monthly Turkey Export Models

Dale Colyer

Introduction

Turkey production and consumption have increased rapidly in the U.S. during recent decades due to increasing production efficiency and lower real prices of turkey meat (Figures 1 and 2). Exports of turkey meats also have become more important as the proportion of production exported has risen from 1-2 percent in the 1970s and 1980s to 6-8 percent in recent years, but trade in turkey products has received relatively little attention. Broilers, on the other hand, have been studied extensively (Aradhyula and Holt 1989; Chavas and Johnson 1982; Heien 1976; Henry and Rothwell 1995; Goodwin, Madrigal and Martin 1996; Kapombe 1997; Leong and Elterich 1985; Malone and Reece 1976; Martinez, et al.1986; Rausser and Cargill 1970). Some studies have begun to emphasize international trade in poultry products (Alston and Scobie 1987; Bishop, Christensen and Witucki 1990; Haley 1990; Henry and Rothwell 1995; Kapombe 1997; Leong and Elterich 1985). Chavas and Johnson (1982) included turkeys in their supply models and trade in turkeys is covered in Henry and Rothwell (1995), as well as in Bishop, Christensen and Witucki (1990) and other mostly descriptive studies. However, turkeys have not been modeled extensively in the context of international markets and trade. This analysis will help alleviate this deficiency through estimation and comparison of models of U.S. turkey exports utilizing time series data and the structural time series (STS) approach.

Background

Turkey production, consumption and trade have been affected by many of the same types of trends that have affected the broiler industry. These include lower real costs and prices, health concerns, and industrialization of production which have impelled poultry production and

FIGURE 1. U.S. TURKEY PRODUCTION, 1960-98

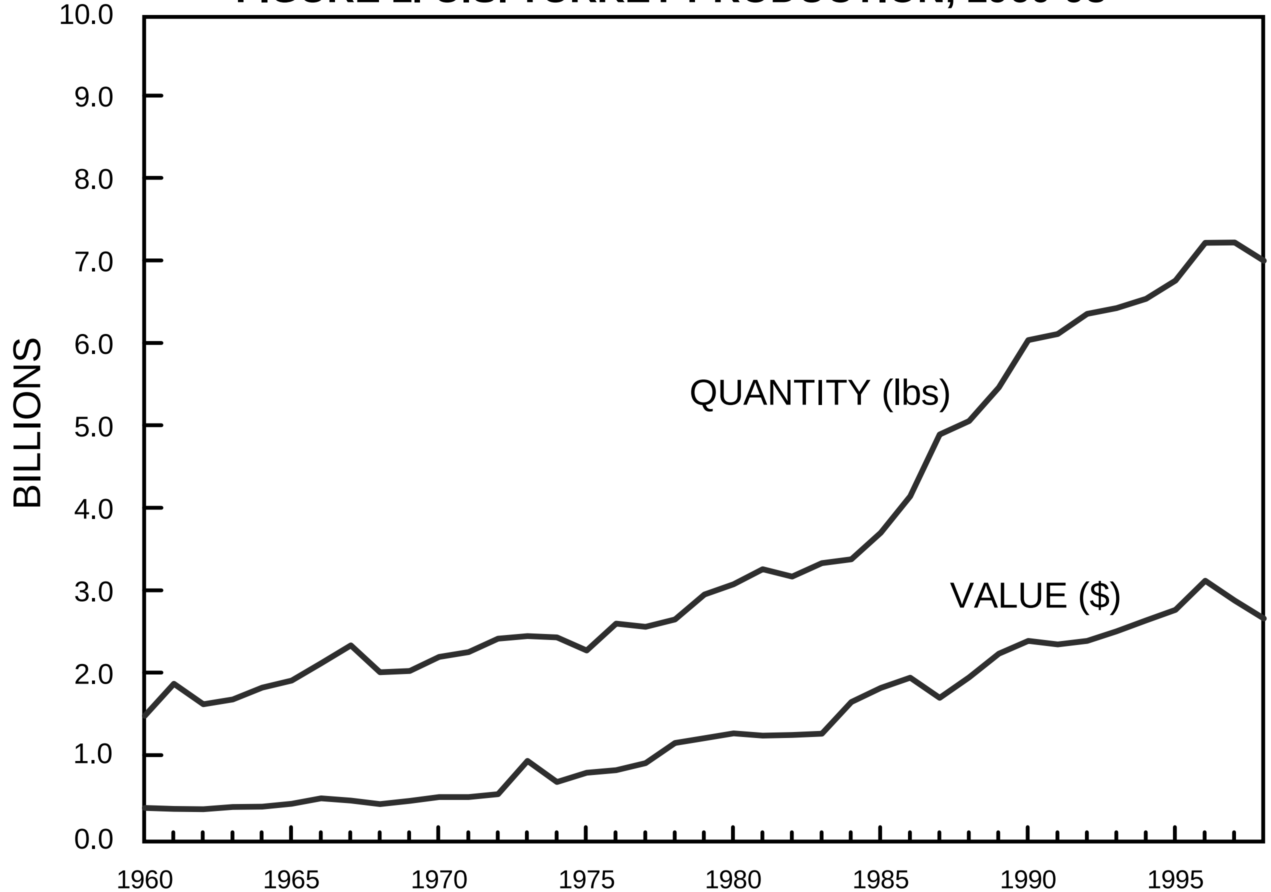
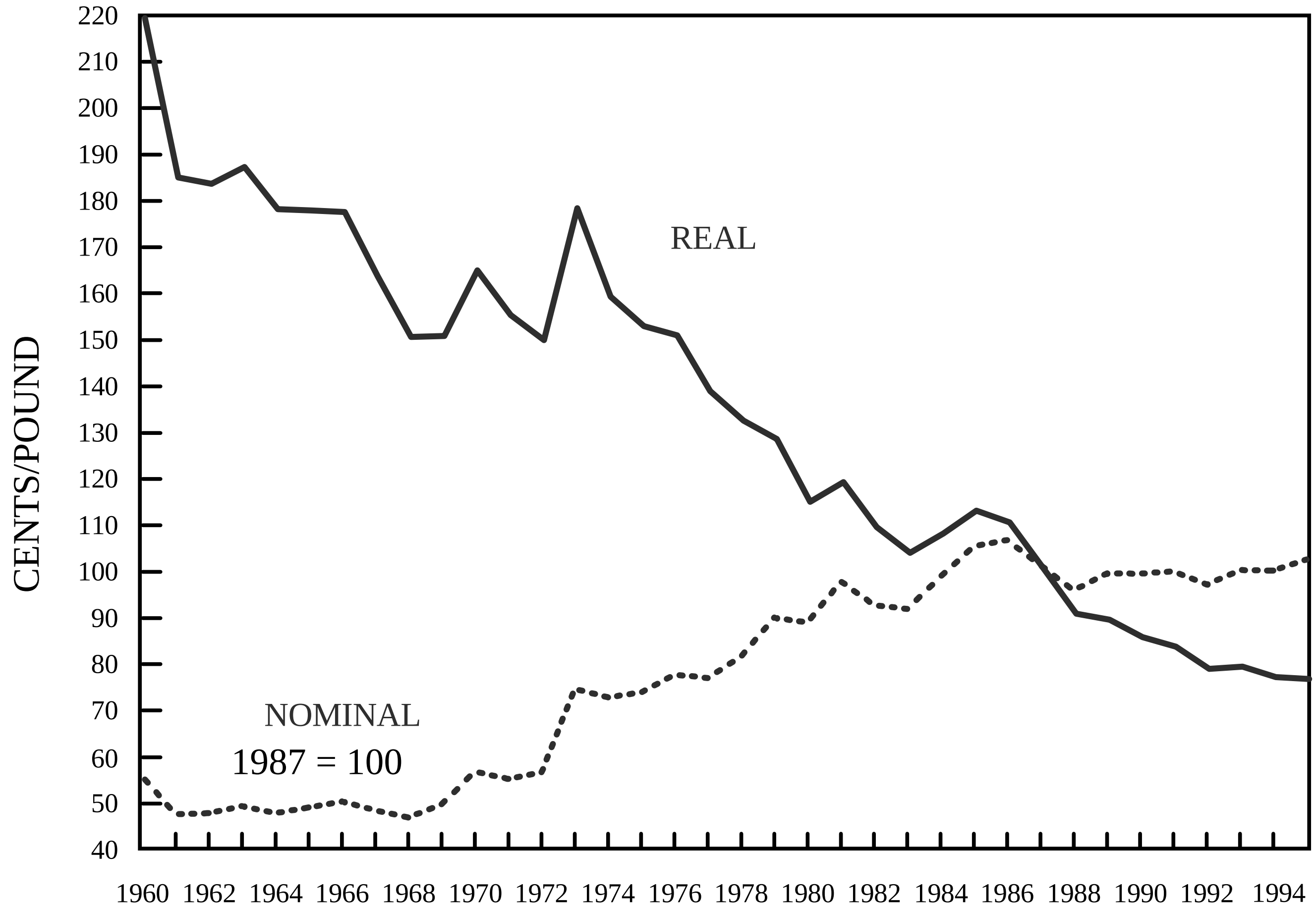


FIGURE 2. NOMINAL AND REAL U.S. TURKEY PRICES



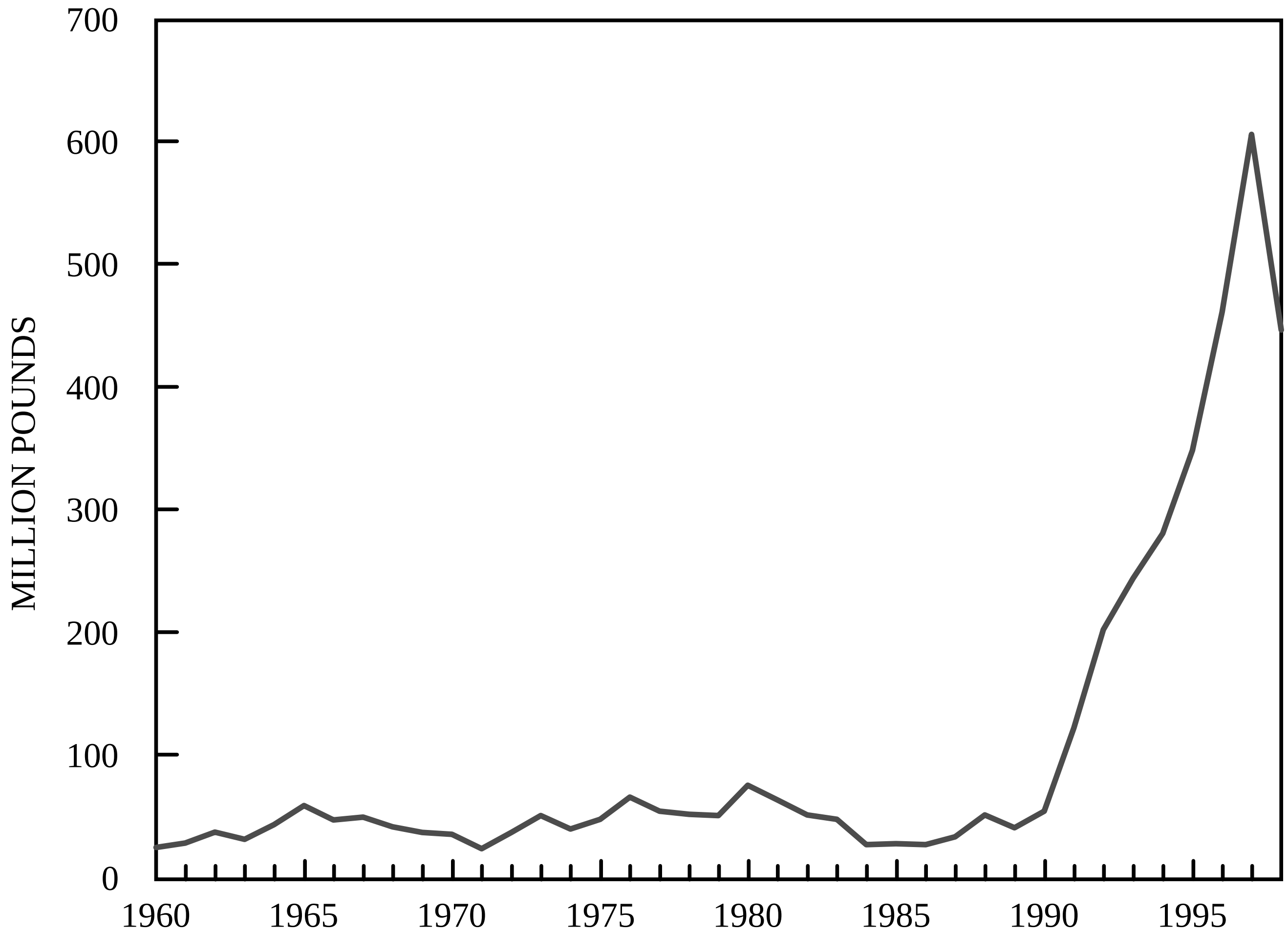
consumption to rise relative to most other meats; per capita consumption of chicken and turkey meats have increased while beef has declined and pork remained relatively constant. Per capita poultry consumption now exceeds that for beef. As shown in Figure 2, real turkey prices declined from about $1.13 per pound in 1970 to $0.41 in 1998 (1982-84 = 100). In addition, white meat contains less fat and has become the choice of many health conscious consumers, a factor that tends to create differences in demands for light and dark poultry cuts and that affects international trade since the preferences for dark meat still exist in many Asian countries.

Internationally, about 4.7 million metric tons (mt) of turkey meat were produced in 1997, of which the U.S. produced nearly one half, 2.3 million mt (FAO 1999). Of the world total, about 18 percent (853,000 mt) were exported. U.S. exports were relatively constant from 1960 to 1990, but increased dramatically in the 1990s, reaching over 600 million pounds in 1997 before declining in 1998 and 1999 due largely to decreased demand from Asia and Russia (Figure 3). Mexico is the largest importer of turkey meat from the U.S., followed by Russia (in recent years), Hong Kong and South Korea. Hong Kong re-exported a substantial amount of its imports, 15,000 of the 22,000 mt imported in 1997; substantial amounts of these went to main land China.

Turkey Export Model

This study utilizes structural time series models (STSM) that can be formulated directly in terms of trend, seasonal, cyclical and residual (irregular) components. These can be entered into the model as either stochastic or fixed variables (Harvey 1989, 1994; Harvey et al. 1986). STS models containing only the components can be estimated or they can include explanatory (independent) variables. In the latter approach, the explanatory variables enter into the model side by side with the unobserved components. In the absence of these components (as statistically significant variables), the model reverts to a standard regression (Harvey 1989, p. 14).

FIGURE 3. U.S. TURKEY EXPORTS, 1960-98



Since the turkey industry is dynamic and many changes have occurred in recent years, the model components, trends and seasonals, are entered in the stochastic form, i.e., their coefficients are allowed to vary over time; the trend variable can have both level and slope coefficients. The genaeral model used for this study is:

$$y_t = \mu_t + \gamma_t + \sum_{j=1}^{k} \delta_j x_{jt} + \lambda w_t + \epsilon_t \,, \tag{1}$$

where $:_t$ is the trend, R_t is the cycle, $(_t$ is the seasonal, x_{jt} is the value of the jth explanatory variable at time t and $*_j$ is its coefficient, w_t is the intervention variable, and $,_t$ is the irregular component. The hypothesized explanatory variables include the real U.S. wholesale turkey real price (PRICE), lagged turkey production (PRODLAG), the poultry trade weighted exchange rate (XRATE), and the real price for broilers (BROILPR); the intervention (dummy) variable is for the end of the cold war (COLDWAR), 0 for years 1970-88, 1 for 1989-98. Models with mostly the same set of variables are used to estimate models with annual, quarterly and monthly data; differences are that no season could be included in the annual model and that the lags are different. In the monthly model price is lagged one month and production one to three months; in the quarterly model both are lagged one quarter, and in the annual model neither is lagged (although all models were tested with different lags).

Following usual theoretic concepts, the price variable is expected to have a negative sign (the wholesale price is used since that is where price formation occurs in the integrated poultry industry). Increased poultry production in one period should lead to increased exports in subsequent periods; while it was anticipated that a one period (month) lag would be reasonable, one, two and three month lags were tested in the monthly model. Increases in the exchange rate make U.S. products relatively more expensive and, therefore, are expected to have a negative effect on exports. Broilers can be a substitute for turkey, indicating that its sign for this variable should be positive. Finally, the end of cold war resulted in an increase in exports of poultry to Russia and other former Soviet Union countries and could be expected to have produced structural changes that might not be captured by the trend variable, its sign should be positive.

Data for the 1970-98 period are used for estimating and testing the models. The source of the data is U.S. Department of Agriculture publications, primarily the *Poultry Yearbook* for 1970-95 data and various issues of the *Livestock, Dairy and Poultry Situation and Outlook* reports for the subsequent years; all data were obtained from the internet data base maintained at the Mann Library, Cornell University. The model is estimated using 1970-95 data, with 1996-98 data reserved for testing the forecasting capabilities of the model. The data were converted to natural logs for the estimation. The Stamp (Structural Time Series Analyser, Modeller and Predictor) program is used to estimate the model (Koopman et al. 1995).

Results

In the initial estimation of the monthly model it was found that a three month lag in turkey production was significant while the others were not. In addition, the intervention and broiler price variables were not significant. Thus, the model was adjusted and re-estimated without the cyclical component, intervention variable, broiler prices, and one and two month production lags.

Regression Results

The diagnostics for the final models generally are very good. The model strongly converged in 11 iterations which is generally an indication of good results (Koopman et al. 1995, p. 222). The results for the final model are given in Tables 1-3.

In the monthly model, the trend level is stochastic and significant, but its slope is not

Table 1. Estimated Coefficients of Final State Vector: Monthly Model

Variable	Coefficient	R.M.S.E.	t-value	Probability
Trend_Level	17.121	3.8219	4.4797	0.0000 *
Trend_Slope	0.0060696	0.00655189	0.926391	0.3550
Sea_1(Jan)	.0530058	0.0416240	1.2734	0.2039
Sea_2 (Feb)	-0.201759	0.0273849	-7.3675	0.0000 *
Sea_3 (Mar)	.0106723	0.0207421	0.514523	0.6073
Sea_4 (Apr)	-0.0651084	0.0211776	-3.0744	0.0023 *
Sea_5 (May)	.0211504	0.0195532	1.0817	0.2803
Sea_6 (Jun)	-0.0707695	0.0190435	-3.7162	0.0002 *
Sea_7 (Jul)	0.0320816	0.0186127	1.7236	0.0858 ***
Sea_8 (Aug)	-0.0397388	0.0186234	-2.1338	0.0337 **
Sea_9 (Sep)	0.0496311	0.0186326	2.6637	0.0081 *
Sea_10 (Oct)	0.00661723	0.0184349	0.358952	0.7199
Sea_11 (Nov)	0.00695860	0.0130149	0.534665	0.5933
XRATE	-1.7706	0.777836	-2.2763	0.0235 **
PRODLAG3	0.218807	0.0676623	3.2338	0.0014 *
PRICELAG1	-0.36356	00.190585	-1.9076	

* Significant at 1%; ** Significant at 5%; *** Significant at 10%.

Table 2. Estimated Coefficients of Final State Vector: Quarterly Model

Variable	Coefficient	R.m.s.e.	t-value	Prob.
Trend: Level	22.051	4.4881	4.9132	0.0000*
Trend: Slope	0.039723	0.029798	1.3331	0.1856
Sea_1	0.039319	0.054103	0.72656	0.4692
Sea_2	0.171817	0.054756	3.1379	0.0022*
Sea_3	-0.026130	0.041133	-0.63531	0.5267
Exchange Rate	-1.94120	0.948217	-2.0472	0.0433**
Price	-0.436896	0.18699o	-2.3364	0.0215**

* Significant at 1%; ** Significant at 5%
Std.Error 0.2544; Normality 15.64; H(32) 0.58619;
r(1) 0.013517; r(9) 0.022442; DW 1.935; Q(9, 6) 7.877;
Rs^2 0.10283

Table 3. Estimated Coefficients of Final State Vector: Annual Model

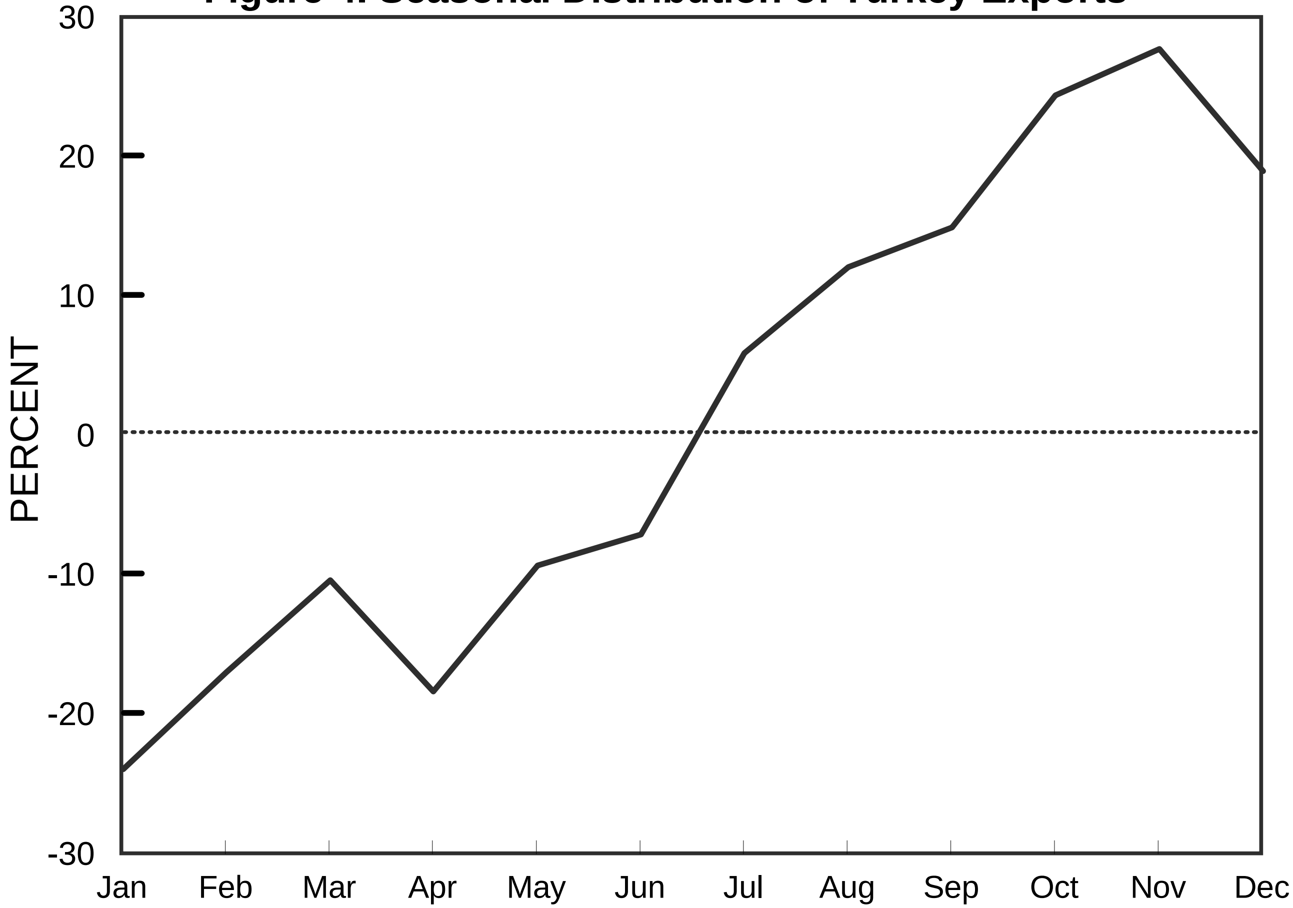
Variable	Coefficient	R.m.s.e.	t-value	Prob.
Trend: Level	13.299	1.6454	8.0826	0.0000**
Trend: Slope	0.207292	0.123778	1.6747	0.1041
Exchange Rate	-0.128426	0.391871	-0.327724	0.7453***

** significant a 5%; *** significant at 10%.; Std.Error 0.29724:
Normality 0.95975; H(10) 1.083; r(1) 0.098182; r(8) 0.011336;
DW 1.802; Q(8, 6) 4.829; Rd^2 -0.011144

statistically significant (Table 1). This that, at the end of the model (1995), the growth rate for exports is 7.28% per year (2.7 million pounds). While there has been an upward trend in turkey exports, this did not become pronounced until the 1990s when both the quantities exported and the percentage of production exported increased. Overall, the seasonal component was highly significant [chi square(11) = 100.8 (prob. = 0.0000)] with six of the individual month's coefficients significant. The seasonals, shown in Figure 4, indicate that exports tend to rise slowly from January through November, drop slightly in December, and then decline sharply in January; this seasonality is closely related to demand for the Christmas holiday season. The seasonal component, however, is fixed, meaning that it did not change significantly over the 1970-95 time period. The significance and fixity of the seasonal component for exports contrasts sharply with the changes in seasonality of domestic production and consumption. The three explanatory variables in the final model were all statistically significant with price response inelastic (-0.36). Exchange rates have a strong negative effect on exports, meaning that a strong dollar, as expected, is harmful to U.S. exports. Finally, increases in production have a positive impact on exports beyond that captured in the trend component.

The quarterly model results (Table 2) are similar to those of the monthly model with respect

Figure 4. Seasonal Distribution of Turkey Exports



to the trend and seasonal components. However, only the price and exchange rate explanatory variables are statistically significant and included in the final model. Price elasticity is -0.44, slightly higher than in the monthly model. Production was not significant, either as a current or lagged variable.

The annual model had a trend similar to the other two models with a level significant but not slope. There could, of course be no seasonal component. The only significant explanatory variable is the exchange rate which has a negative effect as in the other models. Neither the current or lagged price and production variables were statistically significant.

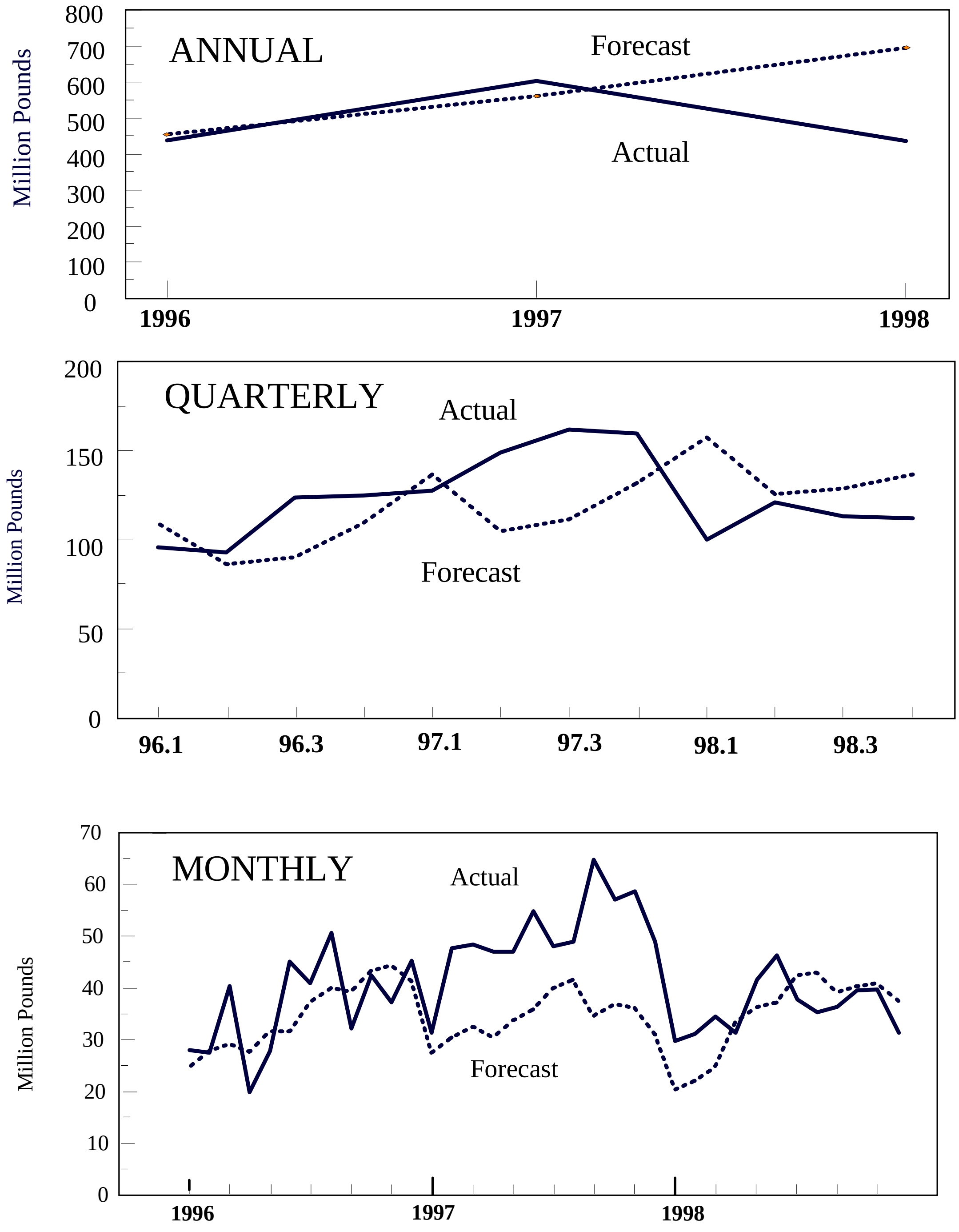
Forecasts

The models were estimated for 1970-95 so that forecasts of turkey exports could be made for 1996-98 and compared with actual exports. The actual and predicted exports for those three years are depicted in Figure 5 for all three models. The forecasts for the annual model were fairly accurate for the first two years, but did not pick up the downturn that occurred in 1998 and predicted, essentially, that the trend toward increased exports existing at the end of the estimation period would continue. Both the quarterly and monthly models made reasonably good forecasts including forecasting downturns although not always during the exact time when they occurred. The monthly model underestimated exports in 1997, the year when they peaked, but was close to the actual for 1998. The quarterly model was fairly close all three years, underestimating a little in 1997 and over estimating for 1998; it also predicted a continued uptrend but did not overestimate as badly as the annual model for 1998.

Conclusions

A main conclusion is that the STS approach does a good job of modeling turkey exports with both the trend and seasonal components being important in explaining export variations in the

FIGURE 5. ANNUAL, QUARTERLY & MONTHLY FORECASTS



monthly and quarterly models. The trend component was, as expected, stochastic, and seemed to effectively capture the changes that occurred after the end of the cold war. However, the highly significant seasonal component was found to be fixed, a situation that does not characterize several other turkey variables, including domestic production and consumption. This is somewhat surprising since U.S. turkey production no longer has a significant seasonal component and the seasonal consumption component has declined in magnitude. While a major factor in the long run trend of increased turkey production, consumption and exports is due mainly to decreasing real prices of turkey meat due to technological advances, exchange rates play a key role in turkey exports.

The monthly and quarterly models were, in general, superior to the annual model. They had more significant variables and did a better jog of explaining exports. There were relatively little difference between the quarterly and monthly models, although the latter is probably slightly better. The models did reasonably good jobs of forecasting exports for three out of estimation years, 19986-98. The annual model made accurate forecasts for the first two years, but failed to pick up the 1998 downturn and, consequently, the 1998 estimate was far from actual exports. The other two models were closer for the third year although the quarterly model also predicted higher than actual exports fotr1998. While the mnonthly model badly underestimated 1998 exports it was close for both 1996 and 1998. Thus, overall the model utilizing monthly data appears slightly supreior.

References

Alston, J. M. and G. M. Scobie. "A Differentiated Goods Model of the Effects of European Policies in International Poultry Markets." *Southern Journal of Agricultural Economics* 19(1987): 59-68.

Aradhyula, S. V. and Holt, M. T. "Risk Behavior and Rational Expectations in the U.S. Broiler Market." *American Journal of Agricultural Economics* 71:4 (1989): 892-902.

Bishop, R. V., L. A. Christensen and L. Witucki. "The World Poultry Market-Government Intervention and Multilateral Policy Reform," AGES 9019, *USDA*, *Economic Research Service*, Washington, DC, 1990.

Chavas, J. P. and S. R. Johnson. "Supply and Dynamics: The Case of U.S. Broilers and Turkeys." *American Journal of Agricultural Economics* 64(1982):558-64.

Food and Agricultural Organization (FAO). *FAOSTAT Data Base.* http://apps.fao.org, downloaded May 27, 1999.

Goodwin, J. W., S. A. Madrigal, and J. E. Martin. *Supply and Demand Responses In the U.S. Broiler Industry*. Report Series 332, Agricultural Experimental Station, University of Arkansas, Fayetteville, Arkansas, 1996.

Haley, L. H. "Measuring the Effectiveness of the Export Enhancement Program for Poultry." AGES 90-16. Economic Research Service. USDA, Washington, DC, 1990.

Harling, K. F. and R. L. Thompson. "Government Intervention in Poultry Industries: A Cross-Country Comparison." *American Journal of Agricultural Economics* 67(1985):243-50.

Harvey, A. C. "*Forecasting Analysis of Time Series Models and the Kalman Filter."* Cambridge: Cambridge University Press, 1989.

Harvey, A. C. *Time Series Models,* 2nd ed. Cambridge, MA: The MIT Press, 1994.

Harvey, A. C., S. G. B. Henry, H. S. Peters and S. Wren-Lewis. "Stochastic Trends in Dynamic Regression Models: An Application to the Employment-Output Equation." *Economic Journal* 96(1986):975-85.

Heien, D."An Econometric Analysis of the U.S. Poultry Industry." *American Journal of Agricultural Economics* 58:(1976):311-16.

Henry, R. and G. Rothwell. *The World Poultry Industry*. Washington: International Finance

Corporation, The World Bank, 1995.

Kapombe, C. M. *Broiler Exports: A Structural Time Series Approach.* Ph.D. Dissertation, West Virginia University, 1997.

Kapombe, C. M. and D. Colyer. “Modeling U.S. Broiler Supply Response: A Structural Time Series Approach.” Submitted to the *Review of Agricultural and Resource Economics* 7:2(Oct 1998):241-251.

Koopman, S. J., A. C. Harvey, J. A, Doornik, and N. Shephard. *Stamp 5.0: Structural Time Series Analyser, Modeller and Predictor.* London: Chapman & Hall, 1995.

Leong, Y. C. and G. J. Elterich. "An Econometric Study of Japan's Broiler Consumption and Production, and Its Import Demand from the U.S.." Bulletin No. 459. Agricultural Experimental Station, University of Delaware, Newark, Delaware, 1985.

Malone, G. W. and J. Reece. "Estimating Broiler Supply and Demand as a Simultaneous System." *Poultry Science* 55:(1976):414-18.

Martinez, S. W., G. W. Norton, O. Capps and W. D. Weaver. "A Demand Model of the Broiler Industry." *Poultry Science* 65(1986): 2071-75.

Rausser, G. C. and Cargill, F. "The Existence of Broiler Cycles: An Application of Spectral Analysis." *American Journal of Agricultural Economics* 32:(1970):109-21.