NCCC-134
APPLIED COMMODITY PRICE ANALYSIS, FORECASTING AND MARKET RISK MANAGEMENT

A Reexamination of a Popular Econometric Model of Pork Supply and Forecasting Performance vs. ARIMA and Composite Approaches

by

John Nwoha, Mark Manfredo,
Mark Ditsch, and Raymond Leuthold

Suggested citation format:

Nwoha, J., M. Manfredo, M. Ditsch, and R. Leuthold. 1997. "A Reexamination of a Popular Econometric Model of Pork Supply and Forecasting Performance vs. ARIMA and Composite Approaches." Proceedings of the NCR-134 Conference on Applied Commodity Price Analysis, Forecasting, and Market Risk Management. Chicago, IL. [http://www.farmdoc.uiuc.edu/nccc134].

A Reexamination of a Popular Econometric Model of Pork Supply and Forecasting Performance vs. ARIMA and Composite Approaches

John O. Nwoha, Mark R. Manfredo, Mark W. Ditsch, and Raymond M. Leuthold*

"A Quarterly Model of the Livestock Industry" by Richard P. Stillman provides a classic example of a structural model of key stages of pork production. Since the publication of the Stillman model in 1985, hog production has moved toward greater industrialization. Hence, structural change in key hog supply variables creates a need to update and reexamine this model and compare its forecasting ability to alternative formulations such as ARIMA and composite forecasts. Structural change was found to be present for sow farrowings, but less obvious for other key supply variables. The forecasting performance of the updated econometric model was strong in the presence of alternative forecasts for both one and four-step ahead horizons.

INTRODUCTION

"A Quarterly Model of the Livestock Industry" by Richard P. Stillman (1985) provides a classic example of a simple to use and implement hog supply model. Since the writing of this ERS bulletin, the hog industry has undergone considerable change, especially in the area of hog production. Hog farrowing and feeding operations are larger, taking advantage of economies of scale. Contract production has become common, with contractors providing growers with feed, feeder pigs, and other inputs while the farmer provides the facility and labor (Rhodes, 1995). Because of this, models of the hog supply sector may have experienced structural changes. Also, the literature in hog supply models is dated in terms of the sample data used. Since policy analysis and forecasting are major uses of economic models, it seems appropriate to update the Stillman model.

The objectives of this paper are twofold. The first objective is to reestimate and respecify the Stillman model with current data in order to better understand the changes that are perceived in the hog industry. Second, the forecasting ability of the updated model is tested in relation to Box-Jenkins ARIMA models and composite econometric/time-series

*Nwoha and Manfredo are graduate research assistants in the Department of Agricultural and Consumer Economics at the University of Illinois, Urbana-Champaign. Ditsch is a merchandiser with Consolidated Grain and Barge, Mandeville, LA. Leuthold is Professor and Director of the Office for Futures and Options Research, Department of Agricultural and Consumer Economics, University of Illinois.

forecasts. The next section outlines the Stillman model and briefly reviews other recent hog supply modeling efforts. Then, the data sources and methods used are discussed. Finally, the results of the reestimated econometric model, ARIMA models, and subsequent forecast evaluations are presented.

SELECTED LITERATURE

The hog production model specified by Stillman is just one part of a total livestock sector model. Stillman originally specified this model to be used by situation and outlook analysts to aid in understanding the livestock industry and to forecast prices and quantities of beef, pork, and chicken. In his formulation of the hog supply sector, Stillman uses a 6-equation recursive model to capture the biological relationships in pork production. Consistent with the recursive model and biology of pork production, the flow of causality is unidirectional, meaning that committed resources cannot be altered for several periods.

The first equation is sow farrowings. Sow farrowings, the number of sows giving birth in a particular quarter, drives the production process of hogs. Stillman specifies the sow farrowings equation as:

(1) **FAR(t) = F(FARL1, FARL4, FARL5, CORNL1, B&GPR)** ,

where FAR(t) is sow farrowings in time period t, FARL1, FARL4, and FARL5, are one, four, and five period lagged farrowings respectively, CORNL1 is one period lagged corn price, and B&GPR is the expected price of barrows and gilts. Stillman formulates B&GPR as a distributed lag of the past three lagged barrow and gilt prices with weights of 1/2, 1/3, and 1/6, respectively. The B&GPR represents producer's expectations about future hog prices, and the lagged corn price represents a major cost component in hog production. The lagged farrowing variables attempt to pick up the biological processes inherent in sow farrowings.

Following the sow farrowings equation, an equation representing pig crop is specified as:

(2) **PC(t) = 7.3*FAR(t),**

where PC is pig crop and FAR is sow farrowings. In essence, pig crop represents the number of pigs born in a quarter. The 7.3 is the average number of pigs saved per litter for the time period of Stillman's study.

Next, barrow and gilt slaughter is formulated as:

(3) **B&GSL(t) = F(PCL1, PCL2, DV1 and DV2)** ,

where B&GSL is barrow and gilt slaughter, PCL1 and PCL2 are one and two period lags of the pig crop, and DV1 and DV2 represent dummy variables for the first and second quarter. Since it takes about five months for piglets to reach market weight, PCL1 and PCL2 are used as explanatory variables in addition to seasonal dummy variables.

In an attempt to further delineate the slaughtering process, an equation is estimated for sow slaughter and an identity specified for total hog slaughter. Stillman formulates the sow slaughter equation as:

(4) **SS(t) = F(FARL1, B&GPR, CORNL1, DV1, DV2, and DV3) ,**

where SS is sow slaughter and FARL1, B&GPR, CORNL1 are as defined above in the sow farrowings equation. DV1, DV2, and DV3 are seasonal dummy variables. Stillman (1985, p. 16) states that "sow slaughter measures the maintenance of the breeding herd and marginal adjustment to the short run production capacity." The identity for total hog slaughter is:

(5) **HS(t) = SS(t) + BS(t) + B&GSL(t) ,**

where BS is defined as the historical mean value of the boar to sow slaughter ratio.

The final equation specified by Stillman is for pork production. Pork production is modeled as the product of hog slaughter times an average carcass weight. The average carcass weight used is 172 pounds.

(6) **PP(t) = HS(t)*172 .**

Several articles in the agricultural economics literature use similar formulations to model the hog production process. Some models utilize more or less equations; however, they all have a similar structure that follows the biology of pork production. One of the more famous articles is by Harlow (1962) who uses a recursive, cobweb specification. Harlow's supply equations are sows farrowing, hogs slaughtered, and quantity of pork produced. A more recent hog production model is that of Holt and Johnson (1988). Unlike Harlow and Stillman who use OLS procedures, Holt and Johnson use an instrumental variable procedure in estimating their model. They identify a seven-equation model. The model is unique in that it models the breeding herd inventory which consists of sows, gilts, and boars with the idea that "breeding herd places a physical limit on the number of sows farrowing, " (Holt and Johnson, 1988, p. 315). Skold (1992) models additions to the breeding herd and breeding herd inventory as well as the behavioral relationships modeled in Stillman.

DATA AND METHODS

This study uses quarterly data for the years 1975.1 to 1996.4. The data come from various USDA and NASS publications and bulletins including Agricultural Prices, U.S. Quarterly Hogs and Pigs Report, and the Livestock Slaughter Report. Definition of the data used are as follows: 10 state sow farrowings, 1000 head; 7 market farm price of 230 lb. barrows and gilts, dollars/cwt.; federally inspected hog, sow, barrow & gilt, and boar slaughter, 1000 head; 10 state pig crop, 1000 head; commercial production of pork, millions of lbs.; and U.S. price of No. 2 yellow corn, dollars/bushel.[1] Nominal prices and quantities are used throughout the study since one of the major objectives of both the Stillman model and the ARIMA models is forecasting. If real prices and quantities were used, then the deflator would also have to be forecasted as well.

In addition to the price and quantity data listed above, expert opinion is used to update the numbers for pigs per litter and average carcass weight in the econometric model. The number used for pigs per litter, 8.2, was provided by Professor G.R. Hollis of the Department of Animal Science at the University of Illinois, Urbana-Champaign. Similarly, the average carcass weight for hogs of 182 pounds was suggested by Professor Darrell Good of the Department of Agricultural and Consumer Economics, University of Illinois, Urbana-Champaign.

OLS regression is used to reestimate Stillman's model. Initially, the model is reestimated over the entire sample period, 1975.1 to 1994.4, and the coefficients are compared to Stillman's results.[2] The presence of structural change is examined using the CUSUM recursive residual test, sequential Chow test, observation of significance levels of the parameters for each part of the sample, and the examination of slope shifting variables. Traditional Box-Jenkins ARIMA model procedures are used in the estimation of the time series models. ARIMA models are identified, estimated, and diagnosed for the price of barrows and gilts, sow farrowings, sow slaughter, and barrow and gilt slaughter. The price of barrows and gilts model is used to forecast the exogenous variable B&GPR (expected price of barrows and gilts) in both the sow farrowings and sow slaughter equations.

Both one-step and multiple-step ahead out-of-sample forecasts are conducted for each of the econometric equations for the period of 1995.1 to 1996.4. Similarly, one and multiple-step

---

[1]In 1992, the hogs and pigs report changed from 10 to 16 states. To remain consistent throughout the data set, the quarterly sow farrowings and pig crop numbers were taken from the original 10 states for 1992 to 1996.

[2]Stillman estimated his model over the period of 1970 to 1981 and evaluated its forecasting performance from 1982 to 1984.

ahead ARIMA and composite forecasts are made to compare against the econometric forecasts. Composite forecasts are constructed by taking a simple average of the econometric and ARIMA forecasts for each equation.[3] The forecasts are evaluated on the basis of Root Mean Squared Error (RMSE), Mean Absolute Deviation (MAD), Mean Absolute Percentage Error (MAPE) and Theil's U2 coefficient. The latter allows comparison of the forecasts with naive forecasts. In addition to statistical evaluation, the ability of the alternative models to predict directional movement is tested.

RESULTS

Over the entire sample (1975.1 to 1994.4) the results of the reestimated equations are strikingly similar to Stillman's results (Table 1). Coefficients for the sow farrowings equation are all of anticipated sign and consistent with Stillman's results. The coefficients on one-, four-, and five-period lagged farrowings are almost identical to those of Stillman's, while the lagged corn, expected farm price, and constant are all considerably smaller than the original formulation. The updated model also shows no signs of autocorrelation. For the updated barrow and gilt slaughter equation there are again strong similarities, especially for the lagged one and two period pig crop variables. However, the dummy variables for our regression are statistically significant while those for Stillman's model are not.[4] The largest discrepancy is with the updated sow slaughter equation. All of the coefficients have the anticipated signs; however, there are large differences in the value of some of the coefficients. Similar to the sow farrowings equation, the coefficients on B&GPR and CORNL1 are approximately half the magnitude of Stillman's model. The lagged one period farrowings are the most similar, with coefficients at 0.432 and 0.525 respectively, for the reestimated model and Stillman's formulation.

It is important to note that the updated barrow and gilt slaughter equation and the updated sow slaughter equation both exhibit first and fourth order autocorrelation. Stillman, however, did not point this out in his article and most likely had similar problems. This autocorrelation will bias the t-tests and therefore, results should be viewed with caution. All three equations pass the Jarque-Bera test for normalcy of error terms and show no significant heteroskedasticity via the Breusch-Pagan LM test.

---

[3]Park and Tomek (1988) reviewed and appraised composite forecasting methods, and concluded that simple averaging of forecasts may be an accurate and inexpensive alternative to more complex composite forecasting techniques.

[4]Note that Stillman did not include a complete set of quarterly dummy variables.

Structural Change

The reduced magnitude of B&GPR and CORNL1 in both the sow farrowings and sow slaughter equation (Table 1) suggests the possibility that structural change has occurred since the time period used by Stillman. The increased industrialization of the hog industry also adds suspicion that the supply structure of the hog industry has experienced structural change. Using the aforementioned tests for structural change, evidence of structural change is most prominent in the sow farrowings equation. The CUSUM recursive residual test suggests that a structural change occurred near 1986.1 for the sow farrowings equation. The sequential Chow test shows an unusual jump at the same time period; however, it fails to reject the null hypothesis of parameter stability.[5] The significance of slope shifting variables for the second part of the sample (1986.1 to 1994.4) and observation of the changing magnitude of both the B&GPR and CORNL1 coefficients estimated observation by observation also confirms structural change beginning at 1986.1. For instance, in the first part of the sample both B&GPR and CORNL1 coefficients are 14.996 and -131.79 respectively. In the post 1986.1 sample, the B&GPR coefficient decreases in magnitude to 6.829 while the lagged corn coefficient goes to positive 8.112. This is not the expected sign on the lagged corn variable, and the t-ratio of 0.152 illustrates no statistical significance.

Similar procedures are conducted for the barrow and gilt slaughter and for the sow slaughter equations. For the barrow and gilt slaughter equation, a structural change according to the CUSUM recursive residual test occurs later in the sample, around observation 1989.1. Again, the sequential Chow test did not indicate a structural change. Splitting the sample at 1986.1, the magnitudes of the coefficients appear to be different for each half of the sample, but the signs and the significance levels remain similar.[6] Overall, the presence of a structural change along the same lines as the sow farrowings equation is more difficult to identify, in fact, it is difficult to conclude that structural change occurred at all in this equation.

Finally, for sow slaughter the CUSUM recursive residual test shows no signs of structural change. The Chow test is deemed unreliable since it suggests parameter instability at each and every breakpoint throughout the sample period. Observation of both parts of the

---

[5]See Alston and Chalfant (1991) for a discussion of problems with Chow tests. Green (1993) also states that the Chow test is invalid under situations where the disturbance variance is different for each part of the split sample. Green (pg. 215) suggests the use of a Wald test for these situations. Results of the Wald test confirmed structural change at the 10% level. However, Green also suggests that this test may not be powerful when used with small samples.

[6]For consistency, the sample was split at the same points as in the sow farrowings equation because the sow farrowings equation is such a vital equation in this recursive model.

sample (split at 1986.1), however, gives some evidence of structural change for sow slaughter. The coefficient on the lagged one period corn price goes from 115.12 to 18.33 and the DV3 goes from -183.76 to 2.91. In addition, both of these coefficients become insignificant with t-ratios at 0.734 and 0.127, respectively.

Overall, structural change is most evident with the sow farrowings equation. The time period of the structural change in this equation (1986.1) appears to be consistent with the start of increased industrialization in the swine industry. During the mid-to-late eighties to the present time, the swine industry has seen a move to larger, more vertically coordinated production. Much of this vertical coordination has come in the form of contract production of hogs. Most of the producers in these types of contract arrangements have very large operations, often represented by multi-million dollar capital investments. Therefore, these operations are probably less apt to respond to short-run price stimuli in lieu of more constant production to keep average fixed costs at a minimum. In addition, contract growers are paid on a pre-negotiated per head basis. Inputs such as feed (corn) are provided by the contractor, contributing to the reduction of importance of the price of corn in sow farrowings and subsequently in sow slaughter.

Final Econometric Model Used for Forecasting

After examining the various results for structural change, all three equations are reestimated using the sample period from 1986.1 to 1994.4, saving eight quarters of observations for out-of-sample forecasting (Table 2).

For sow farrowings, the lagged corn price (CORNL1) is dropped from the estimation since it is statistically insignificant. The expected price variable (B&GPR) is kept in order to retain an economic variable in the equation. B&GPR is significant at the 10% level but not at the 5% level. Since the model contains lagged dependent variables, autocorrelation is tested by regressing the residuals on the exogenous variables and lagged residuals. The t-statistic for the fourth lagged residual is significant at the 10% level suggesting the presence of some fourth order autocorrelation. However, as a group, the coefficients on the lagged residuals are insignificant using an F-test. Because of this weak evidence, the higher order autocorrelation is not modeled.

The barrow and gilt slaughter equation is not modified.[7] The Durbin-Watson is in the undefined range for first order autocorrelation; however, the test of regressing the residuals on the explanatory variables and lagged residuals produces no evidence of significant first or higher order autocorrelation.

---

[7]Note that the complete set of quarterly dummy variables were included in our model.

Similar to the sow farrowings equation, the sow slaughter equation is modified by excluding the lagged corn price as the coefficient is insignificant over the new data set. All of the coefficients are statistically significant; but, the Durbin-Watson statistic shows evidence of first order autocorrelation. Regressing the residuals on the exogenous variables and the lagged residuals suggests some first order autocorrelation with a t-statistic on the one period lagged residual significant at the 10% level but not at the 5% level. Lagged endogenous variables are also used in an attempt to model the autocorrelation; however, adding these variables into the equation actually introduces more autocorrelation. The sow slaughter equation is the only equation that exhibits heteroskedasticity at the 5% level via the Bruesch-Pagan test. Since sow slaughter is only about one percent of the total amount of hogs slaughtered, these nonspherical disturbances are not modeled. Therefore, the t-tests are most likely biased; however, the estimates are unbiased. There is some potential that this may cause error and subsequently compounding error due to the recursive structure of the model.

In addition to the three equations estimated, the other three equations of the original Stillman formulation are updated with current information. For instance, the litter size in the pig crop equation is changed from 7.3 to 8.2 to reflect the recent increase in litter sizes. In equation 5, boar slaughter is calculated as the historical ratio of boar slaughter to sow slaughter (approximately 20%). In the pork production equation the carcass weight for market hogs is changed to 182 pounds to better reflect the larger slaughter weights seen in today's hog industry.

ARIMA Model Results

Box-Jenkins ARIMA models are constructed to forecast the price of barrows and gilts, sow farrowings, barrow and gilt slaughter, and sow slaughter. The ARIMA models are estimated over the entire sample, 1975.1 to 1994.4, since the portion of the data series used in the estimation of the econometric models (post 1986) does not provide enough observations for adequate ARIMA estimation.

The ARIMA model for the price of barrows and gilts (Table 3) is an AR(6). The price forecasts from this model, using the weighted average lag procedure followed in Stillman, are used to compute the exogenous variable for expected price of barrows and gilts (B&GPR) when realized prices are not available (i.e., in the case of mulitple-step ahead forecasts). The price of barrows and gilts was initially estimated as an ARIMA $(3,0,2)x(1,0,0)_5$. When plotting the forecasts, however, the model appeared to be nonstationary, with longer horizon forecasts failing to converge to the mean. Because of this, the model was reidentified as an AR(6) process. The AR(6) process was recommended by the S-Plus statistics package using the Akiake information criteria. The results of the AR(6) model and other ARIMA models are shown in Table 3.

The ARIMA model for sow farrowings is specified as an ARIMA $(1,0,0)x(0,1,3)_4$. Initial observation of the ACF and PACF showed definite signs of seasonality, with ACF spikes tapering off at intervals of four and PACF spikes significant at lags four and five. This specification has no significant spikes in either the residual ACF or PACF, is parsimonious, and passes the Ljung-Box Q-test for all but lag 5. The model was also over and underfitted and forecasts were plotted to ensure model parsimony and stationarity respectively. Alternative specifications were also estimated including an ARIMA $(1,0,0)x(3,1,0)_4$ and an ARIMA $(1,0,0)x(1,1,0)_8$; however, initial examination of out-of-sample forecasting performance using mean square error criteria confirms the use of the ARIMA $(1,0,0)x(0,1,3)_4$.[8]

The barrow and gilt slaughter model estimated as ARIMA $(1,0,0)x(0,1,1)_4$ is the most parsimonious of the four equations. Similar to the sow farrowings equation, observation of the ACF and PACF identified a potential seasonal component with ACF and PACF spikes significant at four lags and four and five lags respectively. Again, alternative models were initially specified, all of which were relatively parsimonious and passed the traditional diagnostic tests. These models included an ARIMA $(1,0,0)x(2,1,0)_4$ and $(5,0,0)x(1,0,0)_4$; however, the ARIMA $(1,0,0)x(0,1,1)_4$ showed superior forecasting performance initially among the models.

Finally, an ARIMA $(1,0,0)x(3,1,0)_4$ is estimated for sow slaughter. An alternative model incorporating a seasonal MA was estimated as ARIMA $(1,0,0)x(0,1,1)_4$ which also passed all diagnostic tests. Despite the greater parsimony of this model, initial testing of its forecasting performance was slightly inferior to that of the ARIMA $(1,0,0)x(3,1,0)_4$ specification.

Forecasting and Comparisons of Forecasts

Out-of-sample forecasts of the econometric, ARIMA, and composite forecasts are conducted for the quarters of 1995.1 to 1996.4. One, two, three, and four-step ahead forecasts are conducted for equations one through six. However, for brevity only the one and four-step ahead forecast evaluation results are presented (Table 4). The composite forecast is developed by taking a simple average (equal weighting) of econometric and ARIMA forecasts for each of the six equations.

Table 4 shows the evaluation of the one-step and four-step ahead forecasts for both econometric and ARIMA forecasts as well as the composite forecasts. For the one-step ahead forecasts, all of the forecasts, except for sow slaughter, perform well compared to a naive forecast as evidenced by the U2 coefficients. Similarly, for all one-step ahead forecasts, the

[8]Models estimated without seasonal differencing continually produced significant spikes in the ACF and PACF for distant lags (i.e., approximately lag 16).

MAPE's are less than 5% except for the sow slaughter forecasts. In measuring the ability to forecast directional movement, all of the one-step ahead forecasts perform well. All forecasts for sow farrowings, barrow and gilt slaughter, hog slaughter, and pork production predict directional movement with 87.5% accuracy. All pig crop forecasts are 100% accurate in predicting directional movement. However, the sow slaughter forecasts demonstrate mixed performance in predicting directional movement, with the ARIMA model at 75%, econometric at 50%, and composite at 37.5%.

Examining the one-step ahead forecast performance for each individual supply factor, both the econometric and ARIMA forecasts for sow farrowings, and subsequently pig crop, are quite similar across performance criteria. For both sow farrowings and pig crop, the econometric model is superior based on RMSE and the U2 coefficient. Based on MAD and MAPE evaluation criteria, however, the composite provides the best forecast. This inconsistency among performance criteria is casued by a large forecast error for 1996.2 in which the error for the ARIMA forecast is almost twice as large as the econometric forecast. Therefore, the squaring of this error accentuates the RMSE and U2 statistic and subsequently favors the econometric forecast. For barrow and gilt slaughter, the composite model dominates both the ARIMA and econometric formulations, especially when based on RMSE and the U2 statistic. As mentioned earlier, the overall performance of the sow slaughter forecasts are poor. For sow slaughter, the ARIMA forecasts are superior across performance criteria but still do not beat the naive forecast as evidenced by a U2 statistic of 1.09. Composite forecasts for hog slaughter are superior to the individual econometric and ARIMA forecasts based on RMSE and U2, however the econometric model performs best based on MAD and MAPE. This result is opposite to that of the sow farrowings and pig crop forecasts. Finally, for pork production, the ARIMA forecasts outperform the econometric and composite forecasts across criteria which is inconsistent with the results of the hog slaughter forecasts. Since all the pork production forecasts consistently underestimate actual pork production, ARIMA forecasts are superior since they are the largest of the forecasts. This result is very sensitive to the assumed carcass weight.[9]

In the case of the four-step ahead forecasts, the econometric forecasts are superior for both sow farrowings and pig crop. This is not surprising since traditionally ARIMA forecasts do not perform well for multiple-step ahead forecasts. Similar to the one-step ahead forecasts, the composite forecasts perform best for barrow and gilt slaughter. However, for sow slaughter it is difficult to delineate superiority between the alternative forecasts since each of the statistical criteria (RMSE, MAD, MAPE, and U2) are almost identical across models. In addition, the sow slaughter forecasts cannot beat the naive model. As with the one-step

---

[9]The pork production to hog slaughter ratio illustrated that carcass weight averaged 189 pounds for the out-of-sample period. Sensitivity analysis showed that the use of 188 pounds for carcass weight would provide consistent results to that of hog slaughter.

forecasts for pork produciton, the ARIMA formulation is superior to the econometric an composite forecasts with results being sensitive to carcass weight assumed. The four-ste ahead forecasts for all equations perform well in predicting directional movement. On average, all forecasts are able to predict the directional movement with 75% accuracy.

SUMMARY AND CONCLUSIONS

This paper updates, reestimates, and forecasts the hog supply model originally set by Stillman (1985). The forecasts from this updated econometric model were then compa with forecasts from Box-Jenkins ARIMA models and composite econometric/ARIMA forecasts. In the reestimation of the econometric model, there was evidence of structural change in the sow farrowings equation starting at 1986.1. However, the evidence in favo structural change for the other estimable equations, barrow and gilt slaughter and sow slaughter, was less evident. The reestimation of Stillman's model with new data suggests economic variables are becoming less important in describing key hog supply variables. T is evidenced by the exclusion of the lagged corn price (due to statistical insignificance) fr the updated sow farrowings and sow slaughter equation and the decreased statistical significance of expected prices in the sow farrowings equation. This structural change is consistent with the increased industrialization of the hog industry. This result suggests th need for further research into the structural change in sow farrowings and its impact throughout the hog production sector.

For one-step ahead sow farrowings, pig crop, and hog slaughter, both the econome and composite forecasts performed well; however, superiority of forecasts among evaluati criteria was mixed. The dominance of the composite model was more evident for barrow gilt slaughter. For sow slaughter the ARIMA forecasts were superior but failed to beat th naive forecast. The ARIMA forecasts were also superior for pork production, but this res was sensitive to carcass weight. In the case of four-step ahead forecasts, the econometric forecasts were superior for sow farrowings and pig crop while the composite was superior barrow and gilt slaughter and hog slaughter. For both one and four-step forecasts of sow slaughter and pork produciton, the ARIMA model was dominant. The general performanc the composite model illustrates that both the econometric and ARIMA forecasts contain use information.

Overall, the results of this study confirm that the Stillman (1985) model is still a fai accurate representation of the pork production process despite the definite presence of structural change found with sow farrowings. In addition, the forecasting performance of t model is strong compared to alternative forecasts; however, composite forecasts were show to be comparable. This study could and should be expanded. Alternative functional forms could be used to determine if the perceived structural change can be described more accuarately. Also, alternative forecasts such as vector autoregressions could be used for a more robust analysis of forecasting performance. In conclusion, the reestimation and forec performance of this popular hog supply model should increase the understanding of the hog production process, improve short-term forecasts of key hog supply variables, and provide a launching pad for further research.

REFERENCES

Alston, J.M. and J.A. Chalfant. "Can We Take the Con Out of Meat Demand Studies." *Western Journal of Agricultural Economics*. 16(1991):36-48.

Greene, W. H., *Econometric Analysis*. Prentice-Hall Inc., New Jersey, 1993.

Harlow, A. A. *Factors Affecting the Price and Supply of Hogs*. U.S.D.A. Technical Bulletin No. 1274, 1962.

Holt, M.T. and S.R. Johnson. "Supply Dynamics in the U.S. Hog Industry." *Canadian Journal of Agricultural Economics*. 36(1988):313-335.

Park, D.W. and Tomek, W.G. "An Appraisal of Composite Forecasting Methods," *North Central Journal of Agricultural Economics*. 10(1988):1-11.

Rhodes, V.J. "The Industrialization of Hog Production." *Review of Agricultural Economics*. 17(1995):107-118.

Skold, K.D. *The Integration of Alternative Information Systems: An Application to the Hogs and Pigs Report*. CARD Monograph 92-M4, The Center for Agricultural and Rural Development, Iowa State University, Ames, IA, 1992.

S-Plus Guide to Statistical and Mathematical Analysis, Version 3.3. StatSci, a Division of MathSoft, 1995.

Stillman, R.P. *A Quarterly Model of the Livestock Industry*. USDA, ERS, Technical Bulletin 1711, 1985.

Table 1. Estimation of Stillman Model, 1975.1 to 1994.4 .

Equation	Variable	Coefficient	Std. Error	T-Ratio	Stillman Results: Coefficient	Stillman Results: T-Ratio
Sow Farrowings:	FARL1	0.683	0.066	10.380 *	0.664	7.090 *
	FARL4	0.869	0.050	17.440 *	0.883	13.508 *
	FARL5	-0.610	0.069	-8.858 *	-0.548	-5.656 *
	CORNL1	-48.440	31.250	-1.550	-93.856	-1.619
	B&GPR	11.049	2.606	4.240 *	20.814	4.631 *
	CONST.	-255.260	241.900	-1.055	-650.807	-1.759
	R-square	0.841			0.906	
	R-square adj.	0.831			na	
	F-statistic	78.519			48.110	
Barrow and Gilt Slaughter:	PCL1	0.359	0.049	7.287 *	0.342	5.21 *
	PCL2	0.779	0.040	19.620 *	0.767	11.38 *
	DV1	455.250	214.800	2.119 *	716.230	1.331
	DV2	2072.000	255.900	8.097 *	968.796	1.728
	CONST.	-1133.900	983.000	-1.154	500.771	1.616
	R-square	0.887			0.854	
	R-square adj.	0.881			na	
	F-statistic	147.260			2037.970	
	D.W.	1.601			na	
Sow Slaughter:	FARL1	0.432	0.044	9.722 *	0.525	7.902 *
	B&GPR	-7.655	1.747	-4.381 *	-18.507	-4.625 *
	CORNL1	89.734	20.990	4.276 *	135.559	2.68 *
	DV1	-84.310	24.500	-3.441 *	-229.546	-4.128 *
	DV2	-59.352	27.100	-2.190 *	-76.876	-1.371
	DV3	-110.160	26.460	-4.163 *	-244.582	-4.434 *
	CONST.	201.060	162.600	1.237	500.771	1.616
	R-square	0.769			0.837	
	R-square adj.	0.750			na	
	F-statistic	40.478			22.180	
	D.W.	1.171			na	

* Significant at the 5% level.

Reestimation of Stillman Model for Use in Forecasting, 1986.1 to 1994.

	Variable	Coefficient	Std. Error	T-Ratio
rowings:	FARL1	0.678	0.117	5.793 *
	FARL4	0.903	0.083	10.820 *
	FARL5	-0.651	0.125	-5.212 *
	B&GPR	6.704	3.667	1.828
	CONST.	-144.930	418.900	-0.346
	R-square	0.848		
	R-square adj.	0.828		
	F-statistic	43.069		
	D.W.	2.002		
w and Slaughter:	PCL1	0.389	0.106	3.659 *
	PCL2	0.788	0.109	7.241 *
	DV1	406.620	257.700	1.578
	DV2	1382.800	242.400	5.705 *
	DV3	-602.840	588.000	-1.025
	CONST.	-1253.100	1194.000	-1.049
	R-square	0.951		
	R-square adj.	0.943		
	F-statistic	116.139		
	D.W.	1.629		
w Slaughter:	FARL1	0.159	0.061	2.602 *
	B&GPR	-8.355	1.632	-5.120 *
	DV1	-73.841	19.940	-3.703 *
	DV2	-98.159	25.080	-3.914 *
	DV3	-0.631	22.190	-0.028
	CONST.	1015.700	187.200	5.426 *
	R-square	0.827		
	R-square adj.	0.798		
	F-statistic	28.696		
	D.W.	1.117		

* Significant at the 5% level.

Table 1. Estimation of Stillman Model, 1975.1 to 1994.4 .

Equation	Variable	Coefficient	Std. Error	T-Ratio	Stillman Results: Coefficient	Stillman Results: T-Ratio
Sow Farrowings:	FARL1	0.683	0.066	10.380 *	0.664	7.090 *
	FARL4	0.869	0.050	17.440 *	0.883	13.508 *
	FARL5	-0.610	0.069	-8.858 *	-0.548	-5.656 *
	CORNL1	-48.440	31.250	-1.550	-93.856	-1.619
	B&GPR	11.049	2.606	4.240 *	20.814	4.631 *
	CONST.	-255.260	241.900	-1.055	-650.807	-1.759
	R-square	0.841			0.906	
	R-square adj.	0.831			na	
	F-statistic	78.519			48.110	
Barrow and Gilt Slaughter:	PCL1	0.359	0.049	7.287 *	0.342	5.21 *
	PCL2	0.779	0.040	19.620 *	0.767	11.38 *
	DV1	455.250	214.800	2.119 *	716.230	1.331
	DV2	2072.000	255.900	8.097 *	968.796	1.728
	CONST.	-1133.900	983.000	-1.154	500.771	1.616
	R-square	0.887			0.854	
	R-square adj.	0.881			na	
	F-statistic	147.260			2037.970	
	D.W.	1.601			na	
Sow Slaughter:	FARL1	0.432	0.044	9.722 *	0.525	7.902 *
	B&GPR	-7.655	1.747	-4.381 *	-18.507	-4.625 *
	CORNL1	89.734	20.990	4.276 *	135.559	2.68 *
	DV1	-84.310	24.500	-3.441 *	-229.546	-4.128 *
	DV2	-59.352	27.100	-2.190 *	-76.876	-1.371
	DV3	-110.160	26.460	-4.163 *	-244.582	-4.434 *
	CONST.	201.060	162.600	1.237	500.771	1.616
	R-square	0.769			0.837	
	R-square adj.	0.750			na	
	F-statistic	40.478			22.180	
	D.W.	1.171			na	

* Significant at the 5% level.

Table 2. Reestimation of Stillman Model for Use in Forecasting, 1986.1 to 1994.

Equation	Variable	Coefficient	Std. Error	T-Ratio
Sow Farrowings:	FARL1	0.678	0.117	5.793 *
	FARL4	0.903	0.083	10.820 *
	FARL5	-0.651	0.125	-5.212 *
	B&GPR	6.704	3.667	1.828
	CONST.	-144.930	418.900	-0.346
	R-square	0.848		
	R-square adj.	0.828		
	F-statistic	43.069		
	D.W.	2.002		
Barrow and Gilt Slaughter:	PCL1	0.389	0.106	3.659 *
	PCL2	0.788	0.109	7.241 *
	DV1	406.620	257.700	1.578
	DV2	1382.800	242.400	5.705 *
	DV3	-602.840	588.000	-1.025
	CONST.	-1253.100	1194.000	-1.049
	R-square	0.951		
	R-square adj.	0.943		
	F-statistic	116.139		
	D.W.	1.629		
Sow Slaughter:	FARL1	0.159	0.061	2.602 *
	B&GPR	-8.355	1.632	-5.120 *
	DV1	-73.841	19.940	-3.703 *
	DV2	-98.159	25.080	-3.914 *
	DV3	-0.631	22.190	-0.028
	CONST.	1015.700	187.200	5.426 *
	R-square	0.827		
	R-square adj.	0.798		
	F-statistic	28.696		
	D.W.	1.117		

* Significant at the 5% level.

Table 3. ARIMA Model Estimation, 1975.1 to 1994.4 .

Equation	Parameter	Estimate	T-Ratio	Equation	Parameter	Estimate	T-Ratio
Price of Barrows	AR(1)	0.798	7.029 *	Barrow and	AR(1)	0.764	9.947 *
and Gilts:	AR(2)	-0.156	-1.363	Gilt Slaughter:	SMA(1)	0.930	33.230 *
AR(6)	AR(3)	0.022	0.202	$(1,0,0)x(0, 1, 1)_4$	CONST.	58.373	2.303 *
	AR(4)	0.275	2.513 *				
	AR(5)	-0.769	-6.933 *		R-square	0.625	Q(20) = 17.03
	AR(6)	0.367	3.336 *		R-square adj.	0.615	p-value=.521
	CONST.	21.331	3.202 *				
	R-square	0.567	Q(20) = 21.51				
	R-square adj.	0.531	p-value=.089				
Sow Farrowings:	AR(1)	0.864	14.030 *	Sow Slaughter:	AR(1)	0.793	10.580 *
$(1,0,0)x(0, 1, 3)_4$	SMA(1)	0.650	5.053 *	$(1,0,0)x(3, 1, 0)_4$	SAR(1)	-0.736	-6.442 *
	SMA(2)	0.138	0.982		SAR(2)	-0.605	-5.003 *
	SMA(3)	0.106	0.907		SAR(3)	-0.342	-3.152 *
	CONST.	2.352	0.881		CONST.	0.683	0.064
	R-square	0.701	Q(20) = 20.11		R-square	0.673	Q(20) = 13.07
	R-square adj.	0.684	p-value=.215		R-square adj.	0.655	p-value=.667

* Significant at the 5% level.

Table 4. (Continued) Forecast Evaluation Measures for One-Step and Four-Step Ahead Econometric, ARIMA, and Composite Forecasts.

	RMSE		MAD		MAPE		U2	
	1 step	4 step	1 step	4 step	1 step	4 step	1 step	4 step
Sow Slaughter								
Econometric	102.729	123.018	93.882	112.412	10.573	13.199	1.303	1.034
ARIMA	86.018	123.262	64.156	114.695	7.304	13.408	1.091	1.036
Composite	88.954	122.564	77.936	113.554	8.816	13.304	1.128	1.030
Hog Slaughter[2]								
Econometric	412.285	671.468	287.422	592.042	1.246	2.592	0.273	0.630
ARIMA	526.199	953.446	422.398	803.644	1.839	3.571	0.349	0.894
Composite	397.296	671.193	306.230	564.661	1.335	2.510	0.263	0.629
Pork Production[3]								
Econometric	180.175	226.807	156.298	185.578	3.516	4.179	0.590	1.036
ARIMA	153.100	131.250	134.600	114.355	3.036	2.643	0.501	0.599
Composite	160.558	163.482	142.358	130.811	3.205	2.974	0.525	0.747

[2]Hog slaughter forecasts are constructed by the summation of forecasted barrow and gilt slaughter, sow slaughter, and boar slaughter.
[3]Pork production forecasts are constructed by multiplying hog slaughter by carcass weight of 182.