The Integration of Alternative Information Systems: An Application to the Hogs and Pigs Report

Karl D. Skold and S. R. Johnson

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Abstract

Two competing econometric models of the U.S. pork sector augment the initial USDA estimates of the U.S. hogs kept for breeding with market information. The first incorporates the rational expectation hypothesis and the second uses futures market prices as the expectation mechanism. By using alternative composite forecasting methods, the model forecasts are weighted optimally with the initial USDA estimates. The results show that the USDA could use this cost-effective method to improve the accuracy of the initial estimates of the U.S. hogs kept for breeding by over 20 percent.

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1. Introduction

In March of 1982, federal budget constraints necessitated a reduction in USDA crop and livestock reporting activities. Twenty-six USDA commodity reports were eliminated, some data series were suspended, and the frequency of selected reports was reduced. The survey coverage of some reports also was reduced (USDA 1982). These reductions, coming at a time of a rapidly expanding agricultural informational base, have renewed interest in an ongoing assessment of the adequacy, reliability, and value of the USDA crop and livestock reporting system (Just 1983; Gardner 1983).

Advances in computer and communications technology have facilitated easier transmission, processing, and manipulation of raw data into useful and timely information for the industry. The increased capacities for assimilation of information by producers, processors, and policymakers have coincided with the development of alternative sources of agricultural market information. The result has been proliferation of market information sources; for example, futures market price quotes and private market forecasts and analyses by firms such as Wharton Econometric Forecasting Associates.

Nevertheless, the inherent public good characteristics of information, combined with the economies of scale in data collection, have left costly primary data collection responsibilities mainly in the public domain (Bonnen and Nelson 1981). The USDA remains the principal supplier of data and information on the current disposition of the U.S. agricultural sector. USDA crop and livestock reports are the benchmark estimates of movements in supplies and stocks of the major U.S. agricultural commodities.

The crop and livestock reports from the USDA's National Statistical Service (NASS) are developed from extensive sampling of producers.[1] The quality of these reports has increased through continued refinements in sampling techniques and data analysis, combined with advances in computer technology. However, coincident with current fiscal constraints, pressures to expand the scope of the current agricultural reporting system have developed. Requirements to more accurately monitor the changing structure of agriculture and to assess the welfare of rural communities are just two examples (Bonnen 1977; Bonnen and Nelson 1981). And, calls have been made to improve the accuracy and reliability of USDA reports by adopting "statistical strategies and methods that can substitute for the more expensive conventional survey and census methods" (Bonnen and Nelson 1981, p. 343).

This paper presents a data evaluation system for the USDA's "Hogs and Pigs" report that augments the survey-based initial estimates with market-demand information. The hogs and pigs report is the primary source of short-term hog supply information and gives an indication of the productive capacity in the U.S. pork sector. It gives quarterly estimates of the breeding herd inventory, market hogs and pigs inventories by weight, pig crop, pigs per liter and sows farrowing. The initial estimates contained in the report are primarily based on sampling of producers in the major hog producing states. These initial estimates are revised in subsequent reports and finalized every five years after the release of the census of agriculture (USDA 1983).

The "Hogs and Pigs" report was chosen for analysis because of recurring concerns about its reliability and accuracy (Kutish 1955; Blanton et al. 1985; Hohmann 1987; Meyer and Lawrence 1988; USDA 1988). Price formation in the hog market is unencumbered by government intervention and is considered to be efficient and responsive to new market information (Miller 1979; Hoffman 1980; Hudson, Koontz and Purcell (1984; Colling and Irwin 1989). However, the reports often contain an element of surprise as evidenced by the dramatic price changes that often occur after the release of the report. This paper shows a cost effective method to broaden the information base of the report, which, in turn improves the reliability and accuracy of the supply and inventory estimates. Accurate supply and inventory estimates are essential in the formation of accurate price expectations and improved efficiency of pork production processes.

2. The Approach

In the present approach, the information base represented by the USDA survey of producers is expanded by incorporating market information, sythesized by two alternative quarterly, econometric models of the U.S. pork sector. The predictions of the U.S. hogs kept for breeding from the two alternative models, which reside on alternative information bases, are used to make a composite forecast with the initial USDA estimate. The size of the breeding herd inventory is the prime indicator of future production in the pork sector. Also adjustments in the level of the breeding herd inventory have impacts on nearby and distant price formation (Carter and Galopin 1989). Of course, the methods presented could be applied to other categories in the hog and pigs report as well as other commodity and livestock reports.

The first quarterly model incorporates the rational expectation (RE) hypothesis into a nonlinear, dynamic model of the pork sector. Rational expectations are based on the structure and behavioral characteristics of the associated estimated structural model; thus, the information set includes a biologically governed specification of supply response, combined with the estimated responses of producers, processors, and consumers to changing market conditions. The Extended Path (EP) method, developed by Fair and Taylor (1983), is used to solve the model for the rational expectation and to close the system.

The second model of the pork sector employs expectations developed from futures market price quotations. This information set represents production decisions that are aligned with the anticipations of futures market participants. Both models incorporate biological parameter restrictions that, as developed by Johnson and MacAulay (1982), force consistency between short-run supply movements and the long-run formation of supply.

The one-step-ahead predictions of the U.S. hogs kept for breeding from the RE and futures market expectations (FME) market models are combined with the initial USDA estimate using alternative composite forecasting techniques. The general approach is indicated by Figure 1, which also details the alternative information sources on which the forecasts reside. Under fairly general conditions, the forecast or composite estimate has an error variance no greater than the smallest of the individual forecasts (Johnson and Rausser 1982). The hypothesis is that initial USDA estimates of the U.S. breeding herd inventory can be improved by the addition of available market information.

3. The Rational Expectations Model

Until recently, solution and computational methods for RE models were available only for simple linear systems (e.g., Goodwin and Sheffrin 1982; Shonkwiler and Emerson 1982). This severely limited the application of the RE hypothesis in modeling the livestock sector, in particular. Quarterly livestock models in general--and pork models specifically--have tended to be nonlinear. Cycles in prices and production often have necessitated the adoption of nonlinear structures. A nonlinear specification also often was required to adequately capture short- and long-run livestock supply responses.

With linear RE models, the RE is obtained by solving for the reduced form of the system of equations; then, after some manipulation, eliminating the unobservable expectation with forecasts of the exogenous variable (Wallis 1980). However, for nonlinear models, the reduced form typically cannot be expressed analytically and instead must be evaluated numerically. The Fair and Taylor EP method provides such a method to numerically solve and estimate nonlinear, dynamic RE models. While computationally burdensome and expensive, it has been applied successfully by Fair and Taylor (1983), Fair (1984), and by Holt and Johnson (1988) for an agricultural market.

In brief, EP method begins with obtaining the RE given a set of initial, or starting, structural parameters. The model is extended along an arbitrary path and then solved using series of Gauss-Seidel iterations. That is, the model is successively extended ahead in time along this new path beyond the planning horizon of producers. The path is extended until the last Gauss-Seidel solution is within some prespecified tolerance level of the previous solution. Given this solution, the model then can be estimated with full information techniques to obtain a new set of structural parameters. The solution-estimation process is repeated until a convergent estimate is obtained of the structural parameters. Full information estimators are required to capture the full force of the RE hypothesis because of the implied cross-equation restrictions (Wallis 1980).

The quarterly RE pork model contains ten stochastic equations and five identities, and it provides behavioral equations for the major components of industry supply and demand. The supply structure employs a disaggregated characterization of the phases in the production process. This sequential supply structure is similar to previous econometric models of the pork sector (e.g., Arzac and Wilkinson 1979; Blanton 1983). Price determination occurs with the demand structure, which includes a simple retail demand specification and a retail-farm margin equation. Stocks, exports and imports, on-farm production, shipments, and military use are considered exogenous. Definitions and sources of variables for both RE and FME models appear in Table 1. The sample period includes 68 quarterly observations from 1970 through 1986.

Biological Restrictions

Historical relationships between stock and flow categories in the supply block are used as prior information to form parameter restrictions in the supply component (Johnson and MacAulay 1982). These parameter restrictions explicitly recognize that the supply of livestock depends in part on the physical growth constraints inherent in the production process, and not entirely on changing economic conditions. For example, for the additions-to-the-breeding-herd equation (2.1 in Table 2), biological restrictions are imposed on the parameters of the pig crop lagged two quarters. This lag length approximates the age at which gilts can enter the breeding herd.

The restrictions are generated by plotting the ratio of additions to the breeding herd to the pig crop, $ABHUS_t/PCUS_{t-2}$, against time. This ratio depicts the proportion of the pig crop retained for breeding. The ratio exhibited a downward trend for the third and fourth quarters until 1974. This apparent structural or technological shift in the third and fourth quarters was exploited by regressing the ratio on a zero-one dummy variable and a time trend with OLS by quarter.[2] The dummy variable was assumed to reflect the two production regimes identified. The resulting parameter estimates then were used as the values of parameter restrictions in the model. In the first and second quarters, the parameters in the model were restricted to the quarterly sample means of the ratio $ABHUS_t/PCUS_{t-2}$. The biological restriction accounts for the seasonality relationship between stocks and flows in the production sequence as well as for the structural or technological shifts in the supply response relationship. The shifts in these ratios are assumed not to be explained by the movements in the conditioning variables for the model.

Likewise, note from Table 2 that the biological-based parameter restrictions are introduced in the equations for sow slaughter (2.2), sows farrowing (2.4), pig crop (2.5), and barrow and gilt slaughter (2.6).

Similar technological and structural shifts were identified and preliminary ratio OLS regressions were estimated to generate the values of the parameter restrictions. The estimation results for all these preliminary equations are imbedded in the RE estimation, shown in Table 2. In the equations for sows farrowing (2.4), pig crop (2.5), and barrow and gilt slaughter (2.6), no economic conditioning variables are included. Thus, these equations are essentially technical identities. This assumes, in the near term, that the number of hogs in production phases between farrowing and marketing is governed primarily by the previous breeding herd decisions of producers, as well as by other random factors not economic in nature, such as death and weather.

Estimation

The biological restrictions are imposed as prior information and constrain 51 parameters in the RE model, leaving 36 parameters unconstrained. Assuming normal and independent distribution of the disturbance terms, the initial starting values for the unconstrained parameters were generated with full information maximum likelihood (FIML) methods estimating the model. However, in obtaining the initial parameter estimates, the expectation of barrow and gilt farm price (to be an RE in the final version of the model) was replaced by an instrument, the two-step-ahead ARIMA forecast. This use of an instrument greatly reduced the number of required solution-estimation iterations.

These initial values were used to start the solution-estimation iterations. In EP solution, the model was assumed to have no serial correlation in the disturbance terms. The values of the disturbance terms were set to their conditional expectation, zero. Thus, essentially a deterministic simulation was used to solve for the RE. Expected values of the stochastic exogenous variable were generated from ARIMA processes, which were considered to be completely determined outside of the structural model. All nonstochastic exogenous variables were assumed to be known with certainty.

The FIML estimates of the 36 parameters were completed with the Davidson-Fletcher-Powell subroutine in GQOPT (Quant and Goldfeld 1987). At the maximum, the log-likelihood function achieved a value of -887.45. The total CPU time required for the solution-estimation iterations was 44.03 minutes on an IBM 9377 miniframe computer (eight-bit processor). The structure and estimation results of the RE model are presented, along with the identities, in Table 2. These FIML estimation results for the RE model are presented with selected simulation statistics and partial elasticities, evaluated at sample means, for selected coefficients.

Results

The supply of hogs is, of course, not entirely governed by the growth process of hogs. The size of the breeding herd (Equation 2.3)--defined as the net change between additions and sow slaughter, plus the carry-in inventory from the previous quarter--is affected by the investment and disinvestment decisions of producers. These decisions, in turn, are assumed to be based on producers' expectations of profitability. These are represented by the expected farm prices of barrows and gilts, and of feed. Both expectations for period t+2 are assumed, made in the time period t. This approximates the time required to finish pigs to slaughter weights. The cost of feed includes corn and soymeal prices, weighted to reflect a typical ration. The current real interest rate reflects the opportunity cost of the investment.

Additions to the breeding herd in equation (2.3) are positively related to the expected farm price and negatively related to expected increases in feed costs and the real interest rate. The opposite response to the same conditioning variables is found in the sow slaughter equation (2.2). This is expected in that sow slaughter represents in part a disinvestment decision of producers. Additions to the breeding herd were found to be more responsive to anticipated output and input prices than to the level of sow slaughter. This result is fairly intuitive, since a large segment of sow slaughter is based on age, not on the expected returns from subsequent litters.

Producers have discretion in the timing of marketings and in their feeding practices, which in turn affects market weights. Producers are assumed to respond to current conditions in determining the time of sale. Thus, the contemporaneous farm price and feed cost are included in the equations for slaughter weights of barrows and gilts (2.7) and sows. The output-input price ratio is positively and significantly related to the respective slaughter weights, reflecting slight delays in marketings when prices are favorable. The time trend was included to capture packers' demands for heavier carcasses, a result of improved carcass composition; it was significant only for the slaughter weight of sows.

Price determination occurs at the retail level. Livestock production is essentially fixed in the short run, and hence the determination of retail price depends on the location of the demand curve. The retail price equation (2.13) is linked to the farm-level price equation (2.15) through a margin equation (2.14). This structure simplifies the retail-farm linkage by essentially circumventing the wholesale market. The simple retail demand equation, estimated in price-dependent form, includes the major determinants of pork demand. All prices and food expenditures are deflated by the consumer price index.

The relationship between food expenditures and the real pork retail price is positive, but insignificant. The insignificant sign on the time trend suggests that evidence of a continual shift away from pork in livestock demand is lacking in this simple specification. The dummy variable D794 was included after preliminary estimation. It reflects an apparent leftward demand shift for pork in the 1980s. Reasons may include changes in tastes and preferences based on health concerns, relative prices of other food commodities omitted from the equation, and changes in the macroeconomic environment. Nevertheless, few conclusions should be gleaned from results of the demand equation given the simplified specification.

The specification of the retail-farm margin (2.14) follows from Wohlgenant and Mullen (1987). Changes in the margin can originate from demand or supply movements and from changes in marketing costs. The results suggest that as the total retail value of production increases, holding population constant, the margin increases. The index of marketing costs has a positive, but insignificant, effect on the retail-farm margin. The index of marketing cost is the simple average of the index of earnings of employees in packing plants and the producer price index of fuels and related power. The magnitude and sign of the lagged dependent variable indicates a good degree of stickiness in the transmission of prices from retail level to farm level. The retail-farm margin, the retail price of pork, and the index of marketing costs are all deflated by the consumer price index.

4. Futures Market Expectations Model

Futures market prices provide an alternative form of price expectations. Futures market prices are easily implemented, and under certain conditions they imply an informationally efficient expectation mechanism (Gardner 1976). Using such prices as proxies for expectations removes the price determination mechanism from the structure of the model. That is, current prices are based on the futures market, not the location of the model demand curve. Thus, only the supply specification was modified, and the demand structure was omitted.

Expectations are unobservable and, consequently, the timing of the formation of expectations is unknown. As with the RE model, the timetable of hog production is used to choose the planning horizon of producers. Expectations are assumed to be formed at the time of breeding for the output and input prices at the time of marketing the resulting offspring. For the FME model, producers are assumed to base their profitability expectations on distant closing prices of live hogs and corn (Table 1). The expected price of barrows and gilts used is a simple quarterly average of the daily closing prices of the distant live hog contract traded at the Chicago Mercantile Exchange. Similarly, closing corn futures price quotations at the Chicago Board of Trade are used to represent the anticipated cost of feed during the finishing period (Table 1).

As shown in Table 3, these quarterly averages of futures market prices for corn and live hogs are introduced into the equations for additions to the breeding herd (3.1) and sow slaughter (3.2). The contemporaneous real interest rate is retained in the specification. The rest of the supply block remains intact. The same biological restrictions are imposed in estimation. Also, the periodicity remains quarterly, and the sample period is 1970 through 1986. Estimation is with restricted least squares (RLS).

The additions to the breeding herd remain more responsive than sow slaughter to changes in conditioning variables. The parameters have the anticipated signs, and in general, they are significant at conventional levels. The partial elasticities suggest that the hog supply is more responsive to expected price as modeled by FME than by RE. Also, the FME model appears to be a slight improvement over the RE model in capturing the behavior of additions to the breeding herd and sow slaughter, as shown by the fit statistics.

5. Composite Forecasts

The one-step-ahead forecasts from the RE and FME models are combined with initial USDA estimates of U.S. hogs kept for breeding to form a single composite prediction. The rationale is transparent; the single composite prediction, in general, will outperform the individual components (Johnson and Rausser 1982). Thus, the market information from the two models can be combined optimally with the USDA estimates, improving the reliability and precision of the initial estimates in the hogs and pigs report. The alternative composite forecasting methods used in this paper are described briefly here and are developed fully elsewhere (Johnson and Rausser 1982; Clemen and Winkler 1986; Granger and Newbold 1986). They are simply alternative procedures to estimate the weights on the competing individual forecasts.

Alternative Methods

The composite forecasting methods used in this paper include solving for the optimal weights with two analytic methods. Neither method assumes the finalized U.S. breeding herd estimate is a random variable; one allows for bias in the individual estimates. The optimal weights are estimated from the sample variance-covariance matrix of the forecast errors from the RE and FME predictions and the USDA initial estimates. The formula for the optimal weights for the first method (NR) is given by (Granger and Newbold 1986)

$$k_0 = \frac{\left[\Sigma^{-1} \begin{pmatrix} 1 \\ 1 \\ 1 \end{pmatrix} \right]}{\left[(1\ 1\ 1)\ \Sigma^{-1} \begin{pmatrix} 1 \\ 1 \\ 1 \end{pmatrix} \right]} , \qquad (1)$$

where Σ is the sample variance-covariance matrix.

The second method (NR-bias) also relies on the estimated sample variance-covariance matrix of the individual errors, but it allows for bias.[3] Here, the estimated error of the variance-covariance matrix is not computed directly, but is derived from the residuals of preliminary OLS calibration curves. The RE, FME, and USDA initial estimates are regressed on the USDA final estimates; i.e.,

$$Y_i = \alpha_i + \beta_i X + e_i ,$$

where Y_i is the RE, FME, and USDA initial predictions; X is the USDA final estimate; e_i is a random disturbance term; and α_i and β_i are the parameters to be estimated. The residuals from these calibration curves are used to estimate an error variance-covariance matrix that accounts for estimate bias. The estimate of the variance-covariance is given by

$$V = \left[\begin{pmatrix} \hat{\beta}_1^{-1} & 0 & 0 \\ 0 & \hat{\beta}_2^{-1} & 0 \\ 0 & 0 & \hat{\beta}_3^{-1} \end{pmatrix} \hat{S}_{ee} \begin{pmatrix} \hat{\beta}_1^{-1} & 0 & 0 \\ 0 & \hat{\beta}_2^{-1} & 0 \\ 0 & 0 & \hat{\beta}_3^{-1} \end{pmatrix} \right], \quad (2)$$

where $\hat{S}_{ee}$ is the variance-covariance matrix of the residuals from the calibration curves; and $\hat{\beta}_1$, $\hat{\beta}_2$, and $\hat{\beta}_3$ are the slope parameter estimates from the respective calibration curves of the individual forecasts on the USDA final estimate. Given the estimate of V, Equation (1) can be applied to obtain the optimal weights, which then can be multiplied by $\hat{\beta}_i^{-1}(Y_i - \hat{\alpha}_i)$ to form the composite forecast.

The random methods used assume that the final USDA estimate of U.S. breeding herd inventory is a random variable. The methods include applying OLS to regression of the final USDA estimate on the nonrandom, composite forecasts (NR and NR-bias). This places these forecasts in a stochastic setting.

Also, the weights are derived directly by the regression of the final USDA estimate on the individual forecasts with and without linear parameter restrictions. Clemen (1986) contends that if the individual forecasts are unbiased estimates, the restriction that the slope coefficients must sum to one must be applied. Even if the individual estimates are biased, the gains in efficiency from applying the restriction will offset the slight biases in the parameter estimates that may result. Clemen also suggests that estimation without a constant may be required, depending on the biases that exist. However, Granger and Ramanathan (1984) recommend applying OLS without linear parameter constraints and with an intercept because it will result in an unbiased composite estimate, even if the individual forecasts are biased.

Composite Results

The estimates of composite forecast weights for the alternative methods are provided (Table 4). Included is the root-mean-square error (RMSE) of the alternative composite forecasts and the USDA initial estimate of the U.S. breeding herd inventory. Also provided is the ratio of the mean-square-error (MSE) of the alternative composite estimates to the USDA initial estimate.

The USDA initial estimate clearly receives the largest weight in forming the composite estimate. The weight on the RE estimate is negative for all methods presented. In general, this is not a desired result in that it implies the RE model provides an inferior forecast. The model's negative weight was retained in the composite forecast on the grounds that the relatively high error variance is outweighed by the relatively large correlation among the forecasts (Johnson and Rausser 1982). That is, part of the actual breeding herd inventory left unexplained by the RE estimate is sufficiently strong in relation to the part unexplained by the FME and USDA forecasts.

The magnitude and signs of the weights are essentially the same for each composite method used. The restriction that all slope coefficients must sum to one in all the OLS models cannot be rejected at the 5 percent confidence level. The coefficients from the two analytic methods (NR and NR-bias) are constrained to sum to one by construction. Based on an MSE criterion, all the composite estimates are an improvement over the USDA initial estimate. The composite methods that treat the final USDA estimate as a randon variable show the greatest improvement. After obtaining the initial OLS estimates, in all stochastic composite equations, the presence of first-order autocorrelation in the disturbance term was detected. This was corrected by applying OLS with the iterative Cochrane-Orcutt procedure. Based on the RMSE criterion, the OLS composite prediction is the most precise and shows a 21 percent improvement over the initial USDA estimate of the U.S. breeding herd inventory.

Implications

To give an indication of the merit of combining market information in the USDA data evaluation and estimation process, the percentage changes from the previous report indicated by the USDA final estimate and the competing forecasts are provided (Table 5). The percentage changes are given for the period 1970 through 1982, and for the June and December reports.[4] This coincides with the period of the sample that the USDA estimates are finalized. Also during this period, the aggregate U.S. figures were only given in these two reports. The composite forecast used in Table 5 is the OLS with no parameter restrictions.

The market information often counterbalances the errors in the initial estimates, thus resulting in a more accurate composite prediction. For example, in December 1970 the initial estimate indicated a drop of more than 12 percent in the breeding herd inventory from the previous June report. The RE and FME predictions indicated the drop would be less, and thus the composite estimate was closer to the final number. Similar effects of combining market information are found in other reports. Moreover, in June 1970, 1977, and 1978, the FME was more accurate than the USDA initial estimate. (The RE predictions are clearly inferior, perhaps because of the model's inadequate structure for price determination or oversimplified methods for projecting conditioning variables.) Only in a few cases (December 1973, 1975 and 1980) did the inclusion of market information cause larger errors in the composite estimate than in the initial estimate. Thus, although the RE and FME models give less accurate predictions, they still provide useful information.

6. Conclusion

Fiscal constraints have reduced the survey coverage of the USDA hogs and pigs report, as well as the overall scope of the crop and livestock reports. Given the diminished resources devoted to the collection and dissemination of agricultural data, the demand exists for the adoption of more cost-effective information systems. Survey sampling is expensive relative to the cost of developing and maintaining econometric models. The cost of improving USDA estimates by adopting econometric market models is minimal compared to that of expanded survey coverage.

Initial estimates of the U.S. breeding herd inventory can be improved by adopting the data evaluation system described here. Based on a MSE criterion, the initial USDA estimates could be improved by over 20 percent. Hence, econometric models of the pork sector that are based on rational and futures market expectations provide a viable means of incorporating additional market information into the data evaluation and estimation process. The value of the improved information and the optimal level of resources devoted to generating estimates remain open questions.

Endnotes

1. See Upchurch (1977) and Trelogan et al. (1977) on the historical developments of the USDA crop and livestock reporting methods, and USDA (1983) for a description of the current system, including estimation methods and revision procedures.

2. The general form of the regression is $R_i = \beta_o + \beta_1 {*} D + \beta_2 {*} D {*} t + e_i$. where R_i is the ratio, D is the dummy variable, t is a time trend, e_i is a random disturbance, and β_o, β_1, and β_2 are the coefficients to be estimated for the respective quarters.

3. This estimation method was suggested by Wayne A. Fuller and is closely related to the inverse regression problem presented in Draper and Smith (1981, pp. 47-51).

4. Beginning in 1989, the fourth quarter report is released in early January, not December.

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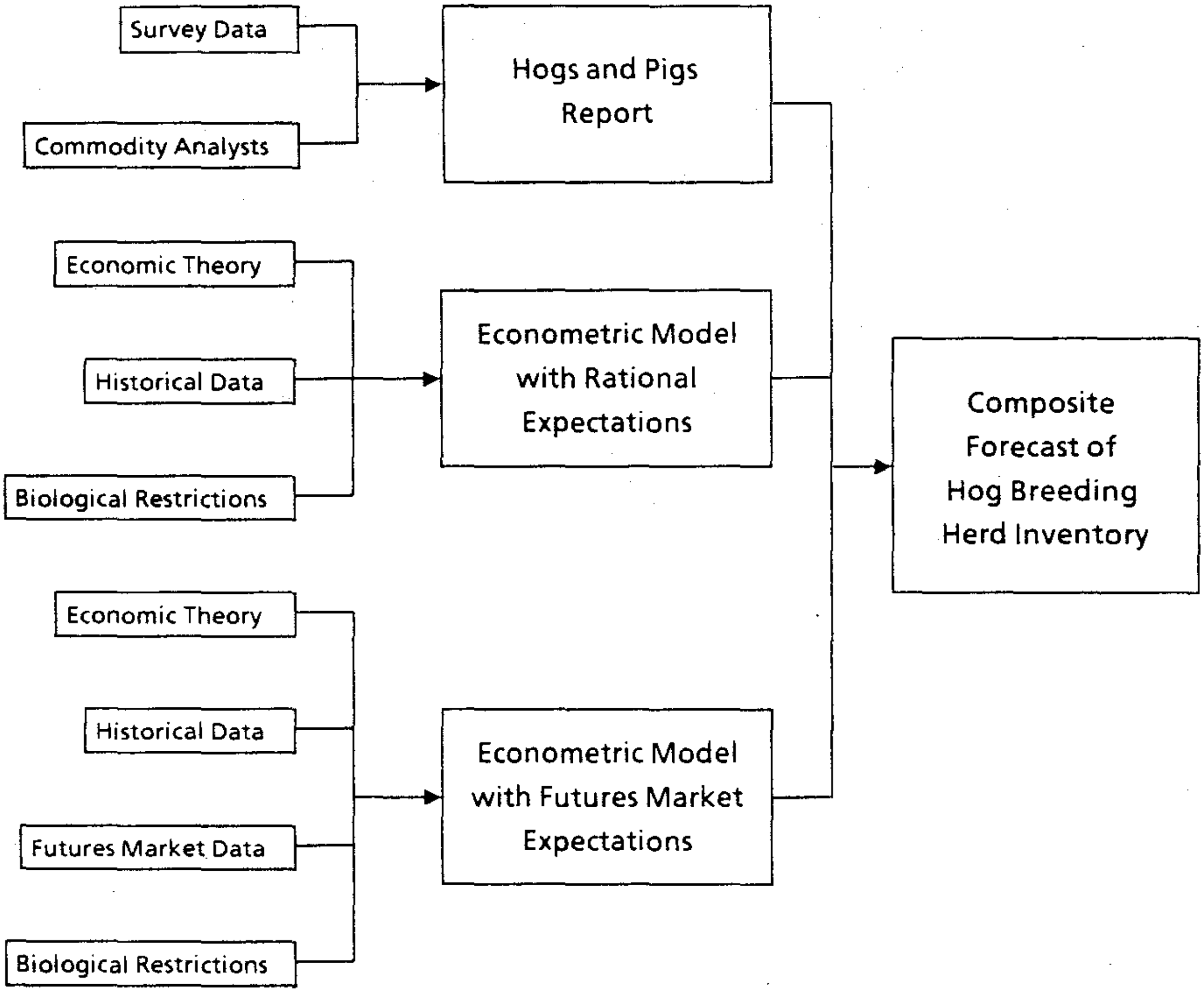

Figure 1. Approach for augmenting survey based forecasts of the breeding herd for hogs.

Table 1. Data description and sources

Variable	Label	Units	Source
Endogenous Variables			
Additions to the breeding herd	ABHUS	1000 head	$BHUS_t - BHUS_{t-1} + SSUS_t$
Sow slaughter	SSUS	1000 head	Livestock and Poultry Situation and Outlook
Breeding herd inventory[a]	BHUS	1000 head	Hogs and Pigs
Sows farrowing[a]	FARROW	1000 head	Hogs and Pigs
Pig crop[a]	PCUS	1000 head	Hogs and Pigs
Barrow and gilt slaughter	BGSUS	1000 head	Livestock and Poultry Situation and Outlook
Liveweight of barrows and gilts	LWBG	pounds	Livestock and Meat Statistics and personal correspondence
Liveweight of sows	LWS	pounds	Livestock and Meat Statistics and personal correspondence
Domestic pork production	PPF	pounds	$BGSUS_t * LWBG_t + SSUS_t * LWS_t$

Table 1. (continued)

Variable	Label	Units	Source
Commercial pork production	TOTSPK	million pounds	Livestock and Poultry Situation and Outlook
Domestic disappearance	TOTDPK	million pounds	Livestock and Poultry Situation and Outlook
Retail price of pork	RPPK	dollars per pound	Livestock and Poultry Situation and Outlook. Divided by the CPI.
Farm price of barrows and gilts (7 markets)	FPPK	dollars per pound	Livestock and Poultry Situation and Outlook
Retail-farm margin	MARGIN	dollars per pound	$RPPK_t$ - $FPPK_t/CPI_t$
Per capita pork consumption	PCPK	pounds per person	$(TOTDPK_t/POP_t)$ * $PVERT_t$
<u>Exogenous Variables</u>			
U.S. population	POP	millions	Survey of Current Business
Demand minus supply	OTHER	millions	TOTDPK - TOTSPK
Retail-carcass conversion	PVERT		Livestock and Poultry Situation and Outlook

Table 1. (continued)

Variable	Label	Units	Source
Feed costs	FC	dollars per bushel	Agricultural Prices and Feed Situation and Outlook
Retail beef price	RPBF	dollars per pound	Livestock and Poultry Situation and Outlook
Per capita food expenditure	FEXP	dollars per person	U.S. Department of Commerce personal correspondence. Divided by CPI.
Marketing costs	MKTCST	1967 = 100	One-half of the index of meat packers, hourly earnings (Employment and Earnings), plus one-half of the producer price index of fuel and related power (Survey of Current Business) divided by CPI.
Real interest rate - feeder cattle loans	RIFCL	percent	Agricultural Finance Databook and Agricultural Letter
Futures market price of live hogs[b]	FUTHOG	dollars per cwt	The Wall Street Journal
Futures market price of corn[c]	FUTCORN	dollar per bushel	The Wall Street Journal

Table 1. (continued)

Variable	Label	Units	Source
Quarterly dummy variable	D1, D2, D3, D4		
Dummy variable	DL74		If year < 1974 = 1; else = 0
	DUM76		If year ≥ 1976 = 0; else = 0
	DUM73		If year ≥ 1973 = 1; else = 0
	D794		If year ≥ 1979.50 = 1; else = 0
Time trend	T65		T65 = 1.00, 1.25, ...
Logarithm of time trend	LT65		Log (T65)

[a] Reported biannually. Second and fourth quarter values as interpolations from ten-state data that are reported quarterly.

[b] Quarterly average of live hog contracts traded at the CME (first quarter--June, second quarter--October, third quarter--December, fourth quarter--April).

[c] Quarterly average of corn contract traded at the CBT (first quarter--March, second quarter--July, third quarter--December, fourth quarter--March).

Table 2. Full information, maximum likelihood estimates of the rational expectation model, 1970-1986

Additions to the breeding herd

$$
\begin{aligned}
ABHUS_t = {} & 0.0434 * D1 * PCUS_{t-2} + 0.0459 * D2 * PCUS_{t-2} \\
& + (0.0773 + 0.1457 * DL74 - 0.0164 * DL74 * T65) * D3 * PCUS_{t-2} \\
& + (0.0376 - 0.0043 * DL74 + 0.00474 * DL74 * T65) * D4 * PCUS_{t-2} \\
& + \underset{\substack{(17.17)^a \\ [0.62]^b}}{16.048} * {}_tFPPK_{t+2} - \underset{\substack{(-114.1) \\ [-0.55]}}{131.469} * {}_tFC_{t+2} - \underset{\substack{(-1.86) \\ [-0.07]}}{17.075} * RIFCL_t
\end{aligned}
$$

$$RMPSE^c = 69.59 \qquad RMSE^d = 387.14 \qquad (2.1)$$

Sow slaughter

$$
\begin{aligned}
SSUS_t = {} & (0.1183 - 0.03599 * DUM76 + 0.00237 * DUM76 * T65) * D1 * BHUS_{t-1} \\
& + (0.1312 - 0.0694 * DUM76 + 0.00348 * DUM76 * T65) * D2 * BHUS_{t-1} \\
& + (0.1620 - 0.0815 * DUM76 + 0.00394 * DUM76 * T65) * D3 * BHUS_{t-1} \\
& + (0.1543 - 0.0393 * DUM76 + 0.00169 * DUM76 * T65) * D4 * BHUS_{t-1} \\
& - \underset{\substack{(-3.68) \\ [-0.10]}}{2.648} * {}_tFPPK_{t+2} + \underset{\substack{(3.59) \\ [0.08]}}{20.159} * {}_tFC_{t+2} + \underset{\substack{(1.51) \\ [0.02]}}{3.624} * RIFCL_t
\end{aligned}
$$

$$RMPSE = 14.93 \qquad RMSE = 170.99 \qquad (2.2)$$

Breeding herd inventory

$$BHUS_t = BHUS_t + ABHUS_t - SSUS_t$$

$$RMPSE = 5.12 \qquad RMSE = 422.67 \qquad (2.3)$$

---

[a] Asymptotic t-ratio.

[b] Partial elasticity evaluated at sample means.

[c] RMPSE is the root-mean-percent-square error.

[d] RMSE is the root-mean-square error.

Table 2. (continued)

Sows farrowing

$$FARROW_t = (0.3041 - 0.1455 * DUM76 + 0.0653 * DUM76 * LT65) * D1 * BHUS_t$$
$$+ (0.4272 - 0.1977 * DUM76 + 0.0689 * DUM76 * LT65) * D2 * BHUS_t$$
$$+ (0.3297 - 0.2881 * DUM76 + 0.1192 * DUM76 * LT65) * D3 * BHUS_t$$
$$+ (0.3389 - 0.3107 * DUM76 + 0.1244 * DUM76 * LT65) * D4 * BHUS_t$$

RMPSE = 6.78 RMSE = 191.50 (2.4)

Pig crop

$$PCUS_t = (7.1332 - 3.0897 * DUM76 + 1.1142 * DUM76 * LT65) * D1 * FARROW_t$$
$$+ (7.2540 - 2.0751 * DUM76 + 0.8109 * DUM76 * LT65) * D2 * FARROW_t$$
$$+ (7.2009 - 2.3626 * DUM76 + 0.8941 * DUM76 * LT65) * D3 * FARROW_t$$
$$+ (7.1814 - 3.2102 * DUM76 + 1.1969 * DUM76 * LT65) * D4 * FARROW_t$$

RMPSE = 6.71 RMSE = 1519.48 (2.5)

Barrow and gilt slaughter

$$BGSUS_t = 0.8764 * D1 * PCUS_{t-2} + 0.8877 * D2 * PCUS_{t-2}$$
$$+ (0.9529 - 0.2324 * DUM73 + 0.0756 * DUM73 * LT65) * D3 * PCUS_{t-2}$$
$$+ (0.7202 - 0.4374 * DUM73 + 0.1932 * DUM73 * LT65) * D4 * PCUS_{t-2}$$

RMPSE = 3.29 RMSE = 618.22 (2.6)

Liveweight of barrows and gilts

$$LWBG_t = \underset{(41.67)}{211.487} + \underset{(4.73)}{7.362} * D2 - \underset{(-3.34)}{4.491} * D3 + \underset{(1.91)}{2.722} * D4$$

$$+ \underset{\substack{(4.53)\\ [0.10]}}{2.764} * (FPPK_t/FC_t) + \underset{(0.10)}{0.0129} * T65_t$$

RMPSE = 2.32 RMSE = 10.55 (2.7)

Table 2. (continued)

Live weight of sows

$$LWS_t = 402.752 + 5.787 * D2 - 16.445 * D3 - 3.875 * D4$$
(59.25) (1.25) (-8.42) (-1.18)

$$+ 3.954 * (FPPK_t/FC_t) + 1.242 * T65_t$$
(4.63) (6.63)
[0.08]

RMPSE = 3.27 RMSE = 7.80 (2.8)

Domestic pork production

$$PFP_t = BGSUS_t * LWBG_t + SSUS_t * LWS_t \quad (2.9)$$

Commercial pork production

$$TOTSPK_t = 0.6542 * (PPF_t/1000) + 75.839 * LT65$$
(116.3) (6.89)
[0.95]

RMPSE = 4.32 RMSE = 156.91 (2.10)

Domestic disappearance

$$TOTDPK_t = TOTSPK_t + OTHER_t \quad (2.11)$$

Per capita consumption

$$PCPK_t = (TOTDPK_t/POP_t) * PVERT_t \quad (2.12)$$

Retail pork price

$$RPPK_t = 1.2116 - 0.0416 * D2 - 0.0423 * D3 + 0.0546 * D4$$
(11.23) (-4.36) (4.28) (4.13)

$$+ 0.4961 * RPBF_t + 0.01299 * FEXP_t$$
(12.32) (1.08)
[0.68] [0.05]

$$- 0.0669 * PCPK_t - 0.00634 * T65 - 0.0979 * D794$$
(21.08) (0.13) (1.24)
[-1.53]

RMPSE = 8.87 RMSE = 0.05 (2.13)

Table 2. (continued)

Retail-farm margin

$$MARGIN_t = \underset{[0.35]}{\underset{(6.78)}{0.2378}} * D1 * RPPK_t + \underset{[0.35]}{\underset{(6.48)}{0.2371}} * D2 * RPPK_t$$

$$+ \underset{[0.37]}{\underset{(7.50)}{0.2506}} * D3 * RPPK_t + \underset{[0.37]}{\underset{(7.05)}{0.2507}} * D4 * RPPK_t$$

$$+ \underset{[0.08]}{\underset{(2.01)}{0.00358}} * (TOTSPK_t/POP_t) * RPPK_t$$

$$+ \underset{[0.04]}{\underset{(0.13)}{0.01293}} * MKTCST_t + \underset{[0.55]}{\underset{(1.97)}{0.5492}} * MARGIN_{t-1}$$

RMPSE = 4.34   RMSE = 0.02   (2.14)

Farm price of barrows and gilts

$$FPPK_t = (RPPK_t - MARGIN_t) * CPI_t$$

RMPSE = 25.11   RMSE = 11.78   (2.15)

Table 3. Estimation results of the futures market expectation model, 1970-1986

Additions to the breeding herd

$$
\begin{aligned}
ABHUS_t = {} & 0.0434 * D1 * PCUS_{t-2} + 0.0459 * D2 * PCUS_{t-2} \\
& + (0.0773 + 0.1457 * DL47 - 0.0164 * DL74 * T65) * D3 * PCUS_{t-2} \\
& + (0.0376 - 0.0443 * DL74 + 0.00474 * DL74 * T65) * D4 * PCUS_{t-2} \\
& + \underset{\substack{(3.29)^a \\ [0.85]^b}}{23.913} * FUTHOG_t - \underset{\substack{(-3.09) \\ [-0.78]}}{348.966} * FUTCORN_t \\
& - \underset{\substack{(-2.68) \\ [-0.09]}}{22.465} * RIFCL_t
\end{aligned}
$$

$$R^2 = 0.93^c \qquad D.W. = 1.95^d \qquad (3.1)$$

$$RMPSE^e = 56.33 \qquad RMSE^f = 307.69$$

Sow slaughter

$$
\begin{aligned}
SSUS_t = {} & (0.1183 - 0.3599 * DUM76 + 0.00237 * DUM76 * T65) * D1 * BHUS_{t-1} \\
& + (0.1312 - 0.0694 * DUM76 + 0.00348 * DUM76 * T65) * D2 * BHUS_{t-1} \\
& + (0.1620 - 0.0815 * DUM76 + 0.00394 * DUM76 * T65) * D3 * BHUS \\
& + (0.1543 - 0.0393 * DUM76 + 0.00169 * DUM76 * T65) * D4 * BHUS_{t-1} \\
& - \underset{\substack{(-2.32) \\ [-0.20]}}{5.831} * FUTHOG_t + \underset{\substack{(2.42) \\ [0.21]}}{94.419} * FUTCORN_t + \underset{\substack{(0.07) \\ [0.0008]}}{0.2007} * RIFCL_t
\end{aligned}
$$

$$R^2 = 0.99 \qquad D.W. = 1.13 \qquad (3.2)$$

$$RMPSE = 15.47 \qquad RMSE = 172.44$$

[a] t-ratio.

[b] Partial elasticity evaluated at sample means.

[c] R^2 is the squared correlation coefficient.

[d] D.W. is the Durbin-Watson d statistic.

[e] RMPSE is the root-mean-percent-square error.

[f] RMSE is the root-mean-square error.

Table 4. U.S. hogs kept for breeding composite forecast results and forecast statistics, 1970-1986

Method (Restriction)	Intercept	RE	FME	USDA	NR[a]	ρ[c]	R^2[b]	RMSE[d]	MSE ratio[e]
Initial USDA								103.41	
NR	-	-0.01	0.12	0.89	-	-	-	97.31	0.89
NR-bias	-	-0.02	0.11	0.91	-	-	-	97.39	0.89
NR-stochastic	89.08 (0.66)[f]				0.99 (89.1)	0.41 (3.75)	0.99	82.18	0.79
NR-bias stochastic	124.21 (0.92)				0.99 (61.2)	0.42 (3.81)	0.99	81.85	0.79
OLS	129.46 (0.88)	-0.04 (-0.64)	0.12 (2.02)	0.91 (23.7)	-	0.42 (3.87)	0.99	81.60	0.79
OLS ($\beta_1+\beta_2+\beta_3 = 1$)	-1.90 (-0.10)	-0.03 (-0.45)	0.12 (2.02)	0.89 (21.6)	-	0.42 (3.78)	0.99	82.58	0.80
OLS ($\beta_0 = 0$)	-	-0.03 (0.45)	0.12 (2.01)	0.91 (23.3)	-	0.42 (3.76)	-	82.47	0.80

[a]NR are the non-random, composite forecasts (NR and NR-bias).

[b]R^2 is the squared correlation coefficient.

[c]Rho, p, is the autocorrelation coefficient.

[d]RMSE is the forecast root-mean-square error.

[e]MSE-ratio is the ratio of the composite forecast to the initial USDA estimate.

[f]Student's statistics are in the parentheses.

Table 5. Percentage change of U.S. breeding herd inventory for final, composite, RE, FME, and USDA initial estimates

Year	Month	Final	Composite	RE	FME	Initial
			(percentage change)			
1970	June	15.68	19.46	18.04	16.26	19.65
	Dec	-9.27	-11.37	-7.16	-2.58	-12.08
1971	June	1.07	4.49	3.28	-1.45	4.89
	Dec	-13.06	-12.83	-10.84	-7.05	-13.81
1972	June	7.93	7.46	0.88	0.96	8.66
	Dec	-5.43	-4.01	-2.91	-2.83	-2.88
1973	June	3.91	1.64	0.46	4.91	1.07
	Dec	-4.26	-3.56	-1.20	-1.83	-4.55
1974	June	2.53	2.44	2.18	0.32	2.72
	Dec	-16.25	-16.70	-9.16	-13.91	-16.72
1975	June	-0.42	-0.19	-8.54	-7.10	-0.15
	Dec	2.94	2.50	-1.43	-0.88	3.09
1976	June	10.75	8.67	13.90	15.85	7.95
	Dec	-4.49	-2.73	-2.51	-5.33	-2.45
1977	June	8.45	6.79	5.93	8.53	6.95
	Dec	-0.97	0.89	-0.42	-1.51	1.94
1978	June	2.94	1.70	0.84	3.61	0.39
	Dec	8.45	8.80	3.96	4.34	8.63
1979	June	7.94	8.48	13.63	16.31	8.53
	Dec	-6.97	-7.45	-4.11	-8.19	-7.92
1980	June	-1.70	-0.88	-6.38	-4.88	-0.24
	Dec	-3.83	-4.69	-3.38	-5.67	-3.82
1981	June	-8.34	-7.46	-1.81	1.43	-8.83
	Dec	-6.15	-5.58	-5.06	-7.45	-6.12
1982	June	-5.48	-6.45	-8.07	-7.13	-5.80
	Dec	0.82	-0.88	-3.31	-3.01	-1.07