# To What Surprises Do Hog Futures Markets Respond?

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We reassess the effect of new information in the *Hogs and Pigs Reports* (*HPR*) focusing on announcements' rationality and alternative surprises. *HPR* announcements are irrational estimates of final estimates, and market expectations are irrational estimates of *HPR* numbers. Using the market's best forecast and incorporating final estimates, we modify conventional information measures. Despite differences as large as 33 cents/cwt in price response, findings suggest there is little to differentiate among surprise measures. Regardless, the message that *HPR* provides new information to the market is strongly supported. On balance, marketing (breeding) information has a larger effect on short-term (long-term) price changes.

*Key Words: HPR*, new information, rationality, two-limit tobit, USDA announcements

**JEL Classifications:** C24, Q13

Previous research demonstrates that the hog futures market responds to information in *Hogs and Pigs Reports* (*HPR*) announcements. However, conflicting findings by Carter and Galopin and Colling and Irwin (1990, 1995) on the economic value of the information suggest that uncertainty persists on the magnitude and importance of the reaction. This uncertainty is heightened by findings that announcement effects in agricultural markets typically are able to explain only small portions of the variability in subsequent price changes (Carter; Garcia and Leuthold). Part of the ambiguity and uncertainty may be related to the accuracy of the measure of surprise, or new information, to which the market responds. In futures markets, conventional procedures examine the effect on price changes of differences between market expectations and the announcement. However, this can be misleading when the announcement does not fully reflect available information, when the market responds to actual or revised final values and not just its preliminary announced value, and when market expectations are difficult to specify. Simply put, markets may be interested in the difference between the true value of a variable and its own expectations, which are difficult for the analyst to appropriately quantify. In this situation, conventional procedures are biased and can underestimate the intensity of the market response to new information (Orazem and Falk).

We examine the response of hog futures prices to different measures of surprise resulting from the *HPR* announcements. In the context of the *HPR*, preliminary breeding and inventory announcements may not be rational forecasts of the final revised figures. In a similar vein, market expectations that have been measured by an average expectation of private market analysts of changes in breeding

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and market inventories may be incomplete if they fail to characterize accurately the vector of dynamic factors affecting market consensus. Using preliminary breeding and market inventories from the USDA *HPR* quarterly report and final revised breeding and market inventories from the USDA *Hogs and Pigs Final Estimates Bulletins*, we investigate whether the preliminary announcements and market expectations are rational forecasts for the period 1982–2002. We then assess the impact of alternative measures of new information from the announcements on hog futures prices.

## Related Literature

Numerous studies have analyzed the impact of *HPR* releases on hog futures prices. For example, Miller studied the adjustments of live hog futures prices to the release of *HPR* farrowing information for the period 1970–1978. Using a partial adjustment model, he tests price responses to farrowing information contained in the *HPR*. His findings show a significant response of prices to new farrowing information, although the response is not instantaneous. The response of futures prices is slower for more distant contracts (6–7 months from delivery) than for nearby contracts (3–4 months). Hoffman and Hudson, Koontz, and Purcell find that hog futures generally react quickly to new information contained in *HPR*s. However, their research does not use market expectations, meaning that price responses could be associated with other sources rather than the information contained in the *HPR*.

Colling and Irwin (1990) were the first to explicitly incorporate market expectations to assess the reaction of hog futures prices to the *HPR*. They use markets analysts' prerelease information to measure market expectations and quantify the effects with a two-limit tobit model to incorporate the effects of exchange imposed price limits. For the period 1981–1988, while considerable noise exists, hog prices quickly and efficiently reflect available information on inventories before the release of USDA reports and only new information contained in the report after the release. Some weak evidence of a predictable price pattern after the USDA announcement was encountered, but profitable postrelease trading strategies could not be constructed.

Using a different tact, Carter and Galopin contend that the *HPR* does not provide new information. They argue that the *HPR* has no economic value because a trader in possession of information prior to the release of the report cannot make significant risk-adjusted profits. They conclude that the market is highly (semistrong) efficient and able to incorporate in futures prices the information in the report prior to its release. In response, Colling and Irwin (1995) demonstrate that Carter and Galopin's findings are highly sensitive to the risk-discounting procedures used and that, under a wide range of reasonable risk premiums, the conclusion that *HPR* contains new information holds. To help further clarify this controversy, Mann and Dowen (1996) tested the effect of information arrival from *HPR* on both price variability and normalized trading volume. They find that the *HPR* does indeed provide new information to the market, with the reaction continuing into the second day after the release for nearby and distant contracts.

Several studies have also shed light on the pricing process by examining the rationality of prerelease expectations in livestock markets. Colling, Irwin, and Zulauf find that prerelease information is a strong-form rational expectation of breeding and market inventories in the *HPR*s. Mann and Dowen (1997) compare informational content of government (USDA) and nongovernment (Knight-Ridder [KR] News Service) reports and conclude that KR expectations are unbiased and efficient estimates of USDA data.

The accuracy of the government livestock reports at predicting final inventory estimates has also been investigated. Meyer and Lawrence show that for the period 1980–1987, total market inventories in the *HPR* do not significantly differ from their predicted values. However, using an econometric model and time-series comparisons, Blanton et al. find that USDA breeding inventory estimates have been overestimated. Similarly, Runkle (1991) presents strong evidence that two-quarter-ahead USDA announcements of sow farrowings intentions are not rational forecasts of actual farrowings. Later, Runkle (1992) finds that errors in USDA announcements of sow farrowing intentions have a predictable component but that hog futures prices are efficient with respect to the farrowing announcements because they efficiently incorporate the predictable component prior to the government announcement of actual sow farrowings. Mills and Schroeder examine the rationality of the USDA *Cattle on Feed* (*COF*) reports and conclude that initial estimates are biased, but the bias is economically small. Revisions of *COF* estimates also are not random and exhibit persistence, suggesting that when revisions are made, subsequent similar types of revisions follow. Schaefer, Myers, and Koontz also test for rationality of *COF*, and their findings suggest that the information contained in the report is irrational with respect to final revised numbers. Further, they conclude that not recognizing the preliminary nature of the USDA announcement would have given very different results about market efficiency and the ability to predict price movements after the release of the *COF* report.

Hence, research suggests that the *HPR* contains new information that is incorporated in hog futures prices, but some controversy exists with regard to the magnitude and length of the effect and the value of the new information. Further, there is evidence that USDA livestock reports are not unbiased estimates of revised final numbers, and this could influence market reaction and its measurement. When government announcements do not fully reflect available information and the market responds to the actual or revised value and not to the preliminary announcement, estimates of its price effects will be downward biased and inconsistent because of the errors-in-variables problem (Orazem and Falk). If this is indeed the case, this may help clarify the existing uncertainty about the nature of the market's reaction to new information and its value. Here, we evaluate the rationality of market and *HPR* announcements by direct comparison with USDA revised estimates and then investigate the market's reaction to alternative surprises based on conventional and modified measures that reflect the effect of revised final estimates on price response.

## Conceptual Framework

*HPR* announcements are released quarterly and include total market (*MK*) and breeding (*BR*) inventories. The report contains information that is released to the market after the close of trading on the announcement day. Subsequent *HPR* releases include revised estimates for data already published. Prior to the announcement, market expectations are based on private analysts' surveys that typically are released after the close of trading 2 days before the *HPR* is released.

The conventional procedure to measure new information from the announcement entering the market is to use the difference between the information contained in the announcement and the information known by the market prior to the release. This measure is then used to assess futures prices reaction to the new information in the market. However, when the *HPR* numbers are not rational estimates of actual realized values, the conventional estimator of the announcement effect may be biased and inconsistent. In turn, the wrong sign and significance of relevant parameter estimates can lead to erroneous inference regarding the effect of new information entering the market (Orazem and Falk). Under this scenario, the specification of the surprise measure needs to be reconsidered. Extending Orazem and Falk's framework, we test the impact the release of the report has on prices using two traditional and two modified measures of surprise.

Let $x^a_{i,t}$ be the *HPR* announcement estimate released at day $t$ for *BR* and *MK* inventories and $x^e_{i,t-1}$ be the market expectation before the *HPR* announcement is released. Further, assume that the *HPR* announcement contains irrational estimates of actual inventories and that other sources (e.g., the Census of Agriculture) with more accurate information become available at a later period $t + n$. Let $x^{f}_{i,t}$ be the final revised estimate for day $t$ that is released at some future day $t + n$. Based on this basic structure, several measures of surprise are developed.

A first measure of surprise is simply the difference between the announcement and market expectations and is the *conventional* representation of information contained in the *HPR* that is unknown to the market,

$$(1)\quad x^{u(1)}_{i,t} = x^{a}_{i,t} - x^{e}_{i,t-1}, \quad i = \{BR, MK\},\ t = 1,\ldots,T,$$

where $x^{u(\cdot)}_{i,t}$ is the unanticipated information. However, because this information might be biased with respect to final estimates, we define a second measure of surprise (i.e., *conventional—final*) as

$$(2)\quad x^{u(2)}_{i,t} = x^{f}_{i,t} - x^{e}_{i,t-1},$$

where $x^{u(2)}_{i,t}$ represents the modified conventional measure accounting for final estimates. The response of prices to this measure might help identify whether the market is able to anticipate revisions to the initial *HPR* announcements. If the market has this extra information, then prices should respond to $x^{u(2)}_{i,t}$.

Under Orazem and Falk's framework, alternative surprises are based on different linear projections of the relevant breeding, marketing, and expectations variables. When the market focuses on the announcements of inventories $x^{a}_{i,t}$, the market's rational preannouncement linear forecasts are the fitted values from the regression

$$(3)\quad x^{a}_{i,t} = \beta_0 + \beta_1 x^{e}_{i,t-1} + \varepsilon_{1i,t},$$

and the new information released to the market is

$$(3.1)\quad x^{u(3)}_{i,t} = x^{a}_{i,t} - \hat{x}^{a}_{i,t} = \varepsilon_{1i,t},$$

where $\hat{x}^{a}_{i,t}$ are the fitted values of $x^{a}_{i,t}$ in Equation (3) and $x^{u(3)}_{i,t}$ is the *linear projection* measure of surprise. However, if the market focuses instead on the final revised estimate, then the market's preannouncement linear forecast are the fitted values from

$$(4)\quad x^{f'}_{i,t} = \beta'_0 + \beta'_1 x^{e}_{i,t-1} + \varepsilon_{2i,t}.$$

After an announcement, the market will update its information to include $x^{a}_{i,t}$ so that the market's optimal forecast of $x^{f}_{i,t}$ are the fitted values from

$$(4.1)\quad x^{f''}_{i,t} = \beta''_0 + \beta''_1 x^{e}_{i,t-1} + \beta_2 x^{a}_{i,t} + \varepsilon_{3i,t}.$$

In this case, new market information is

$$(4.2)\quad x^{u(4)}_{i,t} = \hat{x}^{f'}_{i,t} - \hat{x}^{f''}_{i,t} = \varepsilon_{2i,t} - \varepsilon_{3i,t},$$

where $\hat{x}^{f'}_{i,t}$ are the fitted values from Equation (4), $\hat{x}^{f''}_{i,t}$ are the fitted values from Equation (4.1), and $x^{u(4)}_{i,t}$ is the *linear projection—final* measure of surprise. When preliminary announcements are rational, then Equation (3.1) provides an appropriate representation of the surprise. However, if government preliminary announcements are biased estimates of final inventories, fitted values of Equations (4) and (4.1), along with Equation (4.2), must be used to derive the new information conveyed to the market by the preliminary announcement.[1]

## Data

Breeding and market inventories are taken from the USDA *HPR*. The reports are the result of surveys to hog producers taken by USDA, and for most of the previously mentioned period, they were released quarterly in March, June, September, and December after the close of trading. From January 2001 to September 2003, reports were released on a monthly rather than a quarterly basis. Inven-

[1] Alternative specifications for Equation (4.1) using lagged values of market expectations and *HPR* announcements to allow for a more comprehensive specification of current market expectations were examined. Using standard rationality tests described in the text and statistical criteria, none performed better than Equation (4.1). These findings for alternative market expectations are available from the authors.

tories used in this study are totals of major states.[2]

Actual breeding and market inventories are taken from the USDA *Hogs and Pigs Final Estimates Bulletins*, which are published approximately every 5 years. Final estimates differ from the previously mentioned current estimates in that they make use of additional information including the Census of Agriculture, slaughter data, shipment records, imports, and exports. The final estimates inventories were matched with their corresponding current estimates so that current and actual numbers refer to the same states. The last available *Hogs and Pigs Final Estimates Bulletin* was published in March 2004 and contains inventories' final estimates through 2002. Hence, surprise measures defined by Equations (2), (4), (4.1), and (4.2) can be computed only for the period 1982–2002.

Market expectations are an average of about 15 private market analysts' expectations reported as changes in breeding and market inventories from year-ago levels. The analysts' expectations are released after the close of trading 2 days before the USDA report is released.

Open and close hog futures prices from the Chicago Mercantile Exchange were collected on days 1 through 4 after the report release. Two time horizons were defined in order to capture differences between breeding and market inventory holders. Distant futures prices are expected to react relatively more to breeding inventory announcements because breeding inventory impacts take a longer time to affect market supplies. Near futures contracts, in contrast, are expected to react to market inventory announcements because this category takes a shorter period to enter the market. The near and distant horizons were defined, respectively, as those contracts expiring 2 to 3 months and 7 to 8 months after the day of the report release.[3] Hog futures contracts underlying commodity changed from live to lean hogs in 1996. In order to develop a standardized series, prices before 1997 were transformed to lean hogs using a factor of 1.35.

Prior to estimation of the relationships, we perform the Augmented Dickey–Fuller test for unit root on all the series used in the analysis. We find that market expectations are stationary at the 10% significant level and that all the rest of the series are stationary at the 5% level with little evidence of any structural breaks in the series.

## Rationality Tests

Rationality means that the information released at time $t$ equals its expected value at time $t+n$ given all the information available at time $t$. For instance, the rationality condition for the information contained in the *HPR*'s breeding and marketing inventories is

$$(5) \quad x^{a}_{i,t} = E\left(x^{f}_{i,t} \mid \phi_t\right),$$

where $\phi_t$ is the set of information available on day $t$ and implies that the estimates for *BR* and *MK* are unbiased and efficient with respect to the final revised numbers. The unbiasedness condition is tested with the following equation,

$$(6) \quad x^{f}_{i,t} = \alpha_0 + \alpha_1 x^{a}_{i,t} + u_{i,t}.$$

For the market expectations $\left(x^{e}_{i,t-1}\right)$, we test unbiasedness with respect to both the final estimates and announcements,

$$(6.1) \quad x^{f}_{i,t} = \alpha'_0 + \alpha'_1 x^{e}_{i,t-1} + u'_{it}$$

$$(6.2) \quad x^{a}_{i,t} = \alpha''_0 + \alpha''_1 x^{e}_{i,t-1} + u''_{it},$$

[2] The USDA definition of major states has changed, as some states have experienced a great expansion of hog production, while others have become less important in the hog industry. The data set is composed of 10 states during the period 1982.2–1996.1 and 17 states during the period 1996.2–2000.4. Using a similar data set but for the period 1981–1988, Colling and Irwin (1990) found no bias in the whole period data when compared to a subset restricted to have the same number of states.

[3] Time horizons are not exactly defined because hog futures contracts do not exist for every month of the year.

where unbiasedness implies $\alpha_0 = 0$ and $\alpha_1 = 1$. The tests are performed on both estimates because we are uncertain whether market expectations focus on announcements or final revised estimates. Note that the rationality tests discussed here are similar to the first step of the linear prediction framework (e.g., compare Equation [3] to Equation [6.2])—in both cases the objective is to assess the same systematic error. The efficiency test is a test for the presence of autocorrelation in the error terms of the USDA estimates and market expectations (Equations [6]–[6.2]). A Breusch–Godfrey LM test for autocorrelation with four lags to reflect the quarterly nature of the data is used.

Tests for rationality show that both *HPR* and market analysts estimates of breeding and market inventories are biased and inefficient with respect to final estimates (Table 1). The evidence is less strong for *HPR* market inventories. Also, market analysts provide biased estimates with respect to *HPR* announcements. The evidence of bias is strong for both breeding and market inventories and coincides with Runkle's (1992) findings for sow farrowing intentions but contrasts with Colling and Irwin (1990) and Colling, Irwin, and Zulauf. However, analysts' expectations appear to be efficient with respect to the *HPR* for marketing inventories, which is more consistent with previous research.[4]

## Market Reaction to New Information

The specification of the model to test the effect of the surprises on futures prices relies on institutional features of the futures markets. Hog futures contracts are subject to daily price limits of \$2 per hundredweight from the previous day's closing price. When the price hits that limit, trades may still take place at that price, but the free market equilibrium price is no longer observable.[5]

Table 2 shows the number of days that prices hit the limit during the sample period (1982.2–2002.4). Approximately 40% of the prices in the sample are price limits for the first day after the announcement, limits that might have important consequences in estimation and inference if not taken into account properly. Price limits truncate the distribution of price changes and make prices less variable. Therefore, deviations of prices from their mean values would be harder to detect, and tests are biased toward nonrejection of zero coefficients. Price limits may also induce serial correlation, which would lead to the conclusion that the market is inefficient because prices do not incorporate all the available information (Kodres). In order to overcome these problems and estimate price reactions in the presence of price limits, a two-limit tobit model is used in which prices are truncated on two sides but are allowed to vary freely between the two limits.[6]

The tobit model is estimated for one as well as for several days after the USDA release. Tracking price response to new information over time is significant as an indication of the speed of market reaction. A significant price response on the first day after the announcement would indicate that prices react quickly to new information, whereas significant price

[4] We also performed the rationality tests using dummy variables to account for the years in which the *HPR* was released on a monthly basis. Both the unbiasedness the and efficiency tests led to the same conclusions of irrationality that can be inferred from Table 1.

[5] Before 1996 the price limit was \$1.50 for live hogs. Transforming prices using a factor of 1.35 to make live hog and lean contracts comparable results in a price limit of \$2.025, which is slightly higher than the \$2.00 limit that actually existed in the later period. This difference should not affect our findings to any degree, as examination of the results indicated that all limit observations prior to 1996 are correctly identified.

[6] Based on options prices, Egelkraut, Garcia, and Sherrick identify a procedure to forecast futures price in the presence of limit moves. While useful in a predictive context, their framework does not directly provide estimates of the reaction coefficients between the change in futures prices and the surprise that is the primary motivation of the analysis. Future research that combines their procedure with methods to identify reaction coefficients may lead to a useful framework to study price moves in the presence of limits.

**Table 1.** Rationality Tests of USDA Hogs and Pigs Report Announcements and Market Expectations, 1982.2–2002.4

| Variable | | | Coefficients | | Adjusted | Unbiasedness Test | | Efficiency Test | |
|---|---|---|---|---|---|---|---|---|---|
| Dependent | Independent | Equation | $\alpha_0$ | $\alpha_1$ | $R^2$ | $F$-Statistic | $p$-Value | $\chi^2$-Statistic | $p$-Value |
| Breeding inventories | | | | | | | | | |
| $x^f_{BR,t}$ | $x^a_{BR,t}$ | (6) | 547.68 (171.57) | 0.90 (0.03) | 0.91 | 7.25 | <0.00 | 50.27 (lag 2) | <0.00 |
| $x^f_{BR,t}$ | $x^e_{BR,t-1}$ | (6.1) | 1,076.69 (242.85) | 0.80 (0.04) | 0.81 | 21.26 | <0.00 | 17.81 (lag 1) | <0.00 |
| $x^a_{BR,t}$ | $x^e_{BR,t-1}$ | (6.2) | 671.73 (224.37) | 0.87 (0.04) | 0.86 | 11.29 | <0.00 | 5.88 (lag 1) | 0.02 |
| Market inventories | | | | | | | | | |
| $x^f_{MK,t}$ | $x^a_{MK,t}$ | (6) | 938.77 (553.84) | 0.98 (0.01) | 0.99 | 2.01 | 0.14 | 33.80 (lag 1) | <0.00 |
| $x^f_{MK,t}$ | $x^e_{MK,t-1}$ | (6.1) | 2,523.03 (724.28) | 0.94 (0.02) | 0.97 | 6.28 | <0.00 | 15.48 (lag 1) | <0.00 |
| $x^a_{MK,t}$ | $x^e_{MK,t-1}$ | (6.2) | 1,728.97 (596.84) | 0.96 (0.01) | 0.98 | 4.21 | 0.02 | 0.25 (lag 1) | 0.61 |

Notes: $x^a_{i,t}$ is the *HPR* announcement, $x^e_{i,t-1}$ is the market expectation, and $x^f_{i,t}$ is the final estimate for $i$ = breeding (*BR*) and marketing (*MK*) inventories. Standard errors are in parentheses. The joint null hypothesis for the unbiasedness test is $\alpha_0 = 0$ and $\alpha_1 = 1$. The efficiency test is the Breusch–Godfrey LM test for autocorrelation where the most significant lag from 1 to 4 quarters is reported.

responses on subsequent days would indicate only the degree of delay in prices to incorporating new information. The effect of 1-day price changes beyond the first day after the announcement cannot be directly tested using this model because price limits appear in a sequence after the announcement day, and a limit price following a limit price would yield biased parameter estimates (Colling and Irwin 1990). Hence, the response of prices in subsequent days after the announcement is investigated by cumulating price differences for each day with respect to the announcement day. Because prices are permitted to move by \$2 per day, the effective cumulative 2-, 3-, and 4-day price limit is \$4, \$6 and \$8 respectively. The two-limit tobit price response model is

$$(7)\quad \begin{aligned} &\Delta_k p_t* = \delta_0^j + \delta_{BR}^j x_{BR,t}^{u(j)} + \delta_{MK}^j x_{MK,t}^{u(j)} + e_t^j \\ &e_t \sim N(0, \sigma^2) \\ &\Delta_k p_t = \begin{cases} UL \text{ if } \Delta_k p_t^* \geq UL \\ \Delta_k p_t^* \text{ if } LL < \Delta_k p_t^* < UL \\ LL \text{ if } \Delta_k p_t^* \leq LL \end{cases}, \end{aligned}$$

where $\Delta_k p_t*$ are the latent (sometimes unobserved) equilibrium futures prices in $k$th difference form; $\Delta_k p_t$ are the observed futures prices in $k$th difference form ($\Delta_k p_t = p_{t,k=k} - p_{t,k=0}$, $k = 1, \ldots, 4$ is the $k$th day after the announcement and $k = 0$ is the day of the announcement); $x_{i,t}^{u(j)}$ is the unanticipated information (i.e., measure of surprise to the market); $j = 1, \ldots, 4$ are four measures of surprise defined by Equations (1), (2), (3.1), and (4.2); $\delta_i^j$ are estimated coefficients; and $UP$ and $LL$ are the upper and lower price limits, respectively (UP is 2, 4, 6, and 8 for days 1, 2, 3, and 4, respectively, and LL is −2, −4, −6, and −8 for days 1, 2, 3, and 4, respectively).

Price changes in Equation (7), $\Delta_k p_t$, are defined in two ways. Consistent with previous studies we use close-to-close price changes to measure prices reaction to the *HPR* report. However, since the reports are released after closing on day $t$, close-to-close price differences between day $t$ and day $t + 1$ may contain both the reaction effect and the effect of other information entering the market during day $t + 1$. To avoid this problem and following

**Table 2.** Number of Censored Hog Futures Price Observations Following USDA Hogs and Pigs Reports, 1982.2–2002.4

| | Day 1 | Day 2 | Day 3 | Day 4 |
|---|---|---|---|---|
| Short time horizon | | | | |
| No. price limit days | 29 | 8 | 2 | 0 |
| Percentage | 35% | 10% | 2% | 0% |
| Long time horizon | | | | |
| No. price limit days | 33 | 7 | 2 | 1 |
| Percentage | 40% | 9% | 3% | 1% |

Notes: No. price limit days is the number of days prices hit the limit using close-to-close prices, and percentage is the proportion of those days in the sample. The total number of observations for each day and horizon is $T = 83$. Days 1 to 4 are the first 4 trading days after the USDA announcement.

Isengildina, Irwin, and Good, we also use close-to-open price differences to measure the immediate reaction of prices when trading begins after the report is released.

In the presence of heteroscedasticity, the estimates in Equation (7) are biased and inconsistent (Hurd; Maddala and Nelson). Further, Colling and Irwin (1990) point out that heteroscedasticity has been found in futures price changes, and therefore some corrective estimation may be necessary. Hence, we specify a heteroscedastic tobit model and then conduct a likelihood ratio test ($LR$) to assess whether the difference in the log likelihood between Equation (7) and this model is significantly different from zero. In the heteroscedastic tobit model, the error term is distributed as in Equation (8), and the error variance term is assumed to be explained by the independent variables of the model. Specifically,

$$(8) \quad e_t \sim N\left(0, \sigma_t^2\right)$$

$$(8.1) \quad \sigma_t^2 = \sigma^2\left(1 + \exp\left(\zeta_{BR} x_{BR,t}^u + \zeta_{MK} x_{MK,t}^u\right)\right)$$

$$(9) \quad LR = -2\left(\ln L_r - \ln L\right) \sim \chi_2^2,$$

where $\ln L_r$ is the log likelihood of the restricted model in Equation (7) and $\ln L$ is the log likelihood of the heteroscedastic model represented by Equations (8) and (8.1). $LR$ is asymptotically distributed as $\chi^2$ with degrees of freedom equal to the number of restrictions (i.e., 2, $\zeta_{BR} = 0$, and $\zeta_{MK} = 0$).[7]

Hypothesis testing in the tobit model is performed using likelihood-ratio tests for the parameter estimates. The null hypothesis for the announcement effect is that any of the slope coefficients, $\delta_{BR}$ or $\delta_{MK}$, are equal to zero. If at least one of the independent variables (breeding or market inventory) turns out to be significantly different from zero, then the information in the USDA announcement is not only new to the market but also causing a reaction in prices.

The tobit model was estimated for near and distant contracts and for close-to-close and close-to-open price changes. To help with interpretation of the effect of information on prices, we also estimate the same models in natural logarithm differences using OLS, which permits the effects to be expressed as proportional changes (Greene). To reflect the censoring, the OLS coefficients are scaled by $1/T_c$, where $T_c$ is the number of censored observations. These response coefficients can be interpreted directly as the relationship between percentage price changes in prices and percentage changes in inventories. For example, a coefficient of $-0.6$ would indicate that for a 1% increase in the unexpected inventories, prices will decrease by 0.6%.[8]

For brevity and ease of interpretation and because of similarity in the findings, we present the tobit estimates only for the near-contract, close-to-close price changes but provide the OLS estimates for near and distant contracts and for close-to-close and close-to-open price changes. Table 3 presents parameter estimates for the near (2–3 months)

[7] The model for $\sigma_t^2$ in Equation (8.1) is the most general specification. We also specify linear (i.e., $\sigma_t^2 = \sigma^2\left(1 + \zeta'_{BR} x_{BR,t}^u + \zeta'_{MK} x_{MK,t}^u\right)$) and squared models (i.e., $\sigma_t^2 = \sigma^2\left(1 + \left(\zeta'_{BR} x_{BR,t}^u + \zeta'_{MK} x_{MK,t}^u\right)^2\right)$. We choose the appropriate variance model based on log likelihood, AIC, and BIC measures.

[8] Estimation of the tobit model using natural logarithm differences is problematic because the upper and lower limits will vary with the level of the changes.

**Table 3.** Hog Futures Price Response to the Release of USDA Hogs and Pigs Reports for Near Contracts, 1982.2–2002.4

| | 1-Day | 2-Day | 3-Day | 4-Day |
|---|---|---|---|---|
| Conventional | | | | |
| $\delta_0^1$ | 0.0893 | 0.0286 | 0.1008 | 0.1548 |
| | (0.2317) | (0.2587) | (0.2758) | (0.2846) |
| $\delta_{BR}^1$ | –0.0045* | –0.0063*** | –0.0048* | –0.0048* |
| | (0.0026) | (0.0023) | (0.0025) | (0.0025) |
| $\delta_{MK}^1$ | –0.0010** | –0.0010* | –0.0010** | –0.0009** |
| | (0.0004) | (0.0004) | (0.0004) | (0.0002) |
| $R_{MF}^2$ | 0.12 | 0.07 | 0.06 | 0.05 |
| LR test | 7.87† | 5.01 | 2.74 | 2.97 |
| Conventional—final | | | | |
| $\delta_0^2$ | 0.3325 | 0.2429 | 0.2872 | 0.3217 |
| | (0.2538) | (0.2746) | (0.2328) | (0.2231) |
| $\delta_{BR}^2$ | –0.0012 | –0.0005 | 0.0011 | 0.0011 |
| | (0.0021) | (0.0023) | (0.0024) | (0.0024) |
| $\delta_{MK}^2$ | –0.0011*** | –0.0012*** | –0.0016*** | –0.0018*** |
| | (0.0003) | (0.0004) | (0.0003) | (0.0003) |
| $R_{MF}^2$ | 0.10 | 0.06 | 0.08 | 0.10 |
| LR test | 4.56 | 5.07 | 6.81† | 8.63† |
| Linear projection | | | | |
| $\delta_0^3$ | 1.2250*** | 1.2299** | 1.4687*** | 1.4386*** |
| | (0.4578) | (0.4731) | (0.5008) | (0.5218) |
| $\delta_{BR}^3$ | –0.0068*** | –0.0070*** | –0.0058** | –0.0053** |
| | (0.0022) | (0.0023) | (0.0025) | (0.0025) |
| $\delta_{MK}^3$ | –0.0008*** | –0.0009** | –0.0011*** | –0.0010** |
| | (0.0004) | (0.0004) | (0.0004) | (0.0004) |
| $R_{MF}^2$ | 0.09 | 0.08 | 0.07 | 0.06 |
| LR test | 5.39 | $<0.00$ | $<0.00$ | $<0.00$ |
| Linear projection—final | | | | |
| $\delta_0^4$ | 0.3160 | 0.1941 | 0.1702 | 0.2292 |
| | (0.2118) | (0.2236) | (0.2383) | (0.2589) |
| $\delta_{BR}^4$ | –0.0084*** | –0.0086*** | –0.0071** | –0.0065** |
| | (0.0028) | (0.0029) | (0.0030) | (0.0031) |
| $\delta_{MK}^4$ | –0.0009** | –0.0010** | –0.0012*** | –0.0011** |
| | (0.0004) | (0.0004) | (0.0004) | (0.0005) |
| $R_{MF}^2$ | 0.09 | 0.08 | 0.07 | 0.07 |
| LR test | 4.80 | 2.72 | 1.48 | 0.36 |

Notes: Standard errors are in parentheses under the coefficients. The level of significance is indicated at the 10% (*), 5% (**), and 1% (***) levels. $R_{MF}^2$ is the McFadden's $R^2$, which compares the likelihood for the model with intercept only to the likelihood for the model with the predictors $\left(R_{MF}^2 = 1 - \ln L(M_{\text{full}})/\ln L(M_{\text{int}})\right)$. LR test is the likelihood ratio test for heteroscedasticity, that is, $\zeta_{BR} = 0$ and $\zeta_{MK} = 0$ in Equation (8.1).

† denotes that the null hypothesis of homoscedasticity can be rejected at the 5% significant level, and estimates of the mean equation of the heteroscedastic tobit model as described in Equations (8) and (8.1) are reported.

contracts for Equation (7) and the four measures of surprise, $x_{i,t}^{u(j)}, j = 1 \ldots 4$ using close-to-close price changes. The near- and distant-contract responses are presented for both close-to-close and close-to-open price changes in Tables 4 and 5.

Focusing first on the near-contract, close-to-close price effects in Table 3, we find consistent with the literature (Carter) that the ability of the surprises to explain price changes is relatively small. Nevertheless, several patterns exist. The McFadden $R^2$s de-

**Table 4.** Proportional Effect of Percentage Surprises on Percentage Hog Futures Price Changes for Near Contracts to the Release of USDA Hogs and Pigs Reports, 1982.2–2002.4

| Surprise | | 1-Day | 2-Day | 3-Day | 4-Day |
|---|---|---|---|---|---|
| Close-to-close | | | | | |
| Conventional | *BR* | −0.52 | −0.49 | −0.35 | −0.38 |
| | *MK* | −0.39 | −0.48 | −0.64 | −0.60 |
| | $R^2$ | 0.21 | 0.22 | 0.20 | 0.18 |
| Conventional—final | *BR* | −0.13 | 0.06 | 0.10 | 0.08 |
| | *MK* | −0.60 | −0.69 | −0.87 | −0.92 |
| | $R^2$ | 0.19 | 0.20 | 0.20 | 0.23 |
| Linear projection | *BR* | −0.51 | −0.54 | −0.46 | −0.45 |
| | *MK* | −0.44 | −0.50 | −0.61 | −0.59 |
| | $R^2$ | 0.21 | 0.24 | 0.22 | 0.20 |
| Linear projection—final | *BR* | −0.64 | −0.61 | −0.48 | −0.49 |
| | *MK* | −0.46 | −0.63 | −0.81 | −0.74 |
| | $R^2$ | 0.21 | 0.26 | 0.23 | 0.20 |
| Close-to-open | | | | | |
| Conventional | *BR* | −0.52 | −0.48 | −0.35 | −0.38 |
| | *MK* | −0.39 | −0.48 | −0.64 | −0.60 |
| | $R^2$ | 0.21 | 0.22 | 0.20 | 0.18 |
| Conventional—final | *BR* | −0.13 | −0.06 | 0.10 | 0.08 |
| | *MK* | −0.60 | −0.68 | −0.87 | −0.93 |
| | $R^2$ | 0.19 | 0.20 | 0.20 | 0.23 |
| Linear projection | *BR* | −0.51 | −0.54 | −0.46 | −0.45 |
| | *MK* | −0.44 | −0.49 | −0.61 | −0.60 |
| | $R^2$ | 0.21 | 0.24 | 0.22 | 0.20 |
| Linear projection—final | *BR* | −0.64 | −0.61 | −0.48 | −0.49 |
| | *MK* | −0.46 | −0.62 | −0.81 | −0.75 |
| | $R^2$ | 0.21 | 0.25 | 0.23 | 0.20 |

Notes: *BR* is breeding inventories, and *MK* is marketing inventories. The surprises are defined in the text by Equations (1), (2), (3.1), and (4.2). The coefficients are OLS estimates in natural logarithms scaled by $1/T_c$, where $T_c$ is the number of censored observations. The OLS model is $\Delta_k p_t = \delta_0^j + \sum_i \delta_i^j x_{i,t}^{u(j)} + e_t^j$, $i = \{BR, MK\}$, $j = 1, \ldots, 4$ are the surprise measures. $R^2$ is the adjusted $R^2$.

crease gradually from day 1 to day 4, as one would expect, because of additional information entering the market over time. The statistical significance of the estimates seems to be higher for the linear projection surprise measures, especially for the breeding inventory coefficients. With regard to heteroscedasticity, a problem emerges on day 1 with the conventional model and on days 3 and 4 with the conventional model using final estimates. For these cases we report the estimates of the heteroscedastic model.

A comparison of the coefficients across cumulative price changes provides important information about the reaction of prices. For example, an increase of the slope coefficients $\delta_i$ in absolute value when $k$, the number of days, increases would indicate immediate underreaction of prices to new inventory information. The effects of breeding and marketing information on price changes differ over time. For the near contracts, somewhat unexpectedly, on day 1 breeding inventories have a larger effect on prices than marketings for all surprises except for the conventional—final measure, where breedings never enter the relationship in a statistically meaningful way. Following day 1, the magnitude of the breedings effect appears to gradually decay, and marketings have a larger and increasing effect through day 3 on prices. The relative importance of marketing and breeding inventories on price changes is consistent with Colling and Irwin's (1990) findings, but the

**Table 5.** Proportional Effect of Percentage Surprises on Percentage Hog Futures Price Changes for Distant Contracts to the Release of USDA Hogs and Pigs Reports, 1982.2–2002.4

| Surprise | | 1-Day | 2-Day | 3-Day | 4-Day |
|---|---|---|---|---|---|
| Close-to-close | | | | | |
| Conventional | *BR* | −0.90 | −0.75 | −0.73 | −0.73 |
| | *MK* | −0.03 | −0.16 | −0.28 | −0.31 |
| | $R^2$ | 0.23 | 0.24 | 0.24 | 0.21 |
| Conventional—final | *BR* | −0.42 | −0.35 | −0.36 | −0.30 |
| | *MK* | −0.44 | −0.45 | −0.55 | −0.67 |
| | $R^2$ | 0.21 | 0.22 | 0.24 | 0.24 |
| Linear projection | *BR* | −0.95 | −0.84 | −0.85 | −0.83 |
| | *MK* | −0.08 | −0.18 | −0.27 | −0.32 |
| | $R^2$ | 0.25 | 0.28 | 0.29 | 0.24 |
| Linear projection—final | *BR* | −1.19 | −0.99 | −0.98 | −0.96 |
| | *MK* | −0.06 | −0.28 | −0.41 | −0.45 |
| | $R^2$ | 0.25 | 0.28 | 0.29 | 0.25 |
| Close-to-open | | | | | |
| Conventional | *BR* | −0.88 | −0.77 | −0.72 | −0.73 |
| | *MK* | −0.03 | −0.17 | −0.28 | −0.31 |
| | $R^2$ | 0.23 | 0.24 | 0.24 | 0.21 |
| Conventional—final | *BR* | −0.40 | −0.36 | −0.32 | −0.30 |
| | *MK* | −0.44 | −0.47 | −0.54 | −0.67 |
| | $R^2$ | 0.21 | 0.22 | 0.24 | 0.24 |
| Linear projection | *BR* | −0.93 | −0.86 | −0.84 | −0.83 |
| | *MK* | −0.08 | −0.18 | −0.27 | −0.32 |
| | $R^2$ | 0.25 | 0.28 | 0.29 | 0.24 |
| Linear projection—final | *BR* | −1.17 | −1.01 | −0.97 | −0.96 |
| | *MK* | −0.06 | −0.29 | −0.41 | −0.45 |
| | $R^2$ | 0.25 | 0.28 | 0.29 | 0.25 |

Notes: *BR* is breeding inventories, and *MK* is marketing inventories. The surprises are defined in the text by Equations (1), (2), (3.1), and (4.2), respectively. The coefficients are OLS estimates in natural logarithms scaled by $1/T_c$, where $T_c$ is the number of censored observations. The OLS model is $\Delta_k p_t = \delta_0^j + \sum_i \delta_i^j x_{i,t}^{u(j)} + e_t^j$, $i = \{BR, MK\}, j = 1, ..., 4$ are the surprise measures. $R^2$ is the adjusted $R^2$.

pattern of decay of the breedings effect and the increase of the marketings effect differ from their rather stable coefficients over the 4-day period. For distant contracts, breeding inventories have large and statistically significant effects on prices for all days following the announcement, and marketing inventory coefficients are small and never appear significantly at any conventional statistical level.[9] An exception to this behavior is the conventional—final measure, where the breeding coefficients are not significant but marketing coefficients appear to be significant at the 5% level for the 4 days after the announcement. Overall, the pattern of price changes over time provides only modest evidence to support a contention that the hog market over- or underreacts to new information in the *HPR*.

Evidence from Tables 4 and 5, which provide reaction responses in percent changes, suggests that there is little difference between the close-to-close and the close-to-open estimates. For both the near and the distant contracts, the corresponding OLS estimates for the close-to-open coefficients are almost

[9] This discussion of significance is based on the tobit results for the distant-contracts, close-to-close price change which allow for statistical inference. While inference is inappropriate for the OLS framework, the relative magnitude of the coefficients in the upper portion of Table 5 provides an approximation of statistical importance in these tobit findings, except for the conventional final measure. A complete set of the tobit results is available from the authors.

identical to the close-to-close case. Similarly, the $R^2$s are almost identical. Tobit estimates (not presented) are also practically identical for the two price changes. The McFadden $R^2$s for the tobit models are relatively higher for the close-to-open models but only marginally so.

To further assess the sensitivity of our findings and to identify whether one of the formulations provides a statistically superior representation of how new information affects price, we perform tests for structural change, allow for differential effects for the period when the *HPR* was released monthly, and assess nonnested dominance. As examination of the individual series did not identify any obvious structural breaks, we performed Chow tests for structural change for two dates: 1990.4 and 1995.4. The first date corresponds roughly to when many of the structural changes in the hog industry were beginning, and the second reflects the date when the limit changed from $1.50 to $2.00. We also assess whether there was a differential effect for the period the *HPR* was released monthly by using dummy variables and interaction terms with the surprise measures in Equation (7). More frequent release of the *HPR* might be associated with smaller price changes, as each release presumably provides less new information to the market. Finally, we perform bivariate *J*-tests for the nonnested models by including the projected value of the price change for the alternate or rival model.

The battery of tests is performed on the near and distant contracts. Since there was little difference between the results for the close-to-close and close-to-open price series, we perform the tests on the close-to-close price series only. At the 5% level, we find no significant evidence of a structural change or differential effect for the period when the *HPR* was released monthly. Since the analysis spans roughly two decades during which the hog industry was undergoing considerable change, the first finding is a little surprising. It appears that despite changes in production technology and marketing/contracting arrangements, the fundamental relationship between new information and its effect on price is rather stable. The finding may also reflect the difficulty or imprecision in measuring how daily price changes are influenced by long-term trends in the industry. The lack of a differential effect for the period when the *HPR* was released is likely related to data limitations as well. In the context of our quarterly framework, the number of observations for this period was only eight, making it difficult to identify precise differences in the response coefficients. Lastly, the bivariate *J*-tests showed no systematic pattern of statistical superiority among the surprise measures. While the finding may be influenced by the relatively low power of the test reported in the literature, it is highly consistent with the similarity in the response coefficients and similarity of explanatory power of the different surprise models.

While statistically there appears to be little to separate the surprise effects, economic responses differ across surprise measures. Linear projection surprises identify generally larger market price responses than both conventional surprises. For example, on day 1 the estimate of the breeding inventory effect on prices using the conventional—final surprise is $-0.13$, while the estimate using the linear projection—final surprise is –0.64 (Table 4). Using a representative price of $65/cwt, the linear projection—final surprise would indicate a 33-cent/cwt larger effect on prices, based on the difference in coefficients ($-0.64$ and $-0.13$). The larger responses and higher statistical coherence identified earlier may reflect the ability of linear projection procedures to provide a more appropriate measure of surprise, allowing for a more accurate, less noisy measurement of the effect of new information.

Larger response coefficients for the linear projection—final surprise compared to the surprise measures provide only modest evidence that Orazem and Falk's framework, which highlights the importance of market participants' interest in the final revisions, may be slightly more consistent with the structure of market information. Despite this modest difference, the overall similarity in results for the measures makes it difficult to argue that they are not effectively the same.[10] In Orazem and Falk's framework, conventional and projection surprises provide similar results when the announcements are rational forecasts of the final numbers. In light of the findings in Table 1 that reject rationality, the models also provide similar reflections of the effect of information on prices when expectations of final and announcements are biased in a similar manner.

## Conclusions and Implications

The effect of the USDA *HPR* on prices is complex because the report might not provide new information to the market or might provide irrational estimates of subsequent outcomes and still affect prices. Here we evaluate the impact of the *HPR* on hog prices using four different surprise measures: the conventional method (announcement minus market expectations), a modified conventional method (final minus market expectations), the linear projection of the conventional method (error from the regression of announcements on market expectations), and a linear projection method that allows for revisions.

We find that *HPR* announcements are irrational estimates of final estimates and that market expectations are also irrational estimates of *HPR* announcements. These findings are consistent with the tenor of Runkle's (1991) results suggesting that USDA farrowing intention estimates are biased. However, they differ from Colling and Irwin's (1990) and Colling, Irwin, and Zulauf's rationality results. Modest statistical differences between the conventional and linear projection measures exist. The linear projection measures, which can reduce the effect of noise on the estimate, appear slightly more coherent with the data and provide modestly larger effects of changes in information on prices. Economic differences also exist between the conventional and linear projection measures, with differences in price response as large as 33 cents/cwt emerging when comparing coefficients from the conventional—final measure of surprise to the linear projection measure that accounts for final estimates. Regardless of the procedure used, after the first day of the announcement, marketing inventory information has a larger and more consistent effect on near futures price changes than breeding inventory information, which has a larger effect on distant price changes. These findings are consistent with Colling and Irwin (1990). In contrast to Colling and Irwin (1990), we find marginal evidence of underreaction to marketing inventories in near contracts and overreaction to breeding inventories in distant contracts. Finally, the rather small economic and statistical differences between both linear projection measures suggest that, when similar biases in expectations and announcements relative to final estimates exist, the price effects are similar and that little is gained by focusing on final revised numbers rather than announcement effects.

Several points emerge from the analysis. First, while irrationality exists, *HPR* reports continue to demonstrate that they provide information to the market regardless of the form that is used to measure the effect. While some differences arise, the overall message is quite robust and consistent with the past research that asserts that *HPR* provides new information to the market. Second, the source of the irrationality in forecasting final and announced estimates is not clear, but because it emerges regardless of the supply variable examined, it makes sense to regard a factor such as a time-varying structural or techno-

[10] Since we were primarily interested in comparing the effect of final revisions on price changes, our data period effectively ends in 2002, the date of the last final revision available. To gain further insight into market behavior, we estimate our conventional model, which does not rely on the final revision data, to assess the effect of information on prices with data extending through 2006.1. Since our statistical findings demonstrated no significant differences among the measures, this should provide a good approximation of the market response to new information. For the near contracts, the breeding inventory coefficients of the more recent period are slightly larger and a little more significant, while the marketing inventory coefficients are lower and less significant. However, the $R^2$s do not differ appreciably. The distant-contracts coefficients show practically no change from those reported in the text, and the $R^2$s are almost identical. Overall, these findings support our discussion in the text regarding the value of *HPR* information in the hog market.

logical change in the hog industry as a likely source. If so, this would argue for the importance of allocating resources to develop a better understanding of how structural or technical change directly affects subsequent supplies. Such information might permit market analysts to generate better assessments of subsequent announcements and final estimates and facilitate a more effective market. Finally, while we find that new information does indeed explain changes in prices, consistent with Carter and Garcia and Leuthold, the degree of explanatory power is relatively small. This limited ability, even when we allow for different forms of surprise and market expectations, in an almost quasi-experimental market context remains a puzzle. On a positive note, this may be directing us to other types of data and analyses, such as the investigation of intraday price effects following announcements, as research strategies to better understand the effects of new information on market behavior and performance.

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