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Evaluation of Market Thinness for Hogs and Pork

Jason R.V. Franken and Joe L. Parcell

We investigate thinness of hog and pork markets in terms of quantity and representativeness of negotiated transactions. Transactional volume imparts marginally greater confidence in pricing precision for Iowa-Southern Minnesota negotiated hogs than for the national carcass cut-out, suggesting that contracts tying prices to the former rather than the latter may be more representative of industry conditions. Extending mandatory price reporting to pork may remedy this discrepancy. Despite declining volume, terminal hog markets may price accurately off of Iowa-Southern Minnesota prices. Hog quality differentials across procurement methods are documented, and quality of negotiated hogs is shown to decline with declining volume.

Key Words: Chebyshev's inequality, hogs, pork, thin markets

JEL Classifications: Q11, Q13

The U.S. hog industry, like other livestock/poultry industries, has experienced substantial consolidation and growth in alternative marketing arrangements since the early 1990s when cash transactions dominated trade (Grimes and Plain, 2005, 2007). With lower quantities (and perhaps quality) of livestock traded in cash markets, these negotiated transactions are increasingly scrutinized as being unreliable or unrepresentative of industry trade. Implications reach beyond cash markets as many contracts are tied to cash prices. Concern for market price transparency relates to the quantity of trades from which the market price, or price range, is derived, and the term *thin market* is used to describe markets for which reliability of a supply and demand determined price is questioned due to low volume of transactions (Hayenga et al., 1979; Nelson and Turner, 1995; Tomek, 1980) or perhaps unrepresentative transactions (Anderson et al., 2007).

The objective of this study is to examine thin market issues for U.S. cash markets for hogs and downstream negotiated prices for the wholesale pork carcass cutout. Empirical research on thin markets in agriculture typically examines whether the quantity of reported transactions in local markets is sufficient to accurately reflect general market conditions (e.g., Nelson and Turner, 1995; Tomek, 1980). However, transactional volume is merely a proxy for pricing efficiency (Buschena and McNew, 2008) and may not capture quality differentials in hogs transacted through cash markets and contracts (Anderson et al., 2007). Here, we evaluate pricing accuracy as it relates to volume in hog cash markets (i.e., a declining terminal market in St. Joseph, Missouri and mandatorily reported regional prices for Iowa-Southern Minnesota) and voluntarily reported carcass cutout prices. Specifically, we compare volume in these markets to the level necessary to support various

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degrees of pricing accuracy, given the observed variation in prices. Additionally, using national data, we document purported hog quality differentials across procurement methods and show that quality of negotiated hogs declines with volume.

The paper is organized as follows. The next section presents a brief review of the relevant literature, informing the choice of empirical procedures, which are discussed subsequently and are followed by a description of the data. Then the results are presented, followed by a discussion of their implications in the concluding section of the paper.

Previous Research

Much of the relevant literature in agriculture investigates thin markets in terms of quantity issues. Not only do markets with few transactions (or few participants) hold potential for price manipulation[1] (Mueller et al., 1996; Nelson and Turner, 1995), but more generally, some minimum number of transactions is needed to place confidence in average (equilibrium) prices (Tomek, 1980). Relatively few transactions may be required, provided they are representative, i.e., occur at the margin (Smith, 1982). Transaction representativeness has been recognized as a thin market issue only more recently with some cash markets, which often provide a base price for formula contracting, characterized as residual markets, that is markets for lower quality goods (Anderson et al., 2007; Schroeder and Ward, 2000). However, residual markets may serve an alternative role in facilitating inventory adjustment in addition to (or perhaps in place of) price discovery (Peterson, 2005). Noting that the conventionally accepted definition of a thin market as "one with few negotiated transactions per unit of time" (c.f., Hayenga et al., 1979) has directed researchers' emphasis on transaction volume in empirical studies, Anderson et al. (2007) suggest a more comprehensive taxonomy of thin markets considering both volume and representativeness (i.e., quality or type) issues. The literature is summarized in detail below.

Tomek (1980) uses a statistical sampling concept to show that a declining Denver market for fed cattle became a poor place for price discovery, relative to Omaha, prior to closing. Specifically, Chebyshev's inequality is applied to compute the number of transactions that yield a particular level of (confidence in) pricing precision given price variability during the period observed. The large reductions in volume rendered pricing unreliable in the Denver market.

In an experimental setting, Nelson and Turner (1995) find no evidence of systematic price bias in thin (i.e., eight traders) relative to thick (i.e., 22 traders) auction markets. Using a fed cattle market simulation, Ward and Choi (1998) find that even very large reductions in the number of reported cash transactions had little impact on price accuracy. Smith's (1982) work with double-oral auction markets demonstrates that the number of market participants or transactions required to generate perfectly competitive prices may be relatively small, providing each transaction takes place at the margin.

Other studies identify negative impacts of captive supplies (i.e., declining proportional cash transactions) on (expected) fed cattle cash prices, suggestive of potential price manipulation by buyers (Schroeter and Azzam, 2004; Ward, Koontz, and Schroeder, 1998).[2] Mueller et al. (1996) find that the low volume of transactions and few participants in the National Cheese Exchange (NCE), a residual market for cheese, enable price manipulation by key market participants. Moreover, most cheese is contracted based on NCE prices, though only block

[1] While transactional volume and market structure (i.e., number of participants) are distinct issues, they are inextricably linked. Clearly, consolidation on both sides of a market contributes to declining transactions. Furthermore, the potential for price manipulation under low transactional volume may be exacerbated in a market structure with few participants.

[2] Captive supplies—commonly secured through marketing/purchasing agreements, forward contracts, and packer feeding—refer to livestock committed to a specific buyer two weeks or more in advance of slaughter, whereas negotiated or cash market transactions are those where livestock are scheduled for delivery to packer within a shorter period of time (Schroeter and Azzam, 2004).

and barrel cheddar cheese trade on the exchange (Hamm and March, 1995). In the egg industry, where contract prices are predominately tied to Urner-Barry price quotes, another residual market—Egg Clearinghouse, Inc.—serves primarily to facilitate inventory adjustments (Peterson, 2005). Hence, residual markets may serve important roles beyond price discovery. Vukina et al. (2007) conclude that the increasing proportion of contracted and packer-owned hogs decreases cash hog prices. Vukina et al. (2007) also observe positive correlation between overall hog quality in the industry and the growth of alternative marketing arrangements, thereby attributing detected differences in hog quality across procurement mode to efficiencies of alternative marketing arrangements.

Empirical Methods and Procedures

Following Tomek (1980), the number of transactions n required to assure a *high* probability P that the deviation of intraday or daily mean prices X_n from the true mean (equilibrium) price μ lays within a particular range of accuracy $\pm c$ is found using Chebyshev's inequality,

$$(1) \qquad P(-c \leq X_n - \mu \leq c) \geq 1 - \frac{\sigma^2}{nc^2},$$

where σ^2 is the variance of the distribution of the mean, and n is the number of observations. Rearranging to solve for the minimum n necessary to satisfy the inequality yields follows:

$$(2) \qquad n = \frac{\sigma^2}{(1-P)c^2}.$$

Hence, greater numbers of transactions n are required as the level of pricing precision desired increases (i.e., higher P and lower c), and for any particular chosen level of pricing accuracy, n increases with market variation σ^2.

Up to this point, the discussion has emphasized intraday or daily prices under fixed economic conditions. Over time, economic conditions change as do equilibrium prices, which may also vary with quality and across space. Following Tomek (1980), in such contexts, μ is interpreted as the true price difference across time periods (e.g., weeks), qualities (e.g., grades), or locations. Specifically, in the case of autocorrelated prices across space, μ may be estimated by year using a first-differenced equation:

$$(3) \qquad S_t - S_{t-1} = \mu + \beta(I - I_{t-1}) + v_t,$$

where S_t and I_t are St. Joseph and Iowa-Southern Minnesota (IAMN) prices and v_t is the error term in time period t. In this case, the estimated variance of μ (i.e., the squared standard error of $\hat{\mu}$) serves as the relevant measure of σ^2.

Data

Market Price and Volume Data

Weekly cash hog prices from 1992 through 2010 are obtained from the Livestock Market Information Center (LMIC) for the Iowa-Southern Minnesota interior market and from Plain (2011) for a terminal market in St. Joseph, Missouri. With implementation of mandatory price reporting (MPR) in April 2001, Iowa-Southern Minnesota began reporting prices on a carcass basis along with volume of hogs sold. LMIC adjusted pre-MPR live hog prices for Iowa-Southern Minnesota to reflect lean value, and this adjustment was also applied to the St. Joseph price series.[3] Application of Chebyshev's inequality to these price series yields estimates of the number of transactions necessary to support various levels of pricing precision, which are compared with actual volumes of hogs sold. Weekly volume of hogs sold through negotiated transactions in Iowa-Southern Minnesota, available only from 2001 through 2010, is also obtained from LMIC. Monthly volume of hogs sold in St. Joseph from 1992 through June 2010 is obtained from the United States Department of Agriculture (USDA) Agricultural Marketing Service, and is used to infer estimates of mean weekly volume for comparison with weekly prices. Similar analyses are conducted on negotiated wholesale pork carcass cutout prices and load counts from 2001 through July 2009, obtained from

[3] Due to a typical slaughter yield of about 74%, the lean price is generally computed as the live price divided by 0.74 (Wellman, 1996).

USDA Agricultural Marketing Service office personnel (2010).

Summary statistics for IAMN and St. Joseph hog prices on a carcass basis and national carcass cut-out prices are reported in Table 1. Correlations among hog and carcass cut-out prices exceed 0.90. A small but positive correlation (0.14) indicates that St. Joseph price has decreased with lower volume, but this relationship is not apparent in IAMN or the national carcass cut-out based on correlations between prices and volumes (−0.34 and −0.46).

Mean weekly volumes of IAMN negotiated hogs are divided by 70 hogs per lot to infer an implied number of transactions. Vukina and Zheng's (2010) analysis of major packers' records of 76,850 negotiated transactions involving 4,822,634 hogs sourced from Iowa between October 8, 2002 and March 31, 2005 implies an average transaction size of 63 hogs per lot. After data cleaning, including elimination of very small lots of five or fewer hogs that may not be arms-length transactions, the remaining 51,798 transactions involving 3,548,609 hogs implies about 70 hogs per lot. The larger lot size is assumed here to invoke more stringent volume (i.e., head of hogs) requirements. Transactions are by load counts for the carcass cut-out. Lot sizes average about 35 head at St. Joseph according to University of Missouri Extension Economist Ron Plain (2011). Hence, this value is used to convert St. Joseph receipts to estimated transactions.

Data on Hog Quality

Daily national data on base prices and average prices (accounting for quality premiums and discounts), backfat, loin depth, loineye area, and percent lean by procurement method for producer sold hogs are obtained from LMIC spreadsheets covering prior day national hog slaughter. These data are obtained for the period August 3, 2001 through March 18, 2011. Table 2 provides summary statistics for these data. Although Vukina et al. (2007) find that the highest quality hogs are procured through other procurement arrangements and other market formula contracts, mean statistics in Table 2 suggest that the highest quality hogs are procured through other market formula and market formula contracts on average. Figure 1 illustrates the decline in the proportion of hogs procured through negotiated transactions. Notably, these statistics, which are based on transactions of large packers (greater than 100,000 processed annually), may underestimate the proportion of cash market transactions in the industry, as indicated by surveys with stratified samples of packers (i.e., Vukina et al., 2007). Still, the data that are mandatorily reported by the large processors represent the most widely/publicly available information influencing prices. Pairwise

Table 1. Summary Statistics for Weekly Cash Market Hog and Pork Prices and Volumes

	Max	Min	Mean	SD
St. Joseph				
Price ($/cwt)[a]	83.92	13.38	55.99	11.16
Receipts (head)[b]	37,541	308	10,194	10,932
Receipts (head)[c]	9,385	77	2,549	2,733
IAMN[d]				
Prices ($/cwt)[e]	90.95	14.19	61.21	11.94
Receipts (head)[f]	138,520	17,786	72,159	23,449
Carcass cut-out[g]				
Prices ($/cwt)	93.75	43.89	65.31	8.93
Loads (40,000 lbs)	620	196	359	74

[a] Weekly average prices, $n = 962$ observations (1992 to June 5, 2010).
[b] Monthly receipts, $n = 222$ observations (1992 to June 15, 2010).
[c] Inferred weekly receipts.
[d] IAMN denotes Iowa-Southern Minnesota market.
[e] Weekly average prices, $n = 991$ observations (1992–2010).
[f] Weekly receipts, $n = 505$ observations (May 4, 2001 to 2010).
[g] Data are $n = 448$ weekly observations (2001 to July 31, 2009).

Table 2. Summary Statistics for Hog Quality Measures and Cash Market's Share, National Data

Variable	Max	Min	Mean	SD
Negotiated[a]				
Premium ($/cwt)[b]	4.68	−0.48	1.65	0.63
Backfat (in)	0.84	0.66	0.74	0.03
Loin depth (in)	2.48	2.02	2.28	0.05
Loineye area (in^2)	7.44	6.05	6.85	0.16
Lean (%)	55.45%	51.53%	53.74%	0.46%
Market share (%)	26.82%	2.36%	13.29%	4.00%
Market formula[c]				
Premium ($/cwt)	4.29	−0.23	2.50	0.42
Backfat (in)	1.08	0.68	0.74	0.02
Loin depth (in)	2.90	2.31	2.49	0.06
Loineye area (in^2)	8.72	6.92	7.47	0.19
Lean (%)	55.36%	53.27%	54.59%	0.33%
Market share (%)	70.74%	40.79%	54.49%	4.54%
Other market formula[d]				
Premium ($/cwt)	7.41	−3.02	2.99	0.62
Backfat (in)	0.87	0.66	0.75	0.03
Loin depth (in)	2.85	2.15	2.50	0.08
Loineye area (in^2)	8.58	6.43	7.50	0.23
Lean (%)	55.60%	52.56%	54.43%	0.55%
Market share (%)	26.66%	3.71%	12.32%	3.62%
Other procurement arrangement[e]				
Premium ($/cwt)	4.34	−8.84	1.70	1.23
Backfat (in)	0.99	0.66	0.73	0.02
Loin depth (in)	3.31	2.12	2.30	0.07
Loineye area (in^2)	9.98	6.20	6.90	0.22
Lean (%)	57.85%	53.00%	54.26%	0.31%
Market share (%)	35.20%	4.54%	19.90%	4.43%

Note: n = 2,452 daily observations (August 3, 2001 to March 18, 2011).
[a] Negotiated refers to cash market transactions where livestock are scheduled for delivery to packer within 14 days.
[b] Premium = average price − base price.
[c] Market formula refers to contractual transactions priced based on swine or pork market prices.
[d] Other market formula refers to contractual transactions price based on any market other than the market for swine or pork and includes pricing based on futures and options markets.
[e] Other procurement arrangements include other (e.g., price window and cost plus) contracts but not packer owned hogs.
SD, standard deviation.

t-tests of mean differences permit detection of statistical differences in carcass performance and associated quality premiums paid across procurement method, and regression analysis allows inference of the influence of the declining proportion of cash sales on cash market hog quality.

Results

Sufficient Transactions for Precise Pricing

Table 3 compares the actual volume of hogs procured through negotiated transactions in the IAMN market to transaction requirements per week for three scenarios of pricing accuracy, as estimated by Chebyshev's inequality. Corresponding results for national carcass cut-out data[4] and data on the St. Joseph terminal market are presented in Tables 4 and 5. The variance σ^2 used to establish the required number of transactions is estimated from first differences in weekly average negotiated prices for each market. In each case P = 90%, but the value of c,

[4] See Parcell, Schroeder, and Tonsor (2009) for a similar analysis of primals underlying the carcass cut-out.

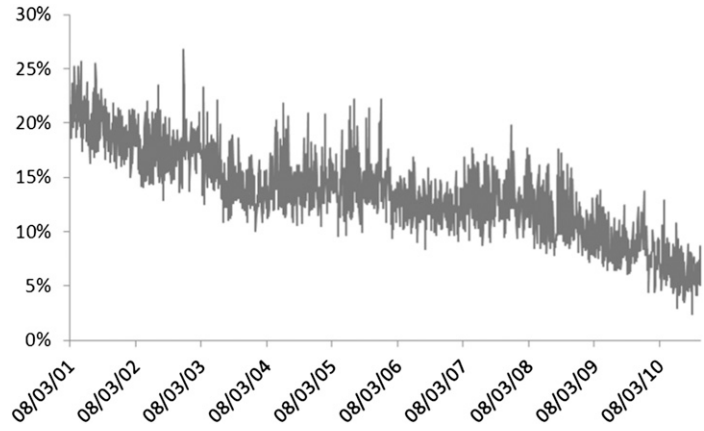

Figure 1. Proportion of Daily National Hog Slaughter (Head) Procured via Negotiated Transactions, 2001–2010

which is in the context of standard deviations of the first differenced prices, varies at ±$0.25, ±$0.35, and ±$0.45 per hundredweight (cwt).[5] Though not reported in tables, sensitivity to $P = 95\%$ is also discussed. Complete results are available from the authors upon request.

Several interesting observations are apparent from the results. First, growing price variance is placing increasing volume requirements to maintain confidence in pricing precision in each market. For IAMN in particular, price variance appears to have increased substantially in the period following enactment of MPR (Table 3). Increased volatility in livestock prices under MPR is at least partly attributable to more comprehensive transaction records under electronic filing and a lessened role of USDA Agricultural Marketing Service market reporters in subjectively filtering mandatorily reported prices (Pendell and Schroeder, 2006; Perry et al., 2005; Ward, 2006).[6] Increased price variance may also reflect greater variation in hog quality observed under mandatory reporting if transactions were reported selectively under the voluntary system.[7] Alternatively, part of the increase in price variance

[5] Based on the suggestions of an anonymous reviewer, we also consider cases where c varies as a percentage of the mean annual price in levels, as assumptions of a fixed mean and variance of price may be unrealistic for lengthy time series. The percentages used are chosen such that the resulting numbers of required transactions are similar to levels required under fixed values of c in the early years of the sample. While the number of transactions required for accurate pricing implied by this approach differs from reported results, the differences are not large enough to qualitatively change conclusions regarding sufficiency of transactional volume. Hence, we focus on the more intuitive fixed values of c. Results for mean varying levels of c are available from the authors upon request.

[6] Clearly, filtering out transactions that are unrepresentative in terms of bargaining quality or animal quality is desirable, but removal of outliers reflecting extreme local supply and demand conditions would diminish the representativeness of reported prices (Perry et al., 2005). USDA Agricultural Marketing Service (AMS) officials claim that the Government Accountability Office's (2005, p. 4) finding that even under mandatory reporting "AMS's instructions to reporters for excluding transactions lacked clarity and precision" has led to improvement in their reporting instructions (Ward, 2006). Pendell and Schroeder (2006) suggest that AMS market reporters' subjective filtering of cattle prices may have caused markets to appear less spatially integrated prior to MPR than they actually were. Similarly, if AMS efforts are indeed leading to more representative price reporting, then underestimation of the number of transactions required for accurate pricing is more likely in the voluntary reporting period when actual market volume is in no danger of falling below adequate levels.

[7] Empirical investigations of prices in live cattle markets yield no evidence of strategic price reporting under a voluntary system, which may reflect that market thinning or noncompetitive behavior had not reached the level necessary to disrupt the ability of the voluntary price reporting system to provide timely and accurate price information (Fausti and Diersen, 2004; Fausti, Diersen, and Qasmi, 2007). However, lower intra-week dispersion among quality premiums and discounts for fed cattle prior to MPR are documented as evidence of unrepresentative sample reporting and validation for MPR (Fausti et al., 2010).

Table 3. IAMN Negotiated Volume and Transactions Needed for Reliable Price Discovery

Year	Mean Weekly Volume (head)	Estimated Transactions/Week (head ÷ 70 head/lot)	Variance in IAMN 1st Differences	Transactions/Week for Accurate Price Discovery (p = 90%, c = stated value)		
				±$0.25/cwt	±$0.35/cwt	±$0.45/cwt
1992	NA	NA	2.04	327	167	101
1993	NA	NA	1.62	260	133	80
1994	NA	NA	2.94	470	240	145
1995	NA	NA	3.46	554	282	171
1996	NA	NA	5.81	930	474	287
1997	NA	NA	4.26	681	347	210
1998	NA	NA	6.73	1,076	549	332
1999	NA	NA	8.86	1,418	723	438
2000	NA	NA	4.06	649	331	200
2001	58,349	834	5.09	814	415	251
2002	86,240	1,232	11.12	1,779	908	549
2003	97,242	1,389	6.54	1,046	534	323
2004	82,848	1,184	12.66	2,025	1,033	625
2005	86,777	1,240	10.05	1,607	820	496
2006	68,271	975	11.88	1,901	970	587
2007	60,422	863	7.18	1,149	586	355
2008	74,020	1,057	10.78	1,726	880	533
2009	53,872	770	9.54	1,526	779	471

Note: n = 991 observations (1992–2010) for weekly average prices, and n = 505 observations (May 4, 2001 to 2010) for weekly receipts.

may reflect increasing variance in the cost of feed inputs, particularly in 2008. Distinguishing the relative contribution of these factors to price variance is beyond the scope of this research.

Notably, the volume of hogs procured through negotiated transactions in IAMN is sufficient to price within ±$0.35/cwt of the *true* price 90% of the time, but not for more precise pricing (Table 3). For the period of 2001 through 2009, IAMN would need about 25% more transactions on average to support pricing within this range 95% of the time, but

Table 4. Carcass Cut-Out Negotiated Volume and Transactions Needed for Reliable Price Discovery

Year	Mean Weekly Load Count	Variance in 1st Differences of Price	Transactions/Week for Accurate Price Discovery (p = 90%, c = stated value)		
			±$0.25/cwt	±$0.35/cwt	±$0.45/cwt
2001	410	3.72	595	304	184
2002	408	3.72	595	303	184
2003	366	4.27	683	349	211
2004	343	5.41	866	442	267
2005	306	4.15	665	339	205
2006	301	4.79	766	391	236
2007	344	3.80	609	311	188
2008	362	7.96	1,273	650	393
2009	422	6.80	1,088	555	336

Note: n = 448 weekly observations (2001 to July 31, 2009). See Parcell, Schroeder, and Tonsor (2009) for comparable calculations for underlying pork primals.

Table 5. St. Joseph, Missouri Negotiated Volume and Transactions Needed for Reliable Price Discovery

Year	Mean Weekly Volume (head)	Estimated Transactions/Week (head ÷ 35 head/lot)	Variance in St. Joseph 1st Differences	Transactions/Week for Accurate Price Discovery (p = 90%, c = stated value)		
				±$0.25/cwt	±$0.35/cwt	±$0.45/cwt
1992	6,753	193	2.28	365	186	113
1993	6,441	184	2.21	354	181	109
1994	7,285	208	3.27	524	267	162
1995	6,170	176	4.14	663	338	205
1996	4,104	117	6.41	1,026	523	317
1997	2,954	84	5.19	830	423	256
1998	2,293	66	7.43	1,190	607	367
1999	1,614	46	10.30	1,648	841	509
2000	1,043	30	5.05	808	412	249
2001	916	26	6.51	1,041	531	321
2002	815	23	12.15	1,944	992	600
2003	688	20	7.89	1,262	644	390
2004	553	16	15.77	2,524	1,288	779
2005	459	13	14.92	2,387	1,218	737
2006	539	15	14.05	2,247	1,147	694
2007	393	11	6.56	1,049	535	324
2008	281	8	11.85	1,896	967	585
2009	157	4	7.00	1,120	571	346

Note: n = 962 observations (1992 to June 5, 2010) for weekly average prices, and n = 222 observations (1992 to June 15, 2010) for monthly receipts which are used to compute mean weekly volumes.

would require 40% more transactions on average in more recent years (2005 through 2009). Put differently, the actual volume of transactions in IAMN supports pricing within a range of ±$0.50/cwt 95% of the time. Similar levels of pricing precision are not supported by the volume of transactions for the national carcass cut-out or for hogs in the terminal market at St. Joseph.

Load counts for the national carcass cut-out support pricing precision of ±$0.45/cwt with 90% confidence (Table 4) and ±$0.60/cwt with 95% confidence. Load counts of carcass cut-outs would need to increase by about 20% to 25% in recent years to support the same level of pricing precision as IAMN (i.e., c = ±$0.35/cwt and P = 90%). Though ranging within a dollar (i.e., ±$0.50/cwt) of the *true* price 90% of the time is a fairly reliable level of accuracy, these results indicate that hog contracts that formula price based off of the mandatorily reported IAMN negotiated hog price are likely more representative of market conditions than those tied to voluntarily reported national carcass cut-out prices. Mandating wholesale pork price reporting may hold potential to increase confidence in the precision of these prices if additional *representative* transactions are reported without substantially increasing the price variance. Currently, it is estimated that less than a quarter of pork buyers' purchases meet USDA qualifications for negotiated transactions, and only 80% of qualifying transactions are reported (Parcell, Schroeder, and Tonsor, 2009).

For St. Joseph, volume has been insufficient for independent price discovery since the mid 1990s (Table 5). Following Tomek's (1980) comparison of a declining Denver market to a more vibrant Omaha market for fed cattle, the St. Joseph terminal hog market need not rely solely on its own volume to arrive at accurate prices if it can anchor to a viable IAMN market.[8]

[8] For example, Franken, Parcell, and Tonsor (2011) found that IAMN prices Granger cause St. Joseph terminal prices.

Table 6. St. Joseph, Missouri Negotiated Volume and Transactions Needed to Reliably Price off of IAMN Prices

Year	Mean Weekly Volume (head)	Estimated Transactions/Week (head ÷ 35 head/lot)	Mean Var of Week-to-Week Relation between 1st Differenced St. Joseph and IAMN Prices	Transactions/Week for Accurate Price Discovery (p = 90%, c = stated value)		
				±$0.10/cwt	±$0.25/cwt	±$0.35/cwt
1992	6,753	193	0.0057	6	1	0
1993	6,441	184	0.0040	4	1	0
1994	7,285	208	0.0030	3	0	0
1995	6,170	176	0.0080	8	1	1
1996	4,104	117	0.0104	10	2	1
1997	2,954	84	0.0078	8	1	1
1998	2,293	66	0.0156	16	2	1
1999	1,614	46	0.0165	17	3	1
2000	1,043	30	0.0156	16	2	1
2001	916	26	0.0258	26	4	2
2002	815	23	0.0188	19	3	2
2003	688	20	0.0130	13	2	1
2004	553	16	0.0276	28	4	2
2005	459	13	0.0303	30	5	2
2006	539	15	0.0383	38	6	3
2007	393	11	0.0449	45	7	4
2008	281	8	0.0651	65	10	5
2009	157	4	0.0781	78	12	6

Note: n = 962 observations (1992 to June 5, 2010) for weekly average prices, and n = 222 observations (1992 to June 15, 2010) for monthly receipts which are used to compute mean weekly volumes.
Var, variance.

Table 6 compares St. Joseph mean weekly transactions with the number required for three levels of pricing accuracy. Here, the variance of $\hat{\mu}$ (i.e., the squared standard error of $\hat{\mu}$), obtained from least squares estimates of Equation (3) by year, is used to establish the required number of transactions.[9] Hence, c is in the context of the precision of changes in price differentials between IAMN and St. Joseph. Until 2004, St. Joseph has been able to peg weekly price changes to IAMN weekly price changes within ±$0.10/cwt of the *true* difference 90% of the time and is able to do so within ±$0.35/cwt with 90% confidence through 2008 (and with 95% confidence through 2007). Transactional volume in 2009 only supports pricing within ±$0.45/cwt with 90% confidence. About a 33% and 66% increase in the volume of transactions would be needed to price within ±$0.35/cwt for 90% and 95% of the time, respectively, in 2009. These results are contingent upon our assumption of smaller 35 head lots, on average, in the St. Joseph market. It is unlikely that lots are much smaller than this, but if lots are larger, then the reported findings underestimate the degree to which transactional volume is insufficient.

Quality Aspects of Thin Markets

In addition to lower volumes in thinning cash markets for hogs and pork, another criticism is that transactions in those markets may not reflect the quality of product generally available. Table 7 reports procurement mode's market share of hogs sold, and pairwise t-tests of mean differences in hog quality between negotiated transactions and

[9] Standard error estimates are computed using the Cochrane-Orcutt transformation and Newey-West variance-covariance matrix to account, respectively, for autocorrelation and heteroskedasticity detected by diagnostic tests of initial regressions.

Table 7. Pairwise *t*-tests of Mean Quality Differentials between Negotiated and Other Procurement Methods

Mean or Mean Difference	Procurement Market Share (%)	Premium[a] ($)	Backfat (in)	Loin Depth (in)	Loineye Area (in^2)	Lean (%)
Full sample ($n = 2452$)						
Negotiated mean	13%	1.65	0.742	2.28	6.85	53.74
Market formula mean	54%	−0.85***	4.853×10^{-4}	−0.20***	−0.62***	−0.84***
Other market formula mean	12%	−1.34***	−0.003***	−0.21***	−0.65***	−0.68***
Other procurement arrangement mean	20%	−0.05**	0.008***	−0.01***	−0.04***	−0.52***
8/3/2001 to 8/3/2004 ($n = 764$)						
Negotiated mean	17%	1.51	0.77	2.24	6.72	53.28
Market formula mean	52%	−1.39***	0.03***	−0.19***	−0.57***	−0.96***
Other market formula mean	12%	−1.36***	0.01***	−0.19***	−0.57***	−0.58***
Other procurementarrangement mean	19%	0.04	0.03***	-2.36×10^{-3}*	−0.01	−0.86***
8/4/2004 to 8/3/2007 ($n = 765$)						
Negotiated mean	13%	1.50	0.74	2.29	6.88	53.76
Market formula mean	53%	−0.94***	-3.91×10^{-3}***	−0.20***	−0.60***	−0.86***
Other market formula mean	12%	−1.51***	−0.02***	−0.24***	−0.73***	−0.65***
Other procurement arrangement mean	22%	-2.85×10^{-3}	4.92×10^{-3}***	−0.03***	−0.10***	−0.39***
8/4/2007 to 3/18/2011 ($n = 923$)						
Negotiated mean	10%	1.89	0.72	2.31	6.95	54.12
Market formula mean	58%	−0.33***	−0.02***	−0.22***	−0.67***	−0.74***
Other market formula mean	13%	−1.20***	-2.36×10^{-3}***	−0.21***	−0.64***	−0.79***
Other procurement arrangement mean	19%	−0.17***	-4.02×10^{-3}***	−0.01***	−0.03***	−0.34***

[a] Premium is average price − base price.

*, **, and *** denote statistical significance at 10%, 5%, and 1% level.

other procurement methods for the entire sample, as well as three consecutive three year subsamples.[10] This design aids in assessing whether differences in hog quality across procurement mode have become more prominent over time. Moreover, subsample periods correspond to typical marketing contract duration of three to five years (Kliebenstein and Lawrence, 1995), facilitating insight into possible adjustments that could be made at contract renewal/renegotiation to make formula pricing representative of the industry conditions.

In each period, mean quality measures for negotiated transactions are presented, followed by mean differences with other procurement in ensuing rows (Table 7). Full sample results reveal statistically lower quality premiums (average price minus base price) for negotiated transactions, corresponding to statistically lower quality hogs in terms of smaller loins and lower percent lean, relative to other procurement methods. Findings for backfat differentials across procurement modes are mixed, as some alternative procurement methods have higher while others have lower values for these quality attributes than negotiated transactions. Statistically significant mean differences for loin depth and loin eye area growing ever more negative across consecutive sub-periods corroborate assertions of decreasing relative quality of cash market hogs, particularly in comparison with the most common procurement mode—market formula contracts. Notably, the proportion of hogs sold on average through these contracts increased 6% from the first to the last sub-period of the sample studied, accounting for most of the 7% decrease in negotiated hog sales.[11] However, evidence of the declining relative quality of cash market hogs in terms of backfat and percentage lean, and consequently quality premiums, is mixed. Backfat and percentage lean are clearly related, and in relation to market formula contract hogs in particular, cash market hogs are closing the gap in terms of leanness. These findings may reflect general industry wide improvements in hog genetics and management over time, as evidenced by the regression analysis results discussed next. Overall, the results are largely consistent with the previous findings of Vukina et al. (2007) in that statistical differences in each measure of quality are detected across procurement mode. Vukina et al. (2007) attribute such differences to efficiencies of alternative marketing arrangements. Next we investigate the possibility that the generally lower quality of cash market hogs may be related to the declining proportion of hogs traded in cash markets.

Generalized autoregressive conditional heteroskedasticity regressions of these measures of negotiated hog quality on the share of hogs marketed through negotiated transactions, denoted *%CASH*, and a trend variable *t* are reported in Table 8.[12] The trend variable *t* indicates improvements in quality (i.e., lower backfat and greater loin size and percentage lean) occur over time, perhaps due to advancements in genetics and/or management. Meanwhile, the quality of cash market hogs tends to decrease with the declining share of hogs procured through negotiated transactions, except in terms of backfat. Specifically, with a 10% decrease in *%CASH*, loin depth decreases about four hundredths of an inch, loin

[10] The Central Limit Theorem implies that *t*-test assumptions of a normally distributed sample mean are well approximated in large samples. The results of nonparametric paired sample Wilcoxon signed-rank test of median differences, not presented here but available from the authors upon request, are largely consistent with the results of *t*-tests presented here.

[11] Several studies suggest that contracting is significantly more likely among larger farms (Franken, Pennings, and Garcia, 2009; Key and McBride, 2003). The number of farms with 2,000 or more hogs increased during the period of study, with 7,155, 7,868, and 8,313 farms on average in the three consecutive sub-periods, according to USDA National Agricultural Statistics Service (2011).

[12] Diagnostic tests of simple ordinary least squares models indicated the presence of autoregressive conditional heteroskedasticity, leading to the use of generalized autoregressive conditional heteroskedasticity (GARCH) models. Specifically, GARCH(1,1) models were chosen, as these models have been shown to be robust in Monte Carlo analyses (Lusdaine, 1995). Augmented Dickey-Fuller tests reject the null hypothesis of a unit root (i.e., nonstationarity) in each case, and hence, the regression analysis is performed on the stationary data in levels. The large inverse correlation (−0.855) between *%CASH* and the trend variable *t* could pose multicollinearity problems, but the potential for such problems is low with the large sample size.

Table 8. Quality Attributes for *Cash* Hogs Regressed on Proportion of Daily National Hog Slaughter Procured via Negotiated Transactions and Time

	Backfat (in)	Loin Depth (in)	Loineye Area (in^2)	Lean (%)
%CASH	-1.928×10^{-4}	0.004***	0.012***	0.0299***
	(1.695×10^{-4})	(4.010×10^{-4})	(0.001)	(0.003)
t	-3.760×10^{-5}***	6.530×10^{-5}***	2.011×10^{-4}***	7.002×10^{-4}***
	(0.003)	(2.590×10^{-6})	(8.040×10^{-6})	(1.95×10^{-5})
Constant	0.790***	2.153***	6.446***	52.503***
	(0.003)	(0.007)	(0.022)	(0.053)
ARCH Model				
ARCH(1)	0.155***	0.209***	0.201***	0.153***
	(0.016)	(0.031)	(0.031)	(0.018)
GARCH(1)	0.801***	0.747***	0.754***	0.815***
	(0.022)	(0.041)	(0.041)	(0.025)
Constant	1.300×10^{-5}***	7.980×10^{-5}***	7.396×10^{-4}***	0.003***
	2.920×10^{-6}	(2.280×10^{-5})	(2.182×10^{-4})	(9.218×10^{-4})

Note: $n = 2{,}452$ daily observations (August 3, 2001 to March 18, 2011). Standard errors in parentheses.
*** denotes statistical significance at 1% level.
GARCH, generalized autoregressive conditional heteroskedasticity; ARCH, autoregressive conditional heteroskedasticity.

eye area decreases twelve hundredths of a square inch, and percentage lean decreases nearly a third of a percent. While these estimates are statistically significant, they are not very large in magnitude. Still, these results imply that the negative relationship between captive supplies of fed cattle (i.e., declining proportional cash transactions) and cash prices, interpreted by Ward, Koontz, and Schroeder (1998) and Schroeter and Azzam (2004) as evidence of potential price manipulation by buyers, may also partly reflect a simultaneous decrease in the quality of animals traded in cash markets.

Conclusions

This study investigates the thinness of hog and pork markets, as measured by quantity and quality based indicators. Statistical sampling procedures indicate that transactional volume for negotiated hogs in the Iowa-Southern Minnesota market and for the national carcass cut-out is sufficient to impart confidence in the reliability of pricing precision. The results further suggest that formula contract prices based off of mandatorily reported Iowa-Southern Minnesota negotiated hog prices may be more representative of industry conditions than contracts tied to voluntarily reported national carcass cut-out prices. Specifically, with a 90% level of confidence, the Iowa-Southern Minnesota market has sufficient volume to support pricing within ±$0.35/cwt of the *true* price, whereas reported volume for the national carcass cut-out only supports pricing within ±$0.45/cwt. Load counts of carcass cut-outs would need to increase by about 20% to 25% in recent years to support the same level of pricing precision as the Iowa-Southern Minnesota market. Mandatory reporting of underlying pork primals may increase the reliability of carcass cut-out pricing precision. Similar analyses indicate that a terminal hog market in St. Joseph, Missouri is no longer viable for independent price discovery, but until very recently could price fairly reliably based off of Iowa-Southern Minnesota prices. At 2009 levels of volume in St. Joseph, pricing accuracy within only ±$0.45/cwt with 90% confidence is supported, and continued declines in volume would likely render pricing unreliable.

Statistically significant, though economically minor deficiencies in negotiated hog quality relative to hogs procured via alternative marketing arrangements are documented. Furthermore, negotiated hog quality is shown to decrease significantly with the declining share of hogs procured through negotiated transactions. This finding has several practical implications and could lead to policy changes.

Industry leaders, academicians, and government agency service providers came together in 2010 and 2011 to undertake negotiated rulemaking to set policy for the mandatory price reporting of wholesale pork prices. One of the motivations for mandatory wholesale pork price reporting is to enable the industry to have access to a reliable and transparent carcass cutout value with respect to quality. Producers and processors believe that with a more transparent cutout value, hog marketing contracts will use the cutout as the base price in the contract. Upon wholesale pork prices being mandatorily reported, those producers using the live hog price as the base price in the contract are expected to transition to the wholesale cutout value. Commodity markets transitioning to quality differentiated markets represent a piece of the history of commodity evolution.

A price series reflective of a good with changing levels of characteristic quality over time is troublesome from a practical standpoint. Buyers, sellers, and resource providers attempt to make future decisions based on historical price-quantity relationships that may no longer be relevant. The U.S. Census Bureau faces similar challenges in reporting index prices in which the quality of the good changes over time, for example, the computer of today is not the computer of last year or five years ago. Characteristic adjusted price series, using the hedonic model methodology, offer a mechanism for a consistent price series to be reported. If the price-quality relationships are known between the price of a commodity and the levels of a set of attributes, then price adjustments can be matched between historical observations and future innovations.

While history suggests there will continue to be some level of spot market hog transactions, the societal value versus the cost of publicly collecting and aggregating data and reporting the information should be analyzed. This is particularly the case when the historical relevance, due to quality differentiation, of the price data is eroded over time. From the authors' perspective, the value of cash price series has declined substantially over time, and without adequately accounting for quality changes over time, the historical practice of pricing contract hogs based on cash market live hog transactions may be misleading due to evolving quality trends.

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