USDA Forecasts: A meta-analysis study

Bahram Sanginabadi

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Economics Department
University of Hawaii at Manoa
bahram@hawaii.edu

Abstract

The primary goal of this study is doing a meta-analysis research on two groups of published studies. First, the ones that focus on the evaluation of the United States Department of Agriculture (USDA) forecasts and second, the ones that evaluate the market reactions to the USDA forecasts. We investigate four questions. 1) How the studies evaluate the accuracy of the USDA forecasts? 2) How they evaluate the market reactions to the USDA forecasts? 3) Is there any heterogeneity in the results of the mentioned studies? 4) Is there any publication bias? About the first question, while some researchers argue that the forecasts are unbiased, most of them maintain that they are biased, inefficient, not optimal, or not rational. About the second question, while a few studies claim that the forecasts are not newsworthy, most of them maintain that they are newsworthy, provide useful information, and cause market reactions. About the third and the fourth questions, based on our findings, there are some clues that the results of the studies are heterogeneous, but we couldn’t find enough evidences of publication bias.

JEL classification: D49, Q10

USDA forecasts, meta-analysis, Publication bias

Introduction

Meta-analysis is a systematic approach to analyze literature review by statistical methods where the goal is to compile and contrast the findings of several related studies. For the first time, this method proposed by Glass (1976). Also, Stanley & Jarrell (1989), Walsh et al. (1989, 1990), Jarrell & Stanley (1990) are among the first researchers who applied meta-analysis. The studies that aim to aggregate and synthesize the literature on a certain topic progressively apply meta-analysis (Olkin,1995). Currently researchers apply this method in many different areas including
psychology, education, science, marketing, and social sciences. Meta-analysis is quite popular among economists as well.

In this paper we do Meta-analysis while we exclusively focus on two types of studies as our inputs. First, the studies that evaluate the United States Department of Agriculture (USDA) forecasts. Second, the ones that evaluate the market reactions to these forecasts. It’s important to mention that almost all the studies that focus on the USDA forecasts can be categorized in one or both of mentioned categories above. We believe it’s important to get this research done because the number of published papers in these areas are quite high and they report a variety of findings which in many cases contradict each other.

We are interested in finding answers for four questions. First, how the academic published studies evaluate accuracy of USDA forecasts? In other words, do their findings show that USDA forecasts are accurate? Second, how the academic published studies evaluate market reactions to the USDA forecasts? Third, are results of the academic papers heterogeneous? Fourth, are there any clues publication bias?

In the rest of this paper, we focus on answering the mentioned questions above. In the next section, we briefly talk about the USDA forecasts. ‘Methodology of data-analyzing’ is the next thing that we discuss. Then, we represent ‘Analysis’, ‘Accuracy of the USDA Forecasts’, ‘Market Reactions to the USDA Forecasts’, ‘Meta-analysis’, and ‘Discussion’ respectively.

The USDA Forecasts

USDA provides the monthly report “World Agricultural Supply and Demand Estimates” (WASDE) which is a comprehensive forecast of supply and demand for major crops (produced in
U.S. and the rest of the world) and livestock (U.S. only). WASDE report applies the statistical reports compiled by the USDA agencies and other government agencies (Xiao et al., 2014).

**Literature Search and Data Collection**

In a comprehensive search in the literature we found 54 relevant studies. We mainly applied the key words “USDA forecast”, “USDA”, “forecast”, “Evaluation”, “Accuracy”, “market reaction”, “market participants”, etc. Search for the studies is done from November 15th to December 8th, 2015. The searching process has been done mainly through UH Manoa Library¹, Google Scholar², and ScienceDirect³ websites. Fig. 1. represents the scatter plot that shows the number of published papers each year.

![Number of Publications](image_url)

**Fig. 1. Scatter plot of Number of relevant publications.** Each dot shows the number of publications in one specific year. Note, the positive slope of the red line shows that the number of publication per year is increasing.

¹ [http://library.manoa.hawaii.edu/](http://library.manoa.hawaii.edu/)
² [https://scholar.google-com.eres.library.manoa.hawaii.edu/](https://scholar.google-com.eres.library.manoa.hawaii.edu/)
³ [http://www.sciencedirect.com.eres.library.manoa.hawaii.edu/](http://www.sciencedirect.com.eres.library.manoa.hawaii.edu/)
Methodology of Data-analyzing

To answer the first and the second questions, we summarize the findings of the relevant studies, and then we refine the results to find the patterns of their findings. To do meta-analysis we apply the metaphor package which provides functions to do the analysis in R. The package enables us to study the fixed and random effect models (Viechtbauer, 2010). Then we test for heterogeneity and publication bias which enable us to tackle the third and the fourth questions.

Analysis

In this section, first, we provide the summary of findings of the studies that evaluate the USDA forecasts, then we summarize the findings of the ones that evaluate market reactions to the USDA forecasts. Then, in the nest section, we put all the major findings in a nutshell. Eventually, we represent meta-analysis.

Researchers & Topics (Accuracy of USDA Forecasts)

Egelkraut et al. (2003). An evaluation of crop forecast accuracy for corn and soybeans: USDA and private information agencies.

Good & Irwin (2005). Understanding USDA corn and soybean production forecasts: Methods, performance and market impacts over 1970-2005.

Gunnelson et al. (1972). Analysis of the accuracy of USDA crop forecasts.

Irwin et al. (2014). Evaluation of Selected USDA WAOB and NASS Forecasts and Estimates in Corn and Soybeans.

Summary of study

Even though, all agencies’ forecast accuracy is improved and relative accuracy is varied by crop and time, the USDA predictions are more accurate than other agencies. However, when it comes to soybeans the forecast errors are very similar for all agencies.

The USDA production forecast errors are largest in August. For August, the private market forecasts for soybeans are more accurate than the USDA forecasts, but the USDA corn production forecasts are more accurate than the private market. In addition, as the growing season goes on the accuracy of the USDA forecast for soybeans improves.

The USDA forecasts are improved moderately over 1929 to 1970, but it still underestimates the crop size, year to year production changes, and its own errors in earlier forecasts when it revises the new forecasts.

Neither for corn nor for soybeans the accuracy of the WAOB forecasts have not changed significantly over time. Also, there is no evidence of bias in NASS forecasts for corn. In addition, there is some evidences of improvement in the accuracy of NASS corn forecasts over time. However, soybean forecasts usually underestimate the yield.
Isengildina-Massa et al. (2013). Do Big Crops Get Bigger and Small Crops Get Smaller? Further Evidence on Smoothing in US Department of Agriculture Forecasts.

Isengildina-Massa et al. (2006). Are Revisions to USDA Crop Production Forecasts Smoothed?

Isengildina-Massa et al. (2011). Empirical confidence intervals for USDA commodity price forecasts.

Isengildina-Massa et al. (2013). When do the USDA forecasters make mistakes?

Isengildina-Massa et al. (2012). A comprehensive evaluation of USDA cotton forecasts.

Isengildina-Massa et al. (2011). What Can We Learn from our Mistakes? Evaluating the Benefits of Correcting Inefficiencies in USDA Cotton Forecasts.

Kastens et al. (1998). Evaluation of extension and USDA price and production forecasts.

Manfredo & Sanders (2004). The value of public price forecasts: Additional evidence in the live Hogs market.

Meyer & Lawrence (1988). Comparing USDA Hogs and Pigs Reports to Subsequent Slaughter: Does Systematic Error Exist?

No & Salassi (2009). A sequential rationality test of USDA preliminary price estimates for selected program crops: Rice, soybeans, and wheat.

Sanders & Manfredo (2002). USDA production forecasts for pork, beef, and broilers: an evaluation.

Sanders & Manfredo (2003a). USDA livestock price forecasts: A

The USDA forecasts for both soybeans and corn increase in big crop years and decrease in small crop years and the magnitude of smoothing is significantly large.

The USDA forecasts are smoothed, but due to smoothing, loss in forecast accuracy happens which is statistically and economically significant in several cases.

This study suggests that empirical approaches such as kernel density, quantile distribution, and best fitting parametric distribution methods might be used to construct more accurate confidence intervals for USDA wheat, soybean, and corn forecasts.

The errors in ending stocks forecasts are usually driven by errors in production forecasts across all commodities. In addition, for all commodities, errors in price forecasts are caused by errors in U.S. ending stocks forecasts.

The USDA forecast overestimates China’s exports, but underestimates China’s domestic use and rest of the world imports. In addition, USDA repeats errors in ROW (i.e. rest of the world except China) production forecasts and overcorrects errors in ROW exports forecasts.

Correction for correlation in forecast revisions does not improve the USDA cotton forecasts. Correction for correlation of errors with previous year’s errors and correlation of errors with forecast levels, result in improvement of USDA cotton forecasts.

For livestock series, Extension forecasts are more accurate than the USDA forecasts, but for the crops USDA forecasts are more accurate. However, in most of the cases Composite forecasts are more accurate than both of Extension and the USDA forecasts.

The lean Hogs futures-based forecast is more accurate than Extension and the USDA forecasts.

Seasonal nature of Hogs production must be scrutinized. Pigs and Hogs forecasts over emphasize this seasonality.

Even though, the USDA estimates are unbiased in the short-run, but they are not rational in the long-run.

The USDA forecasts are unbiased, but they are not efficient. The reason is USDA do not completely consider the information from the previous forecasts.

The USDA forecasts are not optimal. Broiler price forecast is biased and overall all the forecasts repeat errors.
comprehensive evaluation.
Sanders & Manfredo (2005). A Test of Forecast Consistency Using USDA Livestock Price Forecasts.
Sanders & Manfredo (2008). Multiple horizons and information in USDA production forecasts.
Sanders & Manfredo (2003b). Keep up the good work?
An evaluation of the USDA’s livestock price forecasts.
Schaefer & Myers (1999). Forecasting accuracy, rational expectations, and market efficiency in the US beef cattle industry.
Von Bailey & Brorsen (1998). Trends in the accuracy of USDA production forecasts for beef and pork.
Xiao et al. (2014). USDA and private analysts’ forecasts of ending stocks: how good are they?

The USDA quarterly livestock price forecasts are not consistent in the long-run.

Although the USDA forecasts are not rational they provide useful information for their users. Likewise, turkey and milk forecasts show the most consistent performance, but beef provides little information.

USDA Broiler price forecasts are biased. Overall, the USDA price forecasts are not optimal, and almost in all the forecasts it repeats errors.

The USDA forecasts are inefficient and biased.

The USDA forecast underestimates production in the 1980s, but the bias disappears later. So, the accuracy of the forecasts is improved and even though the USDA forecasts are not optimal in 1980s, they show optimality after then.

The USDA forecasts are unbiased, but both of the USDA and private forecasts are inefficient. Also, the accuracy of both of the USDA and private forecasts is the highest for wheat and the lowest for soybeans.

Researcher & Topic (Market Reactions to the USDA forecasts)
Aulerich et al. (2007)
The Impact of Measurement Error on Estimates of the Price Reaction to USDA Crop Reports.
Colling & Irwin (1990)
The reaction of live Hogs futures prices to USDA Hogs and Pigs reports.
Colling et al. (1992)
Weak-and strong-form rationality tests of market analysts' expectations of USDA Hogs and Pigs reports.
Colling et al. (1996)
Reaction of Wheat, Corn, and Soybean Futures Prices to USDA"Export Inspections" Reports.

Summary of study
Implication of Identification by Censoring (ITC) method shows that market reactions to unanticipated information in the USDA forecasts are significantly high.

Live Hogs future prices do not react to anticipated changes in the USDA forecasts, but considerably react to unanticipated changes in the reports. However, the Hogs prices adjust to unanticipated reports on the day following release of the forecasts.

Expectations of Pigs and Hogs reports are strong-form rational.

Soybean prices respond substantially to unanticipated information in “Export Inspections” reports. Also, corn prices react notably to unanticipated information during the December to February quarter, but soybean prices respond to such an unanticipated information during June to August quarter.
Colling et al. (1997)
Future price responses to USDA’s Cold Storage report.
Darby (2015)
Information Content of USDA Rice Reports and Price Reactions of Rice Futures.
Fortenbery et al. (1993)
The effects of USDA reports in futures and options markets.
Good & Irwin (2005)
Understanding USDA corn and soybean production forecasts: Methods, performance and market impacts over 1970-2005.
Irwin at al. (2001)
The value of USDA outlook information: an investigation using event study analysis.
Isengildina-Massa et al. (2004)
Does the Market Anticipate Smoothing in USDA Crop Production Forecasts?
Fortenbery & Sumner (1993)
The effects of USDA reports in futures and options markets.
Hoffman et al. (2015)
Forecast performance of WASDE price projections for US corn
Karali (2012)
Do USDA Announcements Affect Comovements Across Commodity Futures Returns?
McKenzie (2008)
Pre-harvest price expectations for corn: The information content of USDA reports and new crop futures.
Patterson & Brorsen (1993)
USDA Export Sales Report: Is It News?
Pruitt et al. (2014)
End user preferences for USDA market information.
Roberts (2006)
The value of plant disease early-warning systems: A case study of USDA’s soybean rust coordinated framework
Schroeder et al. (1990)
Abnormal returns in livestock

Live Hogs and pork belly prices react significantly to unanticipated information from the USDA forecasts. Therefore, the forecasts provide information to the markets.

The USDA forecasts provide useful information to the rice markets and rice futures react to the USDA information consistently.

The effects of the USDA forecasts are minimal, but regression tests show that market participants cannot forecast market future.

The USDA corn and soybeans production forecasts are reasonably well.

The USDA forecasts have significant impacts in soybeans and corn markets. Also, the reports reduce uncertainty of the expected distribution of the prices which improves the market participants’ welfare.

Except for some cases market participants are aware of USDA smoothing practices and efficiently apply this information into their own forecasts.

During the time, market participants have learned how to digest the USDA reports. Hence, forecasts do not cause abnormally large price changes.

The USDA WASDE projections of corn season-average price provide valuable information to the market and improves the efficiency of the United States agricultural sector.

On the release days of the grain stocks, feed outlooks, and Hogs and Pigs report the largest movements in covariances happen.

Results indicate that the USDA forecasts are newsworthy. Also, price reactions to the reports are rational.

The USDA forecast doesn’t provide new information to the market and indeed the traders predict the reports.

Results show preference for farm level forecasts by Extension agents.

The USDA forecasts provide valuable information to the market. Probably in 2005 the value of information by the USDA forecasts exceeds the cost of getting information.

The USDA forecasts do not have consistent upward or downward influences on the prices, but the volatility of returns increases around
futures prices around USDA inventory report releases. the report release time which suggests forecasts provide new information to the market. Also, comparing to the other markets the forecast contains less information for the Hogs market. Hence, the Hogs prices are more volatile after the release of the USDA forecasts.

There are significant differences between the means and variances of prices following a USDA announcement and the means and variances of prices of the other days.

**Accuracy of the USDA Forecasts**

As the summery of the relevant studies above show, not all the researchers are on a same page about accuracy of the USDA forecasts. On the one hand some studies maintain that USDA estimates are *unbiased* (e.g. No & Salassi (2009), Sanders & Manfredo (2002), Xiao et al. (2014), Irwin et al. (2014)) and on the other hand, some studies claim that USDA forecasts are *biased* (e.g. Sanders & Manfredo (2003a), Sanders & Manfredo (2003b), Schaefer & Myers (1999)).

Some studies, however, maintain that the USDA forecasts are *inefficient* (e.g. Schaefer & Myers (1999), Sanders & Manfredo (2002), Xiao et al. (2014)), *not optimal* (e.g. Von Bailey & Brorsen (1998), Sanders & Manfredo (2003a), Sanders & Manfredo (2003b)), or *not rational in the long-run* (e.g. Also, Sanders & Manfredo (2008), No & Salassi (2009)).

Some of the studies report an *improvement in accuracy* of USDA forecasts (e.g. Gunnelson et al. (1972), Egelkraut et al. (2003), Good & Irwin (2005), Irwin et al. (2014)).

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4 Salassi (2009) argues that USDA forecasts are unbiased in the short-run, but not rational in the long run.
5 Sanders & Manfredo (2002) maintain that USDA forecasts are unbiased but not efficient.
6 Xiao et al. (2014) argue that USDA forecasts are unbiased but inefficient.
7 Irwin et al. (2014) maintain that USDA NASS forecasts for corn are unbiased.
8 Sanders & Manfredo (2003a) and Sanders & Manfredo (2003b) indicate that USDA forecasts of Broiler price is biased.
9 Gunnelson et al. (1972) report a moderate improvement in USDA forecasts.
10 Irwin (2005) report an improvement in accuracy of USDA forecasts for soybeans.
11 Irwin et al. (2014) maintain that USDA NASS forecasts for corn are improved.
Some of the studies compare the accuracy of the USDA forecasts with that of other forecasts (e.g. Kastens et al. (1998), Manfredo & Sanders (2004)). Furthermore, at least two studies indicate that USDA forecasts are more accurate in case of corn production, but this is not the case for soybeans production (e.g. Egelkraut et al. (2003), Irwin et al. (2014)).

Fig. 3, part A represents the summary of major findings of the studies that focus on evaluation of accuracy of USDA forecasts. Overall the authors of 4 studies believe that at least for some of the Agriculture products the forecasts are unbiased, 4 studies point out that the accuracy of the forecasts have improved, and 2 studies maintain that USDA does a better job about corn forecasts comparing to soybeans forecasts. However, 3 studies indicate that the USDA forecasts are biased, 3 of them report inefficiency, another 3 studies specify that the forecasts are not optimal, and 2 of them argue that they are not rational.

**Market Reactions to the USDA Forecasts**

Market reactions to the USDA forecasts are not unambiguously identified. While on the one hand some researchers argue that the forecasts are newsworthy and provide new and useful information to the market (e.g. Summer & Mueller (1989), Schroeder et al. (1990), Fortenbery et al. (1993), Roberts (2006), McKenzie (2008), Darby (2015), Hoffman et al. (2015)), on the other hand other researchers maintain that the USDA forecast are not newsworthy and in fact market participants predict the reports (e.g. Patterson & Brorsen (1993), Isengildina-Massa et al. (2004)).

Also, a couple of studies note that the USDA forecasts cause market reaction or movement in the prices (e.g. Colling & Irwin (1990), Colling et al. (1996), Colling et al. (1997), Irwin at al. (2001) (corn and soybeans), Aulerich et al. (2007), McKenzie (2008), Karali (2012)). Furthermore, Colling & Irwin (1990), Colling et al. (1996), Colling et al. (1997), Aulerich et al. (2007) argue
that *market reacts to the unanticipated changes* in the forecasts. Fortenbery & Sumner (1993) believe that USDA forecasts *do not cause uncertainty*. In addition, Colling et al. (1992) maintain that expectations of Pigs and Hogs reports are *strong-form rational*. Some other researchers such as McKenzie (2008) claim that *reactions to prices are rational*.

Fig. 2, part B represents the summary of major findings of the studies that focus on the market reactions to the USDA forecasts. All in all, 2 studies claim that the forecasts are not newsworthy, while 7 of them argue that they are newsworthy. 7 studies specify that USDA forecasts cause market reactions, 4 of them maintain that markets react to unanticipated information, 2 studies argue that market expectations are rational, and 1 study maintain that the forecasts don’t cause uncertainty.

![Fig. 2. Summary of the major findings of the published studies.](image)

**Fig. 2. Summary of the major findings of the published studies.** A represents a summary of main findings of the studies which focus on analyzing the accuracy of the USDA forecasts, while B shows the ones which study market reactions to the USDA forecasts.

**Meta-analysis**

A possible problem with the USDA forecasts can be repeating the past errors or over-correcting them. A correlation with the past errors represents the forecasts tendency to repeat or overcorrect the past errors. Positive correlation with past forecasts means that the new forecasts repeat the
same errors, while negative correlation represents over-correction of the errors (Isengildina-Massa et al, 2013). Some of the studies calculate the Pearson correlation of the USDA forecasts with their past errors (e.g. Sanders & Manfredo, 2002 and 2003; Isengildina-Massa et al., 2004, 2006, 2012, and 2013; Good & Irwin, 2005; and McKenzie, 2008). We apply their findings which are represented in Table. 1. to do the meta-analysis in this study. Note that AR4 which is a time series model represents a substitute method of forecasting suggested by the authors.

In a meta-analysis study usually two models get discussed: fixed-effect and random-effect models. In a fixed-effect model the assumption is that the dataset in not random and the individuals are from a same population while in random effect models the dataset is from a hierarchy of different populations and the differences among the dataset observations relates to that hierarchy. As an example, the dataset which is collected from a same population in a same library may qualify for the fixed-effect model. The fixed-effect model doesn’t account for heterogeneity and if indeed the dataset is from different populations it overestimates the effect sizes. In that condition, someone may apply the random-effect model. When there is heterogeneity in the dataset the calculated Confidence Intervals (CI) are much wider if the researcher applies the random-effect models, but if the dataset is homogeneous the CI is same as the estimated CI using fixed-effect models.
Table 1. The Dataset to do meta-analysis

| Authors            | Year | Time Period   | Item | Pearson Correlation | Forecast |
|--------------------|------|---------------|------|---------------------|----------|
| Sanders & Manfredo | 2002 | 1982-2000     | beef | 0.31                | USDA     |
| Sanders & Manfredo | 2002 | 1982-2000     | pork | 0.15                | USDA     |
| Sanders & Manfredo | 2002 | 1982-2000     | broiler | 0.25              | USDA     |
| Sanders & Manfredo | 2002 | 1982-2000     | beef | -0.12               | AR4      |
| Sanders & Manfredo | 2002 | 1982-2000     | pork | -0.02               | AR4      |
| Sanders & Manfredo | 2002 | 1982-2000     | broiler | 0.03             | AR4      |
| Sanders & Manfredo | 2003 | 1982-2002     | cattle | 0.24              | USDA     |
| Sanders & Manfredo | 2003 | 1982-2002     | Hogs | 0.18                | USDA     |
| Sanders & Manfredo | 2003 | 1982-2002     | broiler | 0.31             | USDA     |
| Sanders & Manfredo | 2003 | 1982-2002     | cattle | 0.02             | AR4      |
| Sanders & Manfredo | 2003 | 1982-2002     | Hogs | -0.21               | AR4      |
| Sanders & Manfredo | 2003 | 1982-2002     | broiler | 0.17             | AR4      |
| Isengildina et al. | 2004 | 1970-2002     | corn  | 0.45                | USDA     |
| Isengildina et al. | 2004 | 1970-2002     | soybeans | 0.22           | USDA     |
| Good & Irwin       | 2005 | 1970-2005     | corn  | 0.54                | USDA     |
| Good & Irwin       | 2005 | 1970-2005     | soybeans | 0.35            | USDA     |
| Isengildina et al. | 2006 | 1970-2002     | corn  | 0.23                | USDA     |
| Isengildina et al. | 2006 | 1970-2002     | soybeans | -0.8            | USDA     |
| McKenzie           | 2008 | 1970-2005     | corn  | 0.66                | USDA     |
| Isengildina et al. | 2012 | 1985-2009     | corn  | -0.31               | USDA     |
| Isengildina et al. | 2013 | 1987-2010     | soybeans | 0.11           | USDA     |
| Isengildina et al. | 2013 | 1987-2010     | wheat | 0.16                | USDA     |

To determine heterogeneity in the sample sizes we calculate Q-statistic. The null hypothesis for the Q-statistic test is that ‘all of the studies share a same effect size’ and the alternative hypothesis is that ‘the studies do not examine a common effect size’. In other words, a statistically Q-statistic means that the studies do not share a common effect size. However, a non-significant Q-statistic doesn’t prove that the dataset is homogeneous. The test for heterogeneity results show that Q-statistic is 77.3 and p-value < 0.0001 which means that the studies do not share a common effect size and the dataset is heterogeneous.

An alternative test for heterogeneity applies I2-statistic. I2-statistic is a percentage that shows that the proportion of variance is from actual differences between studies rather than within the study.
variance. Higgins et al. (2003) provide thresholds of 25%, 50%, and 75% which indicate low, moderate and high variance for I2-statistic. For our dataset I2-statistic is 70.3% (95% CI: 48.5, 83.8) which represents moderate to high variance.

Even though, the mentioned tests show that there is heterogeneity in the dataset, but they don’t provide any clue that which studies may disproportionately affect heterogeneity. Instead, Baujat plot which introduced by Baujat et al. (2002) makes it possible to see which studies contribute to the heterogeneity and overall influence the results more than the others. For the mentioned plot the horizontal axis shows the study heterogeneity while the vertical axis indicates the influence of studies on the overall results. Fig. 3. represents Baujat plot for our dataset.

![Baujat plot](image)

**Fig. 3. Baujat plot to identify the studies that contribute to heterogeneity.** Each number represents a study. Studies on top right have greater influence on the results and have a bigger contribution to heterogeneity. plot A considers all of the studies. As can be seen in the graph, study 18 which is Isengildina-Messa et al. (2006) for soybeans contributes the most to heterogeneity. In plot B, the AR4 models are eliminated and only the studies which focus on USDA forecasts are left. Here study 12 is in the right corner above. In plot C the studies with biggest variation and small size effects are eliminated.

Another important concept in meta-analysis literature is publication bias which represents that the studies with stronger effect-sizes are more probable to get published. In other words, the publisher looks at the findings of the research and the studies with strong and positive results have more chances to get published. Funnel plot is a helpful tool to determine publication bias. In this plot the vertical axis shows individual effect sizes while the horizontal axis represents standard errors. A symmetric Funnel plot indicates the possibility of unbiase publication while an asymmetric plot shows the possibility of publication bias. If the plot shows a negative correlation that means
probably the studies with small and negative results do not get published and they miss from the left corner of the plot. Fig. 4. represents Funnel plot for our dataset. As can be seen in most of the cases the plot shows positive correlations.

**Fig. 4. Funnel Plot to represent publication bias.** plot A which includes all of the studies in Table. 1. shows a positive correlation and therefore the dataset can be interpreted as asymmetric. In plots B and C, we remove the studies with small effect sizes and big variations. Funnel Plot D includes all of the studies in plot A except the AR4 models. Plot E simulates three removed studies of plot D which if they were there the plot would be symmetric. In Funnel Plot F, the studies with small effect sizes and big variations are removed from Plot D which again sounds like an asymmetric plot. Overall, it sounds that Funnel plot in all of the scenarios is asymmetric which demonstrates the possibility of publication bias.

A weakness of Funnel plot is that it is only a subjective measure of possibility of publication bias. We apply Rank Correlation and Egger’s tests as objective tools to test for publication bias. Begg and Mazumdar (1994) propose Rank Correlation test. Based on their method P<0.05 is consistent with asymmetrical Funnel plot. However, Rank Correlation test cannot be fully trusted for studies with less than 25 studies (Sterne at al. 2000). An alternative test which is more useful for meta-
analysis with less than 25 studies is Egger’s test represented by Egger et al. (1997). Here, Rank Correlation test ($p = 0.0081$) is statistically significant which suggests that there is publication bias in our dataset. However, based on the Egger’s test which is another tool to test for funnel plot asymmetry, $p$ equals to 0.2408 which is not statistically significant. Unlike Rank Correlation test, this finding suggests that the studies are not symmetric in the Funnel plot. In other words, based on the results of Egger’s test there is no evidence of publication bias.

**Discussion**

By combining the findings of a variety of studies, providing useful statistical tests and procedures, and aggregating and synthesizing the results Meta-analysis helps to get resolve uncertainty when the studies contradict and it is certainly useful to get a vivid and pig picture of findings of many studies in one place.

Many researchers have studied USDA forecasts, but almost all of the academic publications in this area can be divided in two groups. The studies which evaluate the accuracy of the USDA forecasts and the ones that evaluate the market reactions to the USDA forecasts. Some of the studies do both. These groups of studies provide a variety of results and in many cases their findings contradict. Therefore, in this study we do a meta-analysis on the published studies in this area to tackle the following questions:

1) how the academic published studies evaluate accuracy of the USDA forecasts?

2) how the academic published studies evaluate market reactions to the USDA forecasts?

3) Is there heterogeneity in the results of the studies?

4) Is there any publication bias in the published studies in this area?
After aggregating and synthesizing all published papers that we could find, we figured out that some of the studies maintain that the forecasts are unbiased, while most of the studies point out that at least for some of the products the USDA forecasts are not efficient, they are biased, and they are not optimal.

About market reactions to the USDA forecasts, we found a few studies that claim that the forecasts are not newsworthy, and the market participants could predict the reports. However, most of the studies argue that the forecasts are newsworthy, they provide useful information to the market participants, and they cause market reactions and change in the prices. We did meta-analysis using a package named “metaphor” in R to tackle the third and the fourth questions. We applied Q-statistic, I2-statistic, and Baujat plot to test for heterogeneity. Based on the findings from the mentioned tests the results of the studies are heterogeneous. Also, we applied Funnel plot, Rank Correlation test, and Egger’s test to test for publication bias. Funnel plot and Rank Correlation test results show publication bias. However, as we already mentioned Egger’s test findings are more accurate for small datasets and the results of this test doesn’t confirm publication bias.

References
1. Aulerich, N., Irwin, S., & Nelson, C. (2007). The Impact of Measurement Error on Estimates of the Price Reaction to USDA Crop Reports. NCCC-134 Conference on Applied Commodity Price Analysis, Forecasting, and Market Risk Management, NCCC-134 Conference on Applied Commodity Price Analysis, Forecasting, and Market Risk Management, 2007 Conference, April 16-17, 2007, Chicago, Illinois.
2. Begg, C., & Mazumdar, M. (1994). Operating Characteristics of a Rank Correlation Test for Publication Bias. Biometrics, 50(4), 1088-1101.
3. Colling, P. L., & Irwin, S. H. (1990). The reaction of live hog futures prices to USDA hogs and pigs’ reports. American Journal of Agricultural Economics, 72(1), 84-94.
4. Colling, P. L., Irwin, S. H., & Zulauf, C. R. (1992). Weak-and strong-form rationality tests of market analysts' expectations of USDA hogs and pigs reports. Review of Agricultural Economics, 14(2), 263-270.
5. Colling, P. L., Irwin, S. H., & Zulauf, C. R. (1996). Reaction of Wheat, Corn, and Soybean Futures Prices to USDA" Export Inspections" Reports. Review of Agricultural Economics, 127-136.
6. Colling, P., Irwin, S., & Zulauf, C. (1997). Future price responses to USDA’s Cold Storage report. Agribusiness, 13(4), 393-400.
7. Darby, J. L. (2015). Information Content of USDA Rice Reports and Price Reactions of Rice Futures (Doctoral dissertation, University of Arkansas).
8. Egelkraut, T. M., Garcia, P., Irwin, S. H., & Good, D. L. (2003). An evaluation of crop forecast accuracy for corn and soybeans: USDA and private information agencies. *Journal of Agricultural and Applied Economics, 35*(01), 79-95.

9. Egger, Matthias, Smith, George Davey, Schneider, Martin, & Minder, Christoph. (1997). Bias in meta-analysis detected by a simple, graphical test. *British Medical Journal, 315*(7109), 629.

10. Flora, C. (1993). Revisiting the USDA reports: Context, capital and organization. *American Journal of Alternative Agriculture, 8*(4), 155-157.

11. Fortenbery, T. R., & Sumner, D. A. (1993). The effects of USDA reports in futures and options markets. *Journal of Futures Markets, 13*(2), 157-173.

12. Fortenbery, T. Randall, & Sumner, Daniel A. (1993). The effects of USDA reports in futures and options markets. *Journal of Futures Markets, 13*(2), 157-173.

13. Global cotton consumption to raise in 2013-14 - USDA. (2013). *Pakistan Textile Journal, 62*(7), Pakistan Textile Journal, July 31, 2013, Vol.62(7).

14. Good, D. L., & Irwin, S. H. (2006). Understanding USDA corn and soybean production forecasts: Methods, performance and market impacts over 1970-2005.

15. Good, D., & Irwin, S. (2005). Understanding USDA Corn and Soybean Production Forecasts: Methods, Performance and Market Impacts over 1970-2004. *University of Illinois at Urbana-Champaign*, University of Illinois at Urbana-Champaign, Department of Agricultural and Consumer Economics, AgMAS Project Research Reports.

16. Gunnelson, G., Dobson, W. D., & Pamperin, S. (1972). Analysis of the accuracy of USDA crop forecasts. *American Journal of Agricultural Economics, 54*(4 Part 1), 639-645.

17. Hoffman, L. A., Etienne, X. L., Irwin, S. H., Colino, E. V., & Toasa, J. I. (2015). Forecast performance of WASDE price projections for US corn. *Agricultural Economics, 46*(S1), 157-171.

18. Irwin, S. H., Good, D. L., Gomez, J. K., & Isengildina, O. (2001, April). The value of USDA outlook information: an investigation using event study analysis. In *NCR Conference on Applied Commodity Price Analysis, Forecasting, and Market Risk Management, St. Louis MO.*

19. Irwin, S. H., Sanders, D. R., & Good, D. L. (2014). Evaluation of Selected USDA WAOB and NASS Forecasts and Estimates in Corn and Soybeans. *Marketing and Outlook Research Report, 1.*

20. Isengildina-Massa, O., Irwin, S. H., & Good, D. L. (2004). Does the Market Anticipate Smoothing in USDA Crop Production Forecasts? In *2004 Annual meeting, August 1-4, Denver, CO* (No. 20145). American Agricultural Economics Association (New Name 2008: Agricultural and Applied Economics Association).

21. Isengildina-Massa, O., Irwin, S. H., & Good, D. L. (2013). Do Big Crops Get Bigger and Small Crops Get Smaller? Further Evidence on Smoothing in US Department of Agriculture Forecasts. *Journal of Agricultural and Applied Economics, 45*(01).

22. Isengildina-Massa, O., Irwin, S., & Good, D. (2006). Are Revisions to USDA Crop Production Forecasts Smoothed? *American Journal of Agricultural Economics, 88*(4), 1091-1104.

23. Isengildina-Massa, O., Irwin, S., Good, D., & Massa, L. (2011). Empirical confidence intervals for USDA commodity price forecasts. *Applied Economics, 43*(26), 3789-3803.

24. Isengildina-Massa, O., Karali, B., & Irwin, S. H. (2013). When do the USDA forecasters make mistakes? *Applied Economics, 45*(36), 5086-5103.

25. Isengildina-Messa, O., Macdonald, Stephen, & Xie, Ran. (2012). A comprehensive evaluation of USDA cotton forecasts. *Journal of Agricultural and Resource Economics: JARE; the Journal of the Western Agricultural Economics Association, 37*(1), 98-113.

26. Isengildina-Massa, O., Tysinger, D., Gerard, P., & MacDonald, S. (2011). What Can We Learn from our Mistakes? Evaluating the Benefits of Correcting Inefficiencies in USDA Cotton Forecasts. In *2011 Annual Meeting, February 5-8, 2011, Corpus Christi, Texas* (No. 98811). Southern Agricultural Economics Association.

27. Isengildina-Messa, O., & Mattos, F. (2015). Accuracy-Informativeness Tradeoff for Interval Forecast Comparison.

28. Karali, B. (2012). Do USDA Announcements Affect Comovements Across Commodity Futures Returns? *Journal of Agricultural and Resource Economics, 37*(1), 78.
29. Kastens, T. L., Schroeder, T. C., & Plain, R. (1998). Evaluation of extension and USDA price and production forecasts. *Journal of Agricultural and Resource Economics*, 244-261.

30. Keegan, Charles E., III, Morgan, Todd A., Wagner, Francis G., Cohn, Patricia J., Blatner, Keith A., Spoelma, Timothy P., & Shook, Steven R. (2005). Capacity for utilization of USDA Forest Service, Region I small-diameter timber. *Forest Products Journal*, 55(12), 143.

31. Lee, Robert D, Nieman, David C, & Rainwater, Marvin. (1995). Comparison of Eight Microcomputer Dietary Analysis Programs with the USDA Nutrient Data Base for Standard Reference. *Journal of the American Dietetic Association*, 95(8), 858-867.

32. Manfredo, M. R., & Sanders, D. R. (2004). The value of public price forecasts: Additional evidence in the live hog market. *Journal of Agribusiness*, 22(2), 119S131.

33. McKenzie, A. M. (2008). Pre-harvest price expectations for corn: The information content of USDA reports and new crop futures. *American Journal of Agricultural Economics*, 90(2), 351-366.

34. Meyer, S. R., & Lawrence, J. D. (1988). Comparing USDA Hogs and Pigs Reports to Subsequent Slaughter: Does Systematic Error Exist? University of Missouri–Columbia, Department of AGRicultural Economics.

35. No, Sung Chul, & Salassi, Michael E. (2009). A sequential rationality test of USDA preliminary price estimates for selected program crops: Rice, soybeans, and wheat. *International Advances in Economic Research*, 15(4), 470.

36. Papendick, R. (1993). Revisiting the USDA reports: Some additional observations. *American Journal of Alternative Agriculture*, 8(4), 154-155.

37. Patterson, P. M., & Brorsen, B. W. (1993). USDA Export Sales Report: Is It News?. *Review of Agricultural Economics*, 367-378.

38. Pruitt, J. R., Tonsor, G. T., Brooks, K. R., & Johnson, R. J. (2014). End user preferences for USDA market information. *Food Policy*, 47, 24-33.

39. Ray, D. (2008). USDA top officials vs. USDA data. *Review of African Political Economy*, 35(117), 514-516.

40. Roberts, M., & United States. Department of Agriculture. Economic Research Service. (2006). The value of plant disease early-warning systems: A case study of USDA's soybean rust coordinated framework (Economic research report (United States. Department of Agriculture. Economic Research Service); no. 18). Washington, D.C.]: U.S. Dept. of Agriculture, Economic Research Service.

41. Sanders, D. R., & Manfredo, M. R. (2002). USDA production forecasts for pork, beef, and broilers: an evaluation. *Journal of Agricultural and Resource Economics*, 27(01), 114-127.

42. Sanders, D. R., & Manfredo, M. R. (2003). Keep up the good work? An evaluation of the USDA’s livestock price forecasts. *NCR-134 Conference on Applied Commodity Price Analysis, Forecasting, and Market Risk Management*, NCR-134 Conference on Applied Commodity Price Analysis, Forecasting, and Market Risk Management, 2003 Conference, St. Louis, Missouri, April 21-22.

43. Sanders, D. R., & Manfredo, M. R. (2003). USDA livestock price forecasts: A comprehensive evaluation. *Journal of Agricultural and Resource Economics*, 316-334.

44. Sanders, D. R., & Manfredo, M. R. (2005). A Test of Forecast Consistency Using USDA Livestock Price Forecasts. In *2005 Conference, April 18-19, 2005, St. Louis, Missouri* (No. 19042). NCR-134 Conference on Applied Commodity Price Analysis, Forecasting, and Market Risk Management.

45. Sanders, D. R., & Manfredo, M. R. (2008). Multiple horizons and information in USDA production forecasts. *Agribusiness*, 24(1), 55-66.

46. Sanders, D., & Manfredo, M. (2003). Keep up the good work? An evaluation of the USDA’s livestock price forecasts. *NCR-134 Conference on Applied Commodity Price Analysis, Forecasting, and Market Risk Management*, NCR-134 Conference on Applied Commodity Price Analysis, Forecasting, and Market Risk Management, 2003 Conference, St. Louis, Missouri, April 21-22.

47. Schaefer, M. P., & Myers, R. J. (1999). *Forecasting accuracy, rational expectations, and market efficiency in the US beef cattle industry* (Master's thesis, Michigan State University. Dept. of Agricultural Economics).

48. Schroeder, T., Blair, J., & Mintert, J. (1990). Abnormal returns in livestock futures prices around USDA inventory report releases. *North Central Journal of Agricultural Economics*, 12(2), 293-304.

49. Shapley, D. (1976). Crops and Climatic Change: USDA's Forecasts Criticized. *Science*, 193(4259), 1222-1224.
50. Sterne, Jonathan A.C, Gavaghan, David, & Egger, Matthias. (2000). Publication and related bias in meta-analysis: Power of statistical tests and prevalence in the literature. *Journal of Clinical Epidemiology, 53*(11), 1119-1129.

51. Summer, D. A., & Mueller, R. A. (1989). Are harvest forecasts news? USDA announcements and futures market reactions. *American Journal of Agricultural Economics, 71*(1), 1-8.

52. United States. General Accounting Office, GAO, United States. Contraloria General, & United States. Comptroller General of the United States. (1991). *Short-term forecasting: Accuracy of USDA's meat forecasts and estimates: Report to the Honorable J. Robert Kerrey, U.S. Senate.* Washington, D.C.: Gaithersburg, MD (P.O. Box 6015, Gaithersburg 20877): The Office; The Office distributor.

53. United States. General Accounting Office, GAO, United States. Contraloria General, & United States. Comptroller General of the United States. (1988). *USDA's commodity program: The accuracy of budget forecasts: Report to the chairman, Subcommittee on Government Information, Justice, and Agriculture, Committee on Government Operations, House of Representatives.* Washington, D.C.: The Office.

54. United States. General Accounting Office, GAO, United States. Contraloria General, & United States. Comptroller General of the United States. (1991). *USDA commodity forecasts: Inaccuracies found may lead to underestimates of budget outlays: Report to the Honorable J. Robert Kerrey, U.S. Senate.* Washington, D.C.: Gaithersburg, MD (P.O. Box 6015, Gaithersburg 20884-6015): The Office; The Office distributor.

55. USDA's Healthy Eating Index and Nutrition Information. (ST). (1998). *Family Economics and Nutrition Review, 11*(4), 57-59.

56. Viechtbauer, W. (2010). Conducting meta-analyses in R with the metafor package. *Journal of Statistical Software, 36*(3), 1-48.

57. Von Bailey, D., & Brorsen, B. W. (1998). Trends in the accuracy of USDA production forecasts for beef and pork. *Journal of Agricultural and Resource Economics, 23*(02), 515-525.

58. Xiao, J., Lence, S., & Hart, C. (2014, May). USDA and private analysts’ forecasts of ending stocks: how good are they? In *2014 Annual Meeting, July 27-29, 2014, Minneapolis, Minnesota* (No. 170642). Agricultural and Applied Economics Association.