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Abstract

To inform their forecasts, U.S. wheat analysts concerned with production, marketing, and policy issues use the U.S. Department of Agriculture all wheat season-average farm price (SAFP) as reported in *World Agricultural Supply and Demand Estimates* (*WASDE*). A futures-based forecasting model linked to hard red winter (HRW) futures prices (Hoffman and Balagtas, 1999) provides important input into the development of the monthly *WASDE* all wheat SAFP projection. However, in recent years, price relationships among the major classes of wheat have changed, suggesting that additional wheat futures prices should be included in the model. This report presents an alternative, aggregate futures-based forecasting model that utilizes the three available wheat futures contract prices: HRW, soft red winter (SRW), and hard red spring (HRS), which represents the majority of U.S. wheat production. Results show the aggregate futures-based model tends to provide forecasts with a lower mean absolute percent error and a more accurate prediction of positive directional movement than the HRW-only model. Further, the aggregate model more closely tracks the monthly *WASDE* SAFP projections.

Keywords: Hard red winter wheat, soft red winter wheat, hard red spring wheat, all wheat season-average farm price (SAFP) forecasts, HRW-only futures-adjusted forecast model, aggregate wheat futures-adjusted forecast model, futures prices, basis, marketing weights

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About the Authors: Linwood Hoffmann retired as an agricultural economist with ERS. Jennifer Bond presently is an agricultural economist with ERS. Mariana Matias formerly with ERS, is now with USDA, FPAC.

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Merits of an Aggregate Futures Price Forecasting Model for the All Wheat U.S. Season-Average Farm Price

Introduction

In this report, an aggregate of hard red winter (HRW), soft red winter (SRW), and hard red spring (HRS) wheat futures price model is developed for monthly forecasts of the U.S. season-average farm price (SAFP) of all wheat, and its performance is compared to a futures-based forecasting model linked only to HRW wheat futures prices. We hypothesize that incorporating additional information from futures prices of other classes of wheat will improve the model's performance, and through a comparison of performance criteria, our analysis reveals that to be true. *World Agricultural Supply and Demand Estimates (WASDE)* projections still provide superior forecasts with lower forecast error and bias than aggregate futures model forecasts. However, the aggregate futures model forecasts are a valuable tool to assist in preparing *WASDE* projections because they provide guidance on the direction and magnitude of movement of the SAFP projections. The monthly all wheat SAFP in the *WASDE* report are the official U.S. Department of Agriculture (USDA) farm price projections—a benchmark for industry comparisons and USDA program analyses. Lastly, we provide an analysis of how futures forecasts can be useful in creating SAFP projections. Improving forecast accuracy is important and can enhance the efficiency of the agricultural sector.

USDA analyzes agricultural commodity markets and provides year-to-date market information, including SAFP projections, for several crops. Information regarding commodity prices is crucial to a variety of market participants, including producers who make production and marketing decisions, elevator operators/processors who make purchase and storage decisions, market analysts who assess the impacts of domestic and international developments, and policymakers who administer commodity programs. Since most producers, millers/bakers, and elevator operators are more concerned with a particular class of wheat and its price, the all wheat price will be important primarily to policy analysts who administer commodity programs. Improved forecast accuracy of the SAFP is very important for budgeting agricultural program costs, and improved forecasts can lead to more accurate farm program budget requests (General Accounting Office, 1988). USDA publishes official SAFP projections in the monthly *WASDE* report (USDA, the Office of the Chief Economist (OCE), and World Agricultural Outlook Board (WAOB), 2005/06 to 2019/20). The SAFP represents the marketing weighted average price received by U.S. producers throughout the marketing year, across all classes and grades of the crop.[1]

Information on the final National Agricultural Statistics Service (NASS) SAFP and its interim projections are key parameters in assessing the U.S. wheat sector's financial health and are also used in determining some commodity program payments. USDA often uses an all wheat price for program purposes. For example, the all wheat price, rather than a class-specific price, is used as a reference price for programs such as Agriculture Risk Coverage (ARC) and Price Loss Coverage (PLC). These forecasts send an early signal about sector financial health and potential farm program costs. Under the 2008 Farm Bill, the final NASS SAFP received by wheat producers was a key policy parameter needed in calculating Counter Cyclical Payment (CCP) rates or Average Crop Revenue Election (ACRE) program payments (U.S. 110th Congress). Under the Agricultural Act of 2014 and the Agricultural Improvement Act of 2018, the wheat SAFP continued as a key parameter in calculating PLC payment rates and ARC payment rates (U.S. 113th Congress; U.S. 115th Congress).

[1]A marketing year is a period of 1 year, designated for reporting and/or analysis of production, marketing, and disposition of a commodity. The marketing year for wheat begins June 1 and concludes May 31.

Literature Review

Cash and futures markets have long been followed as indicators of farm price expectations, and a number of econometric and futures-based price forecasting models have been developed to enhance the accuracy of SAFP forecasts.[2] Econometric price forecasting models based on reported farm prices have been estimated for corn and wheat (Westcott and Hoffman, 1998), rice (Childs and Westcott, 2000), and cotton (Meyer, 1998; Isengildina-Massa and MacDonald, 2009). Westcott and Hoffman's (1998) partial equilibrium wheat model forecasted the all wheat SAFP, where the SAFP was expressed as a function of U.S. and international stocks-to-use ratios, Government stocks-to-use ratios, Government program parameters (loan rates), summer quarter feed use as a share of total use, and the summer quarter corn price to forecast the all wheat SAFP. Their model explained 93 percent of the variation in the annual all wheat SAFP forecast between the 1975/76 and 1996/97 marketing years. Its forecasts had a mean absolute error of $0.13 per bushel and a mean absolute percentage error of 3.9 percent. Their model is also used for sensitivity analysis under various market supply and demand conditions that develop within a year or between years and is used in USDA's short-term market analysis and long-term baseline projections.

Price-forecasting models using forward-looking futures prices for corn, soybeans, wheat, and cotton provide input into the development of the WASDE SAFP projections (Hoffman et al., 2007; Hoffman and Meyer, 2018).[3] Although the Westcott and Hoffman partial equilibrium model developed for all wheat had a low forecast error, its evaluation was based on historical (i.e., backward-looking) information and worked well in situations where traditional wheat price relationships were maintained across the classes. The Hoffman et al. (2007) wheat model, covering marketing years 1980/81 to 2005/06, had a mean absolute error of $0.09 per bushel for its November forecasts along with a 2.9 percent mean absolute percentage error. This indicates that halfway through the marketing year, the wheat futures model forecasts were at least as accurate as those generated by the partial equilibrium model.[4] Futures price forecasting models provide information about the wheat sector's financial health and also complement econometric models. While both types have their strengths, the futures-based model has been a long-standing tool in the development of monthly updates to the all wheat SAFP forecast published in the *WASDE*.

Because HRW is the largest class of wheat produced in the United States, and prices for all classes of wheat tend to be highly correlated, the Hoffman et al. (2007) wheat futures-based model used only HRW wheat futures prices (see box 1: Production and use of the five U.S. wheat classes). Additionally, HRW prices historically tended to range between the price of the other two major wheat classes (HRS

[2]Futures prices are an unbiased predictor of the cash price for a given par delivery location and time period when the futures market is efficient (Fama, 1970; 1991). Tomek (1997), for instance, argued that it is often difficult for structural or econometric models to outperform a futures price forecast.

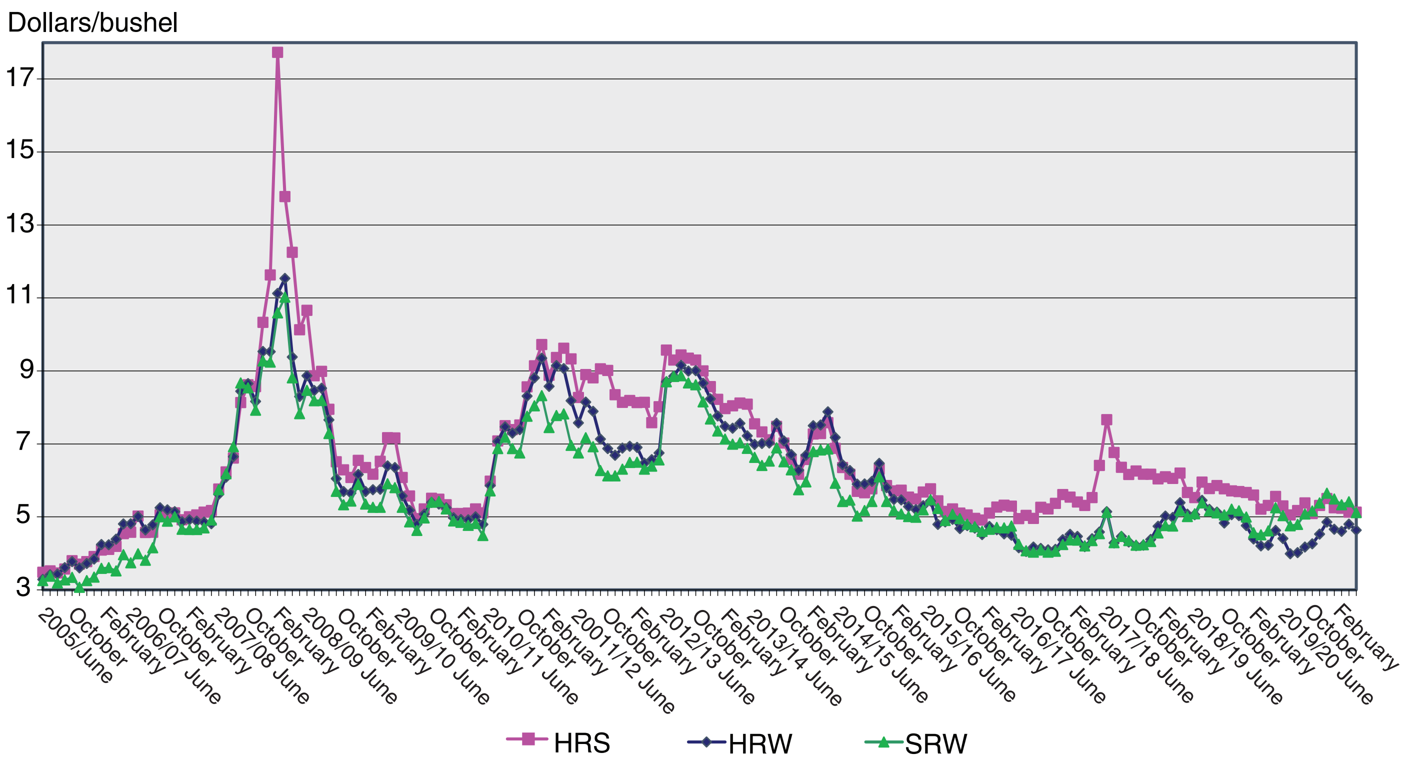
[3]Using futures prices to forecast a season-average price is slightly different from using a futures price to forecast a price for a given location, a given grade, or a specified time period and could contribute to model forecast error. First, the monthly cash price received represents an aggregation of different grades of wheat and thus is different from No. 2 HRW wheat price at the local elevator. The futures model uses the futures price for a specific grade of wheat, U.S. No. 2 HRW wheat, to predict the SAFP for U.S. producers. Second, the model does not focus on a given location but on an average for the United States. The monthly cash price received represents an average U.S. price received by producers, in contrast to a specific location. The monthly cash price received represents a U.S. average, and the basis represents an average for the United States, not a specific location. The farm price received by U.S. producers is an aggregation of all grades of wheat collected by the NASS. A monthly national basis is computed (cash price received less futures price), and we assume the difference in grades will be captured by the basis. Third, the time period is expanded from one period, such as harvest, to the entire marketing year, thus requiring five futures contracts instead of one. Also, the use of hedging, forward pricing, or contracting could potentially create some forecast error because a portion of the price has already been determined early in the marketing year but shows up in prices received by farmers over the next several months.

[4]Equal time periods for each forecast method were not available.

and SRW). In this way, the HRW price provided a natural midpoint price that tracked well with the all wheat season-average farm price. Accordingly, HRS and SRW futures prices were excluded from the HRW-only model, thus creating a simple tool that required minimal time to update. For many years, these rationales were used to support using a single-contract model as a proxy for the all wheat price. However, in recent years, HRW futures and cash prices have varied more widely and increasingly have ranged above and below HRS and/or SRW prices (figure 1). Furthermore, the proportional volume of wheat produced in the United States has shifted out of SRW and into HRS—reducing the offsetting impact of related futures prices in a forecasting model.

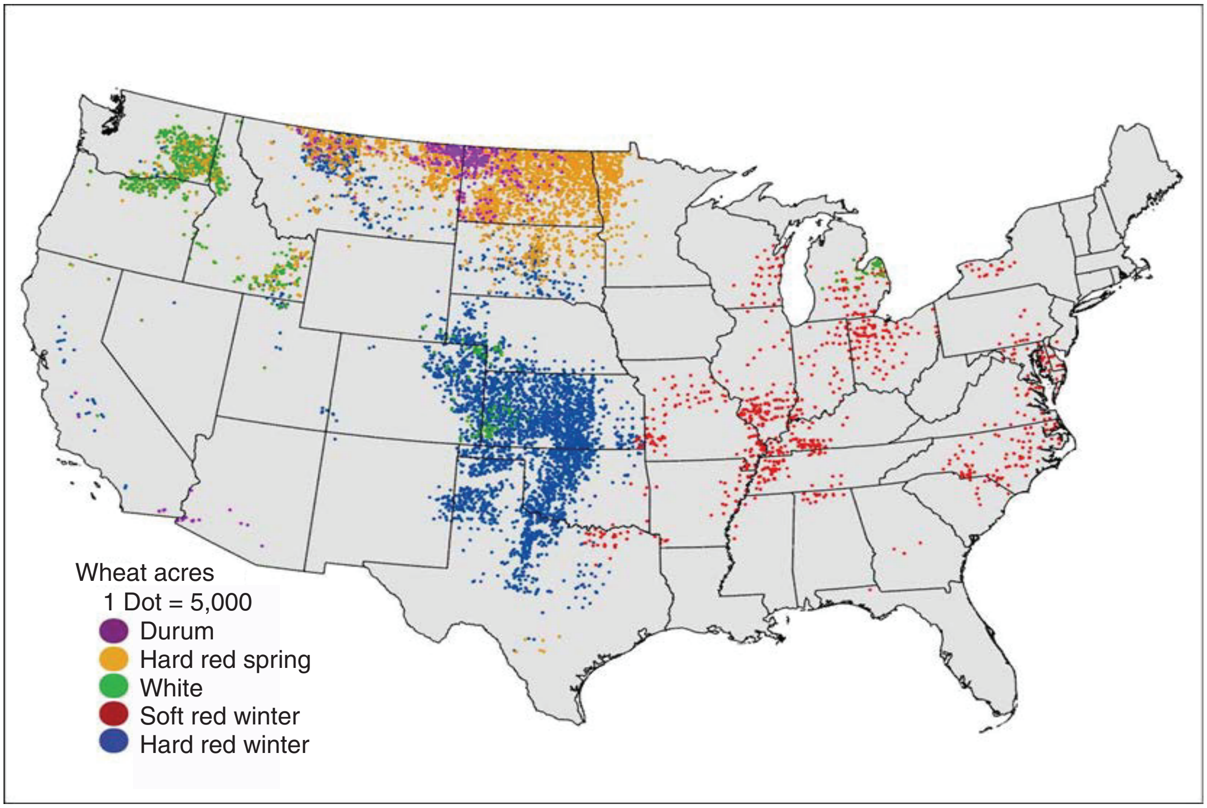
The need for refinements in the single-contract model approach became clear in 2007/08 and 2016/17 when market conditions were anomalous and created price relationships across the classes that led to underperformance of the HRW-focused futures price forecast model. In those 2 marketing years, HRW futures prices were particularly volatile and generally low relative to other wheat markets (see figure 1 for illustration). Ultimately, this caused the HRW futures model to forecast a SAFP that varied to a greater degree than normal from NASS's final all wheat SAFP. This called into question the predictive power of the single-contract focused model, leading to an investigation into the inclusion of SRW and HRS futures prices to help improve forecast accuracy. The conceptualized three-contract aggregate futures model could potentially insulate the forecast somewhat from volatility attributable to a single class.

Figure 1
Average monthly nearby wheat futures prices by class, marketing years 2005/06 to 2019/20



Note: HRS = hard red spring, HRW = hard red winter, SRW = soft red winter, and marketing year = begins June 1st and ends May 31st.
Sources: CME Group and Minneapolis Grain Exchange.

Figure 2
U.S. wheat by class, area planted 2017



Sources: USDA, Farm Services Agency planted and failed acreage data and USDA, Economic Research Service calculations.

For example, a drought in the Northern Plains might reduce production and cause the price of HRS to increase. A model that used only the HRW futures price would miss this price surge and the bolstering effects on the all wheat SAFP. In marketing year 2011/12, flooding led to a sharp drop in North Dakota spring wheat production, which led to an increase in HRS futures prices and an average increase of $0.22 per bushel in the aggregate futures price between October and May of the 2011/12 marketing year (figure 7). Similarly, if HRW prices are profoundly low, a situation that could be caused by low protein quality and/or very high supplies, the predicted all wheat SAFP would underestimate the all wheat SAFP because relatively higher SRW and/or HRS futures prices are not incorporated into the model. Moreover, the standard spread between the three classes of wheat—HRW, SRW, and HRS—has changed during 2005/06 through 2019/20, which reinforces the need for the inclusion of aggregate futures prices and the regular updating of their proportional weights.

Production and use of the five U.S. wheat classes

Wheat is the principal food grain produced in the United States of which there are five different classes: hard red winter (HRW), hard red spring (HRS), soft red winter (SRW), white wheat (WW)—including hard white (HW) and soft white (SW)—and durum. Production of wheat classes tends to be region-specific (figure 2), with HRW wheat production concentrated in the Central Plains and HRS wheat production more closely associated with the Northern Plains. The terms *hard* and *soft* refer to the texture of the starchy interior (endosperm) of the wheat kernel that is ground to produce wheat flour. U.S. wheat varieties are classified either as winter or spring depending on the season each is planted. Winter varieties are sown in the fall and are usually established before the cold weather arrives, then go dormant over the winter, and are harvested in early to mid-summer (figure 3A). Spring varieties are planted in the spring and harvested in late summer (figure 3B). In the past several years, the production shares of HRS and WW have been increasing, while SRW has been declining (figure 4).

- **HRW wheat** accounts for about 40 percent of total U.S. production and is grown primarily in the Great Plains (Texas north through Montana). HRW is a good wheat for bread, hard rolls, flatbread, Asian noodles, and general-purpose flour. It has medium protein and gluten content.

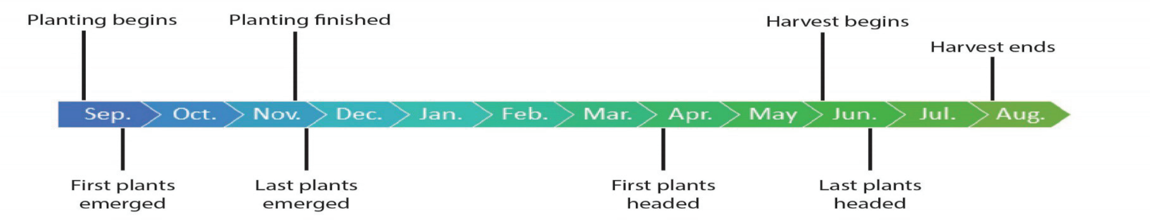
- **HRS wheat** accounts for about 25 percent of production and is grown primarily in the Northern Plains (North Dakota, Montana, Minnesota, and South Dakota). An important bread wheat, HRS is used in pan breads, artisan breads or rolls, and crusts. It generally has high protein and strong gluten. HRS wheat is valued for high protein levels and blending with lower protein HRW wheat for loaf bread.

- **SRW wheat** accounts for 15-20 percent of total production and is grown primarily in States along the Mississippi River and in the eastern States. SRW wheat is used mainly for bakery products other than bread, such as pastries, cakes, and cookies. It is also used for cereals, flatbreads, and crackers. It has lower protein and weak gluten.

- **White wheat**
  - **HW wheat** accounts for less than 1 percent of production and is generally grown in Kansas, Nebraska, and Colorado. This class of wheat serves a dual purpose, used for Asian noodles or breads and domestic whole grain products
  - **SW wheat** accounts for 10-15 percent of total production and is grown in Washington, Oregon, Idaho, and Michigan. SW wheat is used mainly for bakery products other than bread. Examples include pastries, cakes, cookies, cereals, flatbreads, and crackers. It has lower protein and weak gluten.

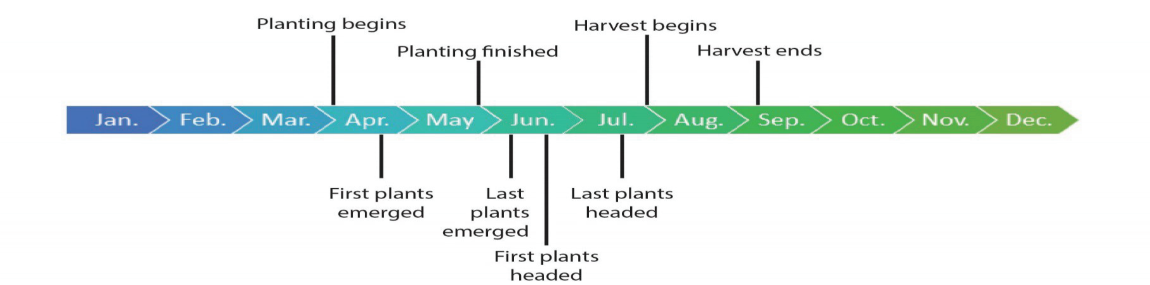
- **Durum wheat** accounts for 3-5 percent of total production and is grown primarily in North Dakota and Montana. It is the hardest of all wheats, golden or amber in color, and used for pasta, couscous, and some flatbreads.

Figure 3A
Usual planting and harvesting dates: U.S. winter wheat



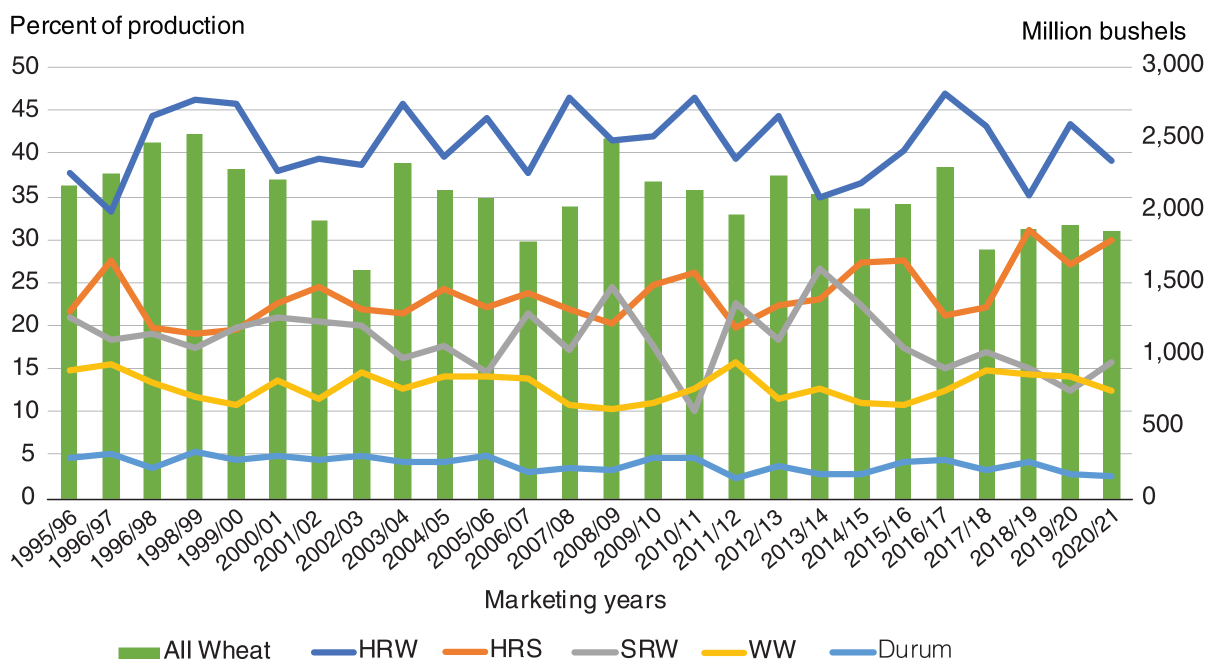
Source: USDA, National Agricultural Statistics Service *QuickStats* database.

Figure 3B
Usual planting and harvest dates: U.S. spring wheat



Source: USDA, National Agricultural Statistics Service *QuickStats* database.

Figure 4
Total U.S. winter wheat production shares by class, marketing years 1995/96 to 2020/21



Note: HRW = Hard red winter, HRS = Hard red spring, SRW = Soft red winter, WW = White wheat, marketing year = begins June 1st and end May 31st

Sources: USDA, National Agricultural Statistics Service; USDA, Economic Research Service calculations.

Computing a Season-Average Farm Price

An estimate of the all wheat price (referred to as the monthly farm price) received by U.S. producers is published monthly by NASS in *Agricultural Prices*. NASS prices are based on monthly surveys of U.S. wheat buyers (merchandisers, mills, and others), which provide information on the quantity and price of wheat purchased directly from U.S. farmers during a given month. The monthly farm price estimate is derived by dividing the total cost (purchase price times quantity) by the total quantity purchased (USDA, NASS, 2011). After the conclusion of the marketing year, NASS publishes the final wheat SAFP received by farmers, which is an average of the final reported monthly prices weighted by monthly wheat marketing.[5]

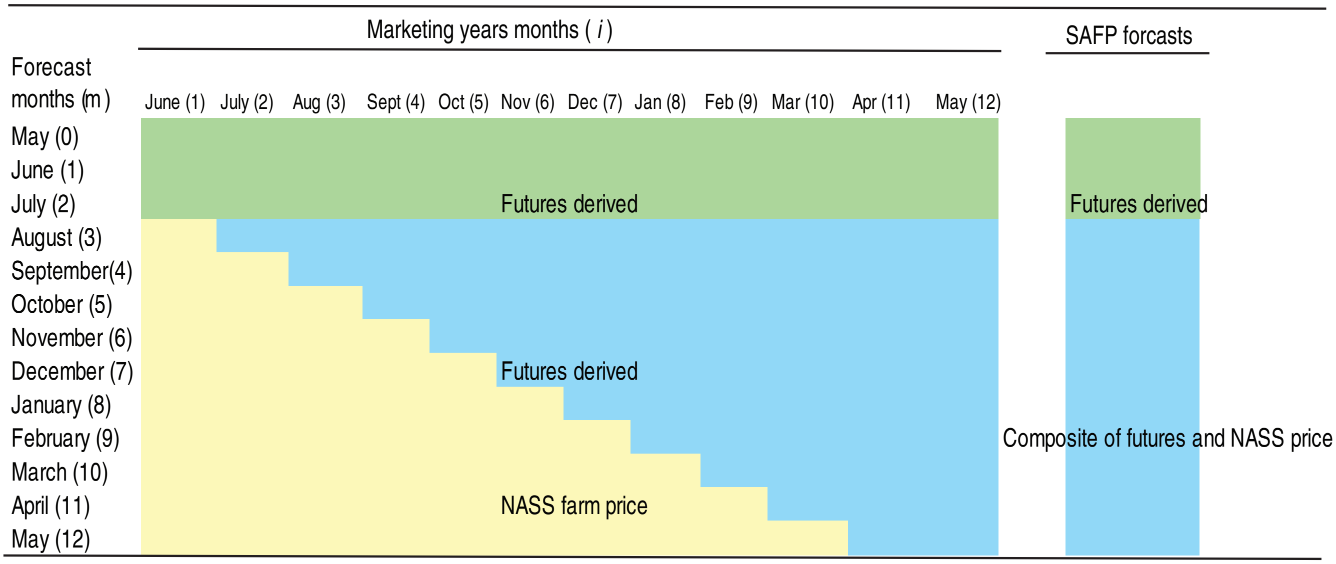
While the NASS SAFP represents the final marketing year (June-May) farm price, USDA publishes projections of this annual price each month (m) of the forecast cycle in the *WASDE* (see figure 5). The *WASDE* provides a projection of the SAFP beginning in May, one month prior to the start of the marketing year.[6] Thus, a total of 13 SAFP projections are generated for each marketing year, and the entire period is considered a forecast cycle. May (the first month of the forecast cycle that begins 1 month prior to the start of the marketing year), June, January, and the second May are the 1st, 2nd, 9th, and 13th forecasts/projections of the SAFP during the forecast cycle, or the 13th, 12th, 5th, and 1st month ahead forecast/projection, respectively. The consecutive months (m) within the forecast cycle are numbered zero through 12 for purposes of model expression. (See figure 4 and equation 1 for further illustration and explanation.)

Generating the *WASDE*-SAFP projections is a complex process and involves the interaction of expert judgment, econometric price forecasting models, futures prices, market information, weather models, satellite imagery, and in-depth research by USDA analysts (USDA, OCE, 2017). Additionally, assumptions are made about normal weather and existing policy. Supply and use balance sheets are estimated for many countries to provide a global balance sheet for all wheat. After the global situation is estimated, the U.S. balance sheet is estimated. Historically, the *WASDE* price projection was reported as a range of the expected price, and the midpoint of this range is used as the *WASDE* point forecast of the all wheat SAFP. Starting in May 2019, the *WASDE* report removed the price range and began publishing a point estimate.

[5]Prior to August 2018, the wheat SAFP was released by NASS in the June *Agricultural Prices* report, one month after the conclusion of the marketing year. Thereafter, this SAFP has been released in the August *Agricultural Prices*

[6]USDA provides long-term projections through the annual baseline process. These forecasts are not evaluated in this study.

Table 1
Aggregate wheat futures model's season average farm price (SAFP) forecast by forecast months (*m*) and marketing year months (*i*)



Note: NASS = National Agricultural Statistics Service.

Sources: USDA, Economic Research Service and USDA, NASS; USDA, Economic Research Service calculations.

Aggregate Futures-Based Forecasting Model

The goal of the aggregate futures-based model is to provide market analysts with an improved tool for translating futures prices into consistent forecasts of the U.S. season-average farm price for all wheat. The updated model uses an aggregate wheat futures price (HRW, SRW, and HRS)[7] and a re-computed basis.[8] The model requires data on the current and past year's aggregate futures prices for the nearby contract months, past monthly, and season-average all wheat farm prices, monthly basis (monthly farm price less nearby aggregate futures price), and past monthly marketing weights (figure 6).

Season-average price forecasts from the aggregate futures-based model are based on expectations reflected in the futures market and, as they become available, monthly farm prices reported by NASS. Using weighted current futures prices, a futures-adjusted farm price forecast is generated for each month in the marketing year. Monthly farm price forecasts are derived from the nearby futures contracts during the marketing year (July, September, December, March, and May). Each monthly

[7]The aggregate futures price is a weighted average of the three futures contracts. Weights for each futures price, HRW, SRW, and HRS, are derived from the proportion of production each class contributes to total wheat production computed as follows: Total HRW and HWW production is used to compute the production allocation share for HW production. This production allocation is then used to weight the HRW futures price. Next, total SWW and SRW production is used to compute the production allocation for SW production. This allocation share is used to weight the SRW futures price. Lastly, HRS wheat, HW spring wheat, SW spring wheat, and durum production is used to compute a production allocation for spring wheat production. This allocation share is used to weight the HRS futures price. These production shares are updated three times for each crop year: May, July, and September. These data come from NASS's Crop Production reports for May and July and Small Grains report for September.

[8]Basis is computed by taking the farm price for each marketing year month and subtracting the nearby futures contract average daily settlement price for that month. The basis calculation as used here reflects a composite of influencing factors since it represents an average of U.S. conditions rather than a specific geographic location. A number of traditional factors affect the basis, including, in particular, local supply and demand conditions, transportation and handling charges, transportation bottlenecks, availability and costs of storage, and crop quality.

forecast begins with the nearby futures contract price except when the contract expires in that month, in which case the next nearby contract is used.[9]

The futures prices are adjusted by an expected basis and weighted by the expected marketing for that month (see equation 1 for clarification).[10] The aggregate futures price is then computed as a weighted average price of the three wheat futures prices (figure 7). Once those weights are computed, they are applied to the monthly nearby average futures price for each of the three classes of wheat.

Because the aggregate futures model comprises prices relating to three classes of wheat instead of one, the futures model basis is better able to reflect cash market conditions. The prior model's basis used the monthly average farm price less the monthly average nearby HRW futures price. The aggregate model's monthly basis is equal to the monthly average farm price less the monthly average nearby aggregate futures price. Monthly farm prices (all wheat) and monthly marketing weights (all wheat) remain the same as in the original HRW wheat futures model.

A timeline of when futures price forecasts are made is provided in table 1. The SAFP forecasts created in May through July are based on adjustments to the nearby aggregate futures prices with the expected basis and monthly marketing weights. NASS-reported monthly farm prices are substituted for the aggregate futures-based forecasts as they become available during the marketing year, beginning in August and continuing through May of the following year. Thus, beginning in August, SAFP forecasts become a composite of actual monthly NASS farm prices and monthly aggregate futures-based forecasts. As the forecast cycle progresses, there are more months with reported farm prices and fewer months with futures-based forecast prices. Forecast error is expected to decline as the forecast period moves closer to the end of the marketing year because of increased information.

Table 2 provides an example of the forecast procedure, illustrating the steps needed to create forecasts in 2 months of the 2017/18 marketing year forecast cycle. The 2 months used for this illustration are May 2017 (1st month of forecast cycle, 13th month-ahead forecast, or month $m = 0$) and January 2018 (9th month of forecast cycle, 5th month-ahead forecast, or month $m = 8$, and marketing year month $i = 8$) (figure 5). A mathematical representation of the aggregate futures forecast model is presented in box 2.

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[9]For the month of May, it also uses the same nearby futures price as April.

[10]The prior HRW-only futures model relied upon a 5-year rolling average for both the basis and marketing weights. Appendix 1 provides an analysis of alternative basis and marketing weight computations to determine whether they provide more accurate estimates of these two variables used in the aggregate futures forecast model. A 3-year rolling average basis and a 5-year rolling average set of marketing weights provided the best estimates.

Panel A in table 2 presents an illustrated example that computes an aggregate futures-based forecast of the all wheat SAFP using data from May 4, 2017, the first month of the 2017/18 forecast cycle. Nine steps are involved in the forecast process:

1. Monthly prices are derived from the settlement prices of nearby futures contracts on May 4, 2017. Aggregate futures settlement prices from the Thursday before *WASDE* was released are used for forecast purposes.

2. The aggregate settlement prices from the July 2017 futures contracts, for example, are used for the monthly wheat prices in June. Subsequent monthly prices are similarly derived.

3. The monthly expected basis (3-year average) is shown for its use in computing the monthly farm price forecast.

4. The U.S. monthly farm price forecast is computed by adding steps 2 and 3.

5. Available actual monthly prices received by farmers are obtained from NASS and used to replace the monthly price derived from futures contracts.

6. Actual monthly farm prices are not available on May 4, 2017, for marketing year 2017/18.

7. Monthly marketing weights are provided. Historical monthly marketing weights (5-year average) are computed from NASS data and used to project current-year weights.

8. A weighted monthly farm price is computed from step 6, which is then multiplied by the weights calculated in step 7.

9. The SAFP forecast for 2017/18 is computed as the sum of the weighted monthly farm prices in step 8, or $4.82 per bushel.

A second illustration of the futures-adjusted forecasting model is presented in table 2, panel B. The forecast is made with data from January 11, 2017, the 9th month of the 2017/18 forecast cycle, which is the 8th month of the marketing year i = 8 (figure 5). Since the actual (NASS-reported) monthly farm price is available for June through November 2017, the corresponding monthly forecasts obtained from futures prices are replaced with the actual prices in step six. Thus, the forecast made on this date is derived from six NASS-reported monthly farm prices and six monthly futures prices. The forecast for 2017/18 as of January 11, 2017, is found in step 9, the sum of the weighted monthly forecasts, or $4.72 per bushel. The final NASS SAFP, as reported in the August *Agricultural Prices* report, was estimated to be $4.72 per bushel.

Table 2

Examples of an aggregate wheat futures model forecast of all wheat's season-average farm price (SAFP) for marketing year 2017/18

	Panel A. Forecasting date 05/04/2017											
	Jun 17	Jul 17	Aug 17	Sept 17	Oct 17	Nov 17	Dec 17	Jan 18	Feb 18	Mar 18	Apr 18	May 18
(1) Aggregate futures price (settlement) by contract		4.71		4.84			5.03			5.16		5.25
(2) Monthly aggregate futures price (cents/pound)	4.71	4.84	4.84	5.03	5.03	5.03	5.16	5.16	5.16	5.25	5.25	5.25
(3) Basis (5-year average)	-0.25	-0.36	-0.33	-0.27	-0.22	-0.02	-0.02	0.21	0.14	-0.04	-0.00	-0.12
(4) Adjusted monthly aggregate futures price [(2)+(3)]	4.46	4.48	4.51	4.77	4.81	5.01	5.14	5.37	5.30	5.21	5.25	5.13
(5) Observed farm price	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
(6) Spliced observed/forecast farm price[1]	4.46	4.48	4.51	4.77	4.81	5.01	5.14	5.37	5.30	5.21	5.25	5.13
(7) Marketing weight (5-year average)	0.136	0.18	0.132	0.091	0.059	0.048	0.076	0.074	0.051	0.064	0.046	0.043
(8) Weighted monthly farm prices [(6)*(7)]	0.607	0.806	0.595	0.434	0.284	0.240	0.391	0.397	0.270	0.333	0.242	0.221
(9) Aggregate futures-based forecast [sum of (8)]						4.82						

	Panel B. Forecasting date 01/11/2018											
	Jun 17	Jul 17	Aug 17	Sept 17	Oct 17	Nov 17	Dec 17	Jan 18	Feb 18	Mar 18	Apr 18	May 18
(1) Aggregate futures price (settlement) by contract										4.90		5.02
(2) Monthly aggregate futures price (cents/pound)							4.90	4.90	4.90	5.02	5.02	5.02
(3) Basis (5-year average)	-0.21	-0.40	-0.37	-0.38	-0.36	-0.15	-0.18	0.07	0.01	-0.13	-0.12	-0.23
(4) Adjusted monthly aggregate futures price [(2)+(3)]							4.72	4.97	4.91	4.89	4.90	4.79
(5) Observed farm price	4.37	4.77	4.83	4.65	4.64	4.73	N/A	N/A	N/A	N/A	N/A	N/A
(6) Spliced observed/forecast farm price[1]	4.37	4.77	4.83	4.65	4.64	4.73	4.72	4.97	4.91	4.89	4.90	4.79
(7) Marketing weight (5-year average)	0.136	0.177	0.132	0.097	0.064	0.047	0.073	0.076	0.051	0.062	0.046	0.037
(8) Weighted monthly farm prices [(6)*(7)]	0.594	0.844	0.638	0.451	0.297	0.222	0.345	0.378	0.250	0.303	0.225	0.177
(9) Aggregate futures-based forecast [sum of (8)]						4.73						
Seasonal Average Price						4.72						

Note: N/A = Not available. If available, use observed farm price; otherwise, use adjusted monthly average futures price from step 4.
[1]If observed farm price is available, use observed farm price, otherwise, use adjusted monthly average futures price from step (4).

Sources: CMEGroup (KCBT and CBOT), Minneapolis Grain Exchange; USDA, National Agricultural Statistics Service; and USDA, Economic Research Service.

Table 3

Directional season-average farm price (SAFP) movements correctly predicted by forecast method, marketing years, 2005/06-2019/20.

Forecast months (*m*)	Positive SAFP movement – 9 times out of 15 years [2]			Negative SAFP movement–6 times out of 15 years[3]		
	Forecast Methods					
	HRW futures forecast	Aggregate futures forecast	*WASDE* projections	HRW futures forecast	Aggregate futures forecast	projections
	Percent			Percent		
Pre-harvest season (*13th month-ahead forecast*)						
May (0)	75.0	75.0	62.5	80.0	80.0	80.0
Harvest season (*12th month to 9th month-ahead forecasts*)						
June (1)	62.5	62.5	62.5	100.0	60.0	80.0
July (2)	87.5	100.0	62.5	100.0	100.0	100.0
August (3)	87.5	87.5	87.5	100.0	100.0	100.0
September (4)	87.5	87.5	87.5	100.0	100.0	100.0
Post-harvest season (*8th month to 1 month ahead forecasts*)						
October (5)	100.0	100.0	87.5	100.0	100.0	100.0
November (6)	87.5	87.5	87.5	100.0	100.0	100.0
December (7)	87.5	87.5	87.5	100.0	100.0	100.0
January (8)	100.0	100.0	87.5	100.0	100.0	100.0
February (9)	100.0	100.0	87.5	100.0	100.0	100.0
March (10)	100.0	100.0	87.5	100.0	100.0	100.0
April (11)	100.0	100.0	87.5	100.0	100.0	100.0
May (12)	100.0	100.0	100.0	100.0	100.0	100.0
	Average of the forecast months			Average of the forecast months		
	90.4	91.3	82.7	98.5	95.4	96.9

Note: HRW = hard red winter, *WASDE= World Agricultural Supply and Demand Estimates*, and marketing year = begins June 1st and ends May 31st.

[1]Between marketing years 2005/06 - 2019/20 (15 years), the SAP rose from the prior marketing year nine times and declined from the prior marketing year six times (figure 5).

[2]It is a correct prediction if the forecast/projection predicts a higher SAP than last year and the actual SAP turns out to be higher.

[3]It is a correct prediction if the forecast/projection predicts a lower SAP than last year and the actual SAP turns out to be lower.

Source: USDA, Economic Research Service.

Mathematical representation of the aggregate futures forecast model

Model

FM_m^t is the aggregate futures-adjusted forecast for the all wheat season-average farm price for marketing year *t* made in month *m* and computed as follows:

Equation 1

$$FM_m^t = \begin{cases} \sum_{i=1}^{12} W_i^t\left(F_{i,m}^t + B_i^t\right) & \text{for } 0 \le m \le 2 \\ \sum_{i=m-2}^{12} W_i^t P_i^t + \sum_{i=m-1}^{12} W_i^t\left(F_{i,m-1}^t + B_i^t\right) & \text{for } 3 \le m \le 12 \end{cases}$$

Where:

FM_m^t = forecasts of the SAFP made monthly, = 0, 1, 2, 3, ……. 12 (table 1),

$0 \le m \le 2$ are the first 3 months of the forecast cycle (May through July), $3 \le m \le 12$ are the next 10 months of the forecast cycle (August through May) (table 1),[11]

i = wheat marketing year has 12 months, June through May, *i* = 1, 2, 3, …12, in June both *m* and *i* are equal to 1 (table 1),

FM_m^t = nearby aggregate futures price (hard red spring (HRS), hard red winter (HRW), and soft red winter (SRW)) for the contracts expiring in month *i* observed on a given day in month *m*,

P_i = actual farm price in month *i*,[12]

W_t = expected marketing weight (rolling 5-year average) for month ,

B_i = expected basis (farm price less aggregate futures price) (rolling 3-year average) for month ,

t = represents marketing years 2005/06 through 2019/20.

Data and Sources

Data for marketing years 2001/02 through 2018/19 are used to construct a rolling 3-year average monthly basis and 5-year average monthly marketing weights. The forecast evaluation periods cover the marketing years 2005/06 through 2019/20. The aggregate futures settlement price for the Thursday before the *World Agricultural Supply and Demand Estimates* (*WASDE)* release is used to capture the market information available at that time. During the sample period, the *WASDE* release time underwent one change, but no change was required in the choice of day for the settlement price.*

[11]The 13 forecasting months are given identifying numbers of 0, 1, 2… 12 so that equation (1) notations can be made. See table 1 for further clarifications.

[12]As of January 2015, an actual December monthly farm price was not available until February, the 10th month of the forecast cycle. NASS discontinued providing all mid-month price estimates. Previously, the December mid-month price estimate would have been used in January as a farm price. Thus, this change requires the use of an additional month of an adjusted futures price.

Data and Sources

Nearby futures prices – Aggregated HRS, HRW, and SRW wheat contracts traded on the Minneapolis Grain Exchange (MGE) and CMEGroup (Kansas City Board of Trade (KCBOT) and Chicago Board of Trade (CBOT)), 2000/01 to 2019/20).

Wheat production – Annual wheat production is reported by National Agricultural Statistics Service (NASS) in the May *Crop Production*, July *Crop Production*, and September *Small Grains Annual Summary*. Each futures price is weighted by its computed proportion of estimated total annual wheat production.

Average farm prices – All wheat prices received by producers (monthly and annual) (USDA, NASS, *Agricultural Prices*, 2000/01 to 2019/20).

Basis – Monthly average farm price reported by NASS minus nearby monthly average aggregate futures price, 3-year rolling average, calculated by the authors.

Marketing weights – Monthly all wheat marketing weights are reported in *Agricultural Prices,* 5-year rolling average, calculated by the authors (USDA, NASS, *Agricultural Prices,* 2000/01 to 2019/20).

WASDE SAFP projections – Midpoint of monthly *WASDE* projections of the season-average price range are reported in *WASDE* (USDA, OCE, 2005/06 to 2019/20).

[*]For example, the futures closing is 1:15 p.m. central time and as of May 1994, the *WASDE* release occurred at 8:30 a.m. eastern time. In January 2013, the *WASDE* release was moved to noon eastern time. Regardless of the change in *WASDE* release time, this analysis uses the futures settlement price from the day before *WASDE* release.

Evaluation Criteria for the Futures-Based Forecasts and *WASDE* Projections

Several criteria were considered to evaluate the performance of the different forecast/projection methods relative to the NASS final SAFP.[13] The evaluation required an assessment of 13 monthly forecasts/projections for 1 forecast cycle. Evaluating forecast performance in each month facilitated an examination of how projections respond when new information becomes available in the market and as the wheat marketing year progresses. Prior to checking the accuracy of the different forecast/projection methods, we also examined whether these forecast methods could correctly predict the direction of movement in the SAFP.[14] Additional performance criteria included the number of times the forecast/projection was above or below the final NASS SAFP and error statistics such as mean error, mean absolute error, and mean absolute percentage error.

The error for a given SAFP forecast made in month *m* for marketing year t was defined as

Equation 2

$$E_m^t = (FM_m^t - SAFP^t),$$

where: is the futures-based model forecast or *WASDE* projection of the SAFP made at month of the forecasting cycle for marketing year. The mean error (ME), mean absolute error (MAE), and mean absolute percentage error (MAPE) were computed and defined for each forecast as follows:

Equation 3

$$ME_m = \frac{1}{T}\sum_{t=1}^{T}(FM_m^t - SAFP^t), \quad \text{(mean error)}$$

Equation 4

$$MAE_m = \frac{1}{T}\sum_{t=1}^{T}\left|(FM_m^t - SAFP^t), \quad \text{(mean absolute error)}\right.$$

Equation 5

$$MAE_m = \frac{1}{T}\sum_{t=1}^{T}\left|(FM_m^t - SAFP^t), \quad \text{(mean absolute percentage error)}\right.$$

where: *t* = for marketing year 2005/06 through 2019/20.

A negative ME implies an under-estimation of the SAFP, while a positive ME implies over-estimation. Although the ME represents forecast bias, this statistic could be misleading due to a few very large over- or under-estimation errors. The MAE avoids the cancellation of positive and negative predication errors when computing the ME. The MAPE accounts for the price level change by representing the forecast errors on a percentage basis. Over time, tracking whether the forecasts are

[13]The forecast performance of *WASDE* projections relative to the SAFP are computed in the same way as for the futures-based forecasts. Instead of using FM_m^t in the above equations, one would use the midpoint for *WASDE* projections.

[14]For example, it is a correct prediction if the forecast/projection predicts higher/lower than last year and the actual SAFP is higher/lower than last year.

Table 4

Comparison of performance criteria by forecast methods: naive model (last year's season-average farm price (SAFP), hard red winter (HRW) only future model1 (actual basis and marketing weights) marketing years 2005/06 - 2019/120.

	Naïve Model (Last year's SAFP)				HRW only futures model forecasts (5-year average basis and marketing weights)				Aggregate futures model forecasts (3-year average basis and 5-year average marketing weights				Aggregate futures model with actual basis and marketing weights			
	Performance criteria				Performance criteria				Performance criteria				Performance criteria			
Forecast months (*m*)	Forecast over/under actual	ME	MAE	MAPE	Forecast over/under actual	ME	MAE	MAPE	Forecast over/under actual	ME	MAE	MAPE	Forecast over/under actual	ME	MAE	MAPE
	Number	Dollars/bushel		Percent	Number	Dollars/bushel		Percent	Number	Dollars/bushel		Percent	Number	Dollars/bushel		Percent
Pre-harvest season (13th month-ahead forecast)																
May (0)	6/9	-0.08	0.93	17.01	8/7	0.16	0.88	14.93	9/6	0.23	0.81	13.26	8/7	-0.09	0.70	12.32
Harvest season (12th month to 9th month-ahead forecasts)																
June (1)	6/9	-0.08	0.93	17.01	10/5	0.23	0.82	14.41	11/4	0.28	0.93	15.15	10/5	0.28	0.70	13.14
July (2)	6/9	-0.08	0.93	17.01	8/7	0.14	0.43	7.85	10/5	0.20	0.45	9.51	12/3	0.24	0.50	8.95
August (3)	6/9	-0.08	0.93	17.01	9/6	0.23	0.37	6.48	10/5	0.27	0.29	6.44	11/3	0.30	0.37	6.16
September (4)	6/9	-0.08	0.93	17.01	8/7	0.08	0.22	3.99	11/4	0.10	0.13	3.50	8/7	0.10	0.24	4.10
Post-Harvest season (8th month to 1 month ahead forecasts)																
October (5)	6/9	-0.08	0.93	17.01	11/4	0.05	0.17	3.04	9/6	0.08	0.11	3.00	8/7	0.05	0.16	2.78
November (6)	6/9	-0.08	0.93	17.01	8/7	0.04	0.15	2.76	8/5	0.06	0.09	2.40	8/7	0.04	0.13	2.18
December (7)	6/9	-0.08	0.93	17.01	7/8	0.04	0.19	3.35	8/7	0.06	0.13	3.30	8/7	0.02	0.11	2.00
January (8)	6/8	-0.05	0.96	18.03	10/4	0.06	0.13	2.53	9/5	0.08	0.09	2.58	8/5	0.04	0.08	1.29
February (9)	6/9	-0.08	0.93	17.01	8/7	0.07	0.13	2.25	9/5	0.09	0.11	2.49	9/4	0.03	0.07	1.14
March (10)	6/9	-0.08	0.93	17.01	10/5	0.07	0.12	2.12	9/5	0.08	0.08	2.06	9/5	0.02	0.04	0.71
April (11)	6/9	-0.08	0.93	17.01	11/3	0.06	0.08	1.32	11/3	0.07	0.05	1.31	6/6	0.01	0.02	0.35
May (12)	6/9	-0.08	0.93	17.01	12/3	0.06	0.07	1.26	11/3	0.06	0.04	1.11	6/2	0.00	0.01	0.16
Average	6.0/8.92				9.2/5.6				9.6/4.8				8.6/5.3			
Total	78/116				120/73				126/61				111/68			
Balance of forecasts/projections (over/under) summary																
	Number	Percent			Number	Percent			Number	Percent			Number	Percent		
Over	78	40			120	62			126	65			111	57		
Under	116	60			73	37			61	31			68	35		
Equal	0	0			1	1			7	4			15	8		
Total	194	100			194	100			194	100			194	100		

Note: ME = mean error, MAE = mean absolute error, MAPE = mean absolute percent error, and markeing year = begins June 1st and ends May 31st.
Shaded area represents the lower MAPE. However, differences are not statistically significant, except December, at the 5 percent level based on Modified Diebold Mariano (MDM) test statistic (Harvery et al. (1997).

Sources: USDA, Economic Research Service and USDA, Office of the Chief Economist.

Table 5

Comparison of performance criteria by forecast methods: Aggregate futures model and *World Agricultural Supply and Demand Estimates (WASDE)* projections, marketing years 2005/06 - 2019/20.

	Aggregate futures model forecasts (3-year average basis and 5-year average marketing weights)				*WASDE* Projections			
	Performance criteria				Performance criteria			
Forecast months (*m*)	Forecast over/under actual	ME	MAE	MAPE	Forecast over/under actual	ME	MAE	MAPE
	Number	Dollars/bushel		Percent	Number	Dollars/bushel		Percent
Pre-harvest season (13th month-ahead forecast)								
May (0)	9/6	0.23	0.81	13.26	7/8	-0.23	0.62	10.86
Harvest season (12th month to 9th month-ahead forecasts)								
June (1)	11/4	0.28	0.93	15.15	8/7	-0.17	0.63	10.77
July (2)	10/5	0.20	0.45	9.51	8/7	-0.09	0.50	8.87
August (3)	10/5	0.27	0.29	6.44	9/6	0.04	0.34	5.90
September (4)	11/4	0.10	0.13	3.50	7/8	0.01	0.27	4.75
Post-harvest season (8th month to 1 month ahead forecasts)								
October (5)	9/6	0.08	0.11	3.00	7/8	0.01	0.16	2.70
November (6)	8/5	0.06	0.09	2.40	6/8	-0.01	0.14	2.44
December (7)	8/7	0.06	0.13	3.30	6/9	-0.02	0.09	1.62
January (8)	9/5	0.08	0.09	2.58	5/9	0.00	0.08	1.49
February (9)	9/5	0.09	0.11	2.49	6/8	0.01	0.06	0.99
March (10)	9/5	0.08	0.08	2.06	7/7	0.02	0.04	0.78
April (11)	11/3	0.07	0.05	1.31	8/6	0.02	0.06	0.99
May (12)	11/3	0.06	0.04	1.11	10/3	0.01	0.03	0.46
Average	9.6/4.8				7.2/7.2			
Total	126/61				94/94			
Balance of forecasts/projections (over/under) summary								
	Number	Percent			Number	Percent		
Over	126	65			94	49		
Under	61	31			94	49		
Equal	7	4			6	2		
Total	194	100			194	100		

Note: Shaded area represents the lower MAPE. However, differences are not statistically significant, except December, at the 5 percent level based on Modified Diebold Mariano (MDM) test statistic, Harvery et al. (1997).

Sources: USDA, Economic Research Service and USDA, Office of the Chief Economist.

Evaluation of the Aggregate versus HRW Wheat Futures Model Forecasts

Prior to comparing the forecasts of the two futures forecast models, HRW-only versus aggregate, these forecasts were compared to a non-futures derived forecast to illustrate the value of futures forecast methods. For comparison, a naïve model (last year's SAFP) was used as our non-futures model. It is clear from table 4 that both the HRW-only futures model and aggregate futures model provide better forecasts than the naïve model, as indicated by the MAPEs, which are generally statistically significant from the naïve model.

After demonstrating the value of a futures-price based forecast in estimating the all wheat SAFP, our main interest turned to whether the aggregate futures-based method improves upon the HRW futures-based price forecasting method. Table 3 shows the directional price movement correctly predicted by each method for both upward and downward movements. As can be seen, the aggregate futures-based forecasts performed slightly better than the HRW futures-based forecasts during upward SAFP movements. From 2005/06 through 2019/20, there were 9 years when the SAFP rose, and the aggregate futures-based model predicted this at an average of 91.4 percent compared to the HRW-only model average of 90.6 percent. However, during this same period, there were 6 years when the SAFP declined, and the HRW model was able to predict downward SAFP movements slightly better than the aggregate futures method 98.7 percent versus 96.1 percent.[15] Overall, the predictability of SAFP directional movement was about the same for both futures-based methods, as the sample size was too small to provide reliable statistical significance.

Based on the evidence provided in an analysis of various error statistics, the aggregate wheat futures model demonstrated better performance than the HRW wheat futures model; however, these differences were not statistically significant (table 4). The MAPE for the aggregate wheat futures model was lower than the HRW futures model for 9 out of 13 forecasting months. In general, MAPE differences between the two forecast methods were small. However, out of all forecasts between marketing years 2005/06 and 2019/20, the aggregate futures model forecasts had lower absolute errors in 111 out of 194 forecasts or 58 percent of the time.[16] Furthermore, the aggregate futures model forecasts generally did better than the HRW model for 8 out of 15 forecast years, representing a forecast cycle where the aggregate model had lower absolute errors at least 8 or more times out of 13 times per marketing year than the HRW model (appendix 2).

Both the aggregate futures model and the HRW futures model tended to have a positive forecast bias, i.e., the SAFP forecasts tended to be higher than the final NASS SAFP (table 4). The aggregate model's positive forecast bias was 65 percent compared to the HRW model at 62 percent. Both model's positive forecast bias could be because the period examined was more volatile than previous periods.[17] When prices rise, the basis tends to widen and marketing increases. Either model is slow to adjust to these changes, and since the basis does not widen immediately, the forecasted futures prices tend to be overstated. A similar situation occurred during the 2007/08 marketing year when prices rose dramatically early in the season, only to decline in the later months of the marketing year (figure 7).

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[15]The year that accounted for the difference between these two models was 2016/17, a year with increased HRW production and lower prices.

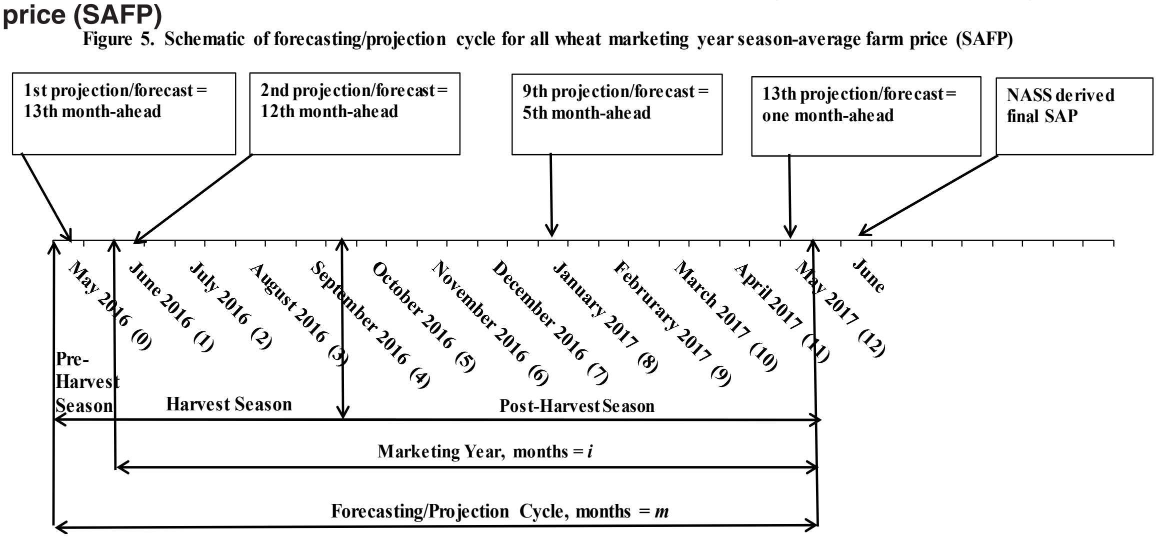
[16]Because the Federal Government was shut down in January 2019, there are 194 forecasts during this period rather than 195.

[17]Coefficient of variation of the SAFPs for 2005/06 to 2019/20 was 23.6 compared to the prior 15 marketing years, 1990/91 to 2004/05, when it was 18.5. Many factors contributed to this volatility, including biofuels and domestic and foreign production shortfalls.

Regardless of which futures model is examined (HRW wheat or aggregate wheat), the pattern of monthly MAPEs followed expectations and declined over the forecast cycle (table 4). Forecasts based on all futures prices prior to the start of the marketing year had large MAPEs because of incomplete information on crop size, crop condition, and demand prospects. However, after the June NASS *Acreage* report and the July NASS *Crop Production* reports were published and reflected in the July forecasts, the MAPEs represented a decline of 4 to 7 percent since the beginning of the forecast cycle. Furthermore, declines were observed during the post-harvest season after the release of the September NASS *Small Grains Annual* report. The October forecast incorporates these changes and is generally one of the more accurate forecasts, as more information is known about the actual crop size, demand prospects, and prices. After October, about 60 percent (5-year average 2015/16 to 2019/20) of the wheat crop is marketed, so thereafter, it takes a large price swing to make a noticeable change in the SAFP.

Despite the analysis of alternative historical bases, marketing weights, and change in basis from a 5-year to a 3-year average discussed in appendix 1, improved estimates of the basis and marketing weights are needed. It is difficult to convert historical bases or marketing weights into ones that reflect current market conditions. For example, if one had the actual basis and marketing weights for the past 15 years, the aggregate futures forecast model could improve, as shown in table 4. Many of the forecast months would have from 1 to 2 percent lower MAPEs. While MAPEs declined for most months, the remaining errors can be attributed to the futures price used or the estimation method used to compute an aggregate futures price. Different basis and marketing weight estimating approaches are possible future extensions of the current research.

Figure 5
Schematic of forecast/projection cycle for all wheat marketing year season average farm price (SAFP)



Note: The National Agricultural Statistics Service (NASS) derived final SAFP was made available in the June *Agricultural Prices* report from 2006 through 2017. However, starting in 2018 and beyond, that release date was changed to the August *Agricultural Prices* report.

Source: USDA, Economic Research Service.

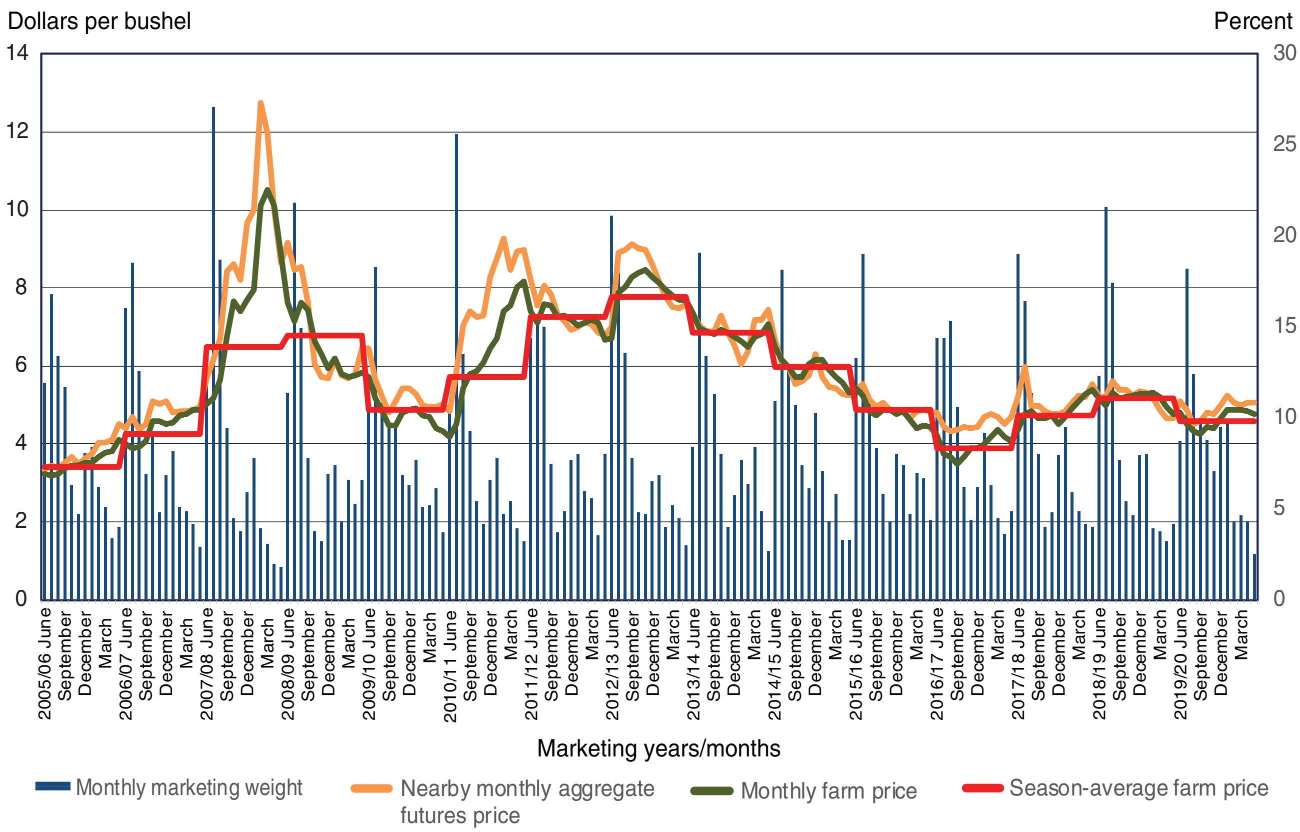
Potential for Contribution to USDA Projections

In addition to examining how the aggregate futures forecasts performed relative to the existing HRW-only model or naïve model, we compared the aggregate forecasts with the *WASDE* SAFP projections, the official USDA projection (a benchmark for industry comparisons). If aggregate wheat futures forecasts compared well (improve direction of change or improve forecast accuracy) with *WASDE* projections, this strengthens the case for using the aggregate futures-adjusted model as a tool to assist analysts in forecasting the monthly all wheat SAFP.

The aggregate futures-based model provided more accurate predictions of upward SAFP movement than *WASDE* projections, particularly during the pre-harvest season, the early part of the harvest season, and most of the post-harvest season (table 3). In contrast, the *WASDE* projections were able to predict downward price movements slightly better than the aggregate futures-based model. Compared to the *WASDE* projections, the aggregate futures-based model was a better predictor of the overall directional moves of the monthly SAFP forecasts. However, it is doubtful that these differences are statistically significant because the small sample size may not lead to meaningful test results. Although *WASDE* projections had lower MAPEs for most of the forecast cycle compared to the aggregate futures forecasts (table 5),

Figure 6

Overview of U.S. wheat prices and marketings



Sources: CME Group, USDA, National Agricultural Statistics Service, and USDA, Economic Research Service calculations.

the aggregate model provided lower absolute errors for 40 percent of the 194 forecasts. Both forecast methods had fairly similar errors during most of the forecast cycle beginning in July and continuing to the following May. A notable difference is that for the first 2 months of the forecast cycle, May and June, the aggregate futures MAPEs and MAEs were noticeably larger than the *WASDE* projections.

This is likely attributable to differences between the futures market and *WASDE* evaluation strategies of the unknown supply and demand situation prior to the actual crop year. For example, the futures market may add a weather premium to its prices early in the forecast cycle. Another difference between the two forecasting methods was the balance in forecasting. Overall, *WASDE* projections had less bias than the aggregate futures forecasts since they were more balanced with 49 percent over, 49 percent under, and 2 percent equal to the actual SAFP, compared to aggregate futures forecasts of 65 percent over, 31 percent under, and 4 percent equal to the actual SAFP.[18] An over-forecasting model is reflected in the ME where the aggregate futures model forecasts are positive compared to a more balanced model, leading to a smaller positive or negative ME error for the *WASDE* projections.

As expected, the MAPEs generally declined throughout the forecast cycle for both forecasting methods but started at a higher level for the aggregate futures model (table 5). What can be seen in table 5 is that as more information becomes available throughout the forecast cycle, forecast errors decline.[19, 20] For instance, there was a MAPE reduction of about 2 to 4 percent for the *WASDE* projections and aggregate futures model forecasts, respectively, between May ($m = 0$) and July ($m = 2$). This reflects the incorporation of new crop information reported in the June *Acreage* report, May and July *Crop Production* reports, and *Crop Progress* reports available during these months. Continued improvement in forecasting accuracy from July to August ($m = 2$ to 3) reflects, in part, the availability of information on the new crop's estimated production.

Improvement in forecast performance between August and October (m = 3 and 5) may, in part, be attributed to information concerning the production of the new crop and the actual NASS monthly farm prices for June and July that were available to aggregate futures forecasts and *WASDE* projections in October.[21]Additional information—such as the global supply and demand outlook—also could contribute to the continued decline in forecast errors for the remainder of the forecast cycle. Further error reduction in the post-harvest period was minimal after January's adjustments to crop production by NASS and reflected in the January MAPEs. The forecasts/projections from both aggregate futures and *WASDE* generally stabilized and approached the final SAFP in the October through November period for many of the marketing years (appendix 2).

[18]Additional research providing improved forecasts of the basis and marketing weights could contribute to a more balanced forecast

[19]Each forecasting method has access to market information such as crop progress, planting intentions, acreage reports, agricultural prices, crop production, weekly export sales reports, and actual monthly exports. Thus, we may not expect to find large differences between the WASDE projections and futures-adjusted forecasts. However, WASDE forecast projections are still lower than the aggregate forecasts in many forecast months because the USDA Interagency Commodity Estimates Committee has access to information not available to the public.

[20]The study objectives do not include testing the statistical significance of the decline in forecast errors between forecast periods. However, conducting these tests would provide logical follow-up work to this study. For recent work on estimating the effect of information on prices, see Adjemian (2012).

[21]Prior to January 2015, there also would have been information about the mid-month price for September. However, as of January 2015, NASS no longer reports mid-month prices.

Aggregate Futures Forecasts Contribute to the *WASDE* SAFP Projections: An Example Provided by Marketing Year 2017/18

When the aggregate model forecasts were compared with the *WASDE* projections and with forecasts from the HRW wheat futures model, the aggregate model's usefulness in forecasting the monthly SAFP was made clear (figure 8). For instance, we examined marketing year 2017/18 and found the aggregate model provided more accurate information about both the SAFP level and direction of change than the HRW wheat futures model alone. Accordingly, by providing improved SAFP forecasts, the aggregate wheat futures model has the potential to enhance the all wheat SAFP projections reported in the monthly *WASDE*.

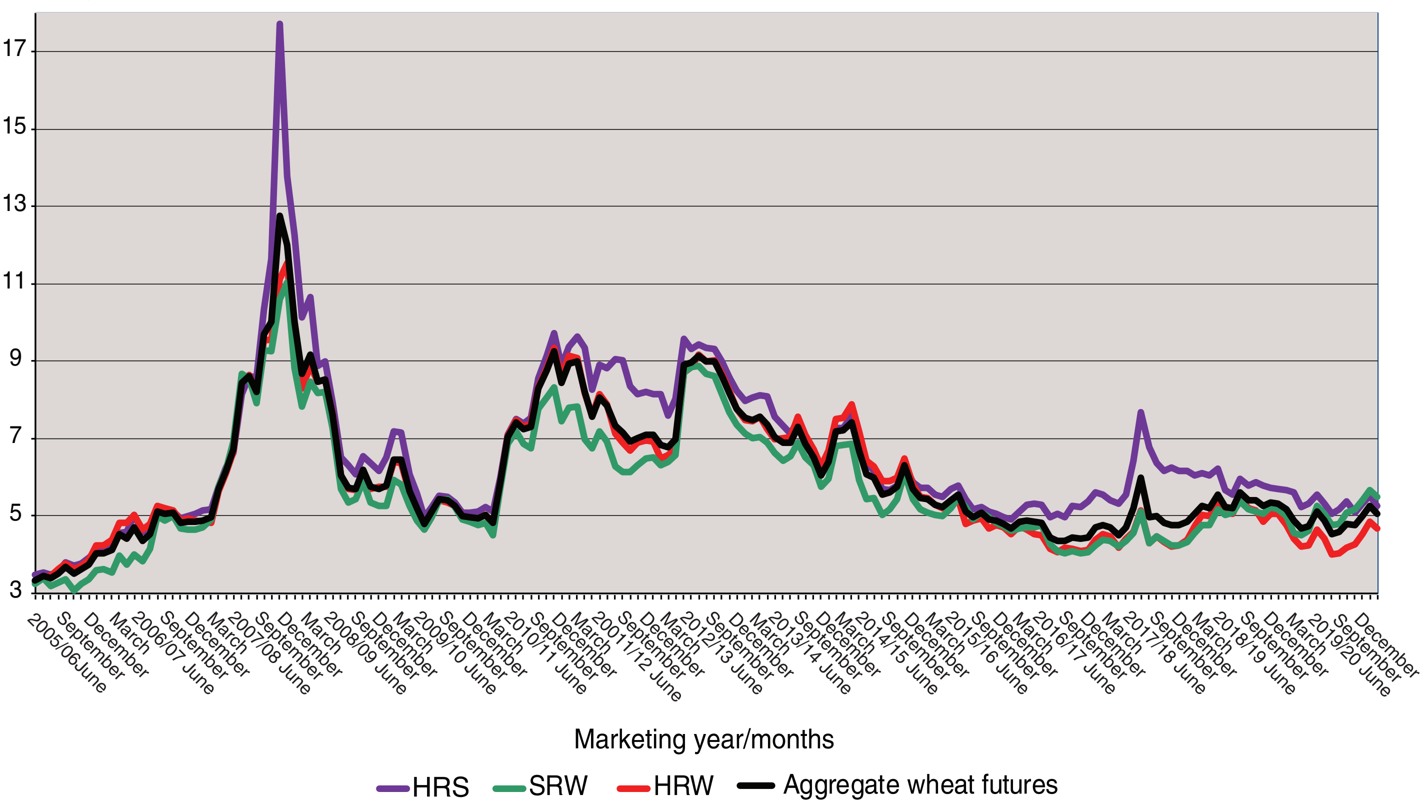
As an example, the May 2017 forecast (marketing year 2017/18) for the all wheat SAFP was the first for the forecast cycle and expected to be greater than the prior year's $3.89 per bushel. The all wheat SAFP was expected to rise based on expectations for reduced production due to reduced planted area and a return to trend yields. While consumption was expected to fall slightly, on net the balance sheet for 2017/18 was expected to be tighter than the year prior with a stock-to-use ratio of 0.417, the lowest in 3 years. Lower stocks-to-use ratios generally represent a tighter balance sheet and provide upward momentum for the all wheat SAFP. During a period of declining stocks-to-use ratios and a tightening balance sheet, both futures models accurately anticipated a larger SAFP (aggregate wheat $4.82 and HRW wheat $4.61) than the *WASDE* projections ($4.25 per bushel).

The July aggregate futures forecast of $5.91 per bushel strongly indicated that wheat prices would strengthen substantially in the coming months. Mirroring the direction of change, the July *WASDE* SAFP projection was raised 50 cents month to month to $4.80 per bushel. Dry conditions in the Northern Plains trimmed away durum and other spring prospects, even as winter wheat yields were lifted, supporting an all wheat production forecast for 2017/18 that was expected to be 24 percent below the 2016/17 estimate. In August, the all wheat U.S. production forecast was cut by an additional 21 million bushels. Growing global supplies of grain more than offset the price-boosting effects of the production cut, and the *WASDE* SAFP projection remained at $4.80 per bushel for another month. In contrast, the aggregate wheat model forecast a $0.77 per bushel decline in the SAFP on the changing global outlook. In September, the aggregate futures price forecast dropped a further 36 cents, sending strong signals of downward pressure on the *WASDE* SAFP projection and ultimately underpinning a 20-cent month-to-month price drop. Marketing and price prospects for the 2017/18 U.S. crop continued to dim after news of phenomenal growing conditions in Russia and the larger Black Sea region.

As the marketing year wore on and export prospects dimmed amid tremendous competition from the Black Sea region, the stock-to-use ratio rose steadily from the initial forecast of 0.417 to a final estimate of 0.555. Under ordinary circumstances, an increasing stocks-to-use ratio would imply a lower SAFP. Also, the HRW-focused futures price model would have reflected the sharp drop in cash HRW prices, the result of both weak use (due largely to strong global competition) and low protein levels. However, the aggregate futures price model considered both global market conditions and the SAFP-boosting effects of strong protein premiums for HRS wheat relative to HRW wheat, which served to offset lower cash prices for low-protein HRW wheat. From September through the balance of the forecast cycle, minor refinements to the SAFP forecasts were suggested by the aggregate price model and mirrored in the *WASDE* SAFP projections. Ultimately, at the conclusion of the forecast cycle, the aggregate price model predicted a SAFP of $4.75 per bushel, slightly above NASS's ultimate SAFP of $4.72 per bushel. The *WASDE* SAFP largely moved in concert with the aggregate price model forecast, albeit at a 5-cent discount or $4.70 per bushel. The sensitivity of the model, which incorporates prices for three wheat contracts, captured well the complex market dynamics across the U.S. wheat classes (figure 7).

Figure 7

Overview of U.S. wheat prices and marketing years 2005/06 to 2019/20



Note: HRS = Hard red spring, HRW = Hard red winter, SRW = Soft red winter, and marketing year = begins June 1st and ends May 31st.

Sources: CME Group, Minneapolis Grain Exchange, and USDA, Economic Research Service calculations.

Summary and Conclusions

In response to interest in refinements to the HRW futures forecast model, we developed an aggregate wheat futures-based forecast model that better reflects the diverse wheat market. The aggregate model performed better than the HRW-focused model at tracking the *WASDE* SAFP price and predicting the official NASS SAFP. Relative to the HRW-only model, the aggregate futures model was more accurate and better able to predict positive directional SAFP forecast movement. Both models tended to over-forecast in contrast to a preferred balance. The aggregate model forecasts were better at tracking *WASDE* projections than the HRW-only model. Although the aggregate model tracked well with the *WASDE* projections, as expected, *WASDE* projections were more accurate and provided a more balanced set of projections. However, the aggregate model forecasts provided a better prediction of positive directional SAFP forecast movement than the *WASDE* projections. The aggregate futures model was also better than the HRW-only model at predicting the final NASS SAFP.

The aggregate model's improved forecasts clearly provide a benefit to all analysts forecasting the SAFP. In addition, the model is easily updated and provides the analyst with the flexibility to adjust the basis or marketing weights, depending on expectations for marketing conditions, thus leading to a potential increase in forecast performance. Additional research on aggregate futures price calculations and basis/marketing weight estimation are suggested as extensions to the current research.

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Appendix 1—Analysis of alternative bases and marketing weights

The hard red winter (HRW)-only futures forecast model used a 5-year monthly rolling average of historical monthly basis and marketing weights for the estimates of these two variables. An additional analysis was conducted that looked at several alternatives for both the basis and marketing weights. For both variables we analyzed the following alternatives: 7-year monthly olympic (7-year average deleting high and low observation) average, 5-year monthly olympic (5-year average deleting high and low observation), 5-year monthly average, 4-year monthly average, 3-year monthly average, 2-year monthly average, and last year's monthly basis. For a basis estimate, we applied a simple regression equation to each of the alternatives. For example, the current monthly basis is a function of a constant and the 5-year monthly average basis, and the same for each of the remaining six alternatives. None of these historical basis functions performed very well. The best performance was by the 3-year monthly average basis function with an adjusted R2 of 0.003, with the constant term statistically significant but not the alternative basis term. The method for basis estimates will require future research. One suggestion was to incorporate an established seasonality of the basis into the basis estimates. Bekkerman et al. (2016) showed that recent futures prices, protein content, and harvest information are more important for accurate basis forecasts than historical basis averages.

Next, we applied a simple regression equation to each of the seven alternative monthly marketing weights. For example, the current monthly marketing weight is a function of a constant and a 5-year monthly average basis and the same for each of the remaining six alternatives. The best performance was by the 5-year monthly average marketing weight function and a tie with the 7-year monthly olympic average marketing weight with an adjusted R2 of 0.82, with the constant term not statistically significant, but the alternative marketing weight term had statistical significance.

Two aggregate futures models were established and analyzed, one with a 3-year average basis and 5-year average marketing weight and one with a 7-year olympic average basis and marketing weight. The aggregate futures forecast model with a 3-year monthly average basis and a 5-year monthly average marketing weight is used for the aggregate futures model, based on the comparative results for the two models' mean absolute percentage error (MAPE).

Appendix 1, Table 1

Comparison of performance criteria by forecast methods: aggregate model (3-year monthly average basis and 5-year monthly average marketing weight) versus aggregate model (7-year monthly olympic average basis marketing weight) marketing years, 2005/06-2019/20.

	Aggregate 3-year average basis and 5-year average marketing weights				Aggregate 7-year olympic average basis and 7-year olympic average marketing weights			
Forecast months	Forecast over/under actual	ME	MAE	MAPE	Forecast over /under actual	ME	MAE	MAPE
	Number	Dollars/bushel		Percent	Number	Dollars/bushel		Percent
Pre-harvest season (13th month-ahead forecast)								
May (0)	9/6	0.23	0.81	13.26	7/8	0.09	0.79	13.88
Harvest season (12th month to 9th month-ahead forecasts)								
June (1)	11/4	0.28	0.93	15.15	10/5	0.19	0.72	13.18
July (2)	10/5	0.20	0.45	9.51	8/7	0.20	0.42	7.94
August (3)	10/5	0.27	0.29	6.44	12/3	0.31	0.37	6.53
September (4)	11/4	0.10	0.13	3.50	9/5	0.13	0.23	3.92
Post-harvest season (8th month to 1 month ahead forecasts)								
October (5)	9/6	0.08	0.11	3.00	12/3	0.10	0.18	3.20
November (6)	8/5	0.06	0.09	2.40	9/6	0.08	0.18	3.30
December (7)	8/7	0.06	0.13	3.30	9/5	0.07	0.21	3.75
January (8)	9/5	0.08	0.09	2.58	9/5	0.07	0.17	3.02
February (9)	9/5	0.09	0.11	2.49	9/5	0.08	0.17	2.97
March (10)	9/5	0.08	0.08	2.06	10/5	0.06	0.14	2.40
April (11)	11/3	0.07	0.05	1.31	11/3	0.04	0.10	1.72
May (12)	11/3	0.06	0.04	1.11	9/4	0.03	0.09	1.58
Average	9.6/4.8				9.5/4.9			
Total	125/63				124/64			
Balance of forecasts/projections (positive/negative) summary								
	Number	Percent			Number	Percent		
Over	125	64			124	64		
Under	63	33			64	33		
Equal	6	3			6	3		
Total	194	100			194	100		

Note: ME = mean error, MAE = mean absolute error, MAPE = mean absolute percent error, and markeing year = begins June 1st and ends May 31st.

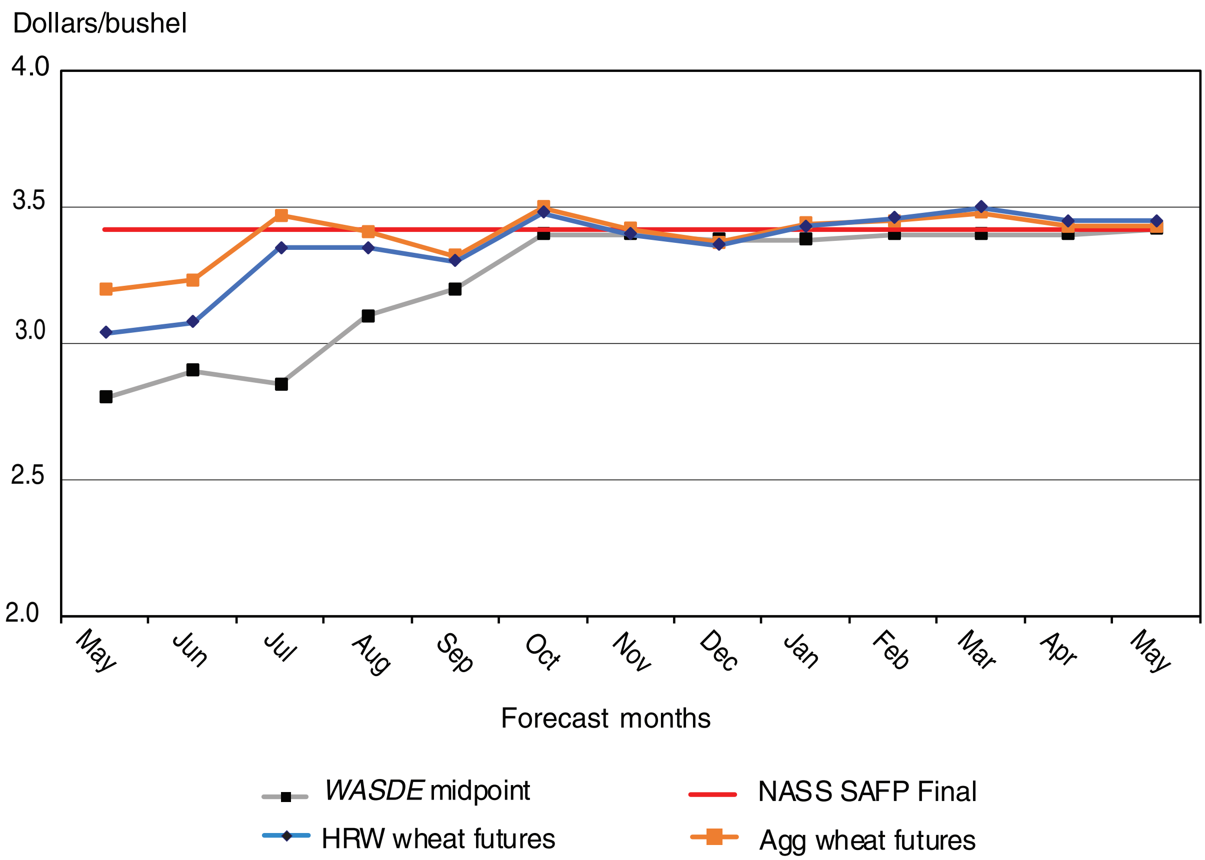
Shaded area represents the lower MAPE. However, differences are not statistically different at the 5 percent level based on Modified Diebold Mariano (MDM) test statistic (Harvery et al. (1997).

Source: USDA, Economic Research Service.

Appendix 2—Forecast comparisons of the three forecast methods relative to the final season-average farm price (SAFP), marketing years 2005/06 — 2019/20

Appendix 2, figure1

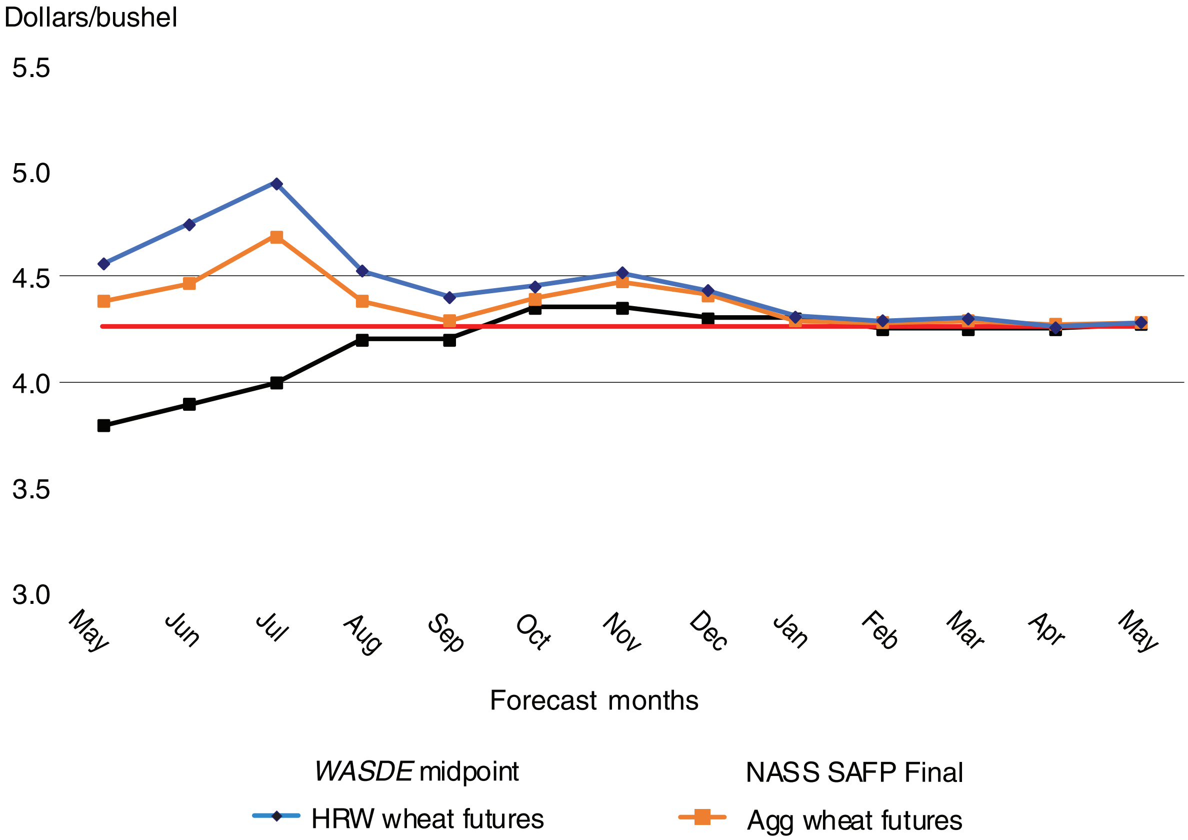
Season average farm price (SAFP) forecasts for U.S. wheat marketing year 2005/06



Note: *WASDE=World Agricultural Supply and Demand Estimates*; NASS=USDA, National Agricultural Statistics Service; Agg=Aggregate; HRW=Hard red winter; and marketing year=begins June 1 and ends May 31.

Sources: USDA, Office of the Chief Economist; USDA, National Agricultural Statistics Service; and USDA, Economic Research Service.

Appendix 2, figure 2
Season-average farm price (SAFP) forecasts for U.S. wheat, marketing year 2006/07

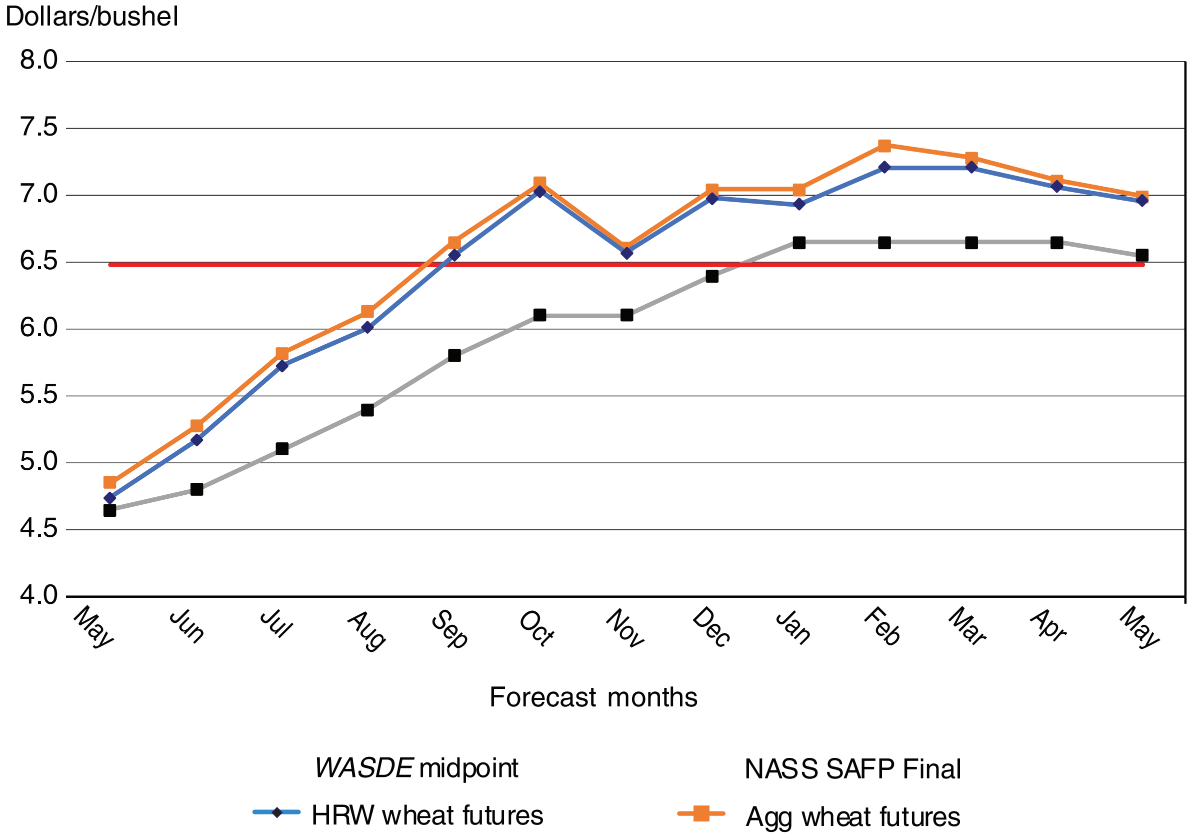


Note: *WASDE=World Agricultural Supply and Demand Estimate*s; NASS=USDA, National Agricultural Statistics Service; Agg=Aggregate; HRW=Hard red winter; and marketing year=begins June 1 and ends May 31.

Sources: USDA, Office of the Chief Economist; USDA, National Agricultural Statistics Service; and USDA, Economic Research Service.

Appendix 2, figure 3

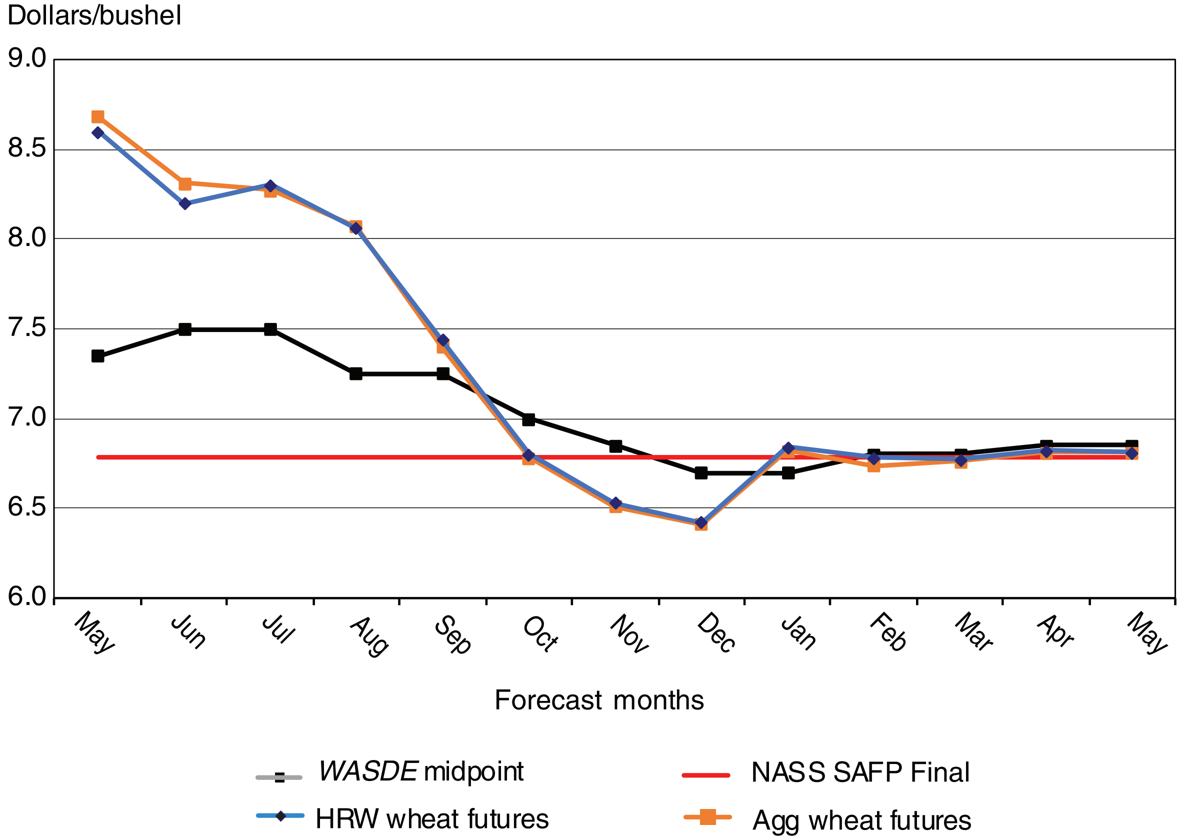
Season-average farm price (SAFP) forecasts for U.S. wheat, marketing year 2006/07



Note: *WASDE=World Agricultural Supply and Demand Estimates*; NASS=USDA, National Agricultural Statistics Service; Agg=Aggregate; HRW=Hard red winter; and marketing year=begins June 1 and ends May 31.

Sources: USDA, Office of the Chief Economist; USDA, National Agricultural Statistics Service; and USDA, Economic Research Service.

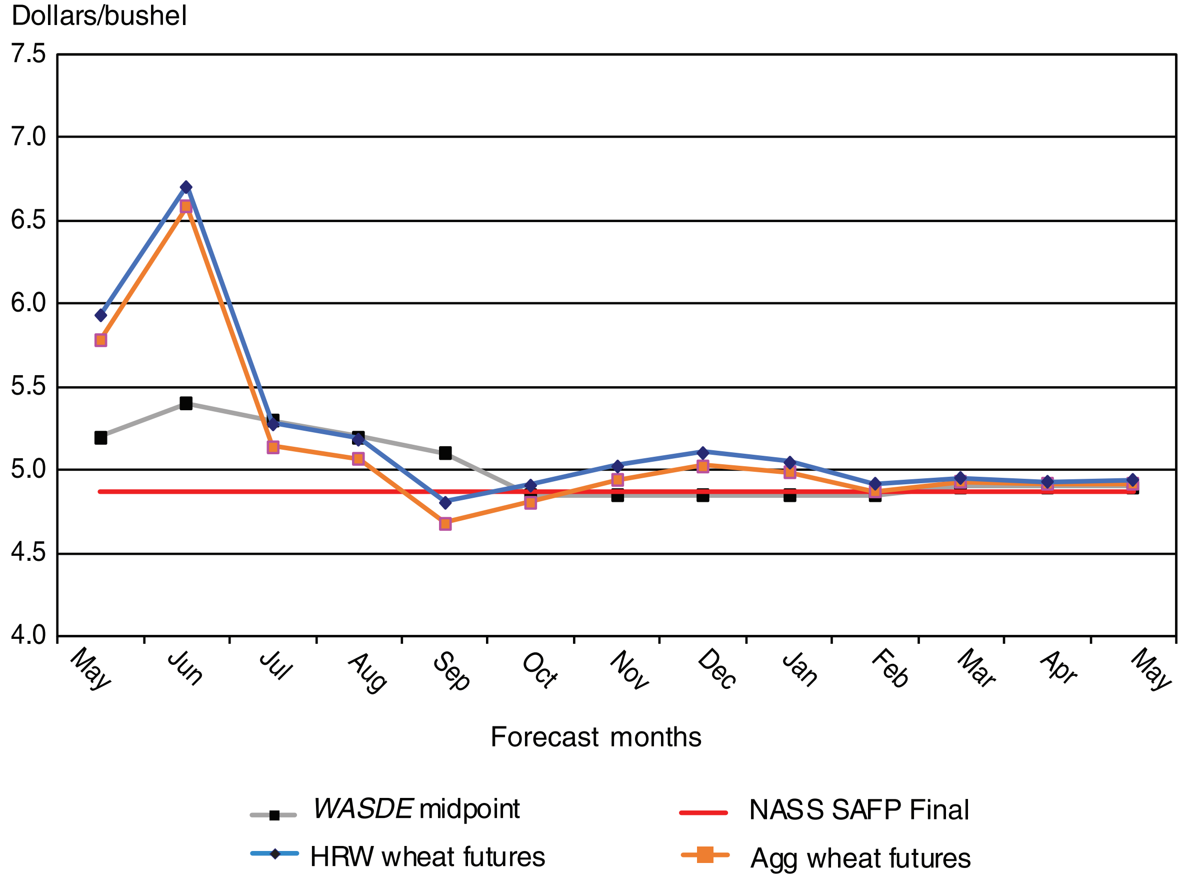
Appendix 2, figure 4
Season-average farm price (SAFP) forecasts for U.S. wheat, marketing year 2008/09



Note: *WASDE=World Agricultural Supply and Demand Estimates*; NASS=USDA, National Agricultural Statistics Service; Agg=Aggregate; HRW=Hard red winter; and marketing year=begins June 1 and ends May 31.

Sources: USDA, Office of the Chief Economist; USDA, National Agricultural Statistics Service; and USDA, Economic Research Service.

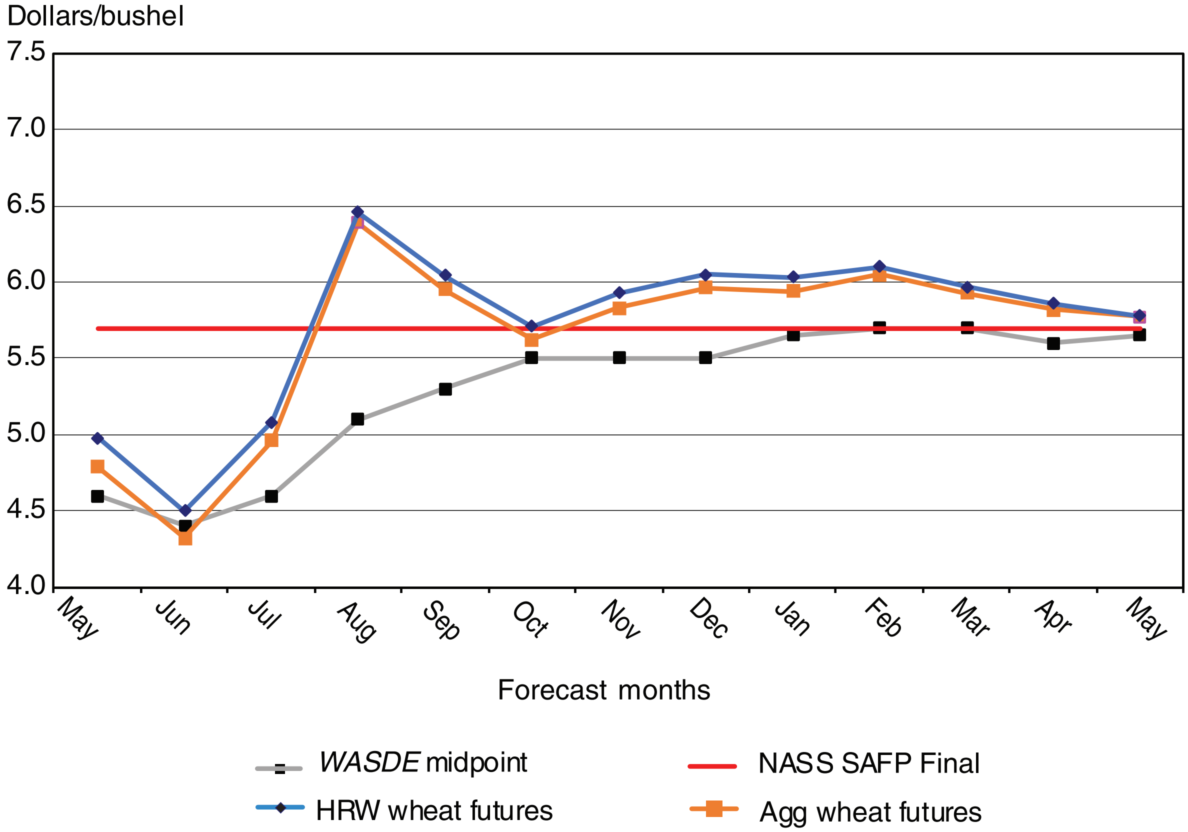
Appendix 2, figure 5
Season-average farm price (SAFP) forecasts for U.S. wheat, marketing year 2009/10



Note: *WASDE=World Agricultural Supply and Demand Estimates*; NASS=USDA, National Agricultural Statistics Service; Agg=Aggregate; HRW=Hard red winter; and marketing year=begins June 1 and ends May 31.

Sources: USDA, Office of the Chief Economist; USDA, National Agricultural Statistics Service; and USDA, Economic Research Service.

Appendix 2, figure 6
Season-average farm price (SAFP) forecasts for U.S. wheat, marketing year 2010/18

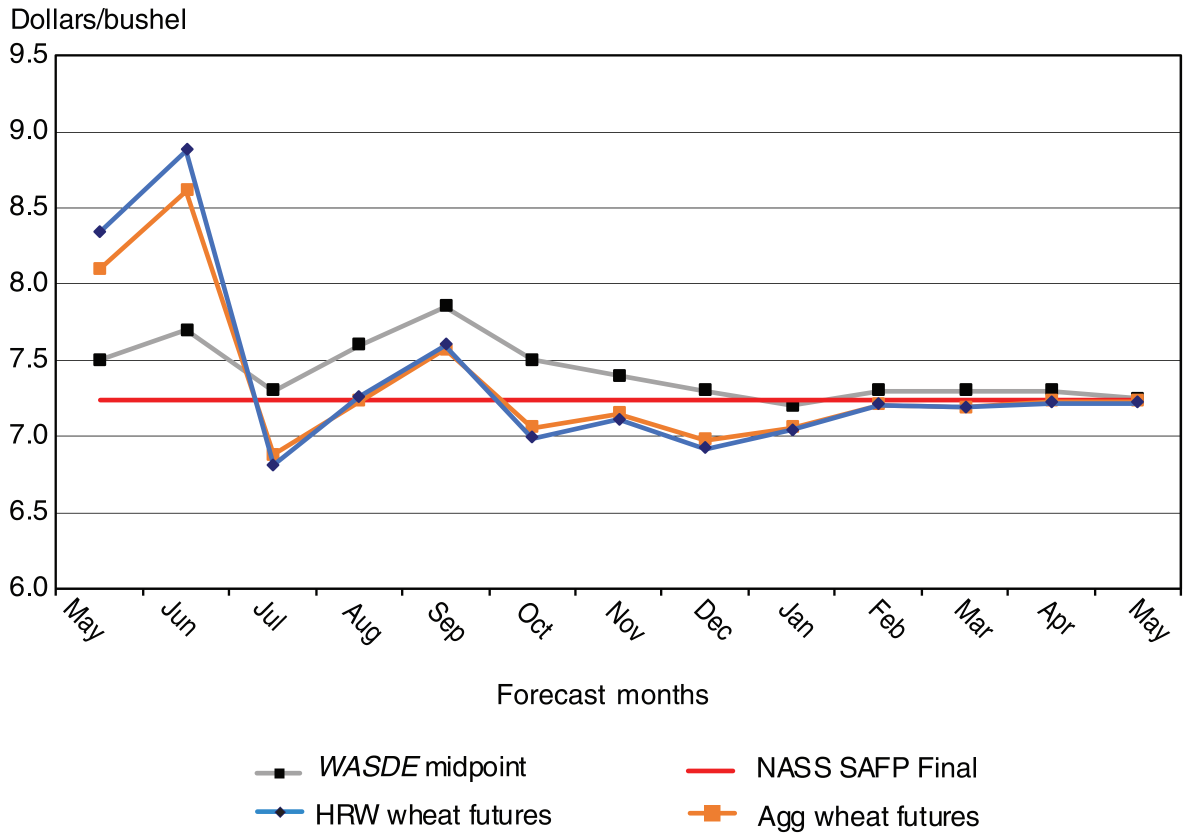


Note: *WASDE=World Agricultural Supply and Demand Estimates*; NASS=USDA, National Agricultural Statistics Service; Agg=Aggregate; HRW=Hard red winter; and marketing year=begins June 1 and ends May 31.

Sources: USDA, Office of the Chief Economist; USDA, National Agricultural Statistics Service; and USDA, Economic Research Service.

Appendix 2, figure 7

Season-average farm price (SAFP) forecasts for U.S. wheat, marketing year 2007/08

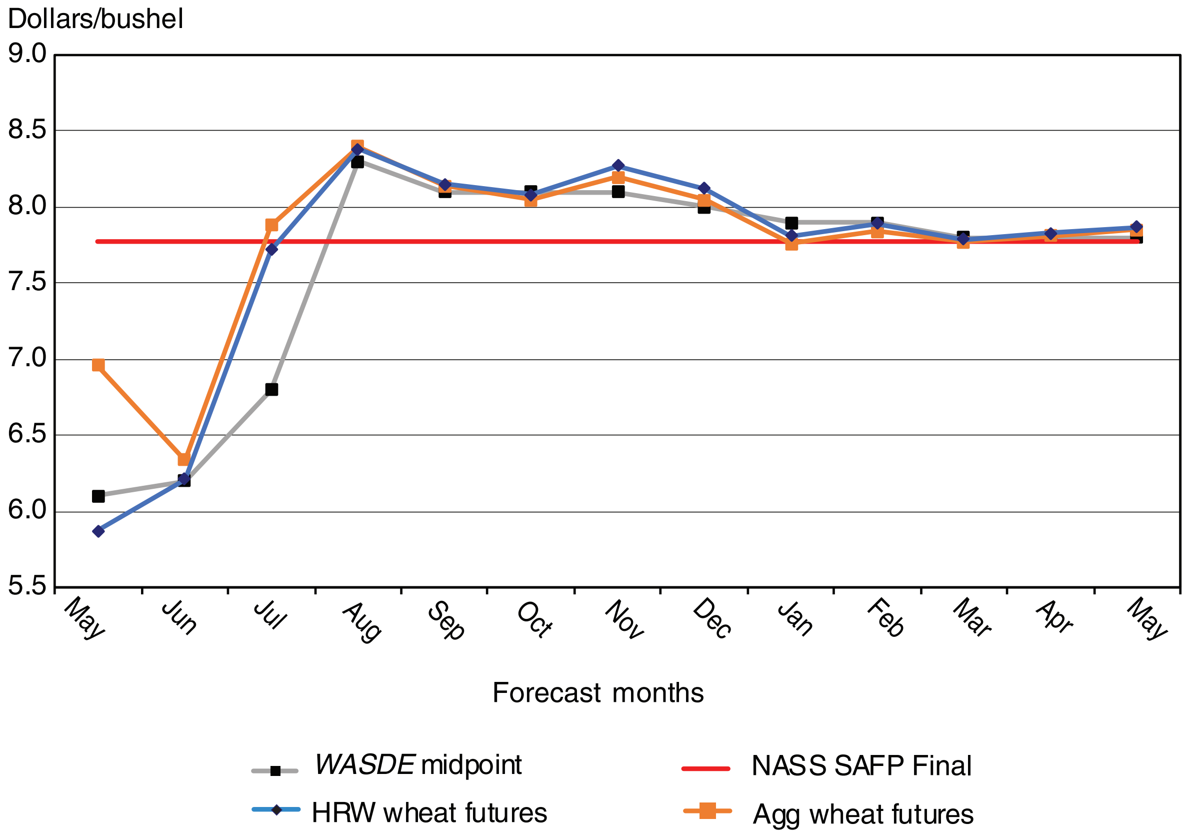


Note: *WASDE=World Agricultural Supply and Demand Estimates*; NASS=USDA, National Agricultural Statistics Service; Agg=Aggregate; HRW=Hard red winter; and marketing year=begins June 1 and ends May 31.

Sources: USDA, Office of the Chief Economist; USDA, National Agricultural Statistics Service; and USDA, Economic Research Service.

Appendix 2, figure 8

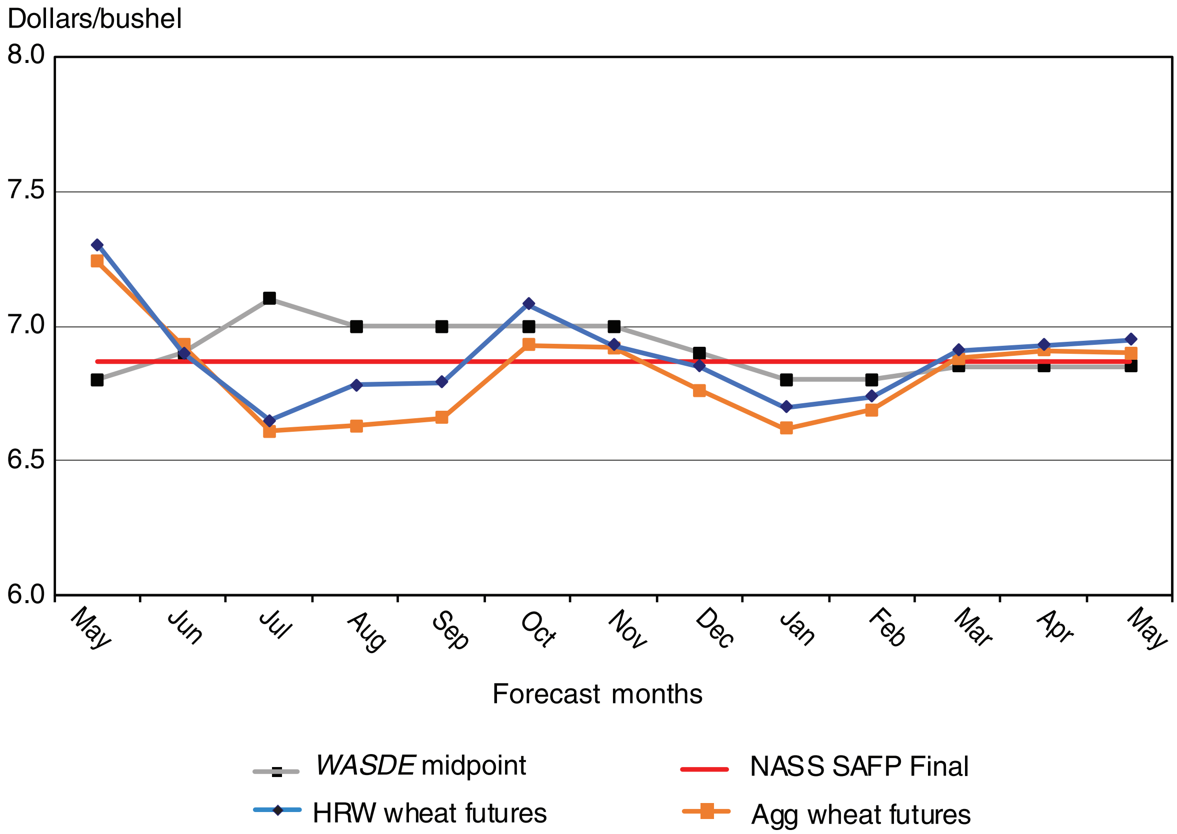
Season-average farm price (SAFP) forecasts for U.S. wheat, marketing year 2011/12



Note: *WASDE=World Agricultural Supply and Demand Estimates;* NASS=USDA, National Agricultural Statistics Service; Agg=Aggregate; HRW=Hard red winter; and marketing year=begins June 1 and ends May 31.

Sources: USDA, Office of the Chief Economist; USDA, National Agricultural Statistics Service; and USDA, Economic Research Service.

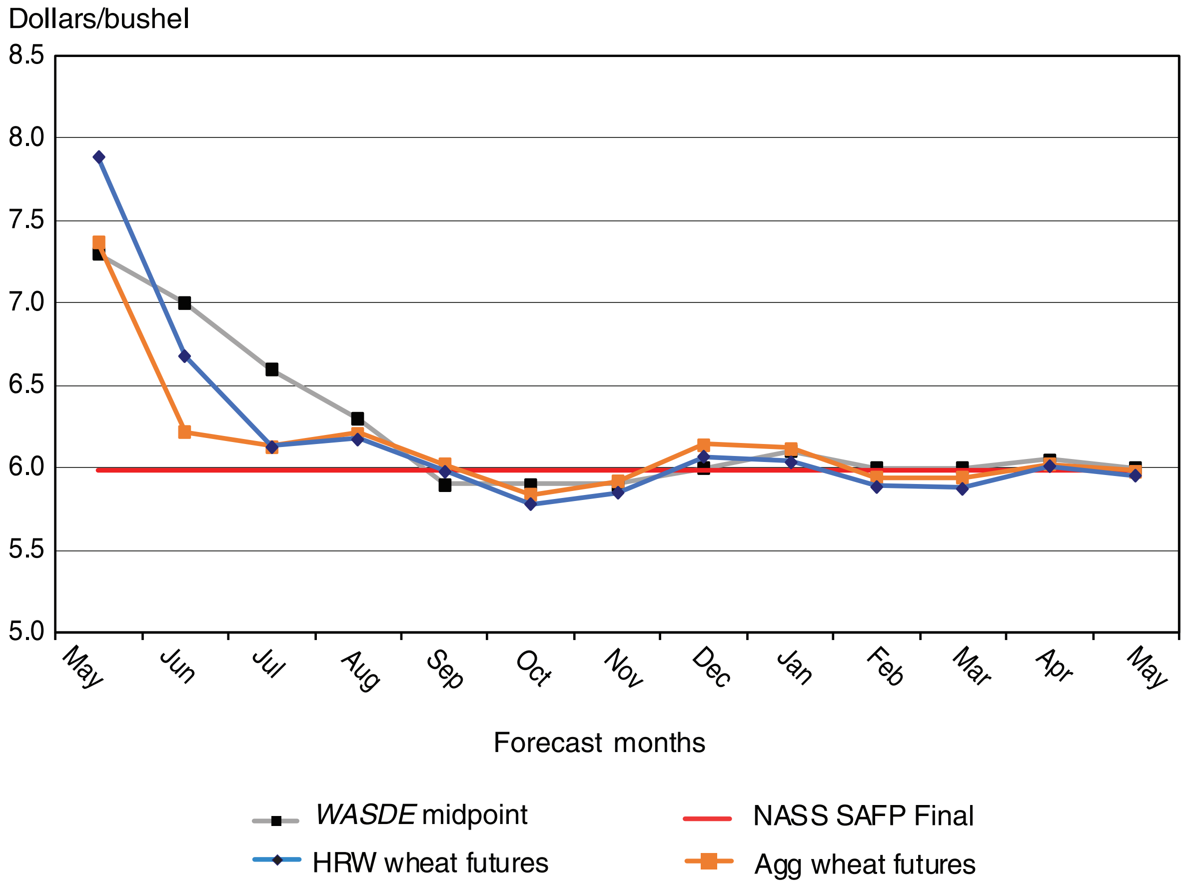
Appendix 2, figure 9
Season-average farm price (SAFP) forecasts for U.S. wheat, marketing year 2013/14



Note: *WASDE=World Agricultural Supply and Demand Estimates*; NASS=USDA, National Agricultural Statistics Service; Agg=Aggregate; HRW=Hard red winter; and marketing year=begins June 1 and ends May 31.

Sources: USDA, Office of the Chief Economist; USDA, National Agricultural Statistics Service; and USDA, Economic Research Service.

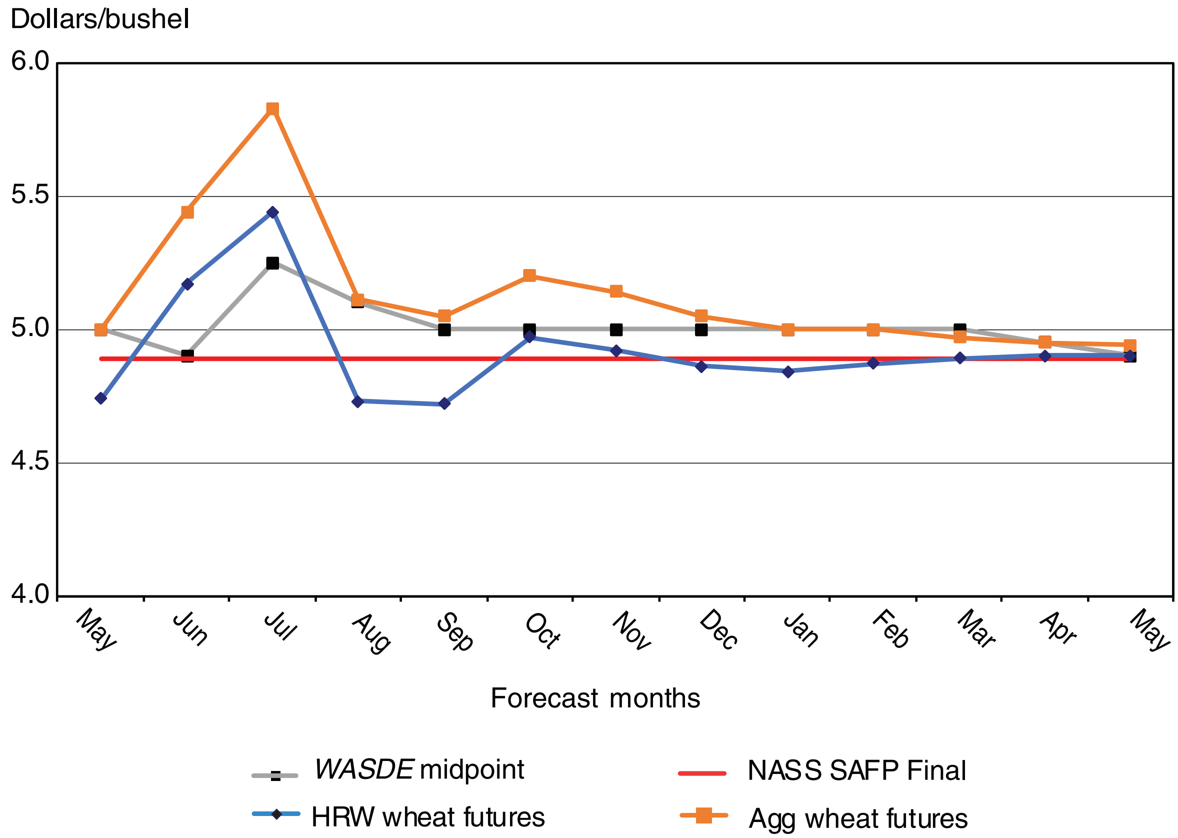
Appendix 2, figure 10
Season-average farm price (SAFP) forecasts for U.S. wheat, marketing year 2014/15



Note: *WASDE=World Agricultural Supply and Demand Estimates*; NASS=USDA, National Agricultural Statistics Service; Agg=Aggregate; HRW=Hard red winter; and marketing year=begins June 1 and ends May 31.

Sources: USDA, Office of the Chief Economist; USDA, National Agricultural Statistics Service; and USDA, Economic Research Service.

Appendix 2, figure 11
Season-average farm price (SAFP) forecasts for U.S. wheat, marketing year 2015/16

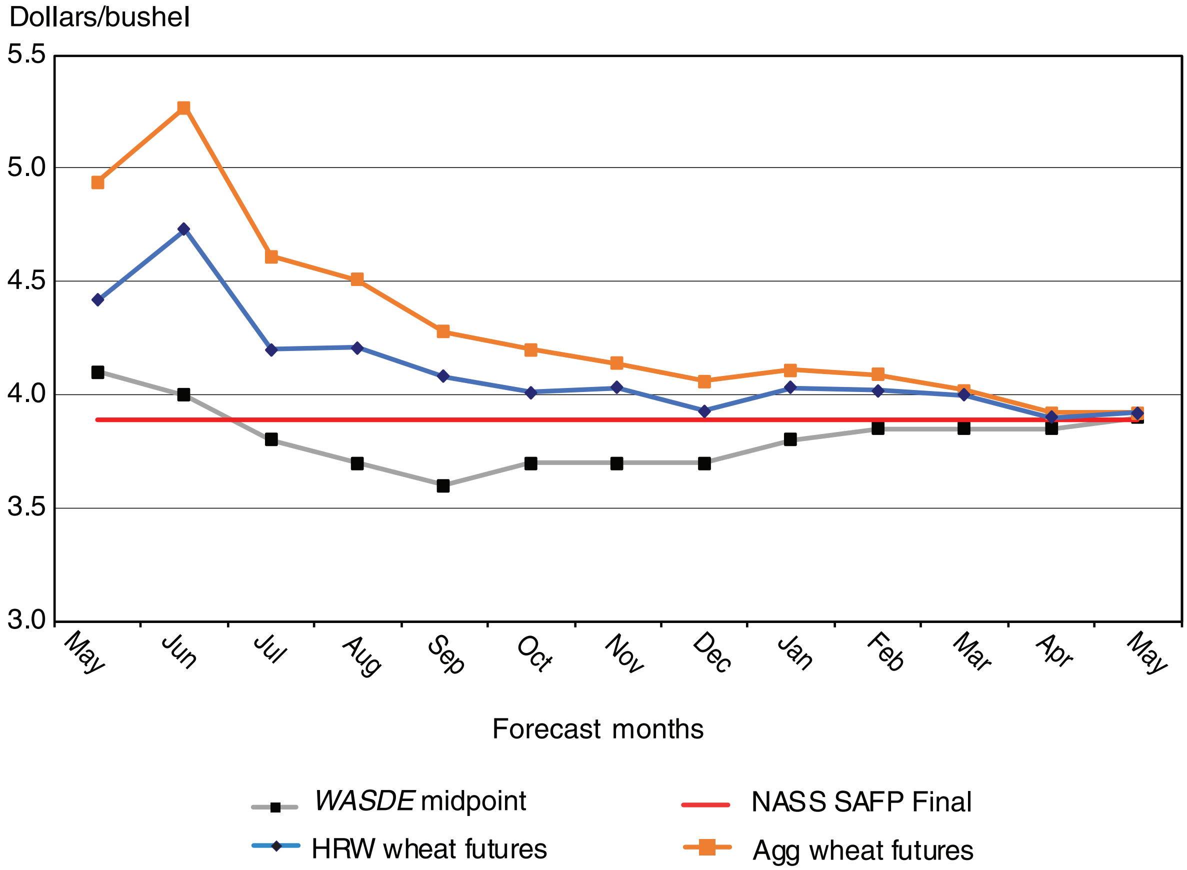


Note: *WASDE=World Agricultural Supply and Demand Estimates*; NASS=USDA, National Agricultural Statistics Service; Agg=Aggregate; HRW=Hard red winter; and marketing year=begins June 1 and ends May 31.

Sources: USDA, Office of the Chief Economist; USDA, National Agricultural Statistics Service; and USDA, Economic Research Service.

Appendix 2, figure 12

Season-average farm price (SAFP) forecasts for U.S. wheat, marketing year 2016/17

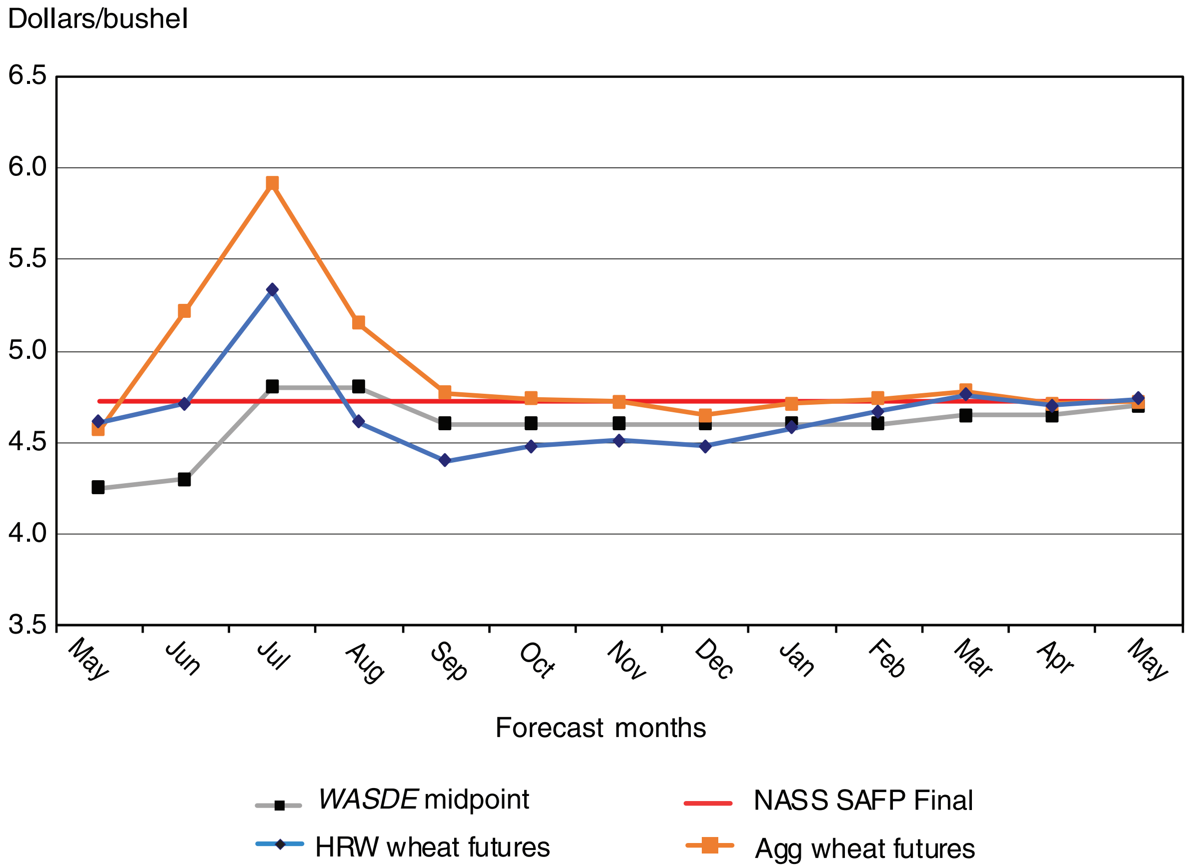


Note: *WASDE=World Agricultural Supply and Demand Estimates*; NASS=USDA, National Agricultural Statistics Service; Agg=Aggregate; HRW=Hard red winter; and marketing year=begins June 1 and ends May 31.

Sources: USDA, Office of the Chief Economist; USDA, National Agricultural Statistics Service; and USDA, Economic Research Service.

Appendix 2, figure 13

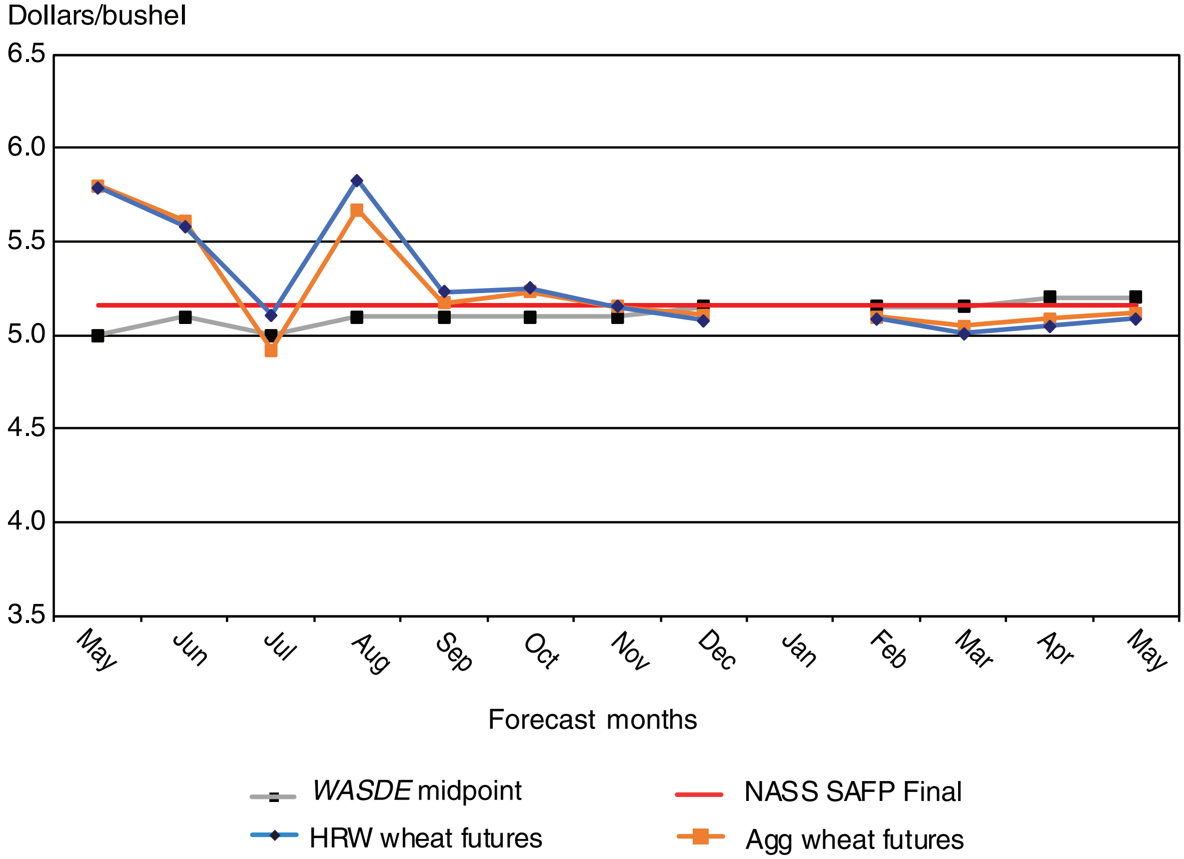
Season-average farm price (SAFP) forecasts for U.S. wheat, marketing year 2017/18



Note: *WASDE=World Agricultural Supply and Demand Estimates*; NASS=USDA, National Agricultural Statistics Service; Agg=Aggregate; HRW=Hard red winter; and marketing year=begins June 1 and ends May 31.

Sources: USDA, Office of the Chief Economist; USDA, National Agricultural Statistics Service; and USDA, Economic Research Service.

Appendix 2, figure 14
Season-average farm price (SAFP) forecasts for U.S. wheat, marketing year 2018/19

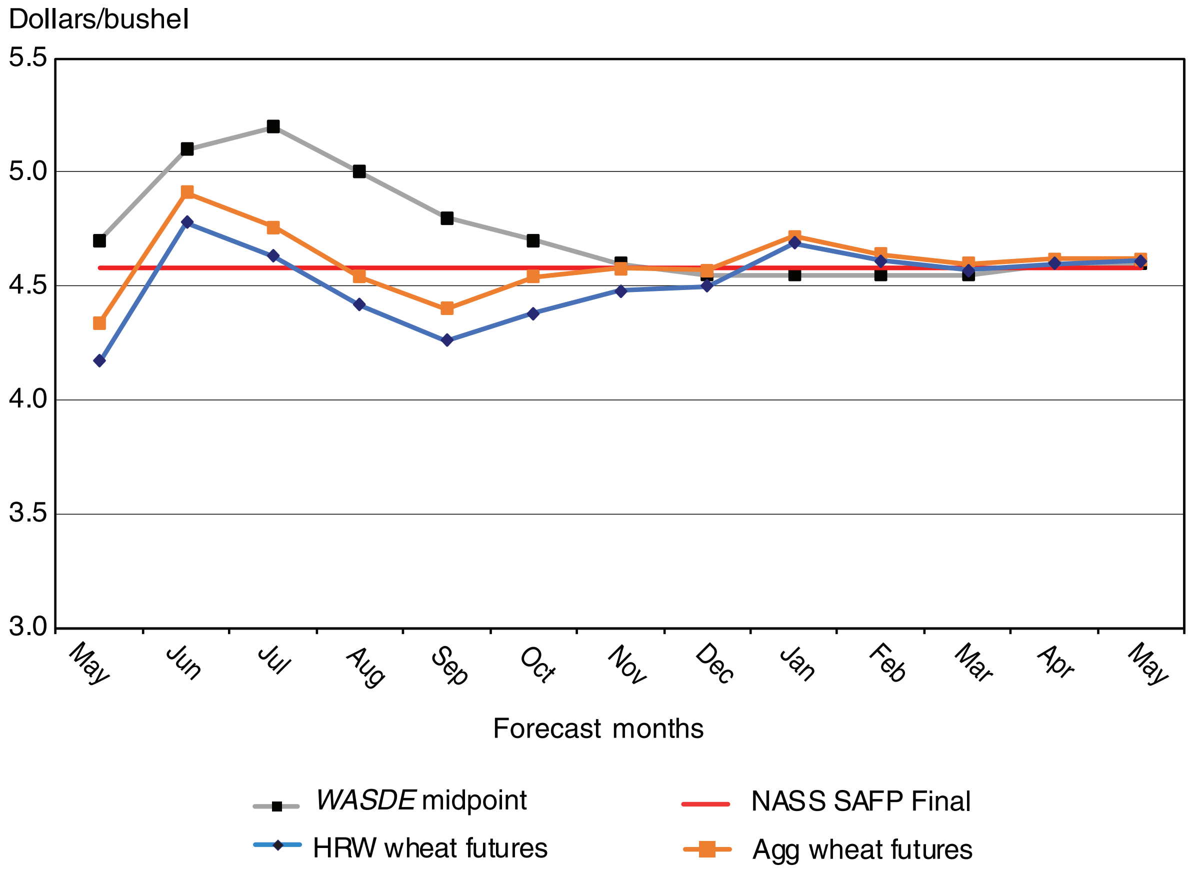


Note: *WASDE=World Agricultural Supply and Demand Estimates*; NASS=USDA, National Agricultural Statistics Service; Agg=Aggregate; HRW=Hard red winter; and marketing year=begins June 1 and ends May 31.

Sources: USDA, Office of the Chief Economist; USDA, National Agricultural Statistics Service; and USDA, Economic Research Service.

Appendix 2, figure 15

Season-average farm price (SAFP) forecasts for U.S. wheat, marketing year 2019/20



Note: *WASDE=World Agricultural Supply and Demand Estimates*; NASS=USDA, National Agricultural Statistics Service; Agg=Aggregate; HRW=Hard red winter; and marketing year=begins June 1 and ends May 31.

Sources: USDA, Office of the Chief Economist; USDA, National Agricultural Statistics Service; and USDA, Economic Research Service.

Table 5

Comparison of performance criteria by forecast methods: Aggregate futures model and *World Agricultural Supply and Demand Estimates (WASDE)* projections, marketing years 2005/06 - 2019/20.

	Aggregate futures model forecasts (3-year average basis and 5-year average marketing weights)				*WASDE* Projections			
	Performance criteria				Performance criteria			
Forecast months *(m)*	Forecast over/under actual	ME	MAE	MAPE	Forecast over/under actual	ME	MAE	MAPE
	Number	Dollars/bushel		Percent	Number	Dollars/bushel		Percent
Pre-harvest season (13th month-ahead forecast)								
May (0)	9/6	0.23	0.81	13.26	7/8	-0.23	0.62	10.86
Harvest season (12th month to 9th month-ahead forecasts)								
June (1)	11/4	0.28	0.93	15.15	8/7	-0.17	0.63	10.77
July (2)	10/5	0.20	0.45	9.51	8/7	-0.09	0.50	8.87
August (3)	10/5	0.27	0.29	6.44	9/6	0.04	0.34	5.90
September (4)	11/4	0.10	0.13	3.50	7/8	0.01	0.27	4.75
Post-harvest season (8th month to 1 month ahead forecasts)								
October (5)	9/6	0.08	0.11	3.00	7/8	0.01	0.16	2.70
November (6)	8/5	0.06	0.09	2.40	6/8	-0.01	0.14	2.44
December (7)	8/7	0.06	0.13	3.30	6/9	-0.02	0.09	1.62
January (8)	9/5	0.08	0.09	2.58	5/9	0.00	0.08	1.49
February (9)	9/5	0.09	0.11	2.49	6/8	0.01	0.06	0.99
March (10)	9/5	0.08	0.08	2.06	7/7	0.02	0.04	0.78
April (11)	11/3	0.07	0.05	1.31	8/6	0.02	0.06	0.99
May (12)	11/3	0.06	0.04	1.11	10/3	0.01	0.03	0.46
Average	9.6/4.8				7.2/7.2			
Total	126/61				94/94			
Balance of forecasts/projections (over/under) summary								
	Number	Percent			Number	Percent		
Over	126	65			94	49		
Under	61	31			94	49		
Equal	7	4			6	2		
Total	194	100			194	100		

Note: Shaded area represents the lower MAPE. However, differences are not statistically significant, except December, at the 5 percent level based on Modified Diebold Mariano (MDM) test statistic, Harvery et al. (1997).

Sources: USDA, Economic Research Service and USDA, Office of the Chief Economist.