Performance of 5-Year Olympic Moving Average in Forecasting U.S. Crop Year Revenue for Program Crops

by

Sanghyo Kim, Carl Zulauf, Matthew Roberts, and Kevin Cook

Performance of 5-Year Olympic Moving Average in Forecasting U.S. Crop Year Revenue for Program Crops

Sanghyo Kim

Carl Zulauf

Matthew Roberts

and

Kevin Cook†

Paper presented at the NCCC-134 Conference on Applied Commodity Price Analysis, Forecasting, and Market Risk Management, St. Louis, Missouri, April 20-21, 2015

†Sanghyo Kim (Kim.3294@osu.edu) is a graduate student, Carl Zulauf (Zulauf.1@osu.edu) is a professor, Matthew Roberts (Roberts.628@osu.edu) is an associate professor, and Kevin Cook (Cook.914@osu.edu) is a graduate student in the Department of Agricultural and Environmental, and Development Economics at the Ohio State University.

Performance of 5-Year Olympic Moving Average in Forecasting U.S. Crop Year Revenue for Program Crops

Sanghyo Kim   Carl Zulauf   Matthew Roberts   Kevin Cook

Abstract

The last two farm bills have used moving averages and Olympic moving averages in computing revenue benchmarks and hence payments in the Average Crop Revenue Election (ACRE) program in the *Food, Conservation, and Energy Act of 2008* and its more recent version, the Agricultural Risk Coverage (ARC) program in the *Agricultural Act of 2014*. Accurate revenue forecasting is important to farmers and agribusiness managers because of the variety of risks associated with farming including price and yield variability, which are often negatively correlated. This paper therefore assesses the performance of various specifications of simple and Olympic moving averages in forecasting U.S. crop year revenue for the program crops of corn, soybeans, wheat, rice, and sorghum over the 1974 through 2013 crop years. In general, forecast error is found to be lower for the moving average than for the Olympic moving average technique. It was also generally lower for the technique of forecasting revenue directly than for forecasting separating the price and yield components of revenue. Last, forecast error was generally smaller for calculation windows smaller than the 5 years used as the underlying method by the ARC farm support program.

Key words: ACRE program, ARC program, forecast accuracy, Olympic moving average, revenue forecast

JEL codes: C53, Q11, Q18

1 Introduction

The last two farm bills used moving averages and Olympic moving averages to compute revenue benchmarks and hence payments by the ACRE (Average Crop Revenue Election) program in the *Food, Conservation, and Energy Act of 2008* and its more recent version, the ARC (Agricultural Risk Coverage) program in the *Agricultural Act of 2014*[2]. A 'moving average' is a fixed length calculation window that moves with time (in the case of ARC, a 5-year calculation window is updated each year). An Olympic average excludes the highest and lowest value in calculating an average, thus reducing the impact of outliers.

Moving averages impart market orientation to the functioning of farm support programs in contrast to the traditional approach of support parameters fixed by Congress, such as loan rates or target prices (now known as reference prices). However, moving averages are also forecasting techniques. Accurate revenue forecasting is important to farmers and agribusiness managers because of the variety of risks associated with farming including price and yield variability, which are often negatively correlated. This paper therefore assesses the performance of various specifications of simple and Olympic moving averages in forecasting U.S. crop year revenue for five major program crops.

The rest of this paper is organized as follows. A brief literature review is followed by a discussion of procedures and data. Next, findings are discussed. The paper closes with a summary, conclusion, and implication section.

2 Literature Review

Forecasting spans a wide variety of topics in the agricultural economics literature. What follows is a brief review of a few recent articles to illustrate the variety of topics and issues that fall within the agricultural forecasting literature.

Irwin, Good and Sanders (2014) evaluated the accuracy of U.S. Department of Agriculture (USDA) forecasts of U.S. average corn yield in its August through November production forecasts against the final yield estimates released in January.

[2]The ARC farm program differs from the ACRE program on several key parameters. In the context of this paper, the key difference is that ARC uses 5-year Olympic moving average (OMA5) method to estimate both the price and yield component of benchmark revenue while ACRE uses OMA5 to estimate only the yield component. ACRE uses a simple 2-year moving average to estimate the price component. Other differences include that (1) ARC uses county or farm yield while ACRE uses state yield, (2) ARC pays on a share of historic program acres while ACRE generally pays on a share of planted acres; and (3) ARC's coverage range is 76-86 percent while ACRE's coverage range is 67.5-90 percent.

Percent difference between the forecasts and final estimates was calculated for the 1990-2013 crop years. No evidence was found of bias in the forecasts. Moreover, they found that the accuracy of USDA corn yield forecasts has improved over time.

Li and Dorfman (2014) examine whether qualitative forecasting of commodity prices can be improved by including in the model specification price forecasts for other commodities. Hog prices are examined as a test case, with a Bayesian approach used to address model specification uncertainty. They found strong support for including other commodity price forecast in the 'best' forecasting model but acknowledged more research is needed.

Hatchett, Brorsen and Anderson (2009) review previous studies of the optimal length of moving averages when forecasting basis and attempt to identify the ideal length of historical observations to include in a moving average forecast of the basis. Preharvest and storage period basis forecasts are compared for hard and soft wheat, corn, and soybeans. Mean absolute error is used to measure the accuracy of forecast. Other than for preharvest hard wheat forecasts, they find that the optimal length is three or fewer years.

3 Procedures and Data

The first set of comparisons involves alternatives raised in recent agricultural policy debates. Because ARC uses a five year Olympic moving average (OMA5) to calculate the yield and price component of its revenue benchmark, one alternative is a five-year moving average (MA5) instead of OMA5, specifically:

$$\widehat{R}_t^{OMA5PY} = \widehat{Y}_t^{OMA5} \times \widehat{P}_t^{OMA5} \tag{1}$$

$$\widehat{R}_t^{MA5PY} = \widehat{Y}_t^{MA5} \times \widehat{P}_t^{MA5} \tag{2}$$

where R is revenue, superscript PY signifies price and yield are calculated separately, $\widehat{Y}_t^{OMA5}$ and $\widehat{P}_t^{OMA5}$ are five year Olympic moving averages of county yield and U.S. crop year price, and $\widehat{Y}_t^{MA5}$ and $\widehat{P}_t^{MA5}$ are five year simple moving averages of county yield and U.S. crop year price. $\widehat{Y}_t^{OMA5}$, $\widehat{P}_t^{OMA5}$, $\widehat{Y}_t^{MA5}$, and $\widehat{P}_t^{MA5}$ are computed:

$$\widehat{Y}_t^{OMA5} = \frac{1}{5-2}\Big[\sum_{i=1}^{5} Y_{t-i} - \min_{1\le i\le 5} Y_{t-i} - \max_{1\le i\le 5} Y_{t-i}\Big] \tag{3}$$

$$\widehat{P}_t^{OMA5} = \frac{1}{5-2}\Big[\sum_{i=1}^{5} P_{t-i} - \min_{1\le i\le 5} P_{t-i} - \max_{1\le i\le 5} P_{t-i}\Big] \tag{4}$$

$$\widehat{Y}_t^{MA5} = \frac{1}{5}\sum_{i=1}^{5} Y_{t-i} \tag{5}$$

$$\widehat{P}_t^{MA5} = \frac{1}{5}\sum_{i=1}^{5} P_{t-i} \tag{6}$$

where i is integer.

A second contemporary policy-based comparison involves calculating revenue directly instead of calculating price and yield separately, specifically:

$$\begin{aligned} \widehat{R}_t^{OMA5R} &= (\widehat{Y_t \times P_t})^{OMA5} \\ &= \frac{1}{5-2}\Big[\sum_{i=1}^{5} (Y_{t-i} \times P_{t-i}) - \min_{1\le i\le 5} (Y_{t-i} \times P_{t-i}) - \max_{1\le i\le 5} (Y_{t-i} \times P_{t-i})\Big] \end{aligned} \tag{7}$$

where superscript R signifies that revenue is calculated directly.

A third contemporary policy-based comparison involves the calculation method underlying the ACRE program, MA2P – OMA5Y, specifically:

$$\widehat{R}_t^{OMA5Y-MA2P} = \widehat{Y}_t^{OMA5} \times \widehat{P}_t^{MA2} \tag{8}$$

where $\widehat{Y}_t^{OMA5}$ is a five year Olympic moving average of county yield and $\widehat{P}_t^{MA2}$ is a simple two year moving average of price.

The second set of comparisons involves identifying the best performing forecast among possible MA and OMA methods. Given the available data (see discussion below), lengths of one through seven years are evaluated.

Consistent with the literature (for example, Hatchett et al., 2009, and Dhuyvetter and Kastens, 1998), forecast accuracy is evaluated using Mean Absolute Error (MAE) and Root Mean Squared Error (RMSE). Since, everything else constant, forecast error tends to increase when actual revenue increases, forecast error is expressed as a ratio to actual revenue to normalize forecast error. They are Mean Absolute *Percentage* Error (MAPE) and Root Mean Squared *Percentage* Error (RMSPE) and are calculated:

$$MAPE = \frac{1}{T}\sum_{i=1}^{T}\frac{|R_t - \widehat{R}_t|}{R_t} \tag{9}$$

$$RMSPE = \sqrt{\frac{1}{T}\sum_{i=1}^{T}\Big(\frac{R_t - \widehat{R}_t}{R_t}\Big)^2} \tag{10}$$

where R_t is actual annual revenue and $\widehat{R}_t$ is predicted annual revenue.

Program crops examined are corn, soybeans, wheat, rice, and sorghum. Data on U.S. crop year price and county yield are from USDA, National Agricultural Statistics Service Quick Stats database. The study period begins with the 1974 crop year, and thus is subsequent to the major change in price level and variability that occurred in the early 1970's (Kenyon, Jones, and McGuirk, 1993). The study period ends with the 2013 crop year, the last available when the analysis began.

For corn, soybeans, and wheat; the analysis examines the five largest and smallest production states that have at least 20[3] counties with all 40 years of yield observations. This decision allows investigation of whether forecast performance varies by the size of a state's production. The large state-small state assessment is not conducted for rice and sorghum due to the small number of states that grow rice and sorghum and that have at least 20 countries of yield data for all 40 years.

Forecast error is examined for two observation periods: 1974-2005 (pre-2006 period) and 1974-2013 (entire period). The pre-2006 period predates the price increase that occurred because of the confluence of increasing demand for food and biofuels along with production problems around the world.

4 Empirical Results

Before discussing the results, it is important to note that both the ACRE and ARC programs have additional parameters that modify the underlying calculation technique of OMA5Y-MA2P for ACRE and OMA5PY for ARC. Changes in the revenue guarantee used to calculate the revenue benchmark in the case of ACRE could not increase or decrease by more than 10 percent from the previous year. For ARC, a minimum price, the reference price, exists when computing its revenue benchmark. OMA5Y-MA2P and OMA5PY are only the techniques that underlay the program.

[3]There is one exception. For wheat, one of the five smallest production states, Kentucky, had only 19 counties with all 40 years of yield observations.

The program's benchmark revenue in a given year may differ from the revenue forecast by these techniques. This perspective needs to be kept in mind when interpreting the results.

Results are presented only for MAPE because the results are nearly the same for MAPE and RMSPE. In addition, results are discussed only for the entire period because of the relative similarity of the results for both observations periods. The RMSPE results are available from the authors while the results for the pre-2006 period are available in Appendix Tables 5-8.

MAPE is similar for the OMA5PY, OMA5R, and MA5PY methods (see Tables 1 and 2). Except for Virginia corn, Kansas sorghum, and especially Texas sorghum; MAPE is within one percentage point for these three forecast methods. In contrast, when averaged across all states, MAPE is eight percent lower for OMA5Y-MA2P than for OMA5PY. OMA5Y-MA2P has the lowest MAPE for all but eight state-crop combinations. Seven involve wheat, with Texas sorghum being the other exception.

On average, MAPE is larger for the small corn and soybean production states compared with their respective large production states for all techniques. In contrast, MAPE is roughly identical for the small and large wheat production states. These findings do not allow a definitive conclusion but are suggestive that forecast error may not be higher for the large production states. Additional analysis is needed.

When the analysis is broadened to moving averages with calculation windows up to seven years, the technique with the lowest MAPE is always a version of moving averages for 1974-2013 observation period (see Tables 3 and 4). Moreover, for 73 percent of the state-crop combinations during the entire observation period, the MA with the lowest MAPE was for revenue, not the price and yield component approach. Length of the calculation window for the moving average averaged 2.9 years across all state-crop combinations, with 78 percent of the state-crop combinations having a calculation window less than five years. The general directions of these findings hold for the pre-2006 period, but are not nearly as definitive (see Appendix Tables 7 and 8)

5 Summary, Conclusions, and Implications

The last two farm bills have used moving averages and Olympic moving averages in computing revenue benchmarks and hence payments in the ACRE program in the *Food, Conservation, and Energy Act of 2008* and its more recent version, the ARC program in the *Agricultural Act of 2014*. Moving averages impart market orientation to the functioning of farm support programs in contrast to the traditional approach of support parameters fixed by Congress. However, moving averages are also forecasting techniques. This paper assesses the performance of various specifications of moving averages and Olympic moving averages in forecasting U.S. crop year revenue.

The analysis is conducted for the program crops of corn, soybeans, wheat, rice, and sorghum over the 1974 through 2013 crop years. In general, forecast error is found to be lower for the moving average than for the Olympic moving average technique. It was also generally lower for the technique of forecasting revenue directly than for forecasting separating the price and yield components of revenue. Last, forecast error was generally smaller for calculation windows smaller than the 5 years used as the underlying method by the ARC farm support program.

These results are suggestive that the calculation technique used by ACRE may forecast more accurately than the calculation technique used by ARC and that other moving average techniques may forecast more accurately than the technique used by ACRE. Obviously this analysis needs to be extended to other crops and counties. It is not clear how important forecast performance is as a farm policy consideration, but policy makers may want to add it to their list of considerations, especially for programs that use parameters not fixed by Congress but that move with the market.

References

Dhuyvetter, K.C., and T.L. Kastens. 1998. "Forecasting Crop Basis: Practical Alternatives." Paper presented at the NCR-134 Conference on Applied Commodity Price Analysis, Forecasting, and Market Risk Management. Chicago, IL. http://www.farmdoc.illinois.edu/nccc134

Hatchett, R.B., B.W. Brorsen, and K.B. Anderson. 2009. "Optimal Length of Moving Average to Forecast Futures Basis." Proceedings of the NCCC-134 Conference on Applied Commodity Price Analysis, Forecasting, and Market Risk Management. St. Louis, MO. http://www.farmdoc.illinois.edu/nccc134

Irwin, S., D. Good, and D. Sanders. 2014. "Are USDA Corn Yield Forecasts Getting Better or Worse over Time?" *farmdoc daily* (4):166, Department of Agricultural and Consumer Economics, University of Illinois at Urbana-Champaign. Accessed at http://farmdocdaily.illinois.edu/2014/08/usda-corn-yield-forecasts-better-or-worse.html

Kenyon, D., E. Jones, and A. McGuirk. 1993. "Forecasting Performance of Corn and Soybean Harvest Futures Contracts." *American Journal of Agricultural Economics* 75: 399-407. Retrieved February 25, 2011 from JSTOR at http://www.jstor.org/stable/1242924

Li, A. and J.H. Dorfman. 2014. "Forecasting of Futures Prices: Using One Commodity to Help Forecast Another." Proceedings of the NCCC-134 Conference on Applied Commodity Price Analysis, Forecasting, and Market Risk Management. St. Louis, MO. http://www.farmdoc.illinois.edu/nccc134

U.S. Congress. 2008. *Food, Conservation, and Energy Act of 2008.* June 18. Washington DC: U.S. Government Printing Office. Accessed at http://www.gpo.gov/fdsys/pkg/PLAW-110publ246/pdf/PLAW-110publ246.pdf

U.S. Congress. 2014. *Agricultural Act of 2014.* February 7. Washington DC: U.S. Government Printing Office. Accessed at http://www.gpo.gov/fdsys/pkg/BILLS-113hr2642enr/pdf/BILLS-113hr2642enr.pdf

Table 1: Mean Absolute Percentage Error (MAPE) of 5-Year Olympic Moving Average (OMA5) vs. Alternative Forecasts of County Revenue, Corn and Soybeans, 1974-2013 Crop Years

Price (P) Forecast[A]: $\longrightarrow$	OMA5	MA5[B]	n/a	MA2
Yield (Y) Forecast: $\longrightarrow$	OMA5	MA5	n/a	OMA5
Revenue (R) Forecast: $\longrightarrow$	n/a	n/a	OMA5	n/a
State (# of Counties)	Average MAPE over Counties for Corn			
Minnesota (65)	0.24	0.24	0.24	0.19
Indiana (69)	0.21	0.21	0.20	0.20
Nebraska (79)	0.21	0.20	0.21	0.18
Illinois (82)	0.23	0.23	0.23	0.22
Iowa (99)	0.23	0.22	0.23	0.20
Average for Large[C] States	0.22	0.22	0.22	0.20
Tennessee (24)	0.27	0.26	0.27	0.24
Pennsylvania (31)	0.28	0.27	0.27	0.24
Virginia (31)	0.40	0.38	0.38	0.36
North Carolina (53)	0.35	0.34	0.34	0.33
Kentucky (55)	0.27	0.26	0.26	0.25
Average for Small[D] States	0.31	0.30	0.30	0.28
Average for All States	0.27	0.26	0.26	0.24
State (# of Counties)	Average MAPE over Counties for Soybeans			
Ohio (54)	0.20	0.20	0.20	0.17
Minnesota (63)	0.22	0.22	0.22	0.19
Indiana (66)	0.17	0.17	0.18	0.15
Illinois (91)	0.18	0.18	0.18	0.15
Iowa (99)	0.20	0.20	0.21	0.17
Average for Large States	0.19	0.19	0.20	0.17
Tennessee (22)	0.28	0.27	0.28	0.24
Virginia (25)	0.31	0.30	0.30	0.29
Kentucky (35)	0.24	0.23	0.24	0.23
Wisconsin (49)	0.22	0.22	0.22	0.20
North Carolina (58)	0.23	0.22	0.23	0.21
Average for Small States	0.26	0.25	0.25	0.23
Average for All States	0.23	0.22	0.23	0.20

Notes: A. Revenue is forecast in two ways: (a) a direct forecast of revenue and (b) a forecast of the price and yield component which are then combined to create a forecast of revenue. MAPE for component forecast is calculated as follow: revenue forecast error = $(P \times Y) - (\hat{P}_{OMA5} \times \hat{Y}_{OMA5})$. MAPE for the direct forecast of revenue is calculated as follows: revenue forecast error = $(P \times Y) - (\widehat{P \times Y}_{OMA5})$. B. MA$n$ stands for simple moving average of previous n years. C. Large states are the five largest production U.S. states among states with at least 20 counties with all years of data. D. Small states are the five smallest production U.S. states among states with at least 20 counties with all years of data.

Source: original calculations using data from U.S. Department of Agriculture (USDA), National Agricultural Statistics Service (NASS), Quick Stats Database

Table 2: Mean Absolute Percentage Error (MAPE) of 5-Year Olympic Moving Average (OMA5) vs. Alternative Forecasts of County Revenue, Wheat, Rice, and Sorghum, 1974-2013 Crop Years

Price (P) Forecast[A]: $\longrightarrow$	OMA5	MA5[B]	*n/a*	MA2
Yield (Y) Forecast: $\longrightarrow$	OMA5	MA5	*n/a*	OMA5
Revenue (R) Forecast: $\longrightarrow$	*n/a*	*n/a*	OMA5	*n/a*
State (# of Counties)	Average MAPE over Counties for Wheat			
Ohio (21)	0.17	0.17	0.17	0.19
Oklahoma (22)	0.26	0.25	0.25	0.26
Nebraska (36)	0.22	0.22	0.22	0.20
Texas (53)	0.28	0.28	0.28	0.28
Kansas (71)	0.26	0.25	0.26	0.24
Average for Large[C] States	0.24	0.23	0.24	0.23
Kentucky (19)	0.28	0.28	0.29	0.29
Missouri (24)	0.25	0.24	0.25	0.25
Indiana (28)	0.20	0.20	0.20	0.22
Michigan (33)	0.21	0.20	0.21	0.21
North Carolina (49)	0.26	0.26	0.27	0.26
Average for Small[D] States	0.24	0.24	0.24	0.25
Average for All States	0.24	0.24	0.24	0.24
State (# of Counties)	Average MAPE over Counties for Rice[E]			
Texas (4)	0.23	0.23	0.22	0.19
Louisiana (5)	0.24	0.25	0.24	0.20
Mississippi (6)	0.24	0.24	0.24	0.19
California (7)	0.25	0.25	0.25	0.21
Arkansas (18)	0.25	0.25	0.25	0.21
Average for All States	0.24	0.24	0.24	0.20
State (# of Counties)	Average MAPE over Counties for Sorghum[F]			
Kansas (21)	0.29	0.29	0.31	0.28
Texas (29)	0.28	0.28	0.23	0.30
Average for All States	0.29	0.29	0.27	0.29

Notes: A. Revenue is forecast in two ways: (a) a direct forecast of revenue and (b) a forecast of the price and yield component which are then combined to create a forecast of revenue. MAPE for component forecast is calculated as follow: revenue forecast error = $(P \times Y) - (\hat{P}_{OMA5} \times \hat{Y}_{OMA5})$. MAPE for the direct forecast of revenue is calculated as follows: revenue forecast error = $(P \times Y) - (\widehat{P \times Y}_{OMA5})$. B. MA$n$ stands for simple moving average of previous n years. C. Large states are the five largest production U.S. states among states with at least 20 counties with all years of data. D. Small states are the five smallest production U.S. states among states with at least 19 counties with all years of data. E. For rice, each state investigated has limited number of counties. F. For sorghum, only two states are chosen for analysis based on data availability.

Source: original calculations using data from U.S. Department of Agriculture (USDA), National Agricultural Statistics Service (NASS), Quick Stats Database

Table 3: Moving Average (MA) and Olympic Moving Average (OMA) Technique with Smallest Mean Absolute Percentage Error (MAPE) in Forecasting County Revenue, Corn and Soybeans, 1974-2013 Crop Years

	Best Forecast Technique[A]	MAPE
State (# of Counties)	Revenue Forecast for Corn	
Minnesota (65)	MA1PY	0.21
Indiana (69)	MA3R	0.18
Nebraska (79)	MA1PY	0.18
Illinois (82)	MA3R	0.21
Iowa (99)	MA2PY	0.20
Average for Large[B] States		0.20
Tennessee (24)	MA3PY	0.25
Pennsylvania (31)	MA2R	0.25
Virginia (31)	MA6R	0.37
North Carolina (53)	MA4R	0.32
Kentucky (55)	MA3R	0.24
Average for Small[C] States		0.29
Average for All States		0.24
State (# of Counties)	Revenue Forecast for Soybeans	
Ohio (54)	MA2R	0.17
Minnesota (63)	MA1R	0.20
Indiana (66)	MA2R	0.15
Illinois (91)	MA2R	0.15
Iowa (99)	MA2PY	0.17
Average for Large States		0.17
Tennessee (22)	MA1R	0.23
Virginia (25)	MA4R	0.29
Kentucky (35)	MA3PY	0.22
Wisconsin (49)	MA3PY	0.20
North Carolina (58)	MA3PY	0.22
Average for Small States		0.23
Average for All States		0.20

Notes: A. MAn stands for simple moving average of previous n years and OMAn stands for Olympic moving average of previous n years. "R" and "PY" mean the direct forecast and the component forecast of revenue, respectively. B. Large states are the five largest production U.S. states among states with at least 20 counties with all years of data. C. Small states are the five smallest production U.S. states among states with at least 20 counties with all years of data.

Source: original calculations using data from U.S. Department of Agriculture (USDA), National Agricultural Statistics Service (NASS), Quick Stats Database

Table 4: Moving Average (MA) and Olympic Moving Average (OMA) Technique with Smallest Mean Absolute Percentage Error (MAPE) in Forecasting County Revenue, Wheat, Rice, and Sorghum, 1974-2013 Crop Years

	Best Forecast Technique[A]	MAPE
State (# of Counties)	Revenue Forecast for Wheat	
Ohio (21)	MA5R	0.17
Oklahoma (22)	MA5R	0.24
Nebraska (36)	MA3R	0.21
Texas (53)	MA4R	0.27
Kansas (71)	MA5R	0.25
Average for Large[B] States		0.23
Kentucky (19)	MA1R	0.26
Missouri (24)	MA5R	0.24
Indiana (28)	MA5PY	0.20
Michigan (33)	MA5R	0.20
North Carolina (49)	MA4R	0.26
Average for Small[C] States		0.23
Average for All States		0.23
State (# of Counties)	Revenue Forecast for Rice[D]	
Texas (4)	MA1R	0.18
Louisiana (5)	MA1R	0.19
Mississippi (6)	MA1R	0.18
California (7)	MA1R	0.20
Arkansas (18)	MA1R	0.19
Average for All States		0.19
State (# of Counties)	Revenue Forecast for Sorghum[E]	
Kansas (21)	MA3PY	0.25
Texas (29)	MA6R	0.22
Average for All States		0.24

Notes: A. MAn stands for simple moving average of previous n years and OMAn stands for Olympic moving average of previous n years. "R" and "PY" mean the direct forecast and the component forecast of revenue, respectively. B. Large states are the five largest production U.S. states among states with at least 20 counties with all years of data. C. Small states are the five smallest production U.S. states among states with at least 19 counties with all years of data. D. For rice, each state investigated has limited number of counties. E. For sorghum, only two states are chosen for analysis based on data availability.

Source: original calculations using data from U.S. Department of Agriculture (USDA), National Agricultural Statistics Service (NASS), Quick Stats Database

(Appendix) Table 5: Mean Absolute Percentage Error (MAPE) of 5-Year Olympic Moving Average (OMA5) vs. Alternative Forecasts of County Revenue, Corn and Soybeans, 1974-2005 Crop Years

Price (P) Forecast[A]: $\longrightarrow$	OMA5	MA5[B]	n/a	MA2
Yield (Y) Forecast: $\longrightarrow$	OMA5	MA5	n/a	OMA5
Revenue (R) Forecast: $\longrightarrow$	n/a	n/a	OMA5	n/a
State (# of Counties)	Average MAPE over Counties for Corn			
Minnesota (65)	0.20	0.21	0.21	0.16
Indiana (69)	0.18	0.18	0.17	0.17
Nebraska (79)	0.17	0.17	0.17	0.15
Illinois (82)	0.20	0.20	0.20	0.18
Iowa (99)	0.21	0.21	0.21	0.17
Average for Large[C] States	0.19	0.19	0.20	0.17
Tennessee (24)	0.26	0.26	0.26	0.24
Pennsylvania (31)	0.27	0.27	0.26	0.24
Virginia (31)	0.42	0.40	0.39	0.39
North Carolina (53)	0.36	0.35	0.35	0.34
Kentucky (55)	0.26	0.24	0.24	0.24
Average for Small[D] States	0.31	0.30	0.30	0.29
Average for All States	0.25	0.25	0.25	0.23
State (# of Counties)	Average MAPE over Counties for Soybeans			
Ohio (54)	0.18	0.17	0.17	0.17
Minnesota (63)	0.20	0.20	0.20	0.19
Indiana (66)	0.16	0.15	0.15	0.15
Illinois (91)	0.16	0.16	0.16	0.15
Iowa (99)	0.19	0.18	0.19	0.17
Average for Large States	0.18	0.17	0.18	0.16
Tennessee (22)	0.28	0.26	0.27	0.25
Virginia (25)	0.31	0.31	0.31	0.32
Kentucky (35)	0.24	0.22	0.23	0.24
Wisconsin (49)	0.20	0.20	0.20	0.19
North Carolina (58)	0.21	0.20	0.20	0.21
Average for Small States	0.25	0.24	0.24	0.24
Average for All States	0.21	0.21	0.21	0.20

Notes: A. Revenue is forecast in two ways: (a) a direct forecast of revenue and (b) a forecast of the price and yield component which are then combined to create a forecast of revenue. MAPE for component forecast is calculated as follow: revenue forecast error = $(P \times Y) - (\hat{P}_{OMA5} \times \hat{Y}_{OMA5})$. MAPE for the direct forecast of revenue is calculated as follows: revenue forecast error = $(P \times Y) - (\widehat{P \times Y}_{OMA5})$. B. MA$n$ stands for simple moving average of previous n years. C. Large states are the five largest production U.S. states among states with at least 20 counties with all years of data. D. Small states are the five smallest production U.S. states among states with at least 20 counties with all years of data.

Source: original calculations using data from U.S. Department of Agriculture (USDA), National Agricultural Statistics Service (NASS), Quick Stats Database

(Appendix) Table 6: Mean Absolute Percentage Error (MAPE) of 5-Year Olympic Moving Average (OMA5) vs. Alternative Forecasts of County Revenue, Wheat, Rice, and Sorghum, 1974-2005 Crop Years

Price (P) Forecast[A]: ⟶	OMA5	MA5[B]	*n/a*	MA2
Yield (Y) Forecast: ⟶	OMA5	MA5	*n/a*	OMA5
Revenue (R) Forecast: ⟶	*n/a*	*n/a*	OMA5	*n/a*
State (# of Counties)	Average MAPE over Counties for Wheat			
Ohio (21)	0.16	0.15	0.16	0.18
Oklahoma (22)	0.22	0.21	0.21	0.21
Nebraska (36)	0.22	0.21	0.21	0.19
Texas (53)	0.26	0.25	0.25	0.25
Kansas (71)	0.25	0.24	0.24	0.23
Average for Large[C] States	0.22	0.21	0.21	0.21
Kentucky (19)	0.29	0.29	0.30	0.29
Missouri (24)	0.25	0.24	0.25	0.24
Indiana (28)	0.20	0.19	0.19	0.22
Michigan (33)	0.20	0.19	0.19	0.20
North Carolina (49)	0.25	0.25	0.25	0.22
Average for Small[D] States	0.24	0.23	0.24	0.23
Average for All States	0.23	0.22	0.23	0.22
State (# of Counties)	Average MAPE over Counties for Rice[E]			
Texas (4)	0.21	0.22	0.20	0.19
Louisiana (5)	0.24	0.25	0.23	0.19
Mississippi (6)	0.24	0.25	0.24	0.19
California (7)	0.26	0.25	0.25	0.21
Arkansas (18)	0.25	0.26	0.25	0.20
Average for All States	0.24	0.24	0.24	0.20
State (# of Counties)	Average MAPE over Counties for Sorghum[F]			
Kansas (21)	0.27	0.26	0.29	0.24
Texas (29)	0.26	0.26	0.21	0.27
Average for All States	0.26	0.26	0.25	0.26

Notes: A. Revenue is forecast in two ways: (a) a direct forecast of revenue and (b) a forecast of the price and yield component which are then combined to create a forecast of revenue. MAPE for component forecast is calculated as follow: revenue forecast error = $(P \times Y) - (\hat{P}_{OMA5} \times \hat{Y}_{OMA5})$. MAPE for the direct forecast of revenue is calculated as follows: revenue forecast error = $(P \times Y) - (\widehat{P \times Y}_{OMA5})$. B. MA$n$ stands for simple moving average of previous n years. C. Large states are the five largest production U.S. states among states with at least 20 counties with all years of data. D. Small states are the five smallest production U.S. states among states with at least 19 counties with all years of data. E. For rice, each state investigated has limited number of counties. F. For sorghum, only two states are chosen for analysis based on data availability.

Source: original calculations using data from U.S. Department of Agriculture (USDA), National Agricultural Statistics Service (NASS), Quick Stats Database

(Appendix) Table 7: Moving Average (MA) and Olympic Moving Average (OMA) Technique with Smallest Mean Absolute Percentage Error (MAPE) in Forecasting County Revenue, Corn and Soybeans, 1974-2005 Crop Years

	Best Forecast Technique[A]	MAPE
State (# of Counties)	Revenue Forecast for Corn	
Minnesota (65)	MA2PY	0.19
Indiana (69)	MA3R	0.17
Nebraska (79)	OMA7R	0.16
Illinois (82)	MA3PY	0.19
Iowa (99)	MA2PY	0.19
Average for Large[B] States		0.18
Tennessee (24)	MA7PY	0.24
Pennsylvania (31)	MA3R	0.25
Virginia (31)	MA7R	0.37
North Carolina (53)	OMA7R	0.33
Kentucky (55)	MA3R	0.23
Average for Small[C] States		0.28
Average for All States		0.23
State (# of Counties)	Revenue Forecast for Soybeans	
Ohio (54)	MA3R	0.16
Minnesota (63)	OMA7R	0.18
Indiana (66)	MA3PY	0.14
Illinois (91)	MA2R	0.14
Iowa (99)	OMA3PY	0.16
Average for Large States		0.16
Tennessee (22)	MA1R	0.22
Virginia (25)	OMA7R	0.29
Kentucky (35)	MA1R	0.21
Wisconsin (49)	OMA7PY	0.19
North Carolina (58)	MA7R	0.19
Average for Small States		0.22
Average for All States		0.19

Notes: A. MAn stands for simple moving average of previous n years and OMAn stands for Olympic moving average of previous n years. "R" and "PY" mean the direct forecast and the component forecast of revenue, respectively. B. Large states are the five largest production U.S. states among states with at least 20 counties with all years of data. C. Small states are the five smallest production U.S. states among states with at least 20 counties with all years of data.

Source: original calculations using data from U.S. Department of Agriculture (USDA), National Agricultural Statistics Service (NASS), Quick Stats Database

(Appendix) Table 8: Moving Average (MA) and Olympic Moving Average (OMA) Technique with Smallest Mean Absolute Percentage Error (MAPE) in Forecasting County Revenue, Wheat, Rice, and Sorghum, 1974-2005 Crop Years

	Best Forecast Technique[A]	MAPE
State (# of Counties)	Revenue Forecast for Wheat	
Ohio (21)	OMA7PY	0.15
Oklahoma (22)	MA5R	0.21
Nebraska (36)	MA2R	0.20
Texas (53)	MA4R	0.24
Kansas (71)	MA5R	0.24
Average for Large[B] States		0.21
Kentucky (19)	MA1R	0.26
Missouri (24)	MA7R	0.24
Indiana (28)	OMA6R	0.18
Michigan (33)	MA5R	0.19
North Carolina (49)	OMA4PY	0.24
Average for Small[C] States		0.22
Average for All States		0.21
State (# of Counties)	Revenue Forecast for Rice[D]	
Texas (4)	MA1R	0.18
Louisiana (5)	MA2R	0.19
Mississippi (6)	MA1R	0.18
California (7)	MA1R	0.21
Arkansas (18)	MA1R	0.20
Average for All States		0.19
State (# of Counties)	Revenue Forecast for Sorghum[E]	
Kansas (21)	MA2PY	0.23
Texas (29)	MA6R	0.20
Average for All States		0.21

Notes: A. MAn stands for simple moving average of previous n years and OMAn stands for Olympic moving average of previous n years. "R" and "PY" mean the direct forecast and the component forecast of revenue, respectively. B. Large states are the five largest production U.S. states among states with at least 20 counties with all years of data. C. Small states are the five smallest production U.S. states among states with at least 19 counties with all years of data. D. For rice, each state investigated has limited number of counties. E. For sorghum, only two states are chosen for analysis based on data availability.

Source: original calculations using data from U.S. Department of Agriculture (USDA), National Agricultural Statistics Service (NASS), Quick Stats Database