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Potential Variability in Commodity Support: Agriculture Risk Coverage and Price Loss Coverage Programs

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Abstract

The Agriculture Risk Coverage (ARC) and Price Loss Coverage (PLC) programs, first authorized in 2014 and reauthorized in the Agriculture Improvement Act of 2018, provide counter-cyclical income support to farmers if county-level revenues or prices fall below either historical county benchmark levels or effective reference prices. The conditionality of these support programs creates uncertainty regarding the future levels of Government outlays. For example, in the first 4 years of the programs, producers received $22.5 billion, with income support ranging from $2.5 billion to $7.5 billion per year. This report estimates cost ranges for ARC and PLC over the next 10 years for the three largest covered commodities by area—corn, soybeans, and wheat. Simulating program costs at both the county and national levels indicate a wide variability of program expenditures due to uncertainty in commodity markets. The results explore how program costs are projected to unfold, given 2014 Farm Bill program election decisions, as well as a scenario with producers updating their election choices using 2018 Farm Bill projections made by the Congressional Budget Office. Simulations at the county level indicate producers are less likely to receive payments from ARC if their county yields are more closely correlated with national yields.

Keywords: Farm Bill, Agriculture Risk Coverage, Price Loss Coverage, ARC, PLC, commodity support, risk coverage

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About the Authors

Erik O'Donoghue's contribution was made while employed by the Economic Research Service.

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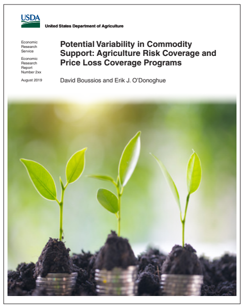

Potential Variability in Commodity Support: Agriculture Risk Coverage and Price Loss Coverage Programs

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What Is the Issue?

The Agricultural Act of 2014 shifted farm support payments from programs with mostly fixed amounts to the Agriculture Risk Coverage (ARC) and Price Loss Coverage (PLC) programs, which provide income support conditional on market outcomes. The Agriculture Improvement Act of 2018 continues these programs with modest changes. For ARC and PLC, payments occur when revenues or prices fall below a certain level. Since these programs are tied to market outcomes, both future payments to producers and the program costs to the Government are uncertain. For example, in the first 4 years of the programs, producers received $22.5 billion, with support ranging from $2.5 billion to $7.5 billion per year. This report analyzes the programs' features and the likelihood of payments being triggered in upcoming years, both nationally and at the county level. The study focuses on the three largest covered commodities by program area—corn, soybeans, and wheat—which make up 88 percent of the acres covered by these programs.

What Did the Study Find?

Using the *USDA Agricultural Projections to 2028*, ERS researchers generated a range of potential commodity prices that were then used to estimate possible ARC and PLC payment levels.

Price trends influence expected ARC and PLC payments. Corn and wheat prices are expected to recover slightly from previous years, while soybean prices have declined due to recent trade uncertainties. These price movements impact not only the payments from each program but also the election choice of farmers. Projected prices above effective reference prices—the trigger values for determining PLC payments—indicate higher payments from ARC than from PLC for corn and soybeans over the next 10 years. With wheat prices projected below the effective reference price, PLC will likely pay more per acre than ARC.

Program costs to the government can vary within a wide range each year
Significant differences between the annual average and median payments for each crop indicate a wide range of potential payments, with sizeable payments if prices decline significantly. Using farmer election choices made under the 2014 Farm Bill, the projected costs for the 2019/20 marketing year for ARC and PLC combined are:

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corn (median and average: $245 million and $1.22 billion respectively), soybeans (median and average: $347 million and $1.02 billion), and wheat ($477 million and $680 million). At projected prices, payments for corn and soybeans would be triggered under ARC only. For wheat, payments are likely with either program. If realized corn or soybean prices decline roughly 5 percent from projected prices, then PLC payments will be triggered. When PLC payments are triggered, the costs of programs jump significantly because PLC payments are triggered nationally.

ARC pays a conditional amount of income support depending on realized county revenues and benchmark revenue thresholds. The most frequent payment level for ARC is expected at either $0 or the program cap each year. While ARC can provide a range of per-acre support for a commodity in a year, the most common per-acre levels observed are either $0 or the maximum per-acre level possible. This is due to the relatively narrow band of revenues over which per-acre support levels can actually vary (regardless of crop type). Because of this formula for payments, the distribution of support payments is bimodal.

The probabilities of ARC payments are related to the location of production and the variability of the county's yield. Farmers in counties where their yields correlate positively with national yields are less likely to receive ARC payments because production and prices provide natural revenue risk mitigation. For example, low national yields (supply) increase national prices, which increase revenue. However, farmers in counties with yields less positively correlated with national yields are more likely to receive ARC payments when county yields are low. The variability of a county's yield also influences the probability of ARC payments. More volatile county yields make ARC payments more likely because revenue fluctuates below the ARC payment threshold more frequently.

How Was the Study Conducted?

Using a simulation approach with the ERS 10-year agricultural projection (baseline) model, random yield and macroeconomic variable scenarios were simulated to project the distributions of uncertain market outcomes, such as prices and production. Instead of the point estimate projections used in the USDA's agricultural baseline projections, this approach develops probability distributions that allow for an examination of the uncertainty and variability of commodity market outcomes, including commodity support programs. Using data on county-level yields and macroeconomic variables spanning 1990 through 2017, the approach projects and simulates county-level crop yields across 1,000 draws to estimate the variation in markets and program payments over 10 years, beginning with the 2019/20 crop year. To project the costs of the ARC and PLC program, two base-acre election scenarios are used to analyze how costs may change due to farmers' choices.

Potential Variability in Commodity Support: Agriculture Risk Coverage and Price Loss Coverage Programs

Introduction

U.S. agricultural policy primarily originates from legislation that gets reauthorized every 5 years, commonly known as the Farm Bill.[1] With this multifaceted bill, the U.S. Congress decides which farm and food-related programs to newly authorize, amend, or repeal. This report analyzes and projects the costs of two of the principal programs housed in Title I—the commodity section of the Farm Bill. In 2014, the Agriculture Risk Coverage (ARC) and Price Loss Coverage (PLC) programs were authorized, while the Direct and Countercyclical Payment (DCP) and Average Crop Revenue Election (ACRE) programs were repealed. This policy shift signaled a move from mostly unconditional to conditional farmer payments.[2] Instead of fixed predetermined payments, farmers now receive payments when either revenue or prices fall below predetermined levels.

As programs change, new ways of analyzing programs and projecting their costs/benefits become vital from both the farmer's and Government's perspective. With mostly fixed payments, expenditures varied modestly and could be built into longrun plans as both an incoming cash flow (for a farmer) and as outlays (for the Government). With these new programs, however, unpredictable swings in commodity prices and weather can upend payment levels. In 2014, the Congressional Budget Office (CBO), which projects the costs of each new piece of legislation, estimated that the cost of the new commodity support programs would total $14.9 billion from 2014 through 2017 (Congressional Budget Office, 2014), foreshadowing a reduction in Title 1 program costs. However, the realized prices and yields resulted in final ARC/PLC outlays over the 4 years of $22.5 billion, 51 percent more than expected (USDA, Farm Service Agency, 2018). Rather than saving taxpayers' money, these programs ended up costing more than the recently eliminated fixed programs due to unforeseen fluctuations in market conditions. Because of the size and range of these payments, anticipating these expenditures is helpful for farmers as well as decision makers responsible for making budget decisions in the coming years.

The reauthorization of the ARC and PLC programs with the Agriculture Improvement Act of 2018 continued the programs for another 5 years. This reauthorization, and the changes made in the new legislation, make analyzing the programs from both farmers' and the Government's perspective relevant. We therefore examine the probabilities of payment—and potential ranges of support—provided from the ARC and PLC programs under the new program rules.

[1]When Congress is designing and writing the legislation for a farm act, it is called a *bill*. Once signed into law, however, it becomes an act. Accordingly, this report uses the phrasing *bill* when referring to potential legislation that is not yet law, and uses act when referring to legislation that has become law.

[2]While countercyclical and ACRE payments were conditional, they accounted for less than 5 percent of the fixed direct payments in the 3 years leading up to that program change.

ARC and PLC pay farmers conditional on different events, and by determining the probabilities of each program's payments, farmers and policymakers can be better prepared for how much and when farmers receive payments. This report examines anticipated cost ranges for the three largest program crops by base acres: corn, soybeans, and wheat, which made up 74 percent of total ARC/PLC outlays and 88 percent of enrolled area in 2016. While other covered commodities such as peanuts and rice have had outsized payments relative to their base acre sizes (peanuts 1 percent base acres and 7 percent payments; rice 2 percent base acres and 9 percent payments in the 2015 and 2016 crop years), this report's focus on the three main commodities is due to the similarity in commodity type and growing areas.

Background and Calculations of ARC and PLC Program Payments

The ARC and PLC programs are administered by USDA's Farm Service Agency (FSA).[3] Eligibility for programs depends upon the classification of farmland into specific covered commodities, based on the history of production on each acre of land. For example, area would be designated as corn base acres if corn was planted on those acres during a specified historical time interval.[4] Program support payments are then tied to the covered commodity for the base acre type, determining payments regardless of the crop actually planted on the land. This design attempts to decouple planting choice from program support to limit distortions in the market incentives of farmers.

Given this classification of land into base acres for a covered commodity, the farmer decides to elect either ARC or PLC for any eligible acres. Under the Agricultural Act of 2014, this election decision was fixed for the entirety of the legislation (5 years). These rules changed with the Agriculture Improvement Act of 2018, as farmers are allowed to change their election choice from the prior bill. Their initial election choice will be fixed for the first 2 crop years (2019 and 2020). Thereafter, farmers will be allowed to change their election choice each year. If a farmer does not make an election choice, the farmer will not receive any payments for the 2019 crop year, and the election choice will default to the selection made under the 2014 Farm Act for the 2020 crop year.

Recent legislation has moved farm programs away from fixed payment systems to those that provide income support conditional on market conditions. This policy movement has not only impacted ARC and PLC programs but also emphasized crop insurance for farmers to manage their risk. One might intuit that ARC and PLC provide support in ways similar to crop insurance since they pay farmers conditional on random yields and prices. Yet they differ in distinct ways. ARC and PLC pay according to base acres and not planting area, so payments are tied to historical patterns of production, not current production decisions. Program price guarantees for crop insurance are based on commodity market prices around the time of harvest, while ARC and PLC use historical or legislatively determined prices for their level of support. Finally, ARC and PLC do not require fees to enroll while producers must pay a premium (or administrative fee) to obtain a crop insurance policy to cover their crops.

[3]The FSA and the ERS websites, as well as O'Donoghue et al. (2016), provide additional program details that are not included here.

[4]For more detail and information on base acres, see the discussion on base acre reallocation in the USDA, FSA 2014 Farm Bill Fact Sheet titled "Base Acre Reallocation, Yield Updates, Agriculture Risk Coverage (ARC) & Price Loss Coverage (PLC), September 2014."

How the Programs Work

In the Agricultural Act of 2014, Congress set reference prices used to establish payment trigger levels for each commodity. These values, which are central to the program's income support payments, were modified with the Agriculture Improvement Act of 2018 to increase payment rates if prices trend upward, through what are called Effective Reference Prices, calculated as:

$$\textit{Reference Price(RP)} = \$ \textit{ value set by Congress in 2014 Farm Act} \quad (1)$$

$$\textit{Effective Reference Price (ERP)} = \begin{cases} RP & \text{if } 85\% \text{ of OA Price} < RP \\ 85\% \text{ of OA Price} & \text{if } RP \leq 85\% \text{ of OA Price} < 115\%\ RP \\ 115\% \text{ of } RP & \text{if } 85\% \text{ of OA Price} \geq 115\% \text{ of } RP \end{cases} \quad (2)$$

The effective reference price (ERP) is equal to the greater of (a) the value set by Congress in the 2014 Farm Act or (b) 85 pecent of the Olympic average (OA) of the previous five marketing/crop year average (MYA) prices or (c) up to a maximum value of 115 (OA) percent of the value set by Congress in the 2014 Farm Act. The Olympic average is calculated by collecting the prior 5 years of data, removing the highest and lowest values, and averaging the remaining three values.

For the PLC program, the payment per enrolled base acre is related to the difference between the effective reference price and the higher of the (a) MYA price each year or (b) loan rate, multiplied by an individual's farm-specific yields (PLC Yield), as shown below:

$$\textit{PLC Payment Rate} \quad (3)$$

$$= \begin{cases} 0 & \text{if MYA Price} \geq ERP \\ (ERP - \text{MYA Price}) * \text{PLC Yield} & \text{if } NMLR < \text{MYA Price} < ERP \\ (ERP - NMLR) * \text{PLC Yield} & \text{if MYA Price} \leq NMLR \end{cases}$$

$$\textit{Nonrecourse Marketing Loan Rate(NMLR)} = \$ \textit{ value set by Congress} \quad (4)$$

$$\textit{PLC Payment Received} = \textit{PLC Payment Rate} * 85\% \quad (5)$$

A farmer receives PLC payments if the MYA price falls below the effective reference price. By including the Nonrecourse Marketing Loan rate (NMLR) for calculating the effective price, it sets a cap on the amount of PLC payments per acre. The payment rate is calculated by the difference in the prices multiplied by the farm- and crop-specific PLC yield. The amount the farmer actually receives is equal to 85 percent of the payment rate. The PLC yield is fixed for the duration of the act, although producers are given a one-time opportunity to update their PLC yield and takes effect beginning with the 2020 crop year based on recent cropping history.

ARC payments per base acre are calculated based on the difference between county-level actual revenues and benchmark revenues.[5] The following six equations present its calculation:

$$\textit{Actual Revenue (AR)} = \begin{cases} \text{Country Yield} * \text{MYA Price} & \text{if MYA Price} \geq NMLR \\ \text{Country Yield} * NMLR & \text{if MYA Price} < NMLR \end{cases} \quad (6)$$

[5]Throughout this report, ARC refers to County-Level ARC (ARC-CO). Individual-Level ARC (ARC-IC) is also an option for farmers under the ARC program, though instead of county-level crop outcomes, there is a farm-specific whole-farm guarantee. ARC-IC however, has been omitted from discussion in this report since only 1 percent of base acres elected this program.

Average Historical Yield (7)

$$= \text{5 year Olympic Avg. County Average Yield}$$

Average Historical Price (8)

$$= \text{OA Price}$$

Benchmark Revenue (BR) (9)

$$= \text{Average Historical Yield} * \text{Average Historical Price}$$

ARC Payment Rate (10)

$$= \begin{cases} 0 & \text{if } AR \geq BR * 86\% \\ [86\% * BR] - AR, & \text{if } [86\% * BR] > AR\ [76\% * BR] \\ 10\% * BR, & \text{if } AR \leq [76\% * BR] \end{cases}$$

$$\text{ARC Payment Received} = 85\% * \text{ARC Payment Rate}. \quad (11)$$

Benchmark revenues are calculated as the product of the Olympic average county yield and national price. Actual revenue is the county average yield for a crop each year multiplied by the higher of the national MYA price or loan rate. ARC payments are generated if actual revenue falls below 86 percent of the benchmark revenue, where the payment makes up the difference in the two values. The value—86 percent of benchmark revenue—is known as the ARC guarantee. ARC payment rates are capped at 10 percent of benchmark revenue. Like the PLC program, payments received are equal to the value multiplied by 85 percent of base acres.

In addition to those basic equations, a couple of nuances help determine ARC payments. If a county yield falls below 80 percent of the county's Transitional Yield (T-yield), then the T-yield replaces the historical value for calculating average historical yield.[6] By removing yields below the T-yield, a higher level of average historical yield is maintained. On the price side of the ARC calculation, if any national marketing year average prices used in the benchmark revenue calculations fall below the effective reference price for a crop, the effective reference price replaces the historical value. The T-yields and effective reference prices place floors on how low the benchmark ARC revenues can go.[7]

Both ARC and PLC have farmer payment limitations. Individuals or legal entities (except a joint venture or general partnership) can receive only $125,000 from both ARC and PLC, while a married couple can receive up to $250,000 annually. (Persons who are married and engaged in the same farming operation (or separate farming operations) can each receive up to the $125,000 limitation providing they each make requisite contributions to their farming operation that meet the requirements of "actively engaged in farming" and "cash rent tenant" rules.)

[6]Transitional yields are determined according to section 502(b) of the Federal Crop Insurance Act (7 U.S.C. 1502(b)), which states in part, "The term 'transitional yield' means the maximum average production per acre or equivalent measure that is assigned to acreage for a crop year by the Corporation in accordance with the regulations of the Corporation whenever the producer fails- (A) to certify that acceptable documentation of production and acreage for the crop year is in the possession of the producer; or (B) to present the acceptable documentation on the demand of the Corporation or an insurance company reinsured by the Corporation."

[7]Also included in the Agriculture Improvement Act of 2018 was a rule that adjusts county-level average historical yields based on a trend of the county yield. As of the time this report was written, the exact formulas and method for adjusting these yields was not yet known. This trend adjustment will likely increase the benchmark revenues for ARC.

Table 1
Reference and marketing loan prices and base acres (Agriculture Improvement Act of 2018)

Crop	Reference price ($)	National marketing loan rate ($)	Base acres (Mil. acres)	Enrolled acreage as share of national base acres (%)
Corn	3.70	2.20	97.4	39
Soybeans	8.40	6.20	56.4	23
Wheat	5.50	3.38	64.9	26

Source: USDA, Farm Service Agency.

Table 1 presents the reference and marketing loan prices for the covered commodities of corn, soybeans, and wheat, as well as the number of base acres enrolled and its proportion of national base acres.[8] Prices greatly influence the level of program payments, while the number of base acres defines the scale of payments. While corn and soybeans are planted on roughly equal amounts of land, ARC and PLC are tied to base acres (which, in turn, are based on historical planting patterns) rather than current planting decisions, so corn base acres play an outsized role (relative to soybeans) in these programs. To further conceptualize these programs, see box, "County-Level ARC and PLC. Example"

County-Level ARC and PLC Example

The following demonstrates the differences in program payment levels for corn, soybean, and wheat base acres for Pettis County, Missouri, a randomly chosen county where all three crops are grown. Program payments for ARC and PLC under the Agricultural Act of 2014 were equivalent to those presented earlier, with slight differences in how benchmark revenue is calculated and the reference price. Under the prior program, the effective reference price was the same as the reference price.

Program support levels for example county, Pettis, Missouri

	Program triggers		Market outcomes			Support payments	
	Benchmark revenue ARC ($/acre)	Reference price* ($/bu)	MYA price ($/bu)	Actual yields (bu/acre)	Actual revenue ($/acre)	ARC payments ($/acre)	PLC payments ($/acre)
Corn							
2014/15	566.03	3.70	3.70	188	695.60	0.00	0.00
2015/16	566.03	3.70	3.61	107	386.27	48.11	4.87
2016/17	512.53	3.70	3.36	166	557.76	0.00	18.41
Soybeans							
2014/15	478.53	8.40	10.10	49	494.90	0.00	0.00
2015/16	478.53	8.40	8.95	34	304.30	40.67	0.00
2016/17	427.32	8.40	9.47	52	492.44	0.00	0.00
Wheat							
2014/15	316.80	5.50	5.99	58	347.42	0.00	0.00
2015/16	355.10	5.50	4.89	42	205.38	30.18	15.24
2016/17	355.10	5.50	3.89	68	264.52	30.18	40.23

*The effective reference prices of the 2018 Farm Act correspond to (are equivalent to) the reference prices of the 2014 Farm Act.
Source: USDA, Farm Service Agency, ARC/PLC program data.

Continue—

[8]Values in the table do not include generic base acres in the calculations. Generic base acres are former upland cotton base acres that are paid based on current plantings of eligible covered commodities. As of this writing, in the Bipartisan Budget Act of 2018, all generic base acres must be reallocated to eligible covered commodities (including seed cotton) or become unassigned.

The table above provides county-level and program-specific details, as well as observed outcomes and program payments, for a representative farmer's base acres enrolled in each program in Pettis County. In calculating the payments, it is key to compare the actual MYA price to the (effective) reference price for each crop and marketing year. For corn base acres, the realized price equaled the reference price in 2014 and fell below the reference price for the other 2 years, signaling PLC support payments for those years. For soybean base acres, prices never dropped below the reference price, so the PLC program did not provide any support payments to producers. For wheat base acres, realized prices fell below the reference price in 2015 and 2016. Once it is established that support will be provided, total PLC payments are then determined using the PLC yield and the difference between actual and reference price.

While the triggering of PLC payments is straightforward, the calculation of ARC payments is more complicated since it must also incorporate realized yields. The differences in ARC payments for corn in 2015 and 2016, as well as a comparison to wheat for those years, offer an interesting contrast to how payments are triggered.

Prices in the 2015/16 marketing year were below the reference prices for corn, signaling an increased likelihood of triggering payments on base acres. However, higher corn yields in 2016 increased actual revenue above the ARC guarantee, while low yields in 2015 resulted in ARC payments being made. For wheat base acres, a similar decline in price and increase in yield occurred in both 2015 and 2016. However, the wheat yield increase was not significant enough to drive revenues above the ARC guarantee and thus triggered payments in both years. Generally, both prices and yields help to determine if payments are made under the ARC program.

Note also that for each of the crops that received ARC payments, the values were capped at 10 percent of benchmark revenue because the difference in the guarantee and the actual revenue exceeded the 10-percent of benchmark revenue threshold. As mentioned previously, once payments are triggered, it is quite likely that the payments will reach the upper bound and be capped, as seen here.

Program Election Decisions Moving Forward

With the passage of the Agriculture Improvement Act of 2018, farmers can switch their ARC or PLC election decisions for each base acre. This decision fixes the program choice for the 2019/20 and 2020/21 crop years. Starting in 2021, the farmers will be able to change their election decision annually. This shift from the prior legislation, which did not allow any modifications for the duration of the act, will allow farmers greater flexibility in selecting the programs that best serve their farm. Annual program changes will enable farmers to choose the program that is more likely to benefit them each year.

While future yields and prices are unknown, producers' ARC/PLC decisions hinge primarily on where they expect prices (and thus, support) to be for the duration of each choice. Table 2 presents the USDA's 10-year agricultural projections (known informally as the USDA Baseline) and the Congressional Budget Office's projected prices for the three crops analyzed here. USDA projects both corn and soybean prices to stay at or above the current reference price for the next 10 years. Wheat prices, on the other hand, are expected to remain below the current reference price for the next 10 years. At these levels, the effective reference price would equal the reference price.

If actual prices are near to or below effective reference prices (e.g., wheat prices), PLC will offer higher payments with much higher caps than ARC, making PLC more attractive to producers. When MYA prices are expected to be above effective reference prices (e.g., corn prices), PLC payments are less likely to be triggered, making ARC a more favorable choice. Because ARC payments are

Table 2
Selected commodity price projections from USDA Baseline and Congressional Budget Office, $/bu

	Corn		Soybeans		Wheat	
Marketing year	USDA	CBO	USDA	CBO	USDA	CBO
2019/20	3.90	3.52	8.75	9.67	5.20	5.10
2020/21	4.00	3.66	9.15	9.81	5.20	5.11
2021/22	4.10	3.76	9.55	9.67	5.30	5.11
2022/23	3.95	3.72	9.95	9.69	5.40	5.11
2023/24	3.80	3.72	9.90	9.70	5.20	5.10
2024/25	3.80	3.69	9.70	9.79	5.10	5.10
2025/26	3.70	3.73	9.65	9.73	5.00	5.10
2026/27	3.70	3.72	9.45	9.74	5.00	5.10
2027/28	3.70	3.70	9.45	9.75	5.00	5.11
2028/29	3.70	3.70	9.45	9.79	5.00	5.11
Reference price	3.70		8.40		5.50	

Source: U.S. Department of Agriculture, November 2018; Congressional Budget Office, April 2018.

tied to yields as well as prices, knowing which program will pay out more is challenging; even if one program is expected to pay more nationally, this may not hold locally given variation in local yields.

With the task of electing either ARC or PLC, the farmers' election decisions will have implications for program costs. While the number of applicants will determine these costs, exact election and subsequent enrollment numbers can only be projected. Table 3 presents the prior (2014 Farm Bill) national proportion of election/enrollment choices for ARC and PLC for the three crops, as well as the CBO's projected 2019-23 enrollment. CBO's large shift of corn base acres into PLC is likely in response to higher payments per acre received recently relative to ARC. However, if prices stay above effective reference prices as projected, ARC will be the higher paying of the two programs. The recent decline in soybean prices due to trade uncertainties makes PLC more attractive than in prior years, though the expected prices of soybeans at the time of the election decision will ultimately influence the decision. For wheat base acres, with effective reference prices significantly above projected prices, PLC is expected to pay farmers the most of the two programs.

Table 3
Prior and projected PLC and ARC enrollment, 2014-23

	Program	Prior enrollment (%) (2014-2018)	CBO projection (%) (2019-2023)
Corn	PLC	7	85
	ARC	93	15
Soybeans	PLC	4	28
	ARC	96	72
Wheat	PLC	45	82
	ARC	55	18

*Does not include generic acres.
Sources: Prior enrollment from USDA, Farm Service Agency. Projected area from Congressional Budget Office, April 2018.

Modeling and Projecting the ARC and PLC Outlays

The ARC and PLC programs are designed to provide income support to farmers in the event of low prices or revenue, but given the structure of these programs, the amount of support is uncertain. While 10-year Baseline projections can indicate where the market is headed, the actual marketing year prices that will be realized and their potential ranges are unknown, as is the level of payments producers would subsequently receive.

To estimate the uncertainty of commodity prices for ARC and PLC program outlays in the future, we use historical data to simulate county-level crop yields and international macroeconomic variables. We then add the simulations to a system of supply, consumption, and storage equations representing U.S. commodity markets to assess a range of possible ARC/PLC outcomes. Including the Baseline projections with county-level yield variation allows us not only to project national program expenditures but also to highlight farmer support (in the event of low revenues and/or prices) on a more granular (and potentially targetable) level.[9] See box, "Partial Equilibrium Model," for greater detail on the simulation process used in this report.

Using this model, we analyze and project the budgetary costs and payments for the ARC and PLC programs using the USDA's baseline projections as a benchmark. A set of scenarios demonstrates the impact of election choices on program costs. We first present results for the costs of the ARC and PLC programs over the next 10 marketing years, given assumptions about base acres. We next further explain these results and the role of base acre choices on program costs by breaking down national payments to amounts per base acre. Next, we highlight the results and the role of idiosyncratic differences across counties on program payments for a select number of counties to show how the probabilities of payments are expected to differ.

Partial Equilibrium Model

The domestic baseline projection model used at ERS is a partial equilibrium (PE) commodity model. More generally, it is a model based on a system of mathematical equations used to represent supply-and-demand behavior where prices are solved, ensuring supply equals demand. This technique is applied for all projection years and commodities, with outcomes linked across years and commodities. To develop this model, we estimated supply-and-demand equations to measure how each component of the market historically responded to changes in prices and other market conditions. In addition to projecting forward, this modeling approach is useful for estimating the impact of policy changes.

The traditional PE approach provides only a point estimate of future conditions (versus a probability distribution), since each equation is based on an average response. To capture the uncertainty of future production and markets, we calculate the differences in the estimated yield and macroeconomic variables from historically observed outcomes. Then using simulation techniques, we simulate these differences as exogenous shocks and add them to the respective supply-and-demand equations, solving for prices and quantity for each simulation draw. Using the collective results of the simulation, we measure and detail how the uncertainty-modeled projections are expected to vary from the point estimate generated for the USDA 10-year projections. While this estimation of ranges might appear and behave similarly to confidence bands of a projection, this approach simply builds in the historical uncertainty of weather-dependent yields and macroeconomic variables to the existing baseline projections (see appendix for more detail on the modeling and simulation approaches).

[9]We assume that ARC and PLC do not distort production decisions. Payments from these programs depend on current prices, but payments are not based on current production decisions. Due to the decoupling of payments and decisions in these programs, we do not model any adjustments to producer behavior based on enrollment in either ARC or PLC.

Simulation Results and Program Costs

With reauthorization of the ARC and PLC programs in the Agriculture Improvement Act of 2018, farmers can change their program election choice. As opposed to the election choice made under the 2014 Farm Act, the initial ARC/PLC election is only fixed for the first 2 crop years (MY 2019 and 2020) and allowed to change every year thereafter. While the switching of election choices presents challenges for budgeting longrun costs, we show the projected costs of the program under two different base scenarios to highlight how costs could differ depending on farmers' choices:

- Scenario 1, with 2014 Farm Act election decisions (the current election decisions in place at the time of this writing), and
- Scenario 2, with CBO projections for election decisions (the projected election decisions once producers have the opportunity to make their updated election decision under the 2018 Farm Act).

While neither representation of the programs will be entirely accurate, these two scenarios do suggest potential outcomes/costs in the future.

Figure 1 presents the simulated range and summary values for ARC and PLC outlays for corn, soybeans, and wheat given two different farmer election scenarios. The range of potential expenditures with either scenario highlight the potential variability of program costs with ARC and PLC. Across the two base-acre scenarios, corn is expected to provide the most support due to the larger number of base acres relative to the other crops. In addition, the ranges of potential costs are larger with corn due to both acreage and higher yields (revenues). While the expected average annual costs for ARC and PLC under the 2014 Farm Act election scenario [CBO projected election scenario] for corn, soybeans, and wheat base acres are $2 billion [$1.5 billion], $583 million [$288 million], and $1 billion [$1.15 billion], respectively, the range of outcomes varies considerably. For corn base acres alone in 2019, 75 percent of simulation draws included values between $90 million and $3.7 billion [$17 million and $3.2 billion], indicating a wide range of possible payments. While these ranges indicate large variability of program costs, comparing this range to historical data, corn base acres cost $3 billion in 2016 and $0.6 billion in 2017. Both these projections and the historical data highlight the variability of ARC/PLC costs.

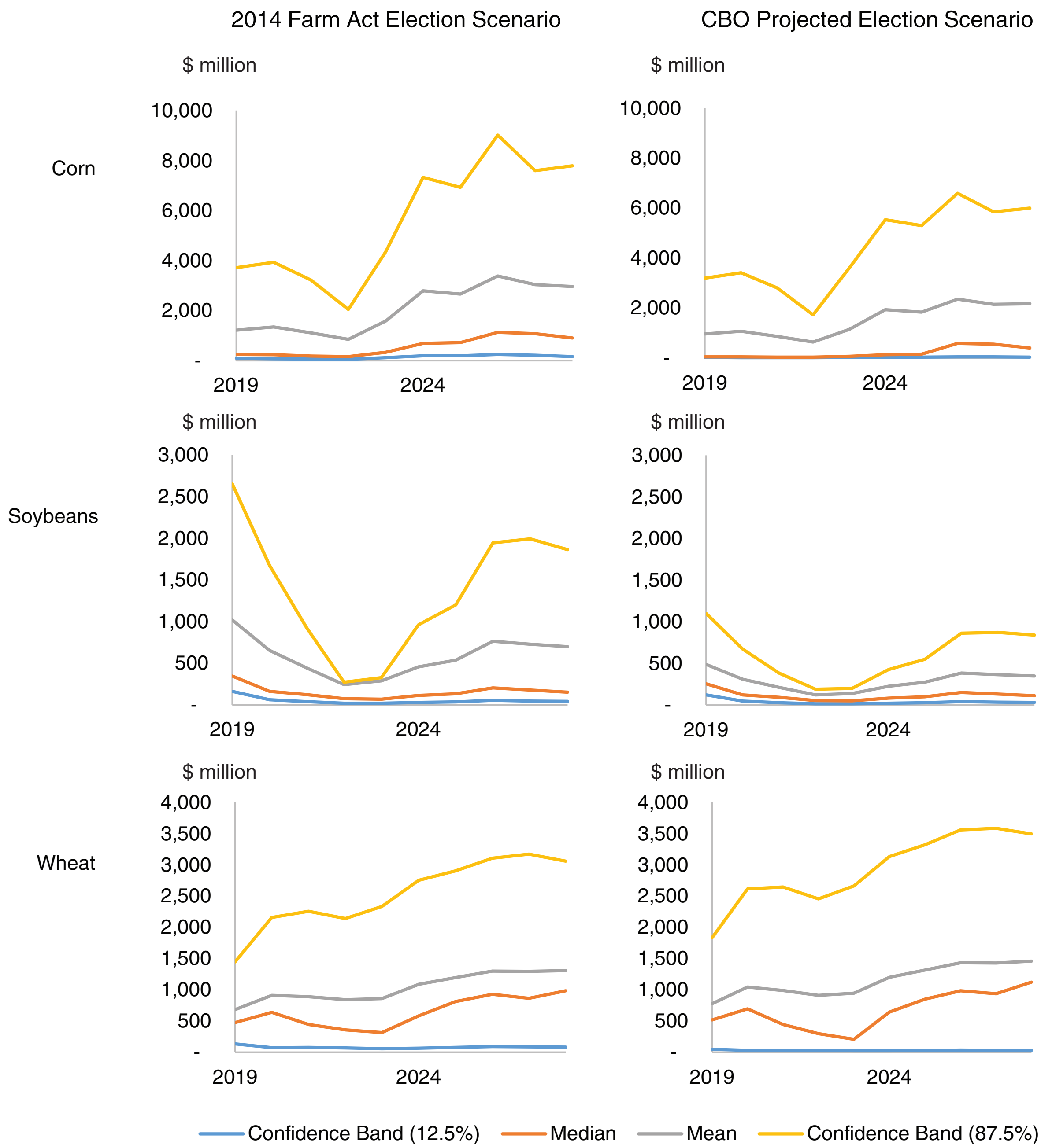
Payments for wheat base acres are expected to be higher than soybean payments due to the relation of projected prices and reference price. Wheat prices are not expected to exceed reference prices in the next 10 years, resulting in PLC payments every year. Conditional on realized yields, wheat producers could receive support from ARC as well. Baseline projections forecast prices for all three commodities to increase from 2019 levels, peak in 2022, and fall thereafter. This movement in prices causes a projected downward movement in program costs until they begin to climb again in 2022 when prices are projected to decline.

One new feature of the 2018 Farm Bill was the move from fixed to variable (effective) reference prices. While this change allows effective references prices to increase with higher commodity prices, in only 4.4 percent (corn), 17.0 percent (soybeans) and 0.5 percent (wheat) of the simulations did effective reference prices exceed the fixed reference prices. This limited increase in effective reference price is due to projected prices being roughly in line with reference prices. For example, Olympic average (5-year) corn prices would have to exceed $4.35 per bushel, making it unlikely to affect the reference price. The other major new feature of the Agriculture Improvement Act of 2018—the annual option to switch election choice between PLC and ARC beginning with crop year

2021/22—will also impact program costs. While these changes are not simulated here, the annual election switches are likely to increase the costs of the program. For example, an expected decline in commodity prices will drive more farmers to elect the PLC program due to higher payments per acre and a much higher cap on payments. On the other hand, an increase in expected prices will drive more farmers into ARC because PLC will have a lower probability of providing support.

Figure 1

The ability to switch programs can have substantial effects on total support levels



Note: Lines indicate projected costs from simulation results for both ARC (Agricultural Risk Coverage) and PLC (Price Loss Coverage). Simulations included 1,000 stochastic draws. The confidence bands were calculated sorting the simulations by expenditures each year, then finding the 125th and 875th values. These represent the range of values for the middle 75 percent of simulated outcomes. The left-hand figures project costs given 2014 election decisions, while the right-hand figures project costs using Congressional Budget Office's (CBO) projected election switch.
Source: U.S. Domestic Stochastic Baseline, 2019.

The two scenarios offer a glimpse into the cost differences with different enrollment switches; under the prior election choices, ARC was more favored by producers, while the CBO projections reflect the expected movement of base acres toward PLC. The actual cost of the elections switch is conditional on actual prices and how farmers project prices into the marketing year.

Not shown in figure 1, but characteristic of any projection, is an expanding range of potential outcomes the farther into the future payments are modeled. For example, a projected corn price of $3.95 per bushel for 2020 has a smaller range of potential outcomes than the same projected price in 2023. This result is due to the dynamics of outcomes and the resolving of events: more unknowns exist in 2023 than in 2020 that increase the range of potential outcomes, even if the average projected level remains the same.

While an expanding range of outcomes is typical of forecasts, this phenomenon has implications for the programs' projected costs. In each panel in figure 1, the median value of the simulations is closer to the lower bound confidence band, while the mean (average) value is closer to the upper confidence band. This indication of a skewed probability distribution highlights the probability of program costs. Although the very costly program years are infrequent in the simulation results, the "high-payout" years disproportionately increase the average program costs above median levels. In addition, in more distant years, the confidence range expands (typical of a forecast), increasing the probability of low-price (high-expenditure) events. This relationship of projections and prices naturally causes the average expected prices of the commodity support programs to rise over time.

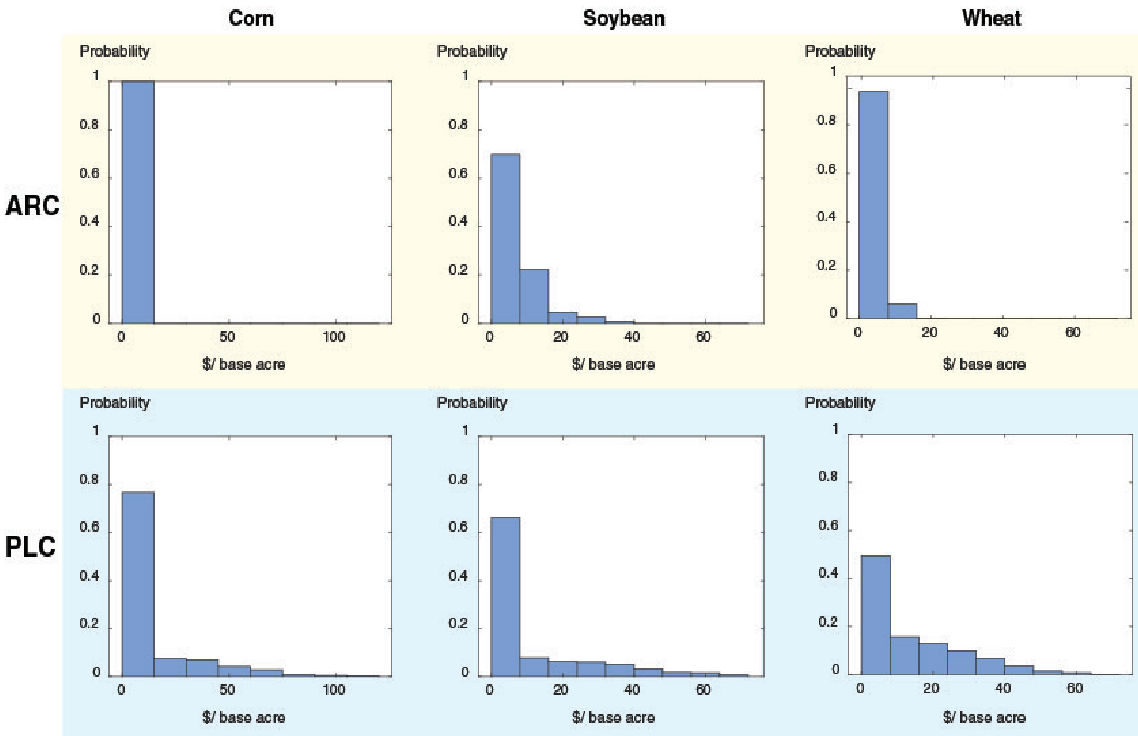
To further illuminate the distributions of payments and why simulated average costs exceed median costs, figure 2 displays histograms of the probability of payments averaged across all national base acres for the 2019/20 marketing year. The skew in the probability distribution is evident by the most likely event occurring near $0 per base acre. While ARC payments are never expected to be zero at the national level, the national average payment can appear near $0 per base acre because variations in county yields diminish average national payments. For PLC, national average payments can be zero if prices are above effective reference prices, though payments can range much further; when PLC payments are triggered, they occur on every base acre across the country. ARC payments for soybeans are more likely than for corn or wheat because the reference prices are higher relative to the price projections.

The projected corn price is above many of the recent MYA prices observed, indicating a lower probability of ARC payments for the 2019/20 crop year. Wheat payments are expected but, due to smaller revenues per acre, are not as high as for corn or soybeans.

For PLC payments, two features of the distribution are prominent: the probability of the lower bound and the declining probability tail away from zero. PLC payments are only triggered if national average MYA prices fall below the reference price. With the exception of wheat, PLC payments appear unlikely (figure 2). However, if prices fall significantly below reference prices, per-acre PLC payments would be higher than for ARC, because PLC payments are triggered nationally. Accordingly, the probability figures indicate the likelihood of MYA prices falling below the reference prices, as lower commodity prices (thus higher payments) are less likely the larger the difference between prices.

Figure 2

Compared to ARC, PLC has a higher range of payments



Note: Histogram of simulation results for the 2019/20 marketing year. ARC = Agricultural Risk Coverage; PLC = Price Loss Coverage.

County-Level Examples: 2019/20 Marketing Year

While projections of national-level costs can help forecast program expenditures, crop producers facing an ARC or PLC election decision would benefit from understanding the possible payout on their individual farm. Four different counties are presented here to illustrate the programs' varied effect (and appeal) across a variety of crops and geographies. For corn and soybeans, the counties of Linn, Iowa, and Lawrence, Alabama, are studied. Iowa was the largest State by area planted to corn and second largest for soybeans in 2017 (USDA NASS, 2018). Linn County is a fairly typical county within Iowa; by area planted, it ranked as the 20th and 46th largest county in Iowa for corn and soybeans. Lawrence, Alabama, a smaller producer of both crops, had the second-largest area planted to corn of counties in Alabama and the third-largest area planted to soybeans. Comparing these counties demonstrates the correlation of yields and national average values.

For wheat, the counties of Sumner, Kansas, and Sheridan, Montana, were chosen. Kansas is the largest producer of wheat by planted area, solely producing winter wheat. Montana is the third-largest wheat-producing State, and is a key supplier of spring-planted wheat. Sheridan County had the fourth-largest area planted to wheat in Montana, and seventh-largest area nationally, in 2017. Sumner is the fifth-largest county nationally by area planted to wheat. Sheridan County exhibits a higher trend-adjusted yield variance than does Sumner County.

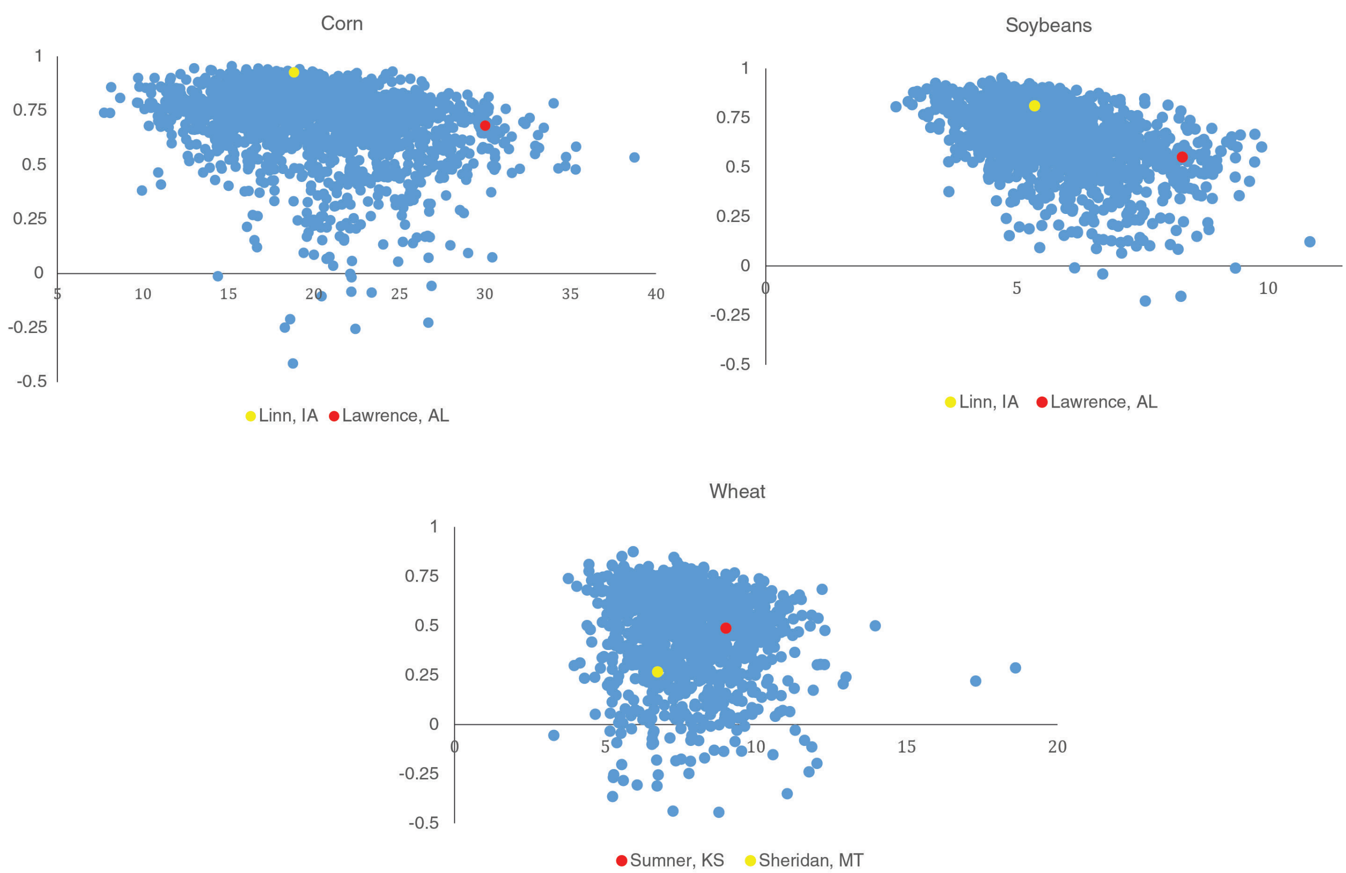
Figure 3 presents scatter plots for the standard deviation of historical yields (detrended) and the correlation of county yields with national yield. On the x-axis, the standard deviation measures the variability of a county's yield, indicating how often revenues might fall below the 86-percent threshold for ARC. Not knowing the true probability distribution of each county's yield limits the predictive ability of the yield standard deviation for projecting the probability of yields falling below a threshold, but does indicate the likelihood of yields differing from a county's average value. The y-axis measures the correlation between county and national yields. The more a county's yield correlates with the national yield, the more closely (negatively) correlated the county yield will be with national prices, necessary for calculating revenue.

A negative relationship between yields and prices creates a natural risk mitigation effect on revenues, and those counties most correlated with national yield are likely to have the lowest probability of receiving ARC payments, holding all else constant. Intuitively, when county and national yields are positively correlated, either prices or yield are low, but never both. However, for counties with yields that are uncorrelated or negatively correlated with national yields, this relationship need not hold.

In figure 3, Linn, Iowa, is more closely correlated with national yields and contains less yield variation for both corn and soybeans, suggesting it is less likely to generate ARC payments for both crops than Lawrence County, Alabama. For wheat, Sheridan, Montana, is less correlated with national yields but also less variable than Sumner, Kansas. Since the wheat grown in Sheridan is planted at a different time than most wheat grown in the United States, this lack of correlation is significant in relating county locations to program payments.

Figure 3

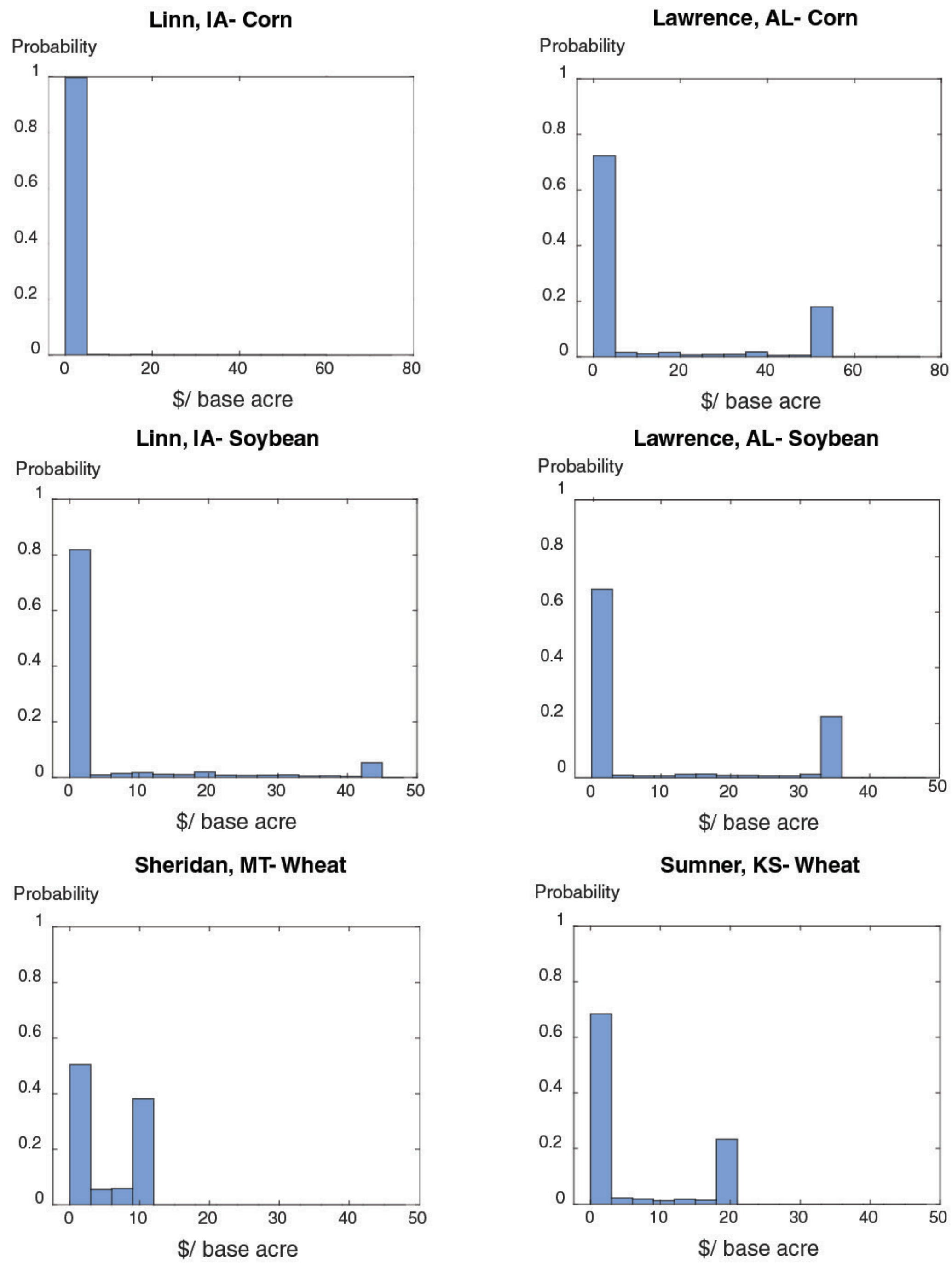
Correlation with national yields and variability of yield determine payments



Notes: (x-axis) Standard deviation of de-trended yield – the lower the value, the less variation in yields; (y-axis) national and county yield correlation. Each dot represents a single county. Red and yellow dots have been included to highlight two example counties for each crop. Source: U.S. Department of Agriculture, National Agricultural Statistics Service (NASS). 2018. "Quick Stats Database."

Figure 4 displays the projected per-acre county payments and their probabilities for ARC from the simulation results. While figures 1 and 2 display the aggregation of all county payments, those payments include the natural variation in yields and payments over the entire country, effectively smoothing the distribution over the possible range of payment levels. When displaying the probability of payment distributions at the county level, a new bimodal story emerges. Except for corn area in Linn County, IA (an area with low yield variability at the county level), these counties show a substantial frequency of payments at the disbursement extremes: either zero or at the capped maximum ARC payment level. While payment levels exist between these extremes, they are more rare.

Figure 4
ARC payments and their probabilities vary by counties



Source: Simulation results for the 2019/20 marketing year. ARC = Agricultural Risk Coverage.

For corn base area in Linn County, payments are unlikely, though they can range up to as much as $15 per acre.[10] In Lawrence County, AL, this value is capped at $53 per acre (the ARC cap) and payments are triggered in 18 percent of the simulations. This difference in frequency is due to a higher probability of differing from average yields, as well as a lower correlation with national yields (and thus simulated prices)

The limited likelihood of payments for corn base acres in Linn, IA, is also potentially due to how yields are simulated in this study and the ARC benchmark yields. Corn yields in Linn, IA, have shown a fairly significant trend upward, while the ARC Olympic average yields are based on the previous 5 years of data. As a result, the projected yield is 199 bushels/per acre while the Olympic average yield is 189 bushels. Higher projected prices and yields above the benchmark yield make payments unlikely. In the 2018 Farm Bill, a yield adjustment based on trend has been included in the legislation, but it is currently unclear how this value will be calculated. This adjustment will increase the likelihood of payments for counties with strong yield trends.

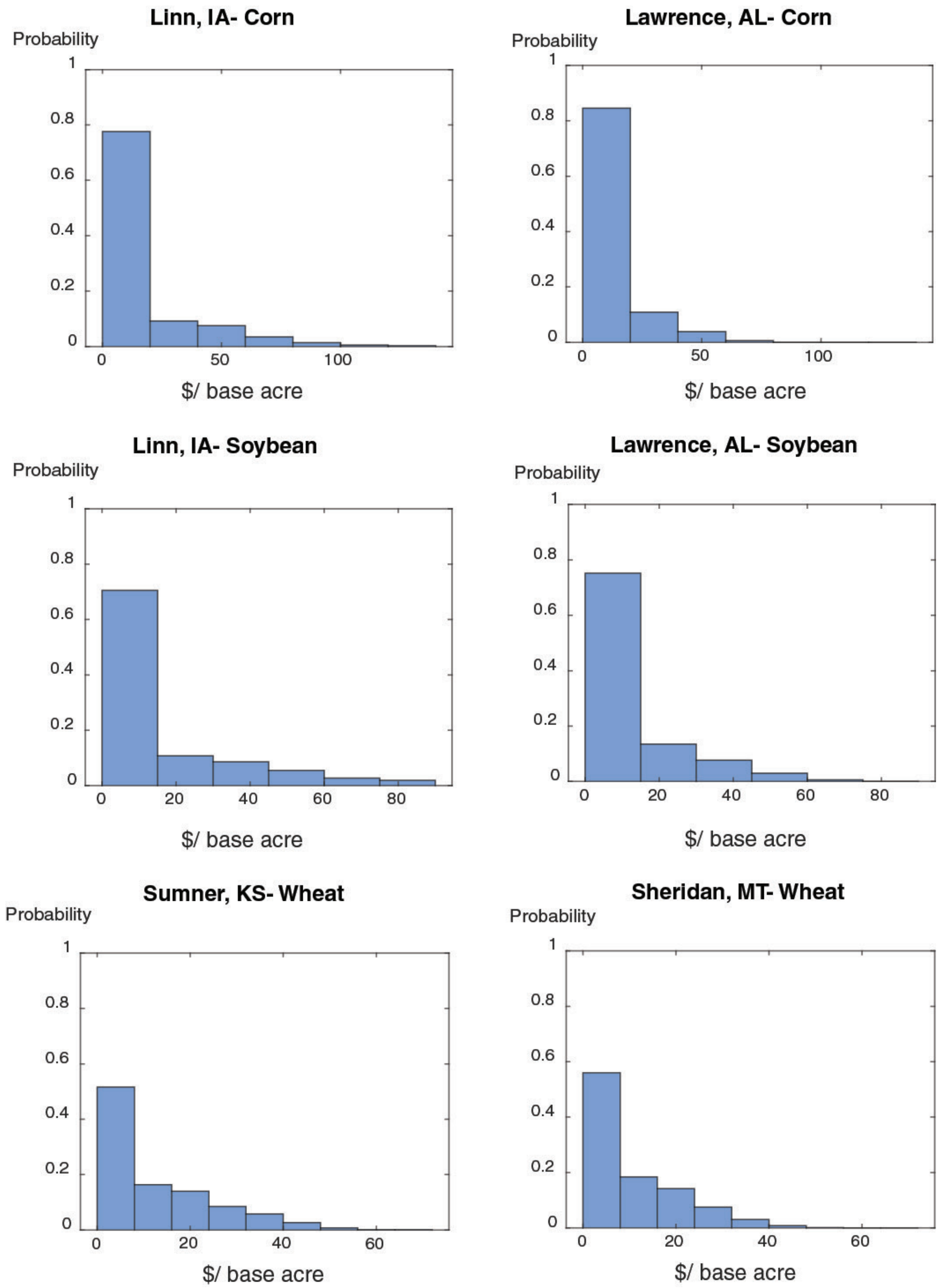
The low variability of soybean yields in Iowa and the high correlation of the county and national yields reduces the probability of soybean ARC payments in Linn County nearly to zero (80 percent are $0). In contrast, the probability of payment for soybeans in Lawrence County, AL, is slightly higher (33 percent result in positive support), with a maximum payment expected to occur roughly 22 percent of the time.

Wheat yields in Sheridan County, MT, are more variable and less correlated with national prices than those in Sumner County, KS. As a result, payments are more likely in Sheridan County than in Sumner County (56 percent versus 33 percent of the draws). However, the higher yields in Sumner, KS, increase the payment caps for ARC.

While ARC payments are conditional on county-level outcomes, PLC payments are tied strictly to national prices and farm-specific PLC yields (figure 5). Accordingly, PLC payment distributions are the same at the county and national scales after controlling for productivity (yield). County-level reference yields are shown here; individual producers' distributions would vary by the scaling of their own yields. On average, Linn County, IA, has higher historical yields and thus receives higher payments per acre for both corn and soybeans, relative to Lawrence, AL. Sumner County, KS, likewise has higher average reference yields for wheat than Sheridan County, MT, exhibiting higher per-acre payments.

[10] The limited likelihood of payments for corn base acres in Linn, IA, is also potentially due to how yields are simulated and the ARC benchmark yields. Corn yields in Linn, IA, have shown a fairly significant trend upward, while the ARC Olympic average yields are based on the previous 5 years of data. As a result, the projected yield is 199 bushels/per acre while the Olympic average yield is 189 bushels. Higher prices and yields above the benchmark yield make payments unlikely. In the 2018 Farm Bill, a yield adjustment based on trend has been included in the legislation, but it is currently unclear how this value will be calculated. This adjustment will increase the likelihood of payments for counties with strong yield trends.

Figure 5
PLC payments are scaled by PLC yields



Note: PLC = Price Loss Coverage.

Conclusion

This report establishes the use of a new approach for projecting the probability distributions for program payments by covered commodity using the USDA's Baseline projection as a benchmark. The approach provides detail to the potential *range* of costs associated with providing commodity farm payments to U.S. agricultural producers. Since the creation of the Agriculture Risk Coverage (ARC) and Price Loss Coverage (PLC) programs in 2014, commodity support payments have been mostly conditional on whether county revenues or prices fall below county benchmark levels or the effective reference price. The conditionality of these programs mean the Government's expenditures and a farmer's payments are variable each year. While these payments are uncertain, this report details the factors that influence program costs and by how much.

The extent of each program's expenditures and crop coverage are conditional on the amount of acres enrolled, as well as the crop type. Since corn is the largest covered commodity and the largest crop by per-acre revenues, it has and is expected to continue to feature prominently in total program costs. Wheat is likely to be the second-most costly covered commodity going forward, given current price projections and reference prices. While soybeans are the second-most planted U.S. crop, ARC and PLC make a relatively small proportion of payments to soybean producers because of (a) proportionally fewer base acres and (b) projected prices that currently lie above reference prices, a trend that is expected to hold even with current trade tensions.

Results show that the ranges of possible ARC program payments look markedly different at the county level than at the national level. The highest likelihood of ARC payments at the county level is at the "no payment" or maximum county program cap levels (10 percent of benchmark revenue). This bimodal payment pattern highlights the frequency of payments, as well as the role of yield variability and the correlation of county and national yields. Higher variability of yields and less correlation of production increases the frequency of ARC payments at the county level.

Given the formulas by which program payments are determined and the evolution of commodity prices and yields, program payments can change from year to year. With the Agriculture Improvement Act of 2018, producers will be given more flexibility in selecting which program to elect for their acres. Higher projected prices will make ARC relatively more attractive due to higher expected payments, while PLC will likely be chosen more frequently with lower projected prices. For wheat base acres, lower projected prices indicate that PLC is the more profitable choice. For corn and soybeans—with prices projected above the reference prices—the optimal choice will likely be more location specific.

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Appendix: U.S. Baseline Model With Stochastic Simulations

The U.S. baseline model used to simulate stochastic variation in commodity markets combines three components: (1) a partial equilibrium (PE) model, (2) USDA's baseline projections, and (3) econometric projections and simulations. While each element can be, and is, used separately, the combination provides a range of scenarios for the stochastic model.

At the core of the model is a PE model of supply, consumption, and storage equations that reflect the behavioral responses of agents to changes in price. The equations ensure supply-and-demand quantities equate within and across years, with equilibrium prices solving the levels of each variable.

The U.S. stochastic PE model can be generalized from the following set of 10 equations, defined below as a reference case using a simplified corn model set of equations:

$$Production_t = Area\ Harvested_t * Yield_t \quad (1)$$

$$Area\ Harvested_t = \beta_0 + \beta_1 * Area\ Planted_t \quad (2)$$

$$Yield_t = Predicted\ Yield_t + Shock_t \quad (3)$$

$$Area\ Planted_t = \Upsilon_0 + \Upsilon_1 * Price_{t-1} + \Upsilon_2 * Area\ Planted_{t-1} \quad (4)$$

$$Imports_t = \delta_0 + \delta_1 * Price_t \quad (5)$$

$$Feed_t = \rho_0 + \rho_1 * Price_t \quad (6)$$

$$Food_t = \phi_0 + \phi_1 * Price_t \quad (7)$$

$$Exports_t = \theta_0 + \theta_1 * Price_t + \theta_2 * Ex.Rate_t + \theta_3 * World\ GDP_t \quad (8)$$

$$Storage_t = \tau_0 + \tau_1 * Price_t \quad (9)$$

$$Storage_{t-1} + Production_t + Imports_t = Feed_t + Food_t + Exports_t + Storage_t \quad (10)$$

Equation 10 provides the market-clearing quantity identity that forces supply to equal use. Equations 1 through 5 plus equation 9 (lagged 1 year, and fixed) represent the supply available to the market in year *t*. Equations 6 through 8 represent consumption. Equation 9 is storage demand, which links quantities across years. The Greek letters are estimated parameter values from econometric equations or the authors' best judgment.

The equations and parameters presented in equations 1 through 9 are simplified from the true model for clarity. In practice, many of the equations include additional exogenous variables, such as population or time trends, which have been omitted here so as to reference only the endogenous variables and the exogenous variables that are affected by the simulation shocks (*Shock, Ex Rate*, *World GPD*). Many of the behavioral equations also include additional cross-price endogenous variables from other commodities, such as the price of wheat in the feed demand equation for corn. See Hjort et al. (2018) for more detail on the approach and how the equations may vary by commodity.

External to this set of equations are USDA's 10-year baseline projections of the prices and quantities for major crops produced and consumed in the United States. These deterministic projections use a variety of information and sources, and the final projections are the product of both expert opinion and statistical forecasting equations. (See Hjort et al. (2018) for a detailed description of PE models applied to commodity markets and the USDA baseline process.) While these baseline numbers provide an estimate of where the market is headed, they do not include projections of the potential uncertainty around the estimated outcomes.

Once USDA determines the final projection numbers, the PE model is benchmarked to the projections. This means that the intercepts of each equation ($\beta_0, \Upsilon_0, \delta_0, \rho_0, \phi_0, \theta_0, \tau_0$) are solved, given the baseline projections for both prices and quantity. This ensures that, when solved, the model (without the simulated shocks) matches the projected values for prices and quantity.

Estimation of the uncertainty and variability of the market is then approximated using econometrics and simulation procedures. While a committee of experts helps determine USDA's final baseline projections, which are reported to the public and used within USDA, it is challenging to similarly project the range of potential outcomes and prices by committee. Accordingly, the approach laid out here attempts to build in a research-based understanding of market behavior and the uncertainty of select variables to simulate the range and probabilities of outcomes in agricultural markets.

The simulations begin by identifying the largest sources of exogenous variation in agricultural markets. We have selected crop yields and macroeconomic variables. Accordingly, we must collect or generate probability distributions for the range of outcomes for each variable. We are interested in county-level yield outcomes across multiple crops as well as the correlation of production across the country since crop yields are spatially correlated (e.g., soybean and corn yields in neighboring counties are correlated).

To simulate this correlation and the probability distribution of outcomes, we use the following procedure. Although it is applied here to a single crop in a single county, it is similarly used for simulating macroeconomic variables. Consider the following equation for the yield of county and crop *i* and year *t*:

$$Yield_{i,t} = f(time) + \varepsilon_{i,t} \qquad (11)$$

The annual yield of a crop, recorded by the USDA, National Agricultural Statistics Service (NASS) (2018), is estimated here as a function of time, which we assume follows a linear trend. County-level yields are estimated, as opposed to national yields, to account for and model heterogeneity of production across the United States. This disaggregation limits any concern with aggregation bias on the distribution of crop yields. Another reason for simulating county yields is that Agricultural Risk

Coverage (ARC) program payments are tied to specific county and crop outcomes, which cannot be directly estimated from national average yields.[11]

The goal of the yield equation above is to project forward and to recover the distribution of uncertainty in crop yields. Since crop yields have grown over time, retrieving the distribution of crop yields conditional on time and productivity growth requires that the yield values be detrended. By estimating equation 7, we can obtain the yield projection ($f(time)$) and the distribution of yields ($\varepsilon_{i,t}$). These two collections of data allow us to measure the variability of yields, as well as tie forecasted county-level crop yields to simulated and benchmarked models. One can simply consider the distribution of the residual as a probability distribution for crop yields with the mean centered on zero.

We use simulations to model the variability of yields across the country into the future. The typical approach to simulating correlated random numbers requires linearly independent rows across the matrix of residuals. However, because the number of county-crop combinations far exceeds the observed yields, the standard approach is unable to simulate the correlated crop yields. Given the residuals for each crop and county and the need to include the correlation of crop yields across the country to accurately reflect crop production, we simulate a new set of yield deviations using Gaussian copula and kernel density approaches.

First, we use a Gaussian copula approach to recover and then simulate the correlation of yield residuals across crops and space. Next, to project the distribution of the yield residuals, we use a kernel smoothing function that fits the simulated outcomes from the copula to the observed probability density for each county and crop. This approach fits simulated yield distributions to the county- and crop-specific yield deviations, thus not requiring assumptions of normality or other standard distributions for the simulations.

Having simulated yield residuals at the county level, we must aggregate the residuals to be used in the national level PE model. The system of equations includes only national yield (equation 3), though yields are simulated down to the county-level. County yield residuals are summed and weighted according to the size of the observed county area planted relative to the national total. Accordingly, larger counties are weighted higher in determining the national yield residual ($shock_t$). By collecting and then weighting each simulated yield residual, we obtain an aggregate yield residual, which corresponds to a national yield distribution that can be used in the PE model ($shock_t$). This weighting is used only for determining the national yield residual, as county payments are determined by county base acres and whether payments were triggered at county (ARC) or national levels (PLC and ARC prices).

[11]This research uses average yields from harvested acres as reported by NASS. ARC-CO payments (county-level ARC payments) use yields calculated by USDA, Farm Service Agency (FSA) from the planted acre yield per county. This difference in yields creates differences between how production is measured and how yields are measured for FSA payments. While we found this difference between the yield numbers to be minimal for large agricultural counties, in smaller counties and crops outside the scope of this report, the yields can differ meaningfully. We have chosen to use the NASS yields for both the calculation of crop production and the historical ARC-CO yields for payments. The differences in the yield values used will create differences between the actual payments received by farmers and those projected here, though, most payments are received in larger counties that have smaller differences between NASS and FSA yields. The reason for simplifying the yields to those reported by NASS relates to the longer data series available (as well as more consistently reported over time) and the desire not to simulate two different set of yields for each crop and county. We used county-level yields from NASS for 1990-2017. Counties with more than five missing observations during that time-span were dropped. All missing values were imputed using county and time period fixed-effects. Pearson correlations were calculated for all counties and crops to simulate historical yield correlations. Counties dropped were added to program costs at the end by extrapolating payments of those measured onto those base acres not simulated.

By simulating the county-level and the national yield residual, the simulation approach allows for an estimation of the ranges of exogenous shocks. Importantly as well, though variable, by construction the exogenous shocks are mean zero. Thus after taking the USDA baseline projections as the forecast, exogenous variation can be added to the existing committee's projection to provide variation to the projections that is consistent with theory and agricultural market behavior. As long as one believes the USDA projections form the mean projection of crop yields, these yield deviations behave as estimated variations for the crop yields, following all modeling and theoretical assumptions.

The justification for simulating the county-level yield deviation, and then aggregating to the national level, is that this approach ties county-level production to national-level prices from the PE model. This combination of aggregate and disaggregate production allows a unique opportunity for national and local policy analysis, important when considering the idiosyncratic variation of county-level production and national production. For example, the combination of national prices and county-level yields allows for the estimation of ARC payments. To connect the county-level yield residuals to actual yields, the projected yields are obtained from equation 7, projecting the time trend out 10 years (*f*(*time*)). The use of the projected county level yields, not just the yield residual, allows for simulating the changing average and realized yields for each county in the model. This approach builds on the econometrically projected crop yields with the stochastic variation of historical observations.

While this approach details how county-level yield variation is tied to the PE model, similar econometric approaches for simulation are used for other variables, such as exchanges rates or global GDP (gross domestic product). The key for those variables is to estimate the residual of each equation in the PE model, then simulate the residual to add variation back to any future projection. Note, however, that the macroeconomic variables do not require any aggregation techniques, and thus are simpler to include in the model. Macroeconomic variables are econometrically estimated using multiple lagged variables after detrending the data.

After all of the yield shocks and macroeconomic variables have been simulated, the simulated values are added to the PE model above. For crop yields, the stochastic shock is implemented through equation 3. *Predicted Yield* is the value predicted from the baseline projections. The yield shocks represent exogenous shocks left or right to the supply curve. For the macroeconomic variables *Ex Rate,World GDP*), these shocks are added externality to the equations above but shift the variables in equation 8. These shocks represent exogenous movements of the demand curve. Given each simulated shock, each marketing year *t* solves for the endogenous prices and quantities equations 1 through 10.

The resulting solutions of prices and quantities for each variable form the distribution of outcomes. This approach combines the strengths of the USDA projections with research's understanding of markets and prices, as well as simulation approaches, to provide ranges and probabilities for expected market outcomes. These scenarios offer a means of understanding and modeling a range of results based on historical deviations at both county and national levels. This is relevant not only for these projections, but it also contributes to the use of scenario building to better understand future policy.