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The "Stover Availability versus Supply" Puzzle and Contracting Options for Cellulosic Biomass[1]

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THE EXISTING US Renewable Fuel Standard (RFS) makes commercial-scale cellulosic ethanol a priority, calling for 16 billion gallons of cellulosic biofuel production by 2022, sourced from grasses, trees, agricultural residues, and municipal waste. The US Department of Energy "US Billion-Ton Update" study (Downing et al. 2011) suggests that to meet the mandates in the RFS, approximately 66 million tons of corn stover may be needed annually. This equates to nearly 50 percent of the total annual stover produced by Illinois, Iowa, Minnesota, and Nebraska (Sesmero et al. 2015).

Stover as an energy crop is appealing because the Midwest produces a lot of it; yet commercialization lags behind the progress made in other cellulosic crops for two significant reasons. First, stover is a crop residue with a high-degree of variability that impacts product quality and processing efficiency, and the most significant cost of production is storage and transport. Tackling the logistical challenges associated with storing and transporting stover and reducing the system costs occupies a substantial portion of the research efforts of agricultural and biosystems engineers working in renewable energy. Second, even as technological innovations advance, commercialization may lag due to farmer participation—cellulosic processors of stover for biofuel report producer participation rates of supplying stover are 20–25 percent, implying that the physical availability of the biomass crop is a poor metric for its supply in the cellulosic biofuel supply chain. If the industry is to achieve scale in cellulosic biofuel from crop residues, particularly stover, it will need to solve both of these issues. Beyond the technological capabilities, the solution is with procurement and pricing contracts.

Photo by Wally Wilhelm, USDA

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From a production standpoint, stover is unique from other cellulosic biomass crops. It is a "second crop," not a dedicated biomass source, and producers do not manage it for yield and quality as they do the primary crop, corn. Also, unlike how producers supply corn and other grains as a standardized commodity at a price revealed daily in the marketplace, stover is not commoditized and no active price discovery mechanisms exist. Producers commonly assign differential values to the stover based on their perception of its contribution to soil quality and productivity, whether collection and transport are likely to interfere with fall field operations, and other factors. Thus, each stover supplier potentially has a unique reservation value at which s/he will participate in the stover supply chain.

On the other side of the transaction, the cellulosic biofuel processor attempting to procure biomass faces the challenge of writing contracts with the heterogeneous suppliers who produce stover. In addition, stover collection outcomes—the product quality characteristics—differ substantially

[1]This is a summary of research emerging from chapter 2 of Li's 2017 dissertation "The Supply Curve for Cellulosic Ethanol," in *Three essays on agricultural economics,* Iowa State University.

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across fields, creating variability in the processor's conversion process and adding to production costs.

Pricing Challenge: What is an Optimal contract to Procure Stover as a Feedstock?

One procurement option is to offer all stover suppliers (farmers) a single price per ton for biomass delivered to the plant—this is analogous to how grain is priced and leaves transportation costs to the supplier. Alternatively, the processor contracts to collect the stover from field-side locations, bearing the transportation costs and paying each supplier a uniform per-ton price. There are few examples in agriculture where this pricing and procurement option is used. Cellulosic processors using stover feedstock in the Midwest have used both procurement strategies, and in both cases, collection regions (distances in miles) were significantly larger—in some cases up to 75 miles to supply the plant—than anticipated due to low production participation.

Processors have not uniformly adopted either the supplier-delivery pricing model, as is familiar to commodity producers, or a processor-collection pricing model, which prevails in more specialized markets. This leaves open the issue of how procurement markets for stover biomass will emerge on a commercial scale and suggests a third contract option—differentiated pricing based on the supplier's distance to the plant and reservation values. In other markets where there is a single buyer (seller) transacting with many sellers (buyers), differentiated pricing—or price discrimination in the economics nomenclature—commonly emerges.

Given that the market has not identified a preferred pricing structure, the question remains, what is the optimal procurement and pricing model for this market? We used a simple theory of spatial price discrimination to answer this question, first comparing the supplier-delivery and processor-collection models. Assuming that suppliers and processors face identical transportation costs, we find that farmer (supplier) welfare is greatest under the supplier-delivery model compared with the processor-collection model, even though total feedstock collection expenditures and draw areas (distances) are identical. This is because when supplier-delivery procurement is used, farmers nearest the plant participate more intensely (increased participation) and are able to take advantage of location rents resulting from higher net prices (net of transportation) than they would receive under the processor-collection model. The same happens in the grain markets—farmers nearest to the delivery point have a higher net price than those further away who receive the same price per bushel. When processor-collection is used, the processor cannot capture the supply efficiencies created through increased participation because all suppliers receive an identical field-side price, and it must offer a price based on capturing the feedstock supplied furthest from the plant. Simply put, a tradeoff exists between paying a higher price for feedstock to increase participation near the plant and accepting a greater procurement area (see also Rosburg, Miranowski, and Jacobs 2016).

The third procurement option—differentiated pricing—was evaluated alongside the other two options using simulations. The modeling assumptions were based on industry engineering and cost factors for a cellulosic ethanol facility requiring 300,000 metric tons of stover per year, and we include transportation costs of $0.65 per ton per mile. Table 1 shows, under varying degrees of price-responsiveness by stover suppliers, how feedstock collection distances from the plant, producer participation (supply), and feedstock per ton prices vary for a fixed plant to meet its feedstock needs. As producers become more price-responsive, collection distances fall and per-ton feedstock prices increase, inducing greater participation in supplying feedstock. The processor-collection and supplier-delivery models generate the same collection distances and total costs (not shown), but increased participation by suppliers closer to the plant increases the overall welfare to suppliers of stover.

Table 1. Simulation Results Comparing Collection Distances, Supplier Participation and Prices for Three Pricing and Collection Mechanisms

Comparison of Procurement Options									
Producer Price Response	Price Differentiation			Processor Collection			Supplier Delivery		
	Distance	Supply %	Net Price	Distance	Supply %	Net Price	Distance	Supply %	Net Price
Least	43.4	12.0%	24.0	54.7	7.5%	15.1	54.7	22.6%	45.3
	37.9	15.7%	20.9	47.8	9.9%	13.2	47.8	29.7%	39.6
	34.5	19.0%	19.0	43.4	12.0%	12.0	43.4	35.9%	35.9
	30.1	24.9%	16.6	37.9	15.8%	10.5	37.9	47.1%	31.4
	27.3	30.2%	15.1	34.5	19.0%	9.5	34.5	57.1%	28.5
	23.9	39.6%	13.2	30.1	24.9%	8.3	30.1	74.8%	24.9
	21.7	47.9%	12.0	27.4	30.2%	7.5	27.4	90.6%	22.6
Greatest	20.2	55.6%	11.1	25.4	35.0%	7.0	25.4	100%	21.0

Note: The participation rate for supplier delivery indicates the maximum value that would be observed in the collection area.

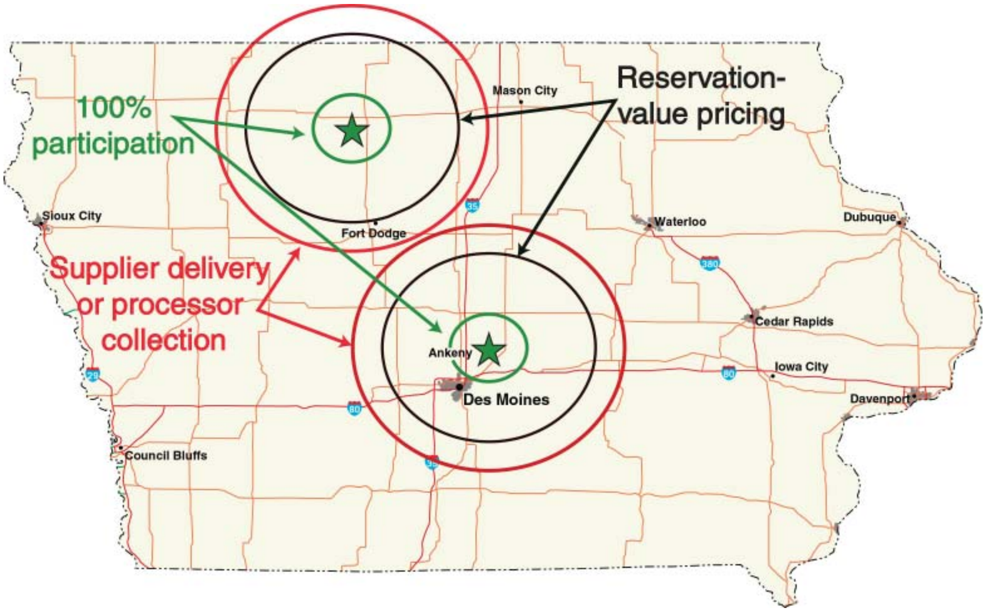

Figure 1. Illustration of simulation on stover collection areas under different pricing mechanisms.

Perhaps the most significant result relative to understanding efficient contracting as a mechanism for commercialization is that, at all levels of price responsiveness, the collection distance to meet plant capacity is smallest when the processor is able to set differential prices with suppliers. In that case overall collection costs are reduced, and as a consequence, overall cellulosic ethanol production costs are lowest of the three options. The highlighted row represents the current participation rates and collection distances observed by processors, and suggests that improvements are possible using a price-differentiated approach.

Figure 1 depicts hypothetical draw regions as they might exist in Iowa when there is no competition for stover (no overlap of stover collection areas by different processors), based on plant locations in central and north-central Iowa and recently-experienced producer participation outcomes. When processors are able to use differentiated price contracts, collection distances fall along with transportation costs, which are primary determinants of the economic feasibility of cellulosic ethanol from stover.

These results are important to policy discussion surrounding the RFS, both in terms of relative feedstock use and costs and also with regard to the marketing mechanisms and contracts that may arise as the industry commercializes. From industry experiences, we know that the availability of a non-dedicated feedstock is not equal to supply and processors are drawing feedstock from significantly larger areas than early studies estimated would be needed based on stover production. It is likely that this market will continue to show low participation by suppliers if processors are compelled to use single-price contracts, which result in larger procurement regions and lower stover prices per ton. One solution to this is price differentiation based on a spatial factors (i.e., suppliers' distances to the processor) and also stover-specific and field-specific characteristics that influence processing quality and quantity.

As a consequence of the current procurement and pricing challenges to commercializing stover as feedstock, meeting the RFS mandate for cellulosic stocks will likely continue to require the use of feedstocks such as grasses and other "high-cost" feedstocks that were previously bid out of the early feedstock and supply cost models.

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Relational Contracts and the Diffusion of Agricultural Technologies in Brazil

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WHAT IS the role of the private sector in scaling agricultural technologies in developing countries? The Brazilian experience, with the soybean boom in the savanna and the expansion of the safrinha corn, suggests that the private sector can play a central role in technology diffusion, even in locations where credit and output markets do not function well.

The constraints of the agricultural technology adoption process in developing countries imposes extra coordination costs for commercialization of new technologies. For example, many farmers lack access to credit, output markets, and technical assistance. Farmers could potentially partner with traders or processors who have the capabilities to commercialize new crops. However, writing a farmer-trader contract that accounts for several contingencies and that can be verified by a third party is challenging in this context. Moreover, contracts involving technology transfer are particularly difficult to enforce given the challenges of measuring the transfer and the use of knowledge. As a result, there is underinvestment in technologies that could promote economic development and environmental benefits. Despite the difficulties, the diffusion of savanna soybean and the recent expansion of safrinha corn in Brazil suggest that there are some combinations of technologies and farmer-trader contracts that enable the private sector to rapidly scale the adoption of agricultural technologies (DePaula 2017).

Relational Contracts and the Soy Boom in Brazil

In the case of the soy boom in the Brazilian savanna, traders and farmers cooperated using a special type of relational contract. A relational contract is an agreement that has features that are not verifiable or enforceable. Relational contracts are based on self-enforcing economic incentives and the self-enforcing nature of these types of agreements increases coordination costs (Levin 2003). For example, a farmer could renege on the contract after the technological transfer, and a trader could renege on performance payments to the farmer. In this case, contracting is only feasible if it generates repeated profits sufficiently large enough that each party commits to a long-term partnership. The adaptation of a crop to production in marginal land can generate an economic surplus sufficiently large for feasible contracting.

A key feature of the farmer-trader contract in Brazil was the bundling of output price guarantees, credit, technology, and technical assistance. Before planting, the farmer commits to supply a specific quantity of soy at harvest for a fixed price in exchange for inputs and financial resources to cover production costs. The agreement includes technical assistance and a "technological package" formed by seeds, fertilizers, and pesticides. In practice, the farmer commits a number of 60kg bags of soy to the trader and receives the resources and inputs to start planting. In 2005, for example, one ton of fertilizers for soy production was worth 19.6 bags of soy (Silva 2012). The technological package represents a "recipe" for soy production in the savanna with inputs provided, and in many cases produced, by the trader. The contract addressed the multiple coordination challenges for soy production in the savanna.

The Adaptation of Soy Production to the Savanna

The technological innovation that enabled soy production in the Brazilian Savanna (the savanna soy) was the development of soy seeds for low latitudes using biological nitrogen fixation (Hungria, Campos, and Mendes 2001). In the 60s, the Brazilian government sponsored a plant breeding program that combined enhanced seeds with nitrogen fixing bacteria strains. The seed-bacteria combination was developed specifically for poor nutrient soils, such as savanna soils, and led to new soybean varieties self-sufficient in nitrogen (Alves, Boddey, and Urquiaga 2002). However, clearing the land and chemically correcting the soil can be very expensive; large quantities of lime and fertilizers are necessary to prepare the soil, and depending on the previous use of land, the clearing process necessary for mechanized farming can be very costly. Rezende reports a conversion cost of $600 per hectare in 2003, three times the cost of the land at the time (Rezende 2003). The technology enables soy production in marginal land in large scale but also requires high upfront investment.

The Contracting Effect

The Brazilian government was initially heavily involved in the soy industry through the development of new technologies and the financing of production, but since the economic crises in the 80s, followed by the implementation of market reforms in the mid-90s, the industry transitioned to a market-oriented model with the expansion of the role of international trading corporations. The trading companies followed a consistent strategy of vertical integration of the soy supply chain, through investments in the production and commercialization of fertilizers, and direct financing of farmers through anticipated sales contracts. Traders offered farmers a package of services that included financing, price guarantees, technical assistance and inputs for production, to guarantee supply of soy at required quality levels (Junior 2011). Figure 1 shows the historical expansion of the savanna soy technology measured in millions of acres of planted area. The expansion of savanna soy progressed slowly for 40 years before the market reforms in the mid-90s. In contrast, in the 20-year period from 1996 to 2016, production of savanna soy boomed with an additional 37 million acres of plantations, an area of the size of Iowa.

The Brazilian soy boom presents a well-suited case for the examination of the benefits of a novel farmer-trader contract on technological diffusion, the contracting effect. I combine farm-level data from the 1996 and 2006 Brazilian agricultural census surveys to disentangle the contribution of contracting from the contribution of other drivers of technology adoption in Brazil. I find that the contracting effect varies significantly across farm types and locations in Brazil. Contracting explained over 80 percent of soy expansion in the Savanna frontier in locations where there was no soy production before the introduction of the contract. In contrast, in locations where soy was previously produced, contracting explained 37 percent of soy expansion. Contracting increased total value of agricultural output by 200 percent in the agricultural frontier and by 65 percent in traditional producing locations (DePaula 2017). The savanna soy technology diffused faster in locations were the total economic surplus from contracting was larger, either because of high yield improvement or because of high production costs without contracting.

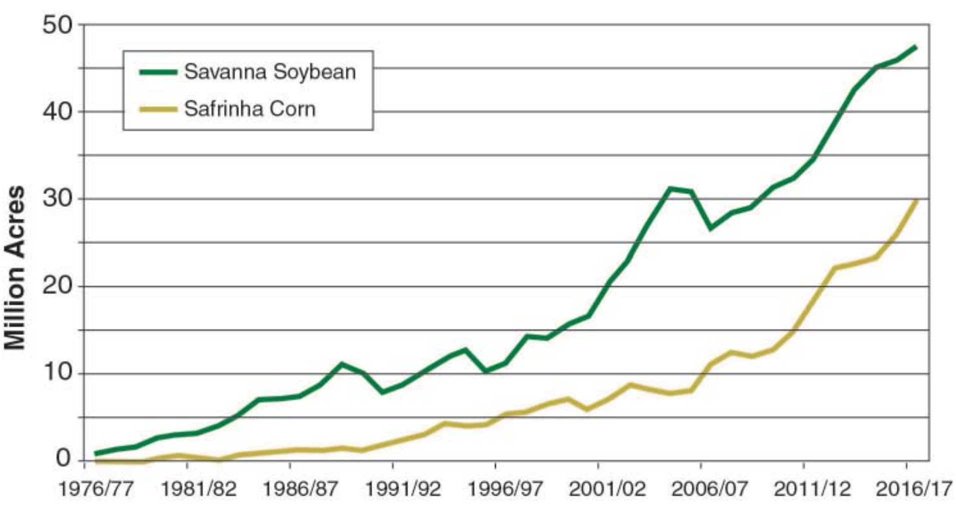

Figure 1. Agricultural land transfer to different types of entities

Notes: Expansion is measured in terms of planted area. The planted area for the savanna soy includes the Midwest region of Brazil and the new agriculture frontier represented by the states of Maranhao, Tocantins, Piaui, e Bahia (MATOPIBA).
Source: Conab, 2018.

Policy Implications

The scaling of agricultural technologies in developing countries depends on the feasibility of contracting. Cost-benefit studies of agricultural innovations should consider coordination costs between commercial partners, as ignoring these difficult-to-measure expenses could overstate the potential profitability and diffusion of new technologies. Public policy can influence the propensity for contracting. In particular, policies that improve protection of property rights and contract enforcement can not only increase the feasibility of contracting, increasing private sector investments, but can also affect the distribution of rents from contracting between farmers and traders.

The Brazilian experience does not end with the soy expansion in the savanna. In the last two decades, the diffusion of safrinha corn, a new production system for cultivation of corn as a second-season crop, is changing commercial agriculture in Brazil. In the 10-year period from 2006 to 2016, the area planted with safrinha corn increased by about 20 million acres, an area close to the size of South Carolina. The specific features of the commercial agreements that accelerated the diffusion of safrinha corn are the subject of ongoing research.

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USDA's Projections for 2018

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US AGRICULTURE continues on an amazing productivity run. The last five corn crops are the five largest ever produced. The last four soybean crops are the four largest ever. Meat production exceeded the $100 billion mark for the first time. The question going forward for the markets is, "Will this streak continue next year?" USDA has provided its outlook for 2018 and the answer seems to be "Yes."

Of course, at this point, we do not know what weather patterns will appear or how agricultural demands might adjust over the next 18 months. Thus, the USDA outlook is based on current trends in production and usage. However, those current trends suggest the run of large crops and growing meat production is not over yet and crop price recovery may be still a ways off. Crop acreage is concentrating in corn and soybean production, as other crops still are not offering significant enough returns to pull farmland back to those other crops. As has been the case for the last few years, projected corn and soybean returns are not very attractive, but they are better than those offered by other crops.

The early estimate for corn acreage shows a slight increase in 2018, moving up to 91 million acres, as shown in Table 1. With the national trendline yield set at 173.5 bushels per acre, that translates to corn production remaining above 14.5 billion bushels. In fact, the projected 2018 corn crop would be the third-largest ever and total corn supply would exceed 17 billion bushels for the first time ever.

Corn usage is projected to remain strong as well, but it is still just below expected production. Feed and residual use is expected to decline slightly, which, as livestock production is increasing, is probably more about residual usage than feed demand. Corn usage for ethanol is set to reach another record next year. Domestic use of E-15 is rising and ethanol exports have been robust. Food, seed, and other uses continue to rise. The weakest demand sector is export. With global supplies of not only corn, but also other feed grains, at extremely high levels, US corn is facing a lot of competition in the international marketplace. With total usage projected at nearly 14.5 billion bushels, corn demand is doing what it can to lift prices. However, ending stocks are expected to rise slightly, reaching 2.6 billion bushels, and corn prices are projected to stay lower. The initial estimate for the 2018/19 season-average prices is $3.30 per bushel.

The projections for soybeans show that this year's run to beans was no one-year phenomenon. As shown in Table 2, USDA projects 91 million acres will be planted to soybeans in 2018, essentially tying with corn for the most acreage. The 2018 trend yield is 48.4 bushels per acre, which would result in 4.36 billion bushels of soybeans. That would be the second-largest crop, behind this year. Paralleling corn, with the increase production of the last few years, ending stocks have grown and that will push total soybean supplies to 4.85 billion bushels, the highest total ever.

Soybean use has been trending higher the last several years, with records being set each succeeding year. The estimates for 2018 continue that run. Domestic crush is set at 1.97 billion bushels, up 20 million from this year. This is being driven by soybean meal demand by livestock and soybean oil use in the biodiesel industry. The increase in acreage implies additional seed use, so seed and residual usage is raised slightly. However, the big story remains exports—while exports for the 2017 crop are down slightly, USDA shows a rebound back to record exports in 2018.

Current corn futures would normally translate to a 2018/19 season-average price around $3.80 per bushel. Current soybean futures point

Table 1. Corn Supply and Use

		2014	2015	2016	2017	2018
Area Planted	(mil. acres)	90.6	88.0	94.0	90.2	91.0
Yield	(bu./acre)	171.0	168.4	174.6	176.6	173.5
Production	(mil. bu.)	14,216	13,602	15,148	14,604	14,520
Beg. Stocks	(mil. bu.)	1,232	1,731	1,737	2,293	2,477
Imports	(mil. bu.)	32	67	57	50	50
Total Supply	(mil. bu.)	15,479	15,401	16,942	16,947	17,047
Feed & Residual	(mil. bu.)	5,280	5,120	5,467	5,550	5,550
Ethanol	(mil. bu.)	5,200	5,224	5,439	5,525	5,525
Food, Seed, & Other	(mil. bu.)	1,401	1,422	1,450	1,470	1,475
Exports	(mil. bu.)	1,867	1,898	2,293	1,925	1,900
Total Use	(mil. bu.)	13,748	13,664	14,649	14,470	14,450
Ending Stocks	(mil. bu.)	1,731	1,737	2,293	2,477	2,597
Season-Average Price	($/bu.)	3.70	3.61	3.36	3.25	3.30

Source: USDA

Table 2. Soybean Supply and Use

		2014	2015	2016	2017	2018
Area Planted	(mil. acres)	83.3	82.7	83.4	90.1	91.0
Yield	(bu./acre)	47.5	48.0	52.0	49.1	48.4
Production	(mil. bu.)	3,927	3,926	4,296	4,392	4,360
Beg. Stocks	(mil. bu.)	92	191	197	302	470
Imports	(mil. bu.)	33	24	22	25	25
Total Supply	(mil. bu.)	4,052	4,140	4,515	4,718	4,855
Crush	(mil. bu.)	1,873	1,886	1,899	1,950	1,970
Seed & Residual	(mil. bu.)	146	122	141	138	140
Exports	(mil. bu.)	1,842	1,936	2,174	2,160	2,325
Total Use	(mil. bu.)	3,862	3,944	4,213	4,248	4,435
Ending Stocks	(mil. bu.)	191	197	302	470	421
Season-Average Price	($/bu.)	10.10	8.95	9.47	9.30	9.40

Source: USDA

Table 3. Meat Production and Livestock Prices

	2017 forecast	2017 Change from December 12	2018 forecast	2018 Change from December 12	Change from 2017
Production			*Billion pounds*		
Beef	26.17	-0.13	27.76	0.17	1.59
Pork	25.59	0.03	26.96	0.05	1.38
Broilers	41.59	0.05	42.45	0.18	0.86
Turkey	5.99	-0.01	6.00	-0.03	0.01
Total meat	100.09	-0.06	103.94	0.37	3.85
Prices			*Dollars/cwt*		
Steers	121.52	0.09	118.25	1.00	-3.27
Hogs	50.48	0.10	47.75	0.25	-2.73
			Cents/lb		
Broilers	93.5	0.1	90.5	2.0	-3.0
Turkey	96.1	0.4	91.0	-5.3	-5.1

Source: USDA

Table 4. Meat Exports

	2017 forecast	2017 Change from December 12	2018 forecast	2018 Change from December 12	Change from 2017
			Exports		
Beef	2,875	--	2,985	--	110
Pork	5,623	35	5,900	--	277
Broilers	6,783	70	6,910	--	127
Turkey	623	--	655	--	32
Mature Chickens	133	--	145	--	12
Total meat	16,044	105	16,603	--	559
			Imports		
Beef	2,976	10	3,030	--	54

-- No change

Source: USDA

to season-average prices in $9.70-$9.80 range. Those projections are, however, likely misleading as the cash markets will maintain wide-than-normal basis levels. The larger stock levels are hampering basis improvement, which will not occur until some of the supplies are cleared from the market. Given current basis levels, projections for the 2018/19 crop margins would be slightly below breakeven for both crops, continuing another streak that is not as pleasant as the record production run. It is often said that the cure for low prices is low prices. However, that cure has not taken affect yet and the USDA projections indicate that will at least be another year before it kicks in.

For the livestock sector, expansion is projected in all of the major product groups, as shown in Table 3. Beef production is set to be six percent higher and pork production will grow by five percent. Broiler production will climb to nearly 42.5 billion pounds and turkey production will reach six billion pounds. For the livestock industry, 2017 turned out to be a good year with record production, but also solid returns as prices held up despite the surge in production. The price projections for 2018 show lower prices, but the drops in prices are being offset by the gains in production.

Moving forward, concerns will center on the pace of expansion. For example, the latest Hogs & Pigs report from USDA highlighted the steady pace of growth in both the number of farrowings and the number of pigs per litter. A slight uptick in either of those trends would accelerate pork production, potentially beyond the current pace of pork consumption.

Much of what is driving this expansion originates from the international marketplace—meat exports were robust in 2017 and the early

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Can China's Rural Land Policy Reforms Solve its Farmland Dilemma?

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THE SCARCITY of arable land is a defining feature of Chinese agriculture (Zhang and Li 2018). In 2015, China fed 18.9 percent of the world's population with only 8.5 percent of the world's arable land. Furthermore, the limited agricultural land resource in China is distributed to 231 million households, resulting in an average farm size of only 0.96 acres per household (China Agricultural Development Report 2016), and even such small farms are usually scattered in several separate plots. Therefore, China faces two challenges: (*a*) preserving the quantity and quality of its arable land amid rapid urbanization; and, (*b*) consolidating land to increase agricultural productivity. China's recent rural land reforms on these two aspects have implications not only for China, but the entire world.

Rural Land Conversion for Urban Use: National Policy and Local Innovation

To achieve food security, the Chinese government tightly controls the net amount of arable land converted to other uses, with the overall goal of maintaining at least 307 million arable acres (called the "redline") by 2020. In addition to the annual quota allocated by the central government, additional arable land converted to other uses has to be compensated by new arable land of at least equal area.

As environmental regulations tighten, the Chinese government increasingly turns to rural construction land, such as that beneath farmhouses, for compensation for converted arable land (State Council 2004). Currently, most regions in China achieve this kind of compensation through administrative means (Southern Weekend 2010). Local governments choose the locations and move farmers from sprawling farmhouses to high-rise buildings and re-cultivate the land beneath the original farmhouses to arable land. The farmers lose their farmhouses (including future development rights), retain the land use right of the land beneath farmhouses for agricultural production, and gain an apartment and/or monetary compensations. The increases in arable land become permits for local governments to convert arable land near cities for urban development and sell urban land use rights for revenue.

The city of Chongqing has experimented with an innovative market-oriented process featuring "land tickets" (Chongqing Municipal Government 2016). Farmers in remote rural areas can voluntarily consolidate farmhouses and re-cultivate arable land. In doing so, they create "land tickets" which are then auctioned off to developers as permits to develop arable land near the city. The key difference between Chongqing and the rest of China is that farmers' decisions to convert land beneath their farmhouses to arable land, and the compensation for the conversion, is determined by the market as opposed to command-and-control (although the city government often buys large amounts of "land tickets" to prevent the price from crashing). This innovation has the potential to increase the equity and efficiency of land conversions.

Rural Land Transfer Reform and the Booming Rental Market

Small farm size and low productivity can be ameliorated by letting farmers transfer farmland to others for agricultural production. Rural land transfer has been permitted since the 1980s and has increasingly gained government support over the years. In 2002, the Land Contract Law of China confirmed the right for farmers to transfer land use rights. As Figure 2 shows, the total amount of land transfer increased from five percent of arable land in 2007 to 36.5 percent in 2017. An important driving force for this increase

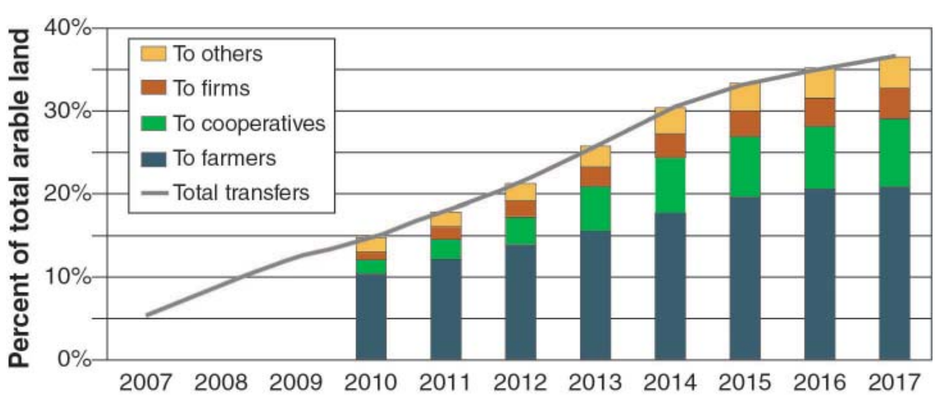

Figure 1. Agricultural land transfer to different types of entities
Note: 2017 data is mid-year value while all others are end-of-year values.
Sources: Data before 2010 are from chinaaidr.com (2018), 2010~15 data are from Agricultural Development Reports, 2016~17 data are from MOA (2018).

is that migrant farmers want to work in cities while keeping their land at home.

The majority of land transfers happen between farmers. For example, migrant farmers may let friends or relatives farm their land. These kinds of transfers often rely on informal agreements, and usually involve zero or very low payments. Although not land rental per se, these informal transfers lay the ground for the future development of the rental market by consolidating small plots and making them attractive to large-scale farms.

Currently, land transfers to firms represent 10.5 percent of all transfers (or 3.8 percent of all arable land), but their growth has been slow in recent years. An important factor is that property rights of rural land are insecure and unclear. This is manifested in inaccurate land borders and sizes, incomplete land use right certificates, and limited HRS tenure (see first text box). The Chinese government just extended HRS tenure to 2057, and is in the process of issuing land use right certificates with more accurate land position and size information. This effort is expected to boost the land rental market in the future.

Who owns China's farmland?
Private land ownership is banned in China. Under China's current Household Responsibility System (HRS), started in the early 1980s, all rural land is owned by rural collectives, which allocate contract rights for parcels of farmland to eligible households. The tenure of contract rights was 15 years in 1983, renewed for 30 years in 1997, and again by 30 years (i.e., starting 2027) in China's 19th Party Congress in 2017 (NPC 2017).

Chinese Farmers Can:

- Decide what to plant and how
- Keep returns from their agricultural production
- Lease their land to others for agricultural production

Chinese Farmers Cannot:

- Convert agricultural land to other uses
- Leave their land uncultivated for more than two years
- Legally resist land acquisition

Implications for China's Crop and Livestock Industries

The percentage of urban population in China increased from 19 percent in 1980 to 57 percent in 2016 (China Statistical Year Book 2017), and is continuing its upward trend. Despite significant demand for farmland acres to be converted for urban development, China has successfully maintained the quantity of its arable land in recent years (China Agricultural Development Report 2017). This is due to policies that compensate arable land lost to development by creating arable land somewhere else, often by converting farmhouses to arable land. The fact that returning rural construction land to cropland can generate valuable permits for urban development somewhere else creates additional opportunity cost for facilities for animal production. This opportunity cost is first felt by municipal governments who depend on selling development rights for revenue. In most of China, local governments restrict or delay the approval of new animal production facilities, especially those with a larger footprint, mandate the conversion of farmhouses to arable land, and move farmers into high-rise buildings. In Chongqing, farmers also have this opportunity cost because they can create and sell permits themselves by voluntarily converting their farmhouses to cropland. Therefore, no matter how the system is designed specifically, the overall effect is to make animal production more expensive. While this affects all producers, the negative effects will be stronger on small, low-profit producers.

The increased opportunity cost for animal production is especially relevant for the hog industry. In southern China, land available for hog production is already so scarce that some hogs are produced in high-rise buildings, a phenomenon unheard of in the United States (Agweb.com 2017). Furthermore, in order to protect the environment, the government has designated areas where hog production is restricted (USDA 2017). The extreme land scarcity and the increasing cost of environmental compliance will compound with increased opportunity cost of maintaining the facility and limit hog production.

Similarly, the development of the rental market gives less productive crop producers an incentive to quit agricultural production. Currently, renting farmland is popular with farmer households, but offers limited appeal to firms. The current reform that clarifies property rights may draw

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Is ARC-CO acting as a Safety Net Program? Evidence from Iowa

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THE AGRICULTURAL Act of 2014, referred to as the 2014 Farm Bill, is the legislative backbone of federal farm income support programs and agricultural disaster assistance programs. These programs, combined with federal crop insurance, are what is typically referred to as the farm safety net. As the debate has begun for the next version of the Farm Bill, policy discussions have centered on improving the effectiveness of the safety net. However, in previous Farm Bills, there had been a concerted effort to utilize decoupled agricultural support to ensure that US farm programs would meet World Trade Organization (WTO) standards. The commodity programs in the 1996 and 2002 Farm Bills were led by the direct payment programs—essentially fixed decoupled payments that flowed to agricultural producers, regardless of the agricultural economy. In the 2008 and 2014 Farm Bills, commodity programs were modified to react to conditions in the agricultural economy. Congress must determine how to balance decoupled agricultural programs, which are less responsive to the agricultural economy but more accepted in the WTO, against safety net agricultural programs, which are more responsive but also seen as more trade distorting.

Current commodity programs include the Price Loss Coverage (PLC) and the Agricultural Risk Coverage (ARC) programs. PLC provides payments when low prices occur and it can be considered a price safety net program. The ARC program at the Individual Level (ARC-IC) provides coverage against low income for an operation, and it can also be considered a farm revenue safety net program. The ARC program at the County Level (ARC-CO) is based on area revenue, decoupled from farm yields and prices. ARC-CO can be considered a revenue safety net program, but given the decoupling from farm yields and prices, its effectiveness is an open question. In fact, ARC-CO can be characterized as a lottery of government payments with probability of payment less than one, equal prizes per base acre within each county, and great variability in prizes across county lines. However, ARC-CO is a very popular program. Base acres enrolled in ARC-CO account for 75 percent of total program base acres in the nation. Furthermore, 92 and 96 percent of corn and soybean base acres are enrolled in the ARC-CO program. The accumulated ARC-CO payments for corn and soybean base acres in 2015 and 2016 amount to nearly $9.2 billion, and represent 89 percent of all ARC-CO payments for all covered commodities, and 71 percent of all ARC-CO and PLC payments in the nation over the same period. Many farmers, in essence, traded the direct payment program for ARC-CO. Did their trade result in a better safety net for agriculture? Plastina and Hart (2018) explore this question by analyzing the distribution of ARC-CO payments across different groups of mid-sized commercial Iowa farms with different income levels, profit levels, as well as liquidity and solvency levels. We summarize the evidence pointing towards a disconnection between ARC-CO payments and farm incomes and profits reported in Plastina and Hart (2018).

> *As the debate has begun for the next version of the Farm Bill, policy discussions have centered on improving the effectiveness of the safety net.*

The database contains nearly 700 observations of mid-sized commercial farms actively managed from 55 of Iowa's 99 counties, and all agricultural districts in Iowa, and covers the production and financial aspects of the farms. Each point in the database is a farm-year combination and accounts for ARC-CO payments made in 2015 and 2016 (corresponding, respectively, to crop years 2014/15 and 2015/16).

ARC-CO Payments by Crop Income

Table 1 shows the descriptive statistics of ARC-CO payments per acre by crop income (accrued) per acre in the previous year for all farm-year combinations (those that received or did not receive payments). Per acre incomes and payments are examined to remove the effect of farm size from the analysis. The median payment for all categories was zero, and the average payments tended to increase with the level of crop income in the previous year. This is counterintuitive for a safety net program, as one would likely expect lower incomes to be paired with higher program payments. A pairwise comparison of average ARC-CO payments for all farm-year combinations (those that received or did not receive payments) across groups of farms using Tukey's Studentized Range (HSD) tests at the five percent confidence level, which indicates that: (a) farms with the

Table 1. ARC-CO Corn and Soybean Payments per Operated Crop Acre by Crop Income per Acre in Previous Year for All Farm-year Combinations

Crop income in previous year	N	Mean	Median	Min	Max	Std
a) <$600	157	$1.84	$0	$0	$62.38	$8.28
b) $600 to $700	209	$5.29	$0	$0	$68.80	$14.82
c) $700 to $800	143	$7.30	$0	$0	$65.93	$16.61
d) >$800	93	$9.16	$0	$0	$87.77	$22.44
e) N/A	82	$2.29	$0	$0	$71.93	$11.94
All	684	$5.08	$0	$0	$87.77	$15.21

Table 2. ARC-CO Corn and Soybean Payments per Operated Crop Acre by Crop Income per Acre in Previous Year For Farm-year Combinations That Received Payments in 2015 and 2016

Crop income in previous year	N	Mean	Median	Min	Max	Std
a) <$600	12	$24.08	$23.87	$0.61	$62.38	$19.72
b) $600 to $700	33	$33.49	$37.42	$0.55	$68.80	$21.30
c) $700 to $800	28	$37.26	$40.57	<$0.01	$65.93	$17.10
d) >$800	16	$53.22	$59.00	$1.76	$87.77	$24.26
e) N/A	3	$62.52	$65.57	$50.07	$71.93	$11.24
All	92	$37.79	$43.30	<$0.01	$87.77	$22.06

largest crop income per acre (>$800) received significantly higher ARC-CO payments per acre than farms with up to $600 in crop income per acre—$9.16 vs. $1.84, respectively; (*b*) farms with crop income between $700 and $800 per acre received significantly higher ARC-CO payments per acre than farms with up to $600 in crop income per acre—$7.30 vs. $1.84, respectively. All other pairwise comparisons across groups of farms with known crop incomes in the previous years are not statistically significant.

Table 2 shows the descriptive statistics of ARC-CO payments by crop income (accrued) in the previous year only for those farm-year combinations that received payments. A similar pattern to that in Table 1 is observed, as average payments tend to increase with the level of crop income in the previous year. A pairwise comparison of average ARC-CO corn and soybean payments per acre across farms grouped by crop income in the previous year using HSD tests at the five percent confidence level indicates that: (*a*) the average payment for the group of farms with more than $800 in crop income per acre, $53.22, is significantly larger than the average payment received by farms with crop income up to $600 per acre, $24.08, and farms with crop income between $600 and $700 per acre, $33.49; (*b*) average payments for the three groups of farms with up to $800 in crop income per acre ($24.08, $33.49, and $37.26) are not significantly different among themselves.

Since ARC-CO payments tend to increase with crop incomes in the previous year, the ARC-CO program seems to fail at protecting farmers against low incomes. In fact, operators with higher incomes are the ones who tend to capture the higher payments under ARC-CO.

ARC-CO Payments by Crop Profits

Crop profits are calculated by subtracting accrued operating expenses and economic depreciation (on machinery and equipment and buildings and improvements) from crop income (accrual). Profits equal the net farm income that is used to compensate unpaid family labor, plus returns to equity and management. As with crop incomes, the crop profits are examined on a per acre basis to remove farm size effects.

Table 3 shows the descriptive statistics of ARC-CO payments by crop profits in the previous year for all farm-year combinations. The median payment for all categories was zero. A pairwise comparison of average ARC-CO payments for all farm-year combinations across groups of farms using HSD tests at the five percent confidence level indicates that: (*a*) the average payment for the group of farms with crop profits larger than $150 per acre, $12.67, is significantly larger than the corresponding averages for the four groups of farms with profits up to $100 per acre—$3.08, $5.39, $4.43, $and $3.60; (*b*) the average payment for the group of farms with crop profits between $100 and $150 per acre is significantly larger than the corresponding average for the group of farms with crop losses of up to $50 per acre—$11.19 vs. $3.08, respectively. All other pairwise comparisons across groups of farms with known crop profits in the previous years are not statistically significant. Once again, the results are generally the opposite of what one would expect from a safety net program. Those farmers with the lowest crop profits (or largest crop losses) tended to receive less from ARC-CO than farmers with better profitability.

Table 4 shows the descriptive statistics of ARC-CO payments by crop profits in the previous year only for those farm-year combinations that received payments. A pairwise comparison of average ARC-CO corn and soybean payments across farms grouped by crop profits fails to find significant differences using HSD tests

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numbers for 2018 are encouraging. Table 4 displays USDA's projections and, as with production, the numbers are higher across the board. Both pork and beef enjoyed roughly 10 percent export growth in 2017. Beef is expected to gain another four percent in 2018, while pork is projected to grow five percent during the year. Broiler and turkey exports are expected to grow as well.

Thus, the underlying agricultural story for 2018 may be due to the global demand for meat. Currently, the surge in meat consumption globally has improved livestock market returns and led to significant increases in production. That is, in turn, providing support for the crop markets, at a time when those markets need a usage boost. Combined, the projections indicate a slight improvement in the US agricultural economy, but the emphasis is on the word "slight." Price improvement is a hard thing to come by when records continue to be set on the production side.■

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more firms into agriculture and further boost productivity. Studies have found that land productivity dramatically increases after transfers (e.g., by 60 percent according to Jin and Klaus' 2009 estimate). Overall, we believe the recent developments in China's land policy are pushing both crop and animal production toward larger scales.

Key Policies Governing Land Use and Conversion in China

- **The "Redline" of farmland** is the lowest limit of arable land in 2020, about 300 million acres, set by the Chinese government in 2006.
- **Permanent basic cropland** is the 255 million acres of designated high cropland that is subjected to stricter protection from conversion to urban use.
- **The "Increase-decrease linkage" policy** (started in 2006) allows local governments to convert certain amounts of arable land to urban uses if they create an equal or larger amount of arable land from rural construction land (e.g. farmhouses).
- **The "Grain for green"** (started in 1999) policy returns marginal farmland in ecologically sensitive areas to forestry.

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at the five percent confidence level. This slightly modifies the previous pattern, as once ARC-CO payments are triggered, they are roughly shared equally across the profit spectrum. In terms of crop profitability, the ARC-CO payments act more like decoupled payments in those counties where payments are triggered, and less like a safety net for all farms.

Conclusions

Using farm-level data from Iowa, we found no support to the hypotheses that ARC-CO payments would be larger for farms with lower incomes or lower profits. On the contrary, we found support that ARC-CO payments tend to be larger for farms with higher crop incomes and profits in the previous year. In summary, ARC-CO payments, instead of acting as a safety net for Iowa farmers, can be more accurately characterized as decoupled support for farms located in counties where payments are triggered, but without the consistency of previous programs, such as the direct payment program. In the end, farmers traded the certainty of the direct payment program for a lottery of government payments with probability of payment less than one, equal prizes per base acre within each county and great variability in prizes across county lines.

Table 3. ARC-CO Corn and Soybean Payments per Operated Crop Acre by Profits in Corn and Soybean Enterprises in Previous Year for All Farm-year Combinations

Crop Profits in previous year	N	Mean	Median	Min	Max	Std
a) <-$50	162	$3.08	$0	$0	$87.77	$12.07
b) -$50 to $0	116	$5.39	$0	$0	$87.14	$16.15
c) $0 to $50	130	$4.43	$0	$0	$62.38	$14.06
d) $50 to $100	88	$3.60	$0	$0	$59.72	$11.00
e)$100 to $150	48	$11.19	$0	$0	$74.79	$22.37
f) >$150	58	$12.67	$0	$0	$67.04	$21.66
g) N/A	82	$2.29	$0	$0	$71.93	$11.94
All	684	$5.08	$0	$0	$87.77	$15.21

Table 4. ARC-CO Corn and Soybean Payments per Operated Crop Acre by Level of Profit in Corn and Soybean Enterprises in Previous Year for Farm-year Combinations That Received Payments in 2015 and 2016

Crop Profits in previous year	N	Mean	Median	Min	Max	Std
a) <-$50	14	$35.66	$37.63	$3.08	$87.77	$23.53
b) -$50 to $0	16	$39.07	$38.99	$2.15	$87.14	$24.39
c) $0 to $50	13	$44.30	$45.02	$6.04	$62.38	$14.60
d) $50 to $100	13	$24.34	$22.38	$0.55	$59.72	$18.17
e) $100 to $150	13	$41.33	$46.27	<$0.01	$74.79	$24.73
f) >$150	20	$36.76	$41.26	$1.29	$67.04	$21.81
g) N/A	3	$62.52	$65.57	$50.07	$71.93	$11.24
All	92	$37.79	$43.30	<$0.01	$87.77	$22.06

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