Agricultural Contracting and the Scale of Production

Nigel Key

This study presents evidence that contracting is positively associated with the scale of production for six major U.S. agricultural commodities. Specifically, contract producers tend to operate at a larger scale than do independent producers, and the likelihood of an operation contracting increases with its scale. This relationship is strongest in the cattle and hog sectors, where it persists even among large commercial operations. Six theoretical explanations for the observed correlation between scale and contracting are proposed, including imperfect capital markets, contractor transaction costs, input leverage, grower risk aversion, asset specificity, and technological change. Information from five annual national surveys is used to examine the validity of three of the proposed mechanisms.

Key Words: marketing contracts, production contracts, risk, scale of production, transaction costs

In recent years there has been a substantial increase in the concentration of agricultural production in the United States—the size of farms and ranches has grown while the number of operations has declined. For example, based on *Census of Agriculture* data, between 1992 and 1997, the number of farms accounting for 75% of sales declined by 22%, while the average farm size for this group increased 8.8% [U.S. Department of Agriculture/National Agricultural Statistics Service (USDA/NASS), 1992 and 1997 census years)]. This consolidation of production has coincided with an increase in the use of marketing and production contracts. Marketing contracts govern the terms of sale of a commodity by specifying the price (or pricing mechanism), quantity to be delivered, and time of delivery. Production contracts contain agreements governing the provision of inputs by the contractor in exchange for a marketing arrangement. Production contracts often assign legal ownership of the commodity to the contractor. Marketing and production contracts may take a variety of forms: some may bind growers to particular management practices or specify that growers meet certain quality standards. USDA data show that the share of agricultural production in the United States under contract increased at an average rate of 3% per year between 1991 and 2002, with production and marketing contracts growing at about 4% and 2% per year, respectively [USDA/Economic Research Service (ERS)]. In 2002, 37% of the value of all agricultural production was produced under contract.

Of the major commodities in the last decade, the hog sector has probably experienced both the greatest consolidation of production and increase in the use of contracts. Between 1994 and 1999, the number of U.S. hog farms fell by more than 50%, from over 200,000 to less than 100,000, while the hog inventory remained relatively stable (USDA/NASS, 1995–1999). During the same six-year period, farms with at least 2,000 head increased their share of total swine inventory from 37% to 81%. Similarly, there was rapid growth among very large operations: operations producing at least 50,000 head increased their share of total hogs marketed from 17% in 1994 to 37% in 1997 to 51% in 2000 (Lawrence and Grimes, 2001). The last decade also saw a rapid increase in contracting, with the share of hog production under contract increasing from about 18% in 1990, to about 28% in 1995, to almost 60% in 2000 (USDA/ERS).

The simultaneous increase in the scale of agricultural production and the incidence of contracting suggests these two phenomena could be related. The first objective of this study is to identify whether

Nigel Key is an economist with the Economic Research Service, U.S. Department of Agriculture. The views expressed are those of the author and do not necessarily correspond to the views or policies of the Economic Research Service or the U.S. Department of Agriculture. The author would like to thank Michael Roberts, William McBride, and James MacDonald for helpful comments and suggestions.

there is a positive correlation between the scale of production and the use of contracts. Using five pooled annual national surveys of the agricultural sector, the findings reveal contracting is associated with a larger scale of the production for all of the major commodities for which information is available. That is, larger-scale producers are more likely to use contracts, and contract producers operate on a larger scale, on average, than do independent producers. This relationship also holds for cattle, hogs, corn, and soybeans even when we consider only those producers with a value of production of at least $250,000.

The second objective of this analysis is to present a comprehensive set of theoretical explanations for the observed relationship between contracting and scale. Six possible mechanisms are considered based on imperfect financial markets, transaction costs, agency theory, and technological change. First, it is shown that contracts may result in greater borrowing and scale if contracts shift profit risk away from farmers in the context of imperfect financial markets. This occurs because lenders respond to the risk-return tradeoff between independent and contract hog production by lending at lower rates to contract producers. Second, it is argued that fixed transaction costs associated with contracting may induce contractors to contract with larger-scale operators. Third, it is demonstrated that, in the context of limited access to credit, contract growers can achieve a greater scale of production than independent growers because contractors provide many inputs, which reduces farmers' financing needs. Three additional mechanisms are also briefly discussed through which contracting can result in larger scale: by providing income insurance which induces a risk-averse grower to exert more effort; by encouraging greater investment in productive specific assets which reduces the farmer's risk of hold-up; and by contributing to scale-enhancing technological change.

The final objective of this study is to use survey data to shed light on the validity of the theories. With the data at our disposal, we are able to examine three of the six proposed mechanisms. The empirical approach adopted here is to compare predictions from the theoretical models with observations from a large pooled cross-sectional survey. Survey evidence which contradicts the prediction of a theory casts doubt on the validity of that theory. Evidence which is consistent with a theory's predictions implies the validity of the theory cannot be ruled out. This empirical approach does not provide statistical "tests" of the mechanisms, but does offer useful information about their validity.[1]

Empirical Relationships

To examine the relationship between scale of production and contracting, data are pooled from five annual Agricultural Resource Management Surveys (ARMS) conducted by the USDA in the years 1996–2000. Each year the USDA surveyed approximately 10,000 farmers, resulting in a total of 53,669 observations in the pooled cross-section. In this study, those commodities are examined for which at least 100 farmers reported contracting in every year of the survey: cattle, hogs, corn, soybeans, wheat, and cotton.[2]

There are several possible ways to illustrate the relationship between contracting and scale of production. Table 1 compares the *enterprise* value of production for contract and independent operations for the six commodities that are produced either independently or under contract.[3] The table also presents information available after 1998 for two sub-categories of the livestock commodities: feeder and finished (market). A commodity is defined as *produced under contract* by an operation if more than 50% of the enterprise value of production of the commodity is sold under contract. Information about assets and borrowing is observed at the farm, rather than the enterprise level. To compare independent and contract producers, it is necessary to categorize a farm as producing under contract or independently. The 50% cutoff provides a logical, if somewhat arbitrary, way of making this distinction.

[1] There are challenging issues of identification that cannot be readily addressed with the pooled cross-sectional data at our disposal. For example, some of the proposed theories imply different levels of debt and value of production relative to net worth for contract and independent producers. The variables of interest—value of production and debt—are simultaneously determined with the decision to contract, and a credible instrument with which to identify these endogenous variables is not available. Consequently, it is not possible to obtain unbiased estimates of the effect of the organizational structure (contracting) on scale or debt, nor is it possible to disentangle the individual contributions of the competing theories.

[2] Poultry and sugar beet production are excluded from the study because these commodities are produced almost exclusively under contract, ruling out a comparison to independent production. In addition, the product categories "fruits" and "vegetables" are excluded because these categories are considered too heterogeneous to make valid comparisons across scale, net worth, or other categories—as is done in this study. With heterogeneous commodity groups like "vegetables" or "fruits," differences between categories may result from the type of crop cultivated rather than the variable of interest.

[3] Since the unit of analysis used in this study is the commodity "enterprise," rather than the whole farm operation, the same operation may appear more than once in a table if that operation produces more than one of the commodities considered.

Table 1. Tests of Equal Mean Enterprise Value of Production for Contract and Independent Operations: All Farms and Those with Value of at Least $250,000 (1996–2000)

	All Producers			Value of Production at Least $250,000		
Commodity	Independent: Mean ($)/[N]	Contract: Mean ($)/[N]	*t*-Statistic[a]	Independent: Mean ($)/[N]	Contract: Mean ($)/[N]	*t*-Statistic[a]
Cattle–All	22,433 [26,852]	686,166 [676]	!18.68	761,717 [1,517]	3,540,000 [257]	!7.73
Cattle–Feeder[b]	18,729 [8,427]	213,671 [282]	!11.50	604,540 [400]	1,345,433 [67]	!3.32
Cattle–Finished[b]	41,369 [2,886]	5,094,657 [90]	!15.23	1,066,752 [320]	8,707,223 [65]	!6.06
Hogs–All	51,678 [4,220]	496,835 [1,140]	!24.83	624,845 [647]	928,361 [837]	!4.07
Hogs–Feeder[b]	23,874 [618]	301,355 [247]	!12.72	390,286 [32]	675,475 [176]	!3.38
Hogs–Finished[b]	52,540 [2,359]	506,338 [616]	!25.30	588,936 [345]	899,237 [416]	!4.94
Corn	51,527 [15,151]	101,792 [1,263]	!15.26	420,913 [1,340]	491,575 [249]	!2.52
Soybeans	42,014 [15,326]	69,583 [1,403]	!15.19	366,159 [1,005]	420,359 [256]	!3.34
Wheat	31,343 [13,451]	46,685 [921]	!4.98	412,810 [524]	498,329 [67]	!0.37
Cotton	153,301 [2,404]	231,215 [1,275]	!7.39	559,437 [849]	542,049 [607]	0.64

Notes: All data are from the 1996–2000 ARMS (USDA/ERS) unless noted. Observations are weighted to account for survey design.
[a] The *t*-statistic corresponds to the test of the null hypothesis of equal means.
[b] Information for 1998–2000 only.

The qualitative results presented in the study were not sensitive to the cutoff values between 40% and 60% of production (more extreme cutoff values were not tried). The left-hand side of table 1 presents a test of equal mean value of production for all producers. On average, scale is observed to be much larger for contract production as compared to independent production for all six commodities. In terms of average scale, contract production ranges from about 50% larger than independent production for the case of wheat, to over 3,000% larger for cattle.

The right-hand side of table 1 tests whether a relationship between scale and contracting exists for large-scale commercial producers. The table presents a test of equal mean value of production for those farms producing more than $250,000 of the commodity.[4] Contract growers of livestock are shown to have much larger average values of production than do independent livestock producers. For field crops, the scale difference between contract and independent production is smaller—corn and soybeans are produced at a significantly larger scale under contract, though the difference is small. For large-scale commercial producers of wheat and cotton, there is no significant difference in scale between contract and independent producers.

Another way of viewing the relationship between scale and contracting is to compare the probability density functions of the value of enterprise production for contract and independent producers. Figure 1 presents estimates of these density functions for the same commodities analyzed in table 1. Density functions are estimated using a kernel density estimator with the bandwidth chosen by Silverman's "rule of thumb" (Silverman, 1986).[5] Because the size distribution is skewed, the density is estimated for the log of the value of production. Figure 1 shows large differences in the size distributions of contract and independent producers of cattle and hogs.

[4] Because farms often produce more than one commodity, almost all commercial farms included in this analysis have a total farm value of production well above $250,000—a value frequently used to distinguish "large" from "small" farms (Hoppe and MacDonald, 2001).

[5] The algorithm used disperses the mass of the empirical distribution function over a regular grid of at least 512 points and then uses the fast Fourier transform to convolve this approximation with a discretized version of the kernel. A linear approximation is used to evaluate the density at the specified points [see Venables and Ripley (1999) for details].

Figure 1. Estimated probability density functions for crop value of production

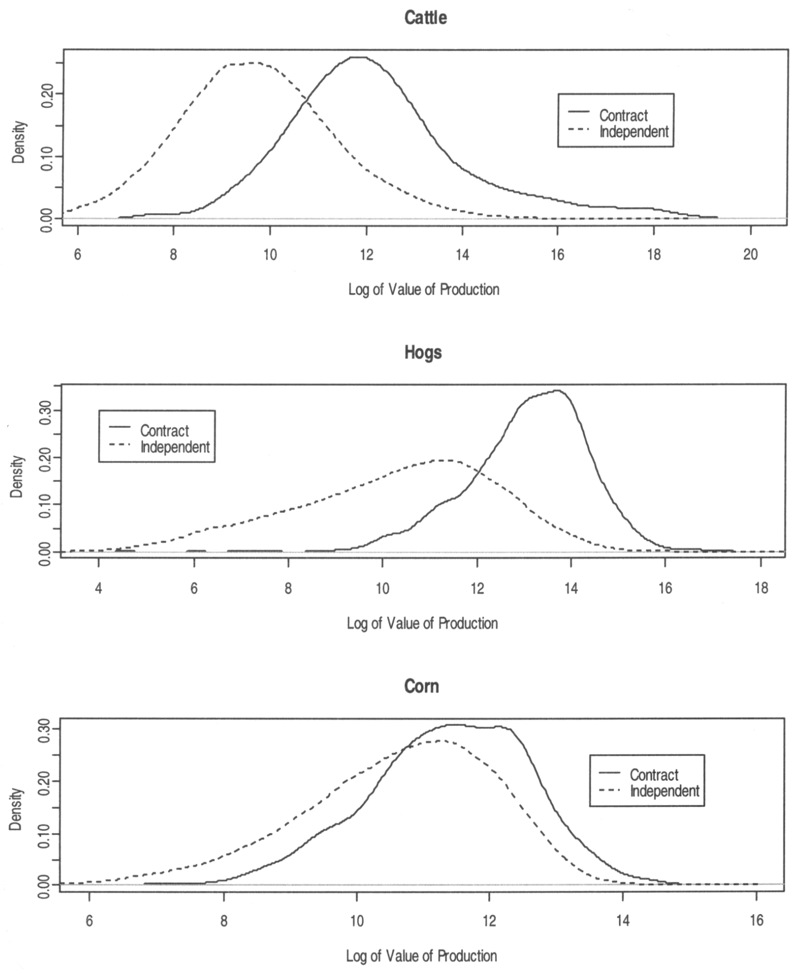
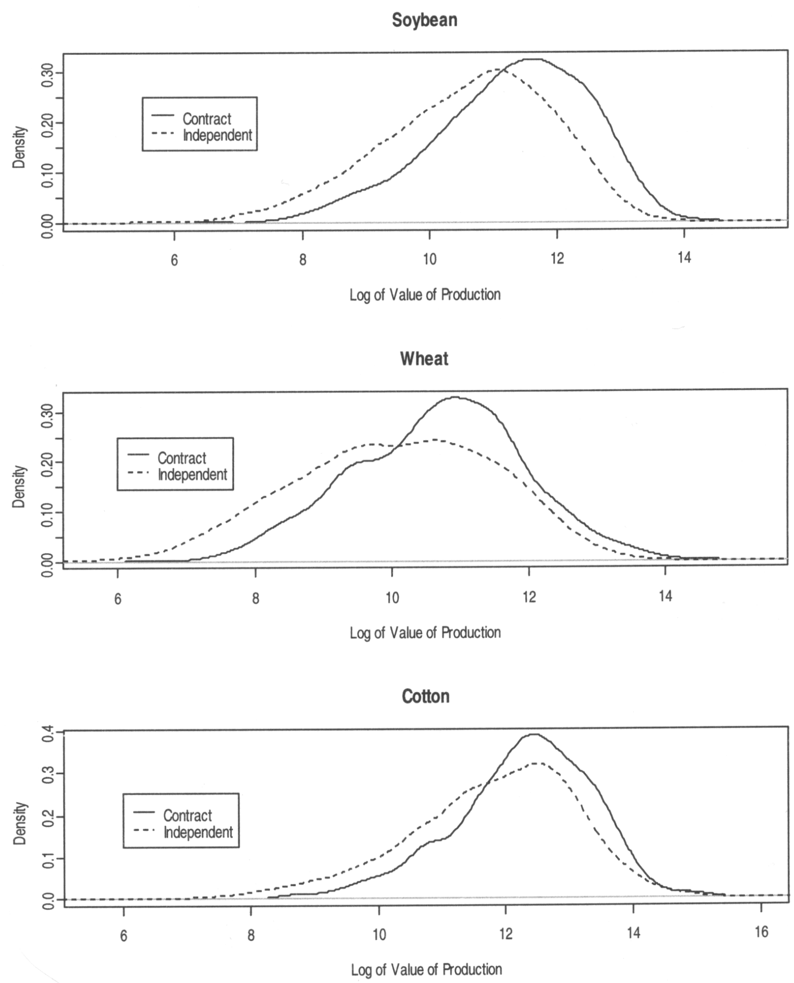


Figure 1. (continued)



Source: 1996–2000 ARMS (USDA/ERS)

Table 2. Percentage of Farms Contracting by Value-of-Production Quintile, 1996–2000

	Value-of-Production Quintile					
Commodity	0–20 (%)	20–40 (%)	40–60 (%)	60–80 (%)	80–100 (%)	N
Cattle–All	0.0	0.2	0.8	2.3	8.9	27,528
	(0.03)	(0.05)	(0.12)	(0.20)	(0.38)	
Cattle–Feeder [a]	0.0	0.3	0.7	3.5	11.9	8,709
	(0.03)	(0.13)	(0.20)	(0.44)	(0.78)	
Cattle–Finished [a]	0.0	0.0	0.4	1.2	9.0	2,976
	(0.05)	(0.00)	(0.26)	(0.45)	(1.17)	
Hogs–All	0.4	4.5	12.6	24.0	61.4	5,360
	(0.18)	(0.64)	(1.02)	(1.31)	(1.49)	
Hogs–Feeder [a]	2.2	2.1	16.7	33.1	56.9	865
	(1.12)	(1.08)	(2.84)	(3.59)	(3.78)	
Hogs–Finished [a]	0.2	3.6	16.1	27.6	67.1	2,975
	(0.16)	(0.76)	(1.51)	(1.83)	(1.93)	
Corn	2.3	3.9	6.6	5.7	10.5	16,414
	(0.26)	(0.34)	(0.43)	(0.40)	(0.53)	
Soybeans	3.4	5.1	6.5	7.6	11.5	16,729
	(0.31)	(0.38)	(0.43)	(0.46)	(0.55)	
Wheat	3.3	5.1	4.2	5.7	6.6	14,372
	(0.33)	(0.41)	(0.37)	(0.43)	(0.46)	
Cotton	19.1	25.3	36.4	39.2	42.8	3,679
	(1.45)	(1.60)	(1.78)	(1.80)	(1.83)	

Notes: Values in parentheses are standard errors. All data are from the 1996–2000 ARMS (USDA/ERS) unless noted. Observations are weighted to account for survey design.
[a] Information for 1998–2000 only.

There are smaller differences between the size distribution of contract and independent producers of the remaining commodities. However, for every commodity, the density function mass for contract producers is clearly to the right of that for independent producers.

Finally, the relationship between scale and contracting can be examined by comparing the rate of contracting for different size producers. Table 2 reports the percentage of farms that contract for each value-of-production quintile. Contracting becomes increasingly common in proportion to the value of production, i.e., farms in larger quintiles are more likely to use contracts than farms in smaller quintiles. This relationship holds for all commodities and quintiles except for wheat between the second and third quintiles. This relationship is statistically significant for many size-commodity comparisons. Focusing on the largest 40% of producers, the reported standard errors indicate there is a large and statistically significant increase in the rate of contracting between the second largest and the largest value-of-production quintiles for all commodities except wheat and cotton.

In sum, the evidence suggests that contracting is positively associated with scale of production for all six major commodities. This relationship persists for large-scale producers of all commodities except wheat and cotton, and is strong for large-scale producers of cattle and hogs. In the next section, six possible mechanisms are presented to explain this relationship.

Mechanisms and Evidence

Many marketing and production contracts have been shown to significantly reduce grower income risk (Johnson and Foster, 1994; Knoeber and Thurman, 1995; Martin, 1997). In general, marketing contracts shift output price risk to contractors, and production contracts shift both output and input price risk to contractors.[6] Production contracts also can reduce

[6] Some marketing contracts may shift little or no risk from growers to contractors. For example, if growers are uncertain of their output, then marketing contracts requiring growers to deliver a fixed quantity of a commodity may be risky. This risk occurs because farmers who cannot meet their contractual obligations must purchase the balance of the commodity owed in the market. Farmers usually minimize this risk by contracting only a portion of their expected harvest. A second example is a marketing contract that ties the contract price to an unknown future market price. Farmers can eliminate most of their risk in this situation by buying and selling futures contracts. Finally, some marketing contracts simply guarantee market access with no effect on price risk.

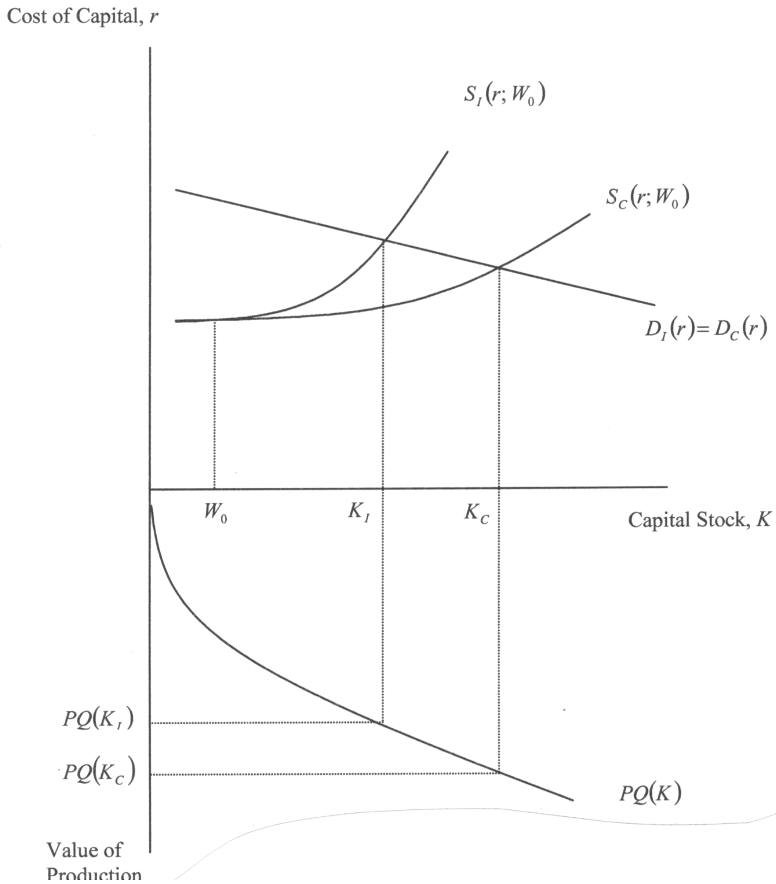


Figure 2. Imperfect capital markets mechanism

some yield (production) risk for growers, depending on the contract's incentive structure. The fact that contracts shift risk from growers to contractors is important for the first and fourth mechanisms discussed below.

Imperfect Capital Markets

Asymmetric information between borrowers and lenders about the quality or riskiness of borrowers' investments can lead to adverse selection and moral hazard costs for lenders. If expenditures on capital investments are not perfectly observable by lenders, then borrowers (farmers) may be tempted to divert funds to risky uses because they can earn higher expected returns. If borrowers face limited liability, they face less downside risk compared to lenders, but stand to gain more on the upside. Hence, borrowers and lenders have a different set of incentives. This is not a problem if the lender can perfectly observe the use of the loan, but if information is imperfect, lenders will face greater costs associated with a risk of default and monitoring. Lenders will require a higher return to compensate for these higher costs and may ration credit to borrowers (e.g., Stiglitz and Weiss, 1981). Lenders will have an incentive to charge interest rates that increase in proportion to the amount of the loan not secured by the borrowers' net worth.

Based on Hubbard (1998), a graphical analysis is used to illustrate the market for capital under imperfect information. Figure 2 illustrates the demand for capital by a firm (in this case a farm) and the supply of funds to the firm. The demand curve *D* slopes downward, suggesting a higher cost of capital reduces the desired capital stock. For simplicity, let the demand for capital by independent farms equal the demand for capital by contracting farms,

Table 3. Mean Debt-to-Net Worth Ratio by Net Worth Quintile, 1996–2000

	Net Worth Quintile									
	0–20		20–40		40–60		60–80		80–100	
Commodity	Indep.	Contract	Indep.	Contract	Indep.	Contract	Indep.	Contract	Indep.	Contract
Cattle–All	0.272	1.534	0.126	0.240	0.123	0.299	0.113	0.177	0.089	0.108
[N = 27,256]	(0.010)	(0.272)	(0.004)	(0.036)	(0.004)	(0.029)	(0.003)	(0.030)	(0.003)	(0.012)
Hogs–All	0.400	1.612	0.246	0.668	0.208	0.417	0.192	0.332	0.146	0.225
[N = 5,250]	(0.033)	(0.183)	(0.014)	(0.053)	(0.010)	(0.028)	(0.009)	(0.026)	(0.008)	(0.016)
Corn	0.495	0.817	0.242	0.375	0.188	0.286	0.152	0.236	0.107	0.163
[N = 16,178]	(0.018)	(0.101)	(0.006)	(0.043)	(0.005)	(0.020)	(0.004)	(0.021)	(0.003)	(0.012)
Soybeans	0.473	0.641	0.246	0.371	0.193	0.213	0.143	0.189	0.114	0.136
[N = 16,434]	(0.018)	(0.066)	(0.007)	(0.038)	(0.005)	(0.018)	(0.004)	(0.016)	(0.003)	(0.009)
Wheat	0.530	0.673	0.245	0.358	0.182	(0.199	0.133	0.246	0.118	0.166
[N = 14,131]	(0.020)	(0.130)	(0.007)	(0.037)	(0.005)	(0.018)	(0.004)	(0.020)	(0.004)	(0.014)
Cotton	0.627	0.635	0.293	0.403	0.202	0.268	0.142	0.192	0.111	0.181
[N = 3,497]	(0.061)	(0.100)	(0.021)	(0.040)	(0.014)	(0.025)	(0.013)	(0.016)	(0.008)	(0.017)

Notes: Values in parentheses are standard errors. All data are from the 1996–2000 ARMS (USDA/ERS). Observations are weighted to account for survey design.

implying both face equal investment opportunities: $D_I(r) = D_C(r)$.

A farm can self-finance if its desired capital stock is less than its net worth (W_0). Consequently, for capital stock smaller than W_0, the supply curve (S) is horizontal at the opportunity cost of capital rate (r)—consistent with the neoclassical investment model. If a farm wants to increase its capital stock beyond its net worth, it must borrow. The slope of the supply curve reflects the information costs of the uncollateralized finance: the higher the marginal information costs for the lender, the steeper the supply curve (Hubbard, 1998, p. 197).

The equilibrium for the farm is the point where the farm's demand curve intersects the supply curve. In figure 2, an independent (non-contracting) farm has a capital stock K_I. Now consider how a contract changes the supply curve in figure 2. For simplicity, assume a contract lowers the risk associated with investment, but does not change expected farm profits. Less risk means lower information costs for lenders, so the supply curve becomes less steep—banks are willing to lend more for the same interest rate. Hence, under contract, borrowing increases, which corresponds to an increase in the capital stock from K_I to K_C.

The lower quadrant in figure 2 illustrates the value of production on the Y-axis as a function of capital. A larger capital stock implies more production, and consequently a greater value of production. Thus, the imperfect capital market mechanism explains why, given the same net worth, contract operations have a greater value of production. If a processor locates in a particular area and randomly selects farmers with whom to contract, then contract and independent farmers should have about the same net worth, on average. The mechanism maintains that, with the same net worth, farmers who contract can borrow more and therefore produce more than farmers who are independent. Hence, it follows that contract operations will have a greater scale of production, on average, than independent operations.

The imperfect capital market mechanism results in two testable implications: (*a*) for a given net worth, contract operations will have greater debt (and therefore greater capital assets); and (*b*) for a given net worth, contract operations will have greater value of production. Table 3 compares the debt-net worth ratio for contract and independent producers of various commodities in each net worth quintile. For almost every net worth quintile in every commodity considered, the debt-net worth ratio is significantly larger for the contract farms compared to independent farms.[7] Table 4 compares the value of production-net worth ratio for contract and independent producers of various commodities in each net worth quintile. Again, for most commodities—and especially for livestock—there is a strong positive relationship between contracting and the value of production-net worth ratio. Hence,

[7] Table 3 also shows a decline in the debt-net worth ratio as the net worth increases, implying a larger share of farm finance comes from own-wealth, as wealth increases. This result neither confirms nor contradicts the imperfect capital market mechanism.

Table 4. Mean Value of Production-to-Net Worth Ratio by Net Worth Quintile, 1996–2000

	Net Worth Quintile									
	0–20		20–40		40–60		60–80		80–100	
Commodity	Indep.	Contract	Indep.	Contract	Indep.	Contract	Indep.	Contract	Indep.	Contract
Cattle–All	0.258	1.564	0.046	0.426	0.047	0.794	0.051	0.543	0.049	0.487
[N = 27,256]	(0.133)	(0.595)	(0.002)	(0.118)	(0.002)	(0.275)	(0.002)	(0.193)	(0.002)	(0.132)
Hogs–All	0.205	2.618	0.138	1.072	0.115	0.839	0.122	0.822	0.115	0.577
[N = 5,250]	(0.028)	(0.622)	(0.011)	(0.096)	(0.007)	(0.082)	(0.009)	(0.069)	(0.010)	(0.049)
Corn	0.357	0.908	0.114	0.183	0.102	0.145	0.081	0.120	0.059	0.089
[N = 16,178]	(0.032)	(0.396)	(0.003)	(0.018)	(0.004)	(0.011)	(0.002)	(0.010)	(0.001)	(0.005)
Soybeans	0.703	0.488	0.102	0.158	0.080	0.101	0.067	0.089	0.051	0.069
[N = 16,434]	(0.048)	(0.195)	(0.002)	(0.014)	(0.002)	(0.009)	(0.001)	(0.006)	(0.001)	(0.003)
Wheat	0.180	0.344	0.072	0.101	0.050	0.038	0.045	0.058	0.031	0.043
[N = 14,131]	(0.012)	(0.217)	(0.003)	(0.010)	(0.002)	(0.006)	(0.001)	(0.005)	(0.002)	(0.003)
Cotton	2.145	1.712	0.393	0.531	0.275	0.353	0.192	0.318	0.160	0.163
[N = 3,497]	(0.523)	(0.538)	(0.024)	(0.040)	(0.013)	(0.020)	(0.011)	(0.017)	(0.011)	(0.010)

Notes: Values in parentheses are standard errors. All data are from the 1996–2000 ARMS (USDA/ERS). Observations are weighted to account for survey design.

the information in tables 3 and 4 supports the testable implications that debt and value of production are greater for contract operations compared to independent operations, holding net worth constant.

The results obtained here are consistent with a study by Barry et al. (1997) which demonstrated that lenders respond to the risk-return tradeoff between independent and contract hog production by providing greater borrowing capacity to contract producers.[8] The authors surveyed 62 lenders to find out how much, and under what terms, they would lend to four representative types of producers: small and large low-risk contract operations and small and large high-risk independent operations. The study found that most lenders approved a higher proportion of the loan request and/or offered a lower interest rate to the contract operations, resulting in a higher debt-asset ratio for large-scale contract growers compared to large-scale independent growers (the resulting debt-asset ratio was approximately the same for the small operations). The results are also consistent with the assumptions of Boehlje and Ray (1999) who maintained contract growers can take on more debt than independent growers because contract growers face less risk. Contract growers in that study, because they operated with greater debt and at a larger scale, earned a higher return on equity than independent growers.

[8] Barry et al. (1997) also show that for a given level of output, contract operations require smaller loans than the independent operations because contract producers do not need to finance "operating" and "feed system" costs. This point is emphasized in our discussion of the "input-leverage" mechanism.

Contractor's Fixed Transaction Costs

Contract operations may be larger than independent operations because contractors find it more profitable to contract with larger-scale operations. When presented with a portfolio of farms of different sizes with whom to contract, contractors may choose to contract with larger operations in order to minimize some contracting transaction costs. Some important transaction costs for a contractor (e.g., an agricultural processing firm or its intermediary) include costs associated with: search for and screening of clients; negotiation of contracts; transfer of goods, services, or property rights; monitoring behavior for breach of contract; and enforcement of contract terms (e.g., Allen and Lueck, 2003; Foss, Lando, and Thomsen, 2000; Shelanski and Klein, 1995; Williamson, 1979). A contractor's transaction costs are often fixed costs that do not depend on the scale of production of the contracting farm. For example, an on-farm visit by a contractor may require the same amount of time regardless of the size of the farm. A contractor can reduce fixed transaction costs by reducing the number of contract agents and raising the average scale of production for each agent.

Because production contracts are generally much more complex than marketing contracts, and often require contractors to provide management and technical assistance in addition to inputs, it is reasonable to assume that production contracts impose higher transaction costs on contractors than do marketing contracts. Accordingly, the contractor's

Table 5. Tests of Equal Mean Value of Production for Production Contract and Marketing Contract Producers, 1996–2000

	Marketing Contract		Production Contract			
Commodity	Mean ($)	N	Mean ($)	N	t-Statistic	Prob > |t|[a]
Cattle–All	183,032	435	1,369,700	227	!2.76	0.0060
Cattle–Feeder[b]	112,470	219	478,400	56	!2.03	0.0428
Cattle–Finished[b]	689,681	37	9,574,600	52	!2.51	0.0139
Hogs–All	399,717	126	497,952	970	!1.40	0.1604
Hogs–Feeder[b]	117,406	19	323,560	218	!2.39	0.0177
Hogs–Finished[b]	416,361	95	530,153	501	!1.54	0.1237

Notes: All data are from the 1996–2000 ARMS (USDA/ERS) unless noted. Observations are weighted to account for survey design.
[a] Prob > |t| is the two-tailed significance probability under the null hypothesis of equal means.
[b] Information for 1998–2000 only.

transaction costs mechanism implies the scale of production under a production contract should be larger, on average, than under a marketing contract.

To examine whether the survey data support this implication of the transaction costs mechanism, we first classify contract production as being produced under a marketing or production contract (recall that a commodity was defined as "produced under contract" if more than 50% of the total value of production was under contract). Now define a commodity as "produced under a market contract" if more than 50% of the value of the commodity that was produced under contract was produced under a marketing contract. Otherwise, the contract-produced commodity is defined as "produced under a production contract."

The weighted shares of production contracts in all contracts for cattle, hogs, corn, soybeans, wheat, and cotton were 40.6%, 83.1%, 1.3%, 4.2%, 0.3%, and 0.03%, respectively. Cattle and hogs were the only commodities for which growers used both production and marketing contracts in sufficient numbers to merit a statistical comparison. Table 5 reports tests of equal mean value of production for production contracts versus marketing contracts. Because different stages of cattle and hog production could be correlated with the use of either production or marketing contracts, table 5 disaggregates cattle and hog production into "all," "feeder," and "finished" (breeding and "other" types of livestock production are not shown because they represent such a small share of total production). For "all," "feeder," and "finished" cattle, and for "feeder" hogs, the value of production is significantly greater under production contracts compared to under marketing contracts. For all remaining categories, production contract producers operate at a larger scale than do market contract producers, but not significantly so. Hence the evidence is consistent with the transaction costs mechanism. However, as shown in the next section, the "input-leverage" mechanism offers an alternative explanation for why production is greater under production contracts compared to marketing contracts.

Next, consider a second implication of the contractor's transaction costs mechanism. As noted above, if contractors face significant contracting transaction costs, they should prefer to contract with larger-scale growers, holding the per unit contract price (or fee) constant. However, it is reasonable to presume that contractors would be willing to bear the additional transaction costs associated with contracting with smaller-scale producers in exchange for paying a lower per unit fee. If this were the case, then we would expect larger-scale contract growers to earn relatively higher per unit fees than smaller-scale contract growers.

To test the implication of the "contractor's transaction costs mechanism" that larger contract operations earn higher per unit fees than smaller operations, we compare the per unit contract fees for different size operations that use *production* contracts. Table 6 presents the fees as a share of value of production for "feeder" hogs and "finished" hogs—the two commodities for which we have a sufficient number of observations to make scale comparisons. As table 6 shows, there is no significant relationship between scale and "per unit" fees for the largest 80% of producers. Production contract fees averaged about 23% of the value of "feeder" hog production, and about 14% of the value of "finished" hog production. The smallest quintile received significantly higher fees as share

Table 6. Mean Contract Fee as a Share of the Value of Production for Feeder and Finish Production Contract Hog Producers by Value-of-Production Quintile, 1998–2000

	Value-of-Production Quintile				
Commodity	0–20	20–40	40–60	60–80	80–100
Feeder Hogs [N = 226]	0.363 (0.0332)	0.241 (0.0214)	0.221 (0.0191)	0.236 (0.0252)	0.247 (0.0330)
Finished Hogs [N = 518]	0.235 (0.0233)	0.148 (0.0111)	0.157 (0.0124)	0.158 (0.0118)	0.127 (0.0081)

Notes: Values in parentheses are standard errors. All data are from the 1998–2000 ARMS (USDA/ERS). Observations are weighted to account for survey design. Value-of-production quintiles were computed separately for each type of hog produced.

of value of production for both types of production. Hence, the evidence from hog production contract fees provides no support for the contractor's transaction costs mechanism.

Input Leverage

The input-leverage mechanism applies only to production contracts, i.e., contracts requiring the contractor to provide inputs to growers. Consider, for example, production contracts to finish hogs. Under the terms of a typical contract, a contractor provides a large share of the "variable inputs"—feed, feeder pigs, veterinary care, managerial assistance, and marketing services. Growers provide labor and "fixed inputs"—growing facilities, and equipment. Growers are paid a fee for raising the animals, which may be based on animal weight gain, death loss, or feed productivity. Because contractors provide most of the variable inputs under a production contract, growers require far fewer financial resources to produce a given quantity of product. For example, the feed and other inputs supplied by a contractor under a production contract to finish hogs represents, on average, over 80% of the total costs of production (McBride and Key, 2003). Hence, a grower with limited financial resources could produce more under a production contract than independently or under a marketing contract (where inputs are not provided by the contractor).

The input-leverage mechanism is illustrated graphically in figure 3. The upper quadrant in the figure illustrates the market for loans. Let the demand for credit by an independent farmer be given by D_I. If the same farmer contracts, he or she receives variable inputs from the contractor. Assume these inputs have the value V. As a result, the farmer demands a smaller loan at any interest rate, shown by the demand curve D_C located to the left of D_I. The bottom quadrant in the figure illustrates the value of production as a function of the amount borrowed. Note that for any loan amount, the contract operation can always produce more output than the independent operation because the contract operation receives variable inputs from the contractor. As shown in figure 3, the value-of-production curve for the contract operations $PQ(V + B)$ is always greater than the value of production for the independent operation $PQ(B)$.

Consider first a perfect capital market where farmers can borrow an unlimited quantity at rate r, as illustrated by the supply curve S_1. The farmer producing independently borrows B_I^1, whereas the farmer producing under contract borrows only B_C^1. The optimal scale for the farm is identical under both organizational strategies: $PQ(B_I^1) = PQ(V + B_C^1)$.

Now consider an imperfect capital market where the cost of capital increases with the amount borrowed, as illustrated by the supply curve S_2. With the imperfect capital market, the independent producer borrows B_I^2 and the contract producer B_C^2. Because the contract producer has access to variable input V from the contractor, the contract grower is affected less by the capital market imperfection, and the value of production drops less for the contract producer compared to the independent producer; therefore, $PQ(B_I^2) < PQ(V \% B_C^2)$. Note that identical conclusions would be reached if the capital market imperfections resulted from capital rationing. With rationing, the supply of capital would be a vertical line at $\overline{B}$. If $B_C^1 < \overline{B} < B_I^1$, then only the independent farmers would be rationed. If $\overline{B} < B_C^1$, then both contract and independent farmers would be rationed. In either case, there would be a scale effect from contracting.

The input-leverage mechanism predicts that for a given level of financial resources (which can be approximated by assets or debt), farmers using

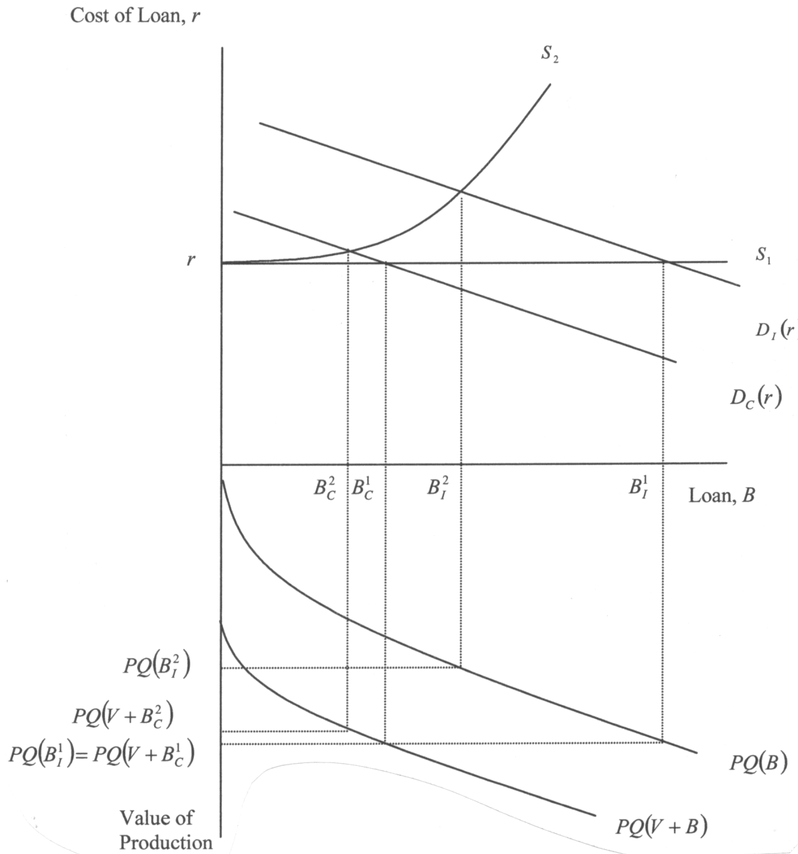


Figure 3. Input-leverage mechanism

production contracts can obtain a larger scale of production than can farmers using marketing contracts or producing independently. If contractors offered production contracts randomly to growers, then those accepting contracts would have about the same average access to financial resources as those who did not, but production contracts would leverage these resources into greater output.

We observed in table 5 that farmers using production contracts produced more output than those using marketing contracts, which is consistent with both the "contractor's transaction costs" mechanism and the "input-leverage" mechanism. The "input-leverage" mechanism also implies more would be produced under a production contract *for a given level of assets or a given level of debt*. Specifically, the average value of the production-asset ratio and the production-debt ratio would be larger for growers using production contracts compared to marketing contracts. This is not a prediction of the "contractor's transaction costs" mechanism.

The left-hand side of table 7 reports tests of equal mean value of production-assets ratio for production and marketing contract production of cattle and hogs for "all" producers (1996–2000), and "feeder" and "finished" producers (1998–2000). For both cattle and hogs, the average values of production-net worth ratios are significantly larger for production contracts compared to marketing contracts. The right-hand side of table 7 presents similar information, this time comparing the average value of production-debt ratios. Hog producers who use production contracts are able to leverage their debt into greater production than can users of marketing contracts. This relationship is less apparent for cattle producers: for both feeder and finished cattle, there is no significant difference in value of production-debt ratios between the types of contracts.

Table 7. Tests of Equal Mean Value of Production-Assets Ratio and Production-Debt Ratio for Production Contract and Marketing Contract Producers, 1996–2000

	Production-Assets Ratio			Production-Debt Ratio		
Commodity	Marketing Contract: Mean/[N]	Production Contract: Mean/[N]	*t*-Statistic[a]	Marketing Contract: Mean/[N]	Production Contract: Mean/[N]	*t*-Statistic[a]
Cattle–All	0.1741 [435]	0.8503 [227]	!5.25	7.777 [418]	11.264 [202]	!2.20
Cattle–Feeder[b]	0.1425 [219]	0.5409 [56]	!3.69	5.071 [217]	3.236 [57]	1.26
Cattle–Finished[b]	0.2494 [37]	3.0802 [52]	!4.32	5.767 [34]	8.931 [42]	!0.96
Hogs–All	0.4045 [126]	0.7042 [970]	!2.20	1.774 [122]	6.611 [869]	!4.73
Hogs–Feeder[b]	0.1376 [19]	0.4822 [218]	!1.73	0.245 [19]	0.903 [194]	!2.21
Hogs–Finished[b]	0.411 [95]	0.6762 [501]	!3.86	2.019 [90]	4.016 [448]	!2.50

Notes: All data are from the 1996–2000 ARMS (USDA/ERS) unless noted. Observations are weighted to account for survey design.
[a] The *t*-statistic corresponds to the test of the null hypothesis of equal means.
[b] Information for 1998–2000 only.

In sum, the evidence generally supports the input-leverage mechanism and suggests that the scale differences in table 5 may be explained by the input-leverage mechanism and the contractor's transaction costs mechanism.

Risk Aversion, Asset Specificity, and Technological Change

There are three additional mechanisms through which contracting may affect scale, including grower risk aversion, asset specificity, and technological change. Unfortunately, the data at our disposal preclude testing these mechanisms in this study. While these mechanisms are briefly discussed in this section, empirical tests are left for future work.

Risk Aversion. Under certain conditions, contracts that shift risk from growers to contractors may induce risk-averse growers to produce more, and therefore operate at a larger scale than they would have without a contract. Consider a simple marketing contract that reduces price variation without altering the expected price. If there is only one input to production, risk-averse farmers will demand more of the input when under contract compared to under independent production, resulting in more output, all else equal (Sandmo, 1971). On the other hand, a marketing contract may reduce the variation in price, but also lower the expected price for the grower. A lower expected price may induce farmers to reduce the input, resulting in a net drop in output despite the reduction in risk.

Production contracts may also influence the optimal scale of production by shifting some (but not all) production risk to contractors (Johnson and Foster, 1994; Knoeber and Thurman, 1995; Martin, 1997). For example, hog contracts typically specify a base payment per head, in addition to bonuses that increase with feed efficiency and decrease with death loss. Production contracts require farmers to share some portion of the production risk to provide an incentive for farmers to apply effort and care in raising the animals and discourage diversion of inputs provided by the contractor to other uses. When growers share the product of their labor with a contractor, growers receive less reward for their effort than they would if they produced independently. Consequently, share contracts, while reducing risk, *may* result in less grower effort, and therefore less output. On the other hand, because a share contract reduces risk, a contract could, under certain conditions, induce risk-averse growers to provide more effort than they would without a contract. In the appendix, a simple principal-agent share contract is used to demonstrate that a contract may increase or decrease the optimal scale of production.

Asset Specificity. When production requires the use of specific assets, contracting can result in a larger scale of production. Asset specificity is the extent to which the value of an asset is lost when it is used outside of a certain context (Klein, Crawford, and Alchian, 1978; Riordan and Williamson, 1985; Hart and Moore, 1988). Assets are specific if they are located near or have physical characteristics tailored to a particular purchaser. Examples of specific assets include the specialized equipment required for hog production such as manure storage facilities, or equipment for manure handling, barn ventilation, or delivering feed and water.

A farmer who makes a costly investment in a specific asset is vulnerable to "hold-up": a purchaser with some degree of market power can lower his offer price, driving the farmer toward his reservation price. Often because of economies of scale there is only one local purchaser of a product (such as broilers or hogs), and transporting the product to an alternative market is costly. Farmers vulnerable to hold-up will be reluctant to invest in specific assets, resulting in a smaller scale of production than would otherwise be the case.

In addition to durable physical assets, the notion of asset specificity also applies to short-term production capital when a commodity becomes "tied" to a particular purchaser because the product is perishable or costly to transport to alternative markets. Farmers who grow commodities like fruits and vegetables that lose value when not sold during an optimal time period, or that are costly to transport, may be vulnerable to hold-up—and would produce less than they would otherwise. A contract can overcome the market failure resulting from asset specificity by guaranteeing a long-term market and price for farmers' output. A contract that specifies a compensation scheme prior to an investment reduces farmers' risk of hold-up, and thereby encourages more investment in specific physical assets or production inputs, which can result in a larger scale of production.

Technological Change. In some situations, contracting may facilitate technological change which allows operations to combine inputs in such a way that average costs are minimized at a larger scale. This is unlikely to occur in the case of marketing contracts, i.e., whether or not a farmer uses a marketing arrangement should have no direct effect on the production technology. In contrast, production contracts may influence the production technology. For example, production contracts may provide access to high quality proprietary inputs, such as feed and genetic stock, which are not available for purchase by independent producers. In addition, contractors may provide managerial expertise to growers that can improve productive efficiency. Higher quality inputs and managerial expertise could result in higher production with the same measurable inputs, resulting in a larger scale of production.

Indeed, Key and McBride (2003) found evidence in the hog sector revealing the technology used under production contracts differs significantly from that under independent production. Using a sample selection model to control for unobservables correlated with the decision to contract and the production technology, they concluded that contracting results in about 20% more output, holding inputs constant. Unfortunately, the data used in the present study do not include information about the levels of inputs used in production, ruling out an application of the Key and McBride approach to cattle—the other commodity examined here for which production contracts are common.

Conclusion

This study has presented evidence that contracting is positively associated with the scale of production. Specifically, contract production tends to be at a larger scale than independent production, and larger-scale producers are more likely to use contracts than smaller-scale producers. This relationship was most striking in the cattle and hog sectors, where contract producers operated at a much larger scale than did independent producers, even when considering only large-scale commercial operations.

Six possible explanations were also presented for the observed correlation between scale and contracting, using information from five annual national surveys as evidence for or against the proposed mechanisms. Evidence that contracting is correlated with the debt-net worth ratio and the value of production-net worth ratio lends support to the "imperfect capital market" mechanism. Information on how production contract fees vary with scale fails to support the "contractor's transaction costs" mechanism. However, a comparison of the value of production under production and marketing contracts is consistent with both the "contractor's transaction costs" and "input-leverage" mechanisms. Finally, a comparison of the value of production-net worth and value of production-debt ratios for production and marketing contracts generally supports the "input-leverage" mechanism. Survey information was not used to test the validity of the "grower risk-aversion," "asset-specificity," or "technological change" mechanisms.

The fact that the data are consistent with multiple mechanisms suggests several of the proposed scale mechanisms may be working simultaneously. The proposed mechanisms are not mutually exclusive. In fact, they are mutually reinforcing. For example, a contract that reduces grower income risk may increase the supply of credit available (imperfect credit market mechanism) and simultaneously induce risk-averse growers to take on more debt (grower risk-aversion mechanism). A production contract could "leverage" this additional borrowing into even greater output by reducing growers' financial costs of production (input-leverage mechanism) and increase the efficiency of input use (technological change mechanism). Finally, if contracts were only offered to large-scale producers, then all the scale-enhancing effects associated with contracting would be limited to large-scale producers (contractor's transaction costs mechanism). We leave it to future work to disentangle the individual contributions of these effects.

It is worth noting that scale differences between contract and independent operations were greatest in those commodities (cattle and hogs) where production contracts are used relatively frequently. The evidence presented in the study suggests several possible reasons for this finding. First, unlike marketing contracts, production contracts require contractors to provide inputs to growers, effectively leveraging growers' financial resources. Second, because production contracts have high fixed transaction costs, contractors may be discouraged from contracting with small-scale growers. Third, because production contracts tend to be in effect for a longer period of time than marketing contracts, and because production contracts tend to shift more risk to contractors than do marketing contracts, lenders may be more willing to lend to growers who have production contracts compared to marketing contracts. Finally, production may raise the quality of managerial and other inputs resulting in greater productivity and scale.

It is also worth noting that there are substantial differences across commodities in the structure of contracts, implying contracting will influence scale through different mechanisms. This is particularly true for the case of cattle and hogs, where there are significant differences in terms of animal ownership, the rights to make management and marketing decisions, and contract length. Cattle contracts are often short-term, may specify multiple owners, and delegate the management and marketing decisions to feedlot managers. In contrast, hog contracts are often multi-year contracts exclusive to one individual, with the animal owner maintaining control over management and marketing decisions. There are also important differences between cattle and hog production that can influence how contracts affect scale. For example, the specificity of productive assets and the financial investment requirements are both higher in hog production relative to cattle. There are also differences in the concentration of production over the animal's life cycle—production is more dispersed for finished hogs compared to market cattle, while feeder pig operations tend to be more concentrated than cowherds. This study has described several general mechanisms through which contracting might influence scale. An understanding of the detailed characteristics of contracts and production is important in identifying how contracts influence scale for individual commodities.

The evidence that contracting is positively associated with scale of production casts doubt on the importance of alternative theories which could explain the relationship between scale and contracting. For example, it has been hypothesized that small-scale producers with lower income and wealth are more risk-averse and less able to cope with risk than larger-scale producers; thus smaller-scale producers would be expected to place more value on the risk-reducing property of contracts and would therefore be more likely to contract (Key and Runsten, 1999). It has also been suggested that contractors may prefer to contract with smaller-scale producers in part because the bargaining strength of contractors is inversely related to the scale of the contracting growers. According to this argument, a contractor's bargaining power may be greater when there is a large number of smaller-scale growers rather than a few large-scale growers, because a smaller number of growers can more easily organize themselves for collective action against the firm.[9] In addition, smaller-scale producers probably have more limited non-contract income and production opportunities, which also strengthen a contractor's bargaining power. The fact that smaller-scale producers are under-represented in contracting suggests, in the United States at least, these alternative theories are less important in determining the relative scale of contract production than the theories elaborated in this study.

[9] Smaller groups may be better able to organize because group members internalize a larger share of the benefits of their own actions; they are better able to observe the behaviors of other group members; communication among the group members is easier; members are more likely to identify with the group; social sanctions may be more effective because of tighter social ties; and transaction costs associated with governance are smaller.

Finally, the results of this study point to the possibility of a link between the recent consolidation of agricultural production and the increased use of contracts. Findings suggest contracting could have allowed some farms to become bigger than they would have otherwise. If there are economies of scale in production, then by facilitating the expansion of certain farms, contracting may enhance the cost advantages of these operations and serve as a catalyst for structural change.

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Appendix: Optimal Scale of Production Illustration Using a Simple Principal-Agent Share Contract

To illustrate that a contract may have an ambiguous effect on scale of production compared to independent production, consider a simple principal-agent share contract. A risk-averse agent (farmer) chooses how much "effort" (an unobservable input) to apply to a risky production technology. In deciding how much effort to apply, the agent makes a tradeoff between higher expected returns and the certain loss of utility from using effort. Let farmer's utility increase in income w and decrease in effort e as follows: agent's utility $= u(w) - g(e)$; $u' > 0$, $u'' < 0$, $g' > 0$.

Also let the uncertain income from agriculture increase linearly with effort: πe, where π is a random variable over a finite range, $\pi \in [\underline{\pi}, \overline{\pi}]$. The farmer's expected utility from independent production is therefore $\hat{a} = Eu(\pi e) - g(e)$.

Let there also be a risk-neutral principal (processor) who cannot observe agent effort (cannot contract on effort). The principal pays the agent a fixed certain payment f (which could represent the inputs to production provided by the contractor) in exchange for a share $(1 - s)$ of the agent's uncertain profits. For any s, the principal sets f so that the agent just receives her reservation utility $\hat{a}$. Given the terms of the contract, the agent chooses the level of effort to apply to maximize utility. With an additively separable utility function, the agent's problem is:

$$\max_{e} Eu(s\pi e) + f - g(e).$$

The first-order condition is:

$$E[u' s\pi] - g' = 0. \tag{A1}$$

Totally differentiating (A1) produces:

$$\begin{aligned} E[u'' s^2 \pi^2]de - g'' de &+ E[u'\pi]ds \\ &+ E[u'' s\pi^2 e]ds = 0, \end{aligned} \tag{A2}$$

and rearranging gives:

$$\frac{de}{ds} = \frac{-E[u'\pi] - E[u'' s\pi^2 e]}{E[u'' s^2 \pi^2] - g''}. \tag{A3}$$

The sign of (A3), which indicates how a change in the contract share affects agent effort, is ambiguous (the sign is ambiguous regardless of the sign of g''). If $de/ds < 0$, then a contract that *increases* the share of agricultural income going to the contractor (i.e., decreases s), induces *more* effort from the grower, resulting in greater output. When the sign of (A3) is negative, the positive output effect from insurance outweighs the negative incentive effect resulting from the sharing of output.

The first-order condition (A1) from which (A3) is derived must hold in the special case where $s = 1$ and $f = 0$, i.e., the case where a contract is equivalent to independent production. Starting at this point, we have shown that decreasing the share of agricultural income s that goes to the farmer (while simultaneously increasing the fixed payment f to maintain the grower's reservation utility) can induce more or less effort from the farmer, depending on the sign of de/ds. Hence, risk-averse growers may produce more or less under contract compared to what they would as independent producers.