Testing for Complementarities and Substitutabilities among Marketing Arrangements Used by U.S. Farmers*

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Two organizational modes or practices are said to be complements (substitutes) if the implementation of one practice increases (decreases) the marginal return of using the other practice. In this study, we test for the implication of complementarities and substitutabilities among various marketing arrangements used by U.S. farmers by examining the correlation among marketing arrangements (practices) conditional on farm/farmer observed and unobserved heterogeneities. The Probit model with unobserved heterogeneity is estimated using the simulated maximum likelihood method (SMLE). In our results, we found substitutabilities among different marketing arrangements. The results are robust across different commodities and across different econometric specifications.

Keywords: *Complementarities, Substitutabilities, Alternative Marketing Arrangements*

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I. Introduction

The idea of complementarity plays an important role in the theory of the firm. Two organizational modes or practices are said to be complements (substitutes) if the implementation of one practice increases (decreases) the marginal return of using the other practice (Milgrom and Roberts, 1990; Holmstrom and Milgrom, 1994). Early empirical findings indicated that various organizational practices are often clustered, which means that their adoptions are highly correlated (Anderson and Schmittlein, 1984; Arora and Gambardella, 1990; Milgrom and Roberts, 1990). This interdependence of the practices implies the existence of complementarities among different organizational modes. As a result, a rich theoretical literature has arisen attempting to explain why organizational practices are clustered, with implications for adoption and performance. Similar theoretical perspectives, developed in both organizational theory and business strategy, suggest that interdependencies among practices can be crucial for determining the payoffs of individual practices (Milgrom and Roberts, 1990; MacDuffie, 1995; Levinthal, 1997; Siggelkow, 2002). On the other hand, very few studies focused on the discussion of the substitutability of organizational modes. Siggelkow (2002) showed that misperceptions about the size and sources of complementarities are more costly to the firm than misperceptions about substitutabilities.

In this article, we present empirical evidence of complementarities and substitutabilities among different marketing arrangements used by U.S. farmers. In the modern U.S. agriculture, farmers rely more and more on alternative marketing arrangements (AMAs) to market their products, such as marketing contracts and production contracts (USDA, 2004). However, the possible complementarities or substitutabilities among the AMAs and between the AMAs and the traditional cash market have not been studied in the literature. The only related study is Vukina, Shin

and Zheng (2009), in which the authors presented the empirical evidence for the existence of complementarities among alternative marketing arrangements in meat packing. The study here focuses on farmers. The observation that spot market and AMAs are simultaneously used by farmers signals the potential for complementarities between different marketing arrangements. On the other hand, the fact that not all farmers use all marketing arrangements implies the potential for substitutabilities between different marketing arrangements. We postulate that complementarities mainly come from risk management, whereas the sources of substitutabilities are mainly savings in transaction costs and exclusivity associated with the production contracts.

Though the idea of complementarity (substitutability) is intuitively simple and appealing, testing whether such complementarities (substitutabilities) among practices really exist is difficult. Previous empirical studies can be categorized into two groups based on the approaches they use. The first approach is to test for complementarities (substitutabilities) in the production function directly (Ichniowski, Shaw, and Presnnushi, 1997; Caroli and Van Reenen, 2001; Bresnahan, Brynjolfsson, and Hitt, 2002; Mohnen and Roller, 2005; Van Biesebroeck, 2007; Vukina, Shin, and Zheng, 2009) and the second approach is to test an important implication of complementarity (substitutability) (Arora and Gambardella, 1990). The idea is that if two individual practices are complements (substitutes), one would expect their adoptions to be positively (negatively) correlated. In practice, this corresponds to testing whether the covariance between the adoption decisions, after controlling for firms' characteristics, is non-negative or not. This approach has been employed by Colombo and Mosconi (1995), Helper (1995), MacDuffie (1995), Pil and MacDuffie (1996), and Bai and Xu (2005). The original approach proposed by Arora and Gambardella ignores firms' unobserved characteristics that can lead to the correlation among the adoption decisions regardless of whether complementarities exist or not (Athey and Stern, 1998). Recent studies have proposed methods to account for this important confounding factor either using the instrumental variables (Novak and Stern, 2009) or a full-blown structural approach (Miravete and Pernias, 2006).

In this study, we adopt and extend the methodology of Arora and Gambardella (1990). We test for complementarities (substitutabilities) by examining the correlation among marketing arrangements (practices) conditional on farm/farmer observed and unobserved heterogeneities. The Probit model with unobserved heterogeneity is estimated using the simulated maximum likelihood method (SMLE). We find fairly robust empirical evidence of substitutabilities among different marketing arrangements.

II. Complementarities and Substitutabilities of Organizational Modes

A fairly rich literature in this area identifies many different sources of complementarities and substitutabilities of organizational modes. First, complementarities can be found among the similar types of practices such as manufacturing, human resources and supply chain management practices. For example, the use of rapid mass data communication, flexible production equipment and flexible production design technology can mutually reinforce each other to increase manufacturing quality and decrease production costs. In case of supply chain management, eliminating production delays can reduce other kinds of delays such as order process delays and shipping delays. For example, Vukina, Shin, and Zheng (2009) found that the main source of complementarities in meat packing comes from the supply chain management where the diverse use of different marketing arrangements minimize the risk of supply interruptions. Ichniowski, Shaw, and Prennushi (1997) found empirical support for the complementarities among innovative human resource practices. For example, the problem solving team will work more efficiently together with the flexible assignment of workers. MacDuffie (1995) found the empirical evidence that bundles of innovative HR practices affect the performance of the firm but individual HR practices do not.

Second, the complementarities could arise among different types of practices. Milgrom and Roberts (1990) model the firm's profit function by including the interdependences among manufacturing, marketing, design, engineering and organization. Due to complementarities, the combination of different practices can either increase productivity or decrease costs of other practices. For example, using flexible equipment in manufacturing can lower the setup cost of switching from producing one product to the next and save time, thereby increasing the productivity of labor. MacDuffie (1995) showed that the connectedness between HR and manufacturing practices is also crucial for labor productivity and product quality. HR practices, such as training and incentive pay, increase employees' working skills and motives. Manufacturing practices (e.g. flexible production systems) decrease the disruptions in the production process. Other empirical evidence pointed to the complementarities between different production inputs such as computers and high skilled labor at the industry level (Autor, Katz, and Krueger, 1998), the establishment level (Black and Lynch, 2001) and the firm level (Bresnahan, Brynjolfsson, and Hitt, 2002).

Finally, complementarities also come from the network-like practices which can boost innovation or technology advance. Arora and Gambardella (1990) showed that the external linkages of the large biotech companies (agreements with other firms, research agreements with universities, investment into small or median size research-intensive firms and the acquisitions of those) are all complementary to each other and their adoptions are highly correlated even when controlled for the firm characteristics.

Substitutabilities of organizational modes are less common and hence less studied in the literature. A good example is found in Siggelkow (2002) who pointed out to the differences in the investment strategies between an internet book retailer such as Amazon and Barnes & Noble who operates both bricks and mortar outfits and internet portals. In case of Amazon adding more categories of products on the website is considered profitable because introducing each new category attracts more customers

to the existing categories, and therefore, the marginal benefit of adding a new category will increase as the number of product categories increases. On the other hand, Barnes & Noble faces a decision whether to invest in marketing its products through the superstore, mall or the internet. These three channels are substitutes in the sense that as the convenience of buying books in one channel increases, the marginal effect of investments in improving the convenience of buying books through another channel decreases.

2.1 Marketing Channels in the U.S. Farm Sector

U.S. farm sector utilizes three different marketing arrangements: spot (cash) markets, marketing contracts and production contracts. Spot or cash markets still govern most of the transactions in the agricultural sector. In 2001, over 60 percent of the total U.S. agricultural products were marketed through the spot markets (USDA, 2004). In the spot market, farmers sell their products to buyers, who can be wholesalers, processors or brokers. When the transaction is done, farmers get paid, and the ownership of the product is transferred from farmers to buyers. The realized prices are prices at the time of sale and the quality differences are accounted for immediately. By selling products in the spot markets, farmers are able to control all of their businesses. They make all production and financial decisions. They are also responsible for finding a buyer, negotiating the price and delivering the product.

A marketing contract is a verbal or written agreement to market a commodity before the completion of a production cycle (e.g., before the crop is harvested or before the animals reach the market weight). The agreement usually includes the price, or an arrangement to determine the price at the time of delivery, or a commitment by the contractor to purchase the product from the farmer/operator with the price negotiated later. Prices may often vary with the quantity and the attributes of the product. Most marketing contracts will specify the base price or price formula such that the price variation will be less than it is in the spot market. With this arrangement, the operator

supplies and finances all or most of the inputs used in production, makes all production decisions, owns the product until delivery, and therefore, often bears all production risks. Marketing contracts are used for both crops and livestock but are more common for crops.[1]

A production contract is an agreement usually reached before the production begins which details the farmer's and contractor's responsibilities for providing inputs and specifies the payment mechanism which will be used to compensate farmers for the provision of their inputs. The contractor remains the residual claimant on the realized profits. The contractor usually owns animals or crops, provides most of the variable inputs (feed, seed, fertilizer, chemical, transportation and technical assistance) and makes major production and marketing decisions. The contractees (operators) supply labor, management services and some of the fixed inputs (land, buildings, etc.). Production contracts often set firm guidelines regarding production practices, and farmer/grower compensation schemes frequently depend on how effectively the contractor supplied inputs have been utilized. In the production contract, the farmer/grower payment will typically not depend on either input or output prices, which makes growers completely insulated from price risk. For example, under poultry production contracts, contract growers are required to tend company owned chickens or turkeys until the birds are market-ready (with specific age or weight). The contractor normally provides young chicks, feed, medical care and transportation and the contract operator provides chicken houses and equipment, supplies his labor and management attention and pays for utilities and some other small inputs. In return for his services, the grower gets paid a variable piece rate per pound of live poultry delivered where the variability in the piece rate is determined in a tournament setting where the individual performance is compared against the group average performance. For above average performance (below average feed conversion) the grower receives a bonus, and for the below average performance (above average feed conversion), the grower receives a penalty (for details see Vukina (2003)). Production contracts are mainly used in the production of hogs, poultry and a limited number of crops.

2.2 Complementarities and Substitutabilities of Marketing Channels

The main source of complementarities in the farm sector is risk management. Risk shifting is one of the most important incentives for farmers to adopt AMAs. Price, production and market access uncertainties result in volatile income for farmers, which negatively impact the welfare (utility) of risk-averse farmers and increases the costs and difficulty of obtaining credit. The use of AMAs reduces those risks and offers farmers relatively stable income and access to credit. Lawrence and Grimes (2001) showed that the use of marketing or production contracts can reduce farmers' financial risks. However, the use of AMAs can impose some other types of risks upon farmers as well. For example, buyers may default on their commitment to buy the products and the quality and quantity of the commodity or product might not be able to meet the requirements specified in the contract (USDA, 2004). In this case, combining the open market sales with AMAs can help reduce those risks. As a result, we should expect the spot markets and AMAs to be complementary in the sense that the combination of the two channels can give farmers a preferred portfolio to manage risks.

Meanwhile, the substitutability of marketing channels mainly arises from two sources. First, as the name "alternative marketing arrangements" suggests, marketing contracts and production contracts are alternative ways to the spot market farmers can use to market their commodities. As long as one channel can serve a farmer's need to market his commodities, he does not need to use other channels. Contract writing, monitoring and enforcing are too costly for small and/or multienterprise farms to use (Lambert and Wilson, 2003). Pricing mechanism in the contracts might be complicated, especially for the livestock. It is difficult for farmers to compare comtract prices under different circumstances (USDA, 2004) Besides, using AMAs is likely to reduce farmers' business autonomy. For those farmers value their autonomy, contract farming increases the cost of production (Key, 2005). All of these could be translated into higher transaction costs. Second, some production contracts are exclusive in the sense

that the contracts do not allow farmers to produce and sell the same commodity through other channels (USDA, 2004). For example, if a hog farmer has a production contract with a meat processing plant, he will not be allowed to raise additional hogs for other companies or for sale on the spot market because if allowed, the farmer can free ride on the inputs and services provided by the processing plant under the contract.

III. Data

The data set used in this study is the 2004 Agricultural Resource Management Survey (ARMS) collected jointly by the Economics Research Service (ERS) and the National Agricultural Statistics Service (NASS), both in the United States Department of Agriculture (USDA). ARMS data are nationally representative farm level data and provide detailed information on farms' structure, finances and crop or livestock production practices. Farm and farmer characteristics variables include total acres operated, total value of production, tenure or not, number of family members, occupation, age, education, on-farm and off-farm working hours, etc. The financial part of the data reports a farm's income statement, balance sheet and financial ratios, as well as operator's income. In the production practices part, it collects the year round field-level commodity specific data.

ARMS is a series of interviews containing three phases in the data collection process from the summer (June) of the reference year to the spring (April) of the year following the reference year. In phase I, farmers are selected and filtered by a variety of the planting commodities during the summer. Then farmers in phase I are randomly chosen and interviewed during the fall and winter (phase II). In this stage, a series of field-level or production-unit level enterprise surveys are done. Next, in spring of the following year, phase III is conducted. Information on a farm's costs and returns are collected at the whole farm level by interviewing the representative farmers, who are selected from the nationwide samples in phase II. The research presented in this manuscript uses phase III ARMS data.

We focus our analysis on producers of corn, soybeans, wheat, cotton, peanuts, tobaccos, cattle, hogs and milk.[2] After dropping observations with missing values, we compute the summary statistics and the variables used in estimation, which are reported in Table 1 by commodity. Farmers of different commodities have similar age and education levels. Hog and dairy farmers have slightly larger families. Crop farmers own more land than livestock farmers. The exceptions are tobacco and cattle producers. In terms of net worth, dairy farmers are the richest and hog farmers are the poorest. Finally, more producers of grain crops, hogs and milk are located in the Midwest than in the South, while most of the producers of industrial crops (cotton, peanut and tobacco) are located in the South.

In Table 2 we show the pattern of use of various marketing arrangements by U.S. farmers by commodity. There are seven possible combinations of three marketing arrangements: cash market (C), marketing contract (M) and production contract (P). The percentage of farms using the specific marketing arrangement is the sum of all combinations. For example, the percentage of farmers using the spot market is the sum of the percentages under C, CM, CP and CMP. As seen from Table 2, the spot (cash) market is still the dominant marketing outlet with very high percentage of corn, soybean and wheat farmers relying on it. Marketing contracts are commonly used by various crops and milk farmers but rarely by livestock producers. Production contracts are common in livestock but rare in crops (0.56% for corn, 0.51% for soybeans and 0.12% for wheat). Since our empirical analysis requires estimation by commodity-marketing arrangement combination and estimation based on a sample with less than 30 observations is likely to yield biased estimates, in the empirical analysis below, we only focus on testing the complementarity/substitutability between the spot market and the marketing contracts arrangement for corn, soybean, wheat, cotton, peanuts, tobacco and milk. For cattle and hogs, we have enough observations for testing complementarity/substitutability between the spot market and the marketing contracts arrangement, the spot market and the production contracts arrangement, and the marketing contracts arrangement and the production contracts arrangement.

Table 1. Summary Statistics

Variable	Description	Corn[1]	Soybeans[1]	Wheat[1]	Cotton[1]	Peanuts[1]
age	age of the operator (10s)	5.27 (1.17)	5.27 (1.16)	5.34(1.22)	5.25(1.20)	5.34(1.28)
educ	education level:1-5 [2]	2.73 (0.94)	2.69 (0.93)	2.81(0.96)	2.80(0.95)	2.68(1.01)
hhsize	number of family members	2.92 (1.37)	2.93 (1.39)	2.87(1.42)	2.79(1.19)	2.77(1.23)
acres	total acreage used (1000s)	1.26 (1.42)	1.24 (1.40)	1.93(2.73)	1.79(1.66)	1.22(1.35)
hhnw	household net worth ($100,000)	13.69 (18.32)	13.46(19.01)	13.42(17.97)	12.63(14.38)	11.92(13.42)
off-farm	off-farm income ($100,000)	0.46 (0.89)	0.46 (0.93)	0.42(0.81)	0.42(0.84)	0.40(0.45)
asset	value of farm assets ($100,000)	16.55 (20.19)	16.21(21.06)	15.84(19.89)	15.02(15.23)	13.76(14.21)
midwest [3]	located in the Midwest	0.80 (0.40)	0.78(0.42)	0.51(0.50)	0.02(0.15)	--
south [4]	located in the South	0.16 (0.37)	0.21(0.41)	0.18(0.39)	0.90(0.30)	1.00(0.07)
q [5]	quantity produced	7.32 (9.68)	1.95(2.49)	1.93(3.18)	6.31(7.73)	7.72(11.14)
# of observations	quantity for cash corn (bushel)	4,428	4,881	3,159	764	456

Variable	Description	Tobacco[1]	Cattle[1]	Hogs[1]	Milk[1]
age	age of the operator (10s)	5.37(1.12)	5.51(1.25)	5.13(1.08)	5.11(1.12)
educ	education level:1-5 [2]	2.43(0.98)	2.66(1.03)	2.69(1.03)	2.44(0.95)
hhsize	number of family members	2.84(1.26)	2.86(1.45)	3.29(1.70)	3.49(1.96)
acres	total acreage used (1000s)	0.74(0.94)	1.52(5.41)	0.63(1.06)	0.58(0.86)
hhnw	household net worth ($100,000)	11.98(22.42)	13.31(22.01)	11.13(18.63)	16.08(24.83)
off-farm	off-farm income ($100,000)	0.41(0.46)	0.56(1.24)	0.41(0.50)	0.29(0.71)
asset	value of farm assets ($100,000)	13.42(22.90)	15.37(23.56)	13.67(20.93)	20.06(29.11)
midwest [3]	located in the Midwest	0.05(0.22)	0.40(0.49)	0.56(0.50)	0.52(0.50)
south [4]	located in the South	0.93(0.25)	0.42(0.49)	0.35(0.48)	0.17(0.37)
q [5]	quantity produced	0.08(0.11)	1.94(12.10)	71.13(299.03)	5.36(12.28)
# of observations	quantity for cash corn (bushel)	460	8,893	1,599	1,633

Data source: ARMS and arranged by this study.

Note 1: mean (standard deviation).

Note 2: 1: less than high school; 2: high school; 3: college; 4: BA or BS; 5: graduate school.

Note 3: IL, IN, IA, KS, MI, MN, MO, NE, ND, OH, SD, and WI.

Note 4: DE, MD, DC, VA, WV, NC, SC, GA, FL, KY, TN, MS, AL, OK, TX, AK, and LA.

Note 5: units: 10,000 bushels for corn, soybeans and wheat; 10,000 pounds for cotton and peanuts; 1,000,000 pounds for tobacco; 100 heads for cattle and hogs; 10,000 cwt for milk.

Table 2. Marketing Arrangements Frequencies by Commodity

	Percentage of Farmers Using Different Marketing Arrangements						
	C	M	P	CM	CP	MP	CMP
Corn	68.75	3.62	0.20	27.05	0.25	0.02	0.11
Soybean	74.87	3.15	-	21.43	0.33	0.04	0.18
Wheat	84.55	2.25	0.09	13.07	0.03	-	-
Cotton	54.32	30.89	-	14.66	0.13	-	-
Peanuts	18.20	59.21	-	22.59	-	-	-
Tobacco	57.39	11.52	-	31.09	-	-	-
Cattle	97.44	0.34	0.47	1.50	0.25	0.01	-
Hogs	59.00	1.13	36.31	2.63	0.88	0.06	-
Milk	59.22	33.80	-	6.98	-	-	-

Data source: ARMS, and arranged by this study.

Note: cash market only (C); marketing contract only (M); production contract only (P); cash and marketing contract (CM); cash and production contract (CP); marketing and production contract (MP); all three (CMP).

IV. Empirical Approach and Estimation

Complementarity (substitutability) between continuous practices can be defined using the second-order cross partial derivatives. Let f be a function of two practices (x_1, x_2). These two practices are complementary if and only if $\partial^2 f/\partial x_1 \partial x_2 \geq 0$ and strict inequality holds for at least one value of (x_1, x_2). In other words, complementarity exists if the implementation of one practice increases the marginal return (profit or some other performance measure) of the other practice. On the other hand, these two practices are substitutes if and only if $\partial^2 f/\partial x_1 \partial x_2 \leq 0$ and strict inequality holds for at least one value of (x_1, x_2), that is to say, substitutability exists if the implementation of one practice decreases the marginal return of the other practice.

In the case where the two practices under consideration are discrete, complementarity (substitutability) between two practices can be defined using the concept of supermodularity (submodularity). A function f is supermodular (submodular) if, for all $x, x' \in R^2$,

$$f(x \vee x') + f(x \wedge x') \geq f(x) + f(x') \qquad \text{(supermodular)};$$

$$f(x \vee x') + f(x \wedge x') \leq f(x) + f(x') \qquad \text{(submodular)}, \qquad (1)$$

where $x \vee x'$ is the vector whose ith element is $max(x_i, x_i')$ and $x \wedge x'$ is the vector whose ith element is $min(x_i, x_i')$. Based on (1) the practices x_1 and x_2 will be complements if $f(x_1+1, x_2+1) + f(x_1, x_2) \geq f(x_1+1, x_2) + f(x_1, x_2+1)$; x_1 and x_2 will be substitutes if $f(x_1+1, x_2+1) + f(x_1, x_2) \leq f(x_1+1, x_2) + f(x_1, x_2+1)$. For example, assume that the two practices, x_1 and x_2, are the spot market and the AMA respectively. Farmer's return, $f(.)$, is a function of x_1 and x_2. The spot market and the AMA are complements if $f(1, 1) + f(0, 0) \geq f(1, 0) + f(0, 1)$, and are substitutes if $f(1, 1) + f(0, 0) \leq f(1, 0) + f(0, 1)$.

To test for complementarity (substitutability), the first empirical approach is to examine the sign of the second-order cross partial derivative in the case of continuous practice variables or examine whether equation (1) holds in the case of discrete practice variables. This testing approach is direct as it is based on the definitions of complementarity (substitutability). With this approach, for both continuous and discrete practice decisions, researchers often specify and estimate the following regression (e.g. Ichniowski, Shaw, and Presnnushi, 1997):

$$f(y_1, y_2) = \theta_0 + \theta_1 y_1 + \theta_2 y_2 + \theta_{12} y_1 y_2 + X\beta + \varepsilon, \qquad (2)$$

where f is a performance measure, y_1 and y_2 denote the adoption decisions for the two practices, X is a vector of other control variables and ε is the error term. If $\theta_{12} \geq (\leq) 0$, then the two practices are said to be complements (substitutes). A slightly different specification often used when the adoption decisions are discrete (e.g. Mohnen and Roller, 2005) is:

$$f(y_1, y_2) = \theta_{00}(1-y_1)(1-y_2) + \theta_{01}(1-y_1)y_2 + \theta_{10}y_1(1-y_2) + \theta_{11}y_1y_2 + X\beta + \varepsilon. \quad (3)$$

With this specification, one can examine whether equation (1) holds by examining whether the following two inequalities hold for the estimated coefficients:

$$\theta_{11}+\theta_{00}\geq\theta_{01}+\theta_{10}\qquad\text{(complementarity);}$$

$$\theta_{11}+\theta_{00}\leq\theta_{01}+\theta_{10}\qquad\text{(substitutability).}\tag{4}$$

No matter which specification is used, this approach requires the availability of rich data. First, one needs to observe the dependent variable in (2) and (3), usually a performance measure. Second, good-quality control and instrumental variables need to be available to control for the potential endogenous practice adoption variables y_1 and y_2. This is because it is likely that there are unobserved characteristics of the firm that simultaneously influence the performance measure and the practice adoption decisions, causing the endogeneity problem.

However, in practice, these types of data sets are often not available to researchers. To overcome this difficulty, Arora and Gambardella (1990) propose to test an important implication of complementarity (substitutability) instead of testing for complementarity (substitutability) directly. They proved that if two individual practices are complements (substitutes), then

$$\operatorname{cov}\left[y_1-E(y_1\mid X),\,y_2-E(y_2\mid X)\right]\geq(\leq)0\,.\tag{5}$$

Intuitively, this means that if two individual practices are complements (substitutes), then one would expect their adoptions to be positively (negatively) correlated, conditional on firm characteristics. Arora and Gambardella (1990) implement their method by fitting OLS models for each adoption decision (their adoption decisions are continuous) and then compute the covariance of residuals, as in (5).

Same as in the previous approach, one important potential confounding factor for the analysis here is the unobserved firm heterogeneity (Athey and Stern, 1998). The unobserved heterogeneity, if not controlled for, can lead to a positive or negative covariance estimate in (5) even when in reality no complementarities (substitutabilities) exist between the two practices. To address this concern, recent studies (Novak and Stern, 2009) have proposed the following regression.

$$y_1 = \theta_0 + \theta_{12} y_2 + X\beta + \varepsilon . \quad (6)$$

In order to estimate (6), one does not need the data on any of the performance measures, one still needs the data on instrumental variables to identify the key parameter θ_{12}. Miravete and Pernias (2006) propose a structural approach to address the unobserved heterogeneity problem. They specify a firm's profit to be a function of the individual practice adoption decisions, observed as well as unobserved firm heterogeneity and unknown parameters (which include the key complementarity parameter). They then solve the firm's maximization problem and derive the optimal adoption decisions as a function of both observed and unobserved firm heterogeneity as well as the unknown parameters. Specifying the unobserved heterogeneity to follow a stochastic distribution, they write the probability for each strategy profile and estimate the structural model using the maximum likelihood method.

In this study, we cannot use the direct approach described above because it is very hard to find a suitable performance measure in the dataset. Profit would be a very good measure but the farm level cost data are extremely difficult to obtain. It would be easier to obtain revenue or income data, but they are at the aggregated farm level, which means it is hard to tell whether or not the revenue or income comes from a specific set of commodities and/or marketing channels. Also, we cannot use any of the methods described above that rely on instrumental variables as good instrumental variables are not available. For example, good instrumental variables required to estimate (6) need to satisfy two conditions. First, they need to be correlated with the endogenous variable, that is, the decision on whether to adopt one marketing arrangement (e.g. marketing contracts). Second, they need to be uncorrelated with the farmer's decision to adopt another marketing arrangement (e.g. production contracts). It is very difficult to find variables that can satisfy these two conditions in the ARMS dataset.

To complete the estimation, we follow Arora and Gambardella (1990) and test for complementarities or substitutabilities by examining whether two marketing arrangements are positively or negatively correlated conditional on farm/farmer

characteristics. Our approach differs from that of Arora and Gambardella (1990) in two aspects. First, the adoption decision variables in this study are discrete. Hence a Probit model instead of an OLS model is used to fit $E(y \mid X)$. Second, we control for unobserved farm/farmer heterogeneity (Miravete and Pernias, 2006) by including an unobserved term in $E(y \mid X)$, that is, $E(y \mid X, u)$. Besides the Probit model with unobserved heterogeneity, we also calculate two more correlation coefficients, unconditional on any farm/farmers' characteristics and conditional on observed farm/farmers' characteristics only. For the unconditional covariance, we simply calculate the pair-wise correlation coefficient based on the outcomes observed in the data. The outcomes are farmers' decisions on whether or not to use a specific marketing strategy (practice). For the correlation coefficient conditional on observed farm/farmers' characteristics, the procedure is similar to the Probit model with unobserved heterogeneity, but the term of unobserved heterogeneity is not included. That is, the standard Probit model is applied. As a result, there will be one unknown parameter less (the standard deviation of unobserved heterogeneity).

The definition of the dependent variables used in estimation is as follows: *y* is a farmer's decision on whether or not using a specific marketing arrangement (practice). *X*'s, the explanatory variables used in estimation, are observed farm/farmers characteristics, e.g. age, education level, number of family members, total acre operated, household net worth, off-farm income, total asset, regional dummies and the quantity of the commodity produced.

The probability for farmer *i* to adopt marketing arrangement *j* is specified to be

$$E(y_{ij} \mid X_i, u_{ij}) = \Pr(y_{ij} = 1 \mid X_i, u_{ij}) = \Phi(X_i \beta_j + u_{ij}), \tag{7}$$

where u_i is a normally distributed random variable with mean 0 and variance σ_j^2. Zero mean reflects the fact that the average effect of the unobserved heterogeneity will

be captured by the constant term in $X's$. $\beta's$ are unknown parameters needed to be estimated. As a result, the likelihood function for the Probit model can be written as

$$l_{ij}(X_i, u_{ij}) = \Phi(X_i\beta_j + u_{ij})^{1(y_{ij}=1)}\left[1-\Phi(X_i\beta_j + u_{ij})\right]^{1(y_{ij}=0)}, \quad (8)$$

where 1(.) is the indicator function. As u_i is unobserved, (8) cannot be used for estimation purpose. We use the simulation method to solve this problem (Train, 2009). We simulate the term of unobserved heterogeneity M times (M=100) and calculate the average of the M likelihood functions. That is, we compute the likelihood function using

$$l_{ij}(X_i) = \frac{1}{M}\sum_{m=1}^{M}\Phi(X_i\beta_j + \sigma_j v_i^m)^{1(y_{ij}=1)}\left[1-\Phi(X_i\beta_j + \sigma_j v_i^m)\right]^{1(y_{ij}=0)}, \quad (9)$$

where $v_i^1, ..., v_i^M$ are *M* random draws from the standard normal distribution. σ is the standard deviation which needs to be estimated.

After the Probit model is estimated, residuals for each adoption decision can also be estimated using the simulation method,

$$\varepsilon_{ij} = y_{ij} - \frac{1}{M}\sum_{m=1}^{M}\Phi(X_i\hat{\beta}_j + \hat{\sigma}_j v_i^m). \quad (10)$$

Finally, the covariance between the residuals for two marketing arrangements can be computed. If the covariance is positive (negative), then we conclude the two marketing arrangements are complements (substitutes).

V. Results

For brevity purpose, we only present in Table 3 and discuss here the estimation results from the Probit models for corn. Results for other commodities are fairly similar

Table 3. Estimation Results from Probit Models for Corn

	Without Unobserved Heterogeneity				With Unobserved Heterogeneity			
	Cash		Marketing Contracts		Cash		Marketing Contracts	
Variable	Estimate	t-stat	Estimate	t-stat	Estimate	t-stat	Estimate	t-stat
age	0.1106	2.99	-0.1506	-7.38	0.1125	2.89	-0.1517	-7.26
educ	-0.0380	-0.95	0.1034	4.67	-0.0397	-0.97	0.1039	4.64
hhsize	-0.0035	-0.12	-0.0280	-1.69	-0.0037	-0.12	-0.0283	-1.69
acres	-0.0338	-1.14	0.0090	0.46	-0.0338	-1.12	0.0094	0.47
hhnw	0.0179	2.42	-0.0069	-1.35	0.0182	2.38	-0.0070	-1.36
off-farm	-0.0872	-3.32	0.0467	2.11	-0.0885	-3.20	0.0471	2.11
asset	-0.0176	-2.60	0.0064	1.37	-0.0179	-2.54	0.0065	1.37
midwest	0.5142	3.55	0.3050	2.68	0.5241	3.39	0.3080	2.68
south	0.3305	2.05	0.1028	0.83	0.3365	2.02	0.1041	0.84
q	0.0015	0.31	0.0299	10.26	0.0014	0.30	0.0301	9.99
constant	1.0700	3.47	-0.4749	-2.50	1.0911	3.31	-0.4783	-2.50
sigma					0.1883	0.39	0.1170	0.54
log likelihood	-622.1811		-2519.0898		-622.1265		-2518.94	

Data source: This study.

and are available upon request from the authors. Several results are worth mentioning. First, older farmers are more likely to use the spot market and less likely to use the marketing contracts arrangement. This is consistent with the notion that older farmers are more old-fashioned and are likely to stick with the traditional cash markets. Second, farmers with more education are more likely to adopt the marketing contracts arrangement. This is consistent with the hypothesis that education increases the level of human capital and helps farmers better understand the concept of risk management (Goodwin and Schroeder, 1994; Musser, Patrick, and Eckman, 1996). With better understanding, farmers tend to use more AMAs. Third, richer farmers (in terms of higher net worth) are more likely to rely on the spot market and are less likely to use the marketing contracts arrangement, though the latter effect is insignificant. This is consistent with the hypothesis that richer farmers are less risk averse and less risk averse farmers are less likely to use AMAs (Hu, Vukina, and Zheng, 2011). Fourth, farm households with more off-farm income are less likely to use the spot market and are more likely to use the marketing contracts arrangement. This might be due to the

fact that the opportunity costs of time for these farm households are higher and the use of marketing contracts arrangement requires less amount of time. Fifth, farms with more output are more likely to use the marketing contracts arrangement. To sell all the products, they need to rely on multiple marketing arrangements rather than just the traditional cash markets. Finally, the unobserved heterogeneity seems to play a minor role in the marketing arrangement choice by the farmers. The estimated variance of the unobserved heterogeneity term is not significantly from zero and including it into the Probit model does not change the estimates for other coefficients much.

Our main results are presented in Tables 4, 5 and 6. The first column of these tables present the correlation coefficients between the dependent variables, that is, indicators for whether a particular marketing arrangement is used by the farmer or not. The second column reports the correlation coefficients between the residuals from the Probit models without unobserved heterogeneity and the third column reports the correlation coefficients between the residuals from the Probit models with unobserved heterogeneity.

Table 4. Correlation Coefficients between the Spot Market and the Marketing Contracts Arrangement

	Simple Correlation	Residuals from Probit Model	Residuals from Probit Model with Unobserved Heterogeneity
Corn	-0.2565*	-0.2592*	-0.2592*
Soybean	-0.3070*	-0.3032*	-0.3033*
Wheat	-0.3467*	-0.3432*	-0.3435*
Cotton	-0.7310*	-0.7373*	-0.7321*
Peanuts	-0.5683*	-0.5774*	-0.5726*
Tobacco	-0.4188*	-0.4088*	-0.4085*
Cattle	-0.2683*	-0.2701*	-0.2699*
Hogs	0.0260	0.0192	0.0387
Milk	-0.8611*	-0.7995*	-0.7993*

Data source: This study.

Table 5. Correlation Coefficients between the Spot Market and the Production Contracts Arrangement

	Simple Correlation	Residuals from Probit Model	Residuals from Probit Model with Unobserved Heterogeneity
Cattle	-0.6257*	-0.6334*	-0.6331*
Hogs	-0.9572*	-0.9508*	-0.9386*

Data source: This study.

Table 6. Correlation Coefficients between the Marketing Contracts Arrangement and the Production Contracts Arrangement

	Simple Correlation	Residuals from Probit Model	Residuals from Probit Model with Unobserved Heterogeneity
Cattle	-0.0019	0.0007	0.0005
Hogs	-0.1466*	-0.1458*	-0.1800*

Data source: This study.
Note: * indicates significance at 1% level.

As seen from the tables, different marketing arrangements are substitutes. Our results are fairly robust, both across different econometric specifications and across different commodities. There are only two exceptions: the relationship between the spot market and the marketing contracts arrangement for hogs and the relationship between the marketing contracts arrangement and the production contracts arrangement for cattle. In both cases, the estimated correlation coefficients are not significantly different from zero. This is most likely due to the fact that there are not many farmers in the dataset (though larger than 30) that use marketing contracts to market their hogs and cattle.

The substitutability between the spot market and the marketing contracts arrangement comes from the fact that the two arrangements are simply alternative ways farmers can use to market their commodities. As long as one channel can serve a farmer's need to market his commodities, he does not need to use the other channel. By using only one channel and one buyer, the farmer may enjoy some savings in the

transaction costs. Relying on more than one channel to market his commodities requires the farmer to negotiate with multiple buyers, arrange for more than one delivery and split the volume into smaller lots. All of these could be translated into higher transaction costs.

The substitutability between the spot market and the production contracts arrangement for cattle and hogs and the substitutability between the marketing contracts arrangement and the production contracts arrangement for hogs come from the exclusivity of the production contracts. Usually, production contracts have explicit clauses banning farmers to produce and sell the same commodity through other channels or for other contractors. This is because if allowed, the farmer can free ride on the inputs and services provided by the processing plant under the contract.

Finally, it is worth mentioning that though our results indicate strong substitutabilities among different marketing arrangements, it does not necessarily mean that complementarities are totally absent. Some farmers indeed choose to use multiple marketing arrangements at the same time for risk management purposes. Our results simply mean that overall the forces from substitutabilities dominate those of complementarities. The degrees of dominance differ across different commodities. For example, for hogs, the spot market and the production contracts arrangement are close to be perfect substitutes, with the correlation coefficient close to -1, while the correlation coefficient between the spot market and the marketing contracts arrangement is close to -0.3.

VI. Conclusions

Farmers have long used formal contracts for selling their output. One of the most important characteristics of modern agriculture in the U.S. is the increased reliance on various types of Alternative Marketing Arrangements (AMAs). Nowadays, the AMAs are ubiquitous. They are used in livestock, fruits and vegetables, wine grapes, tobacco,

and even for exchange of traded commodities such as corn and soybeans. The main motive for farmers to enter into contractual relationships with a buyer is related to risk management. Besides price and quantity risks, producers typically face the risk of inadequate market access that manifests itself in having difficulty finding buyers, or more likely in scheduling deliveries consistent with the timing of their production systems. Contracts eliminate market access risk and provide the producer with a secure outlet for their products.

Despite many benefits that famers derive from having access to AMAs, their use has been controversial, especially in the livestock sectors. The opponents of AMAs cite the negative impacts of AMAs on farm level prices due to processors/packers' s market power as well as the inability of farmers to efficiently renegotiate contracts when they come up for renewal, the so called hold-up problem. Despite the fact that the scientific support (both theoretical and empirical) for government regulation in this area is rather weak, there is a constant pressure on both federal and states legislators to regulate the AMAs to the point of banning them altogether.

An entirely neglected aspect of various regulatory proposals concerning agricultural contracts is the question of whether they might be complementary to each other. Complementarity among individual marketing practices implies that the magnitude of the productivity effect of the portfolio of practices is larger than the sum of the marginal effects from adopting each individual practice. This suggests that interdependencies among marketing arrangements can be crucial for determining the payoffs for individual practices and therefore the welfare effects of proposed regulation or some other type of government intervention. If marketing arrangements are complements, then eliminating the use of one marketing arrangement would have a direct effect reflected in an economic loss, because the practice is no longer available. However, it also will have an indirect effect arising from the fact that the eliminated practice may be complementary to some other practice, and the efficiency of that other practice may be diminished as its complementary practice use is reduced or eliminated.

On the other hand, if marketing arrangements are substitutes, then the direct effect and the indirect effect of eliminating one marketing arrangement will have opposite signs and the final impact will be a lot less.

The concept of complementarity/substitutability has never been applied and tested in the context of the farm marketing strategies before. Our results show that to farmers, different marketing arrangements are substitutes, and the main sources of substitutabilites are possibly savings in the transaction costs and the exclusivity of the production contracts.

Finally, it is worth mentioning that in this paper, we focus on testing for complementarity/substitutability among different marketing arrangements given production. It will also be interesting to test for complementarity/substitutability among different commodities in production, that is, the question of diversification versus specialization. For example, producing livestock and crops on the same farm might be complementary or substitutable to each other depending on whether the benefits from diversification dominate those from specialization. Besides, this study only provides some empirical evidence that different marketing arrangements are substitutes, but could not specifically determine the sources of substitutabilities. These are all left for future research.

Endnotes

1. Since the ARMS survey is our main data source, the marketing contract and production contract are defined correspondingly to their definitions used by the ARMS survey.
2. We also looked into producers of oats, alfalfa hay, broilers and turkeys. But since less than 30 farmers in the data set use marketing arrangements other than the cash market for oats and alfalfa hay, and less than 30 farmers in the data set use marketing arrangements other than the production contracts for broilers and turkeys, we cannot perform our tests for these commodities.

References

Anderson, E. and D. Schmittlein, 1984. “Integration of the Sales Force: An Empirical Examination,“ *Rand Journal of Economics*. 15(3): 385-395.

Arora, A. and A. Gambardella, 1990. “Complementarity and External Linkages: The Strategies of the Large Firms in Biotechnology,” *Journal of Industrial Economics*. 38: 262-379.

Athey, S. and S. Stern, 1998. “An Empirical Framework for Testing Theories about Complementarities in Organizational Design,” NBER Working Paper 6600, National Bureau of Economic Research (NBER), Inc.

Autor, D., L. Katz, and A. Krueger, 1998. “Computing Inequality: Have Computers Changed the Labor Market?” *Quarterly Journal of Economics*. 113(4): 1169-1213.

Bai, C. and L. C. Xu, 2005. “Incentives for CEOs with Multitasks: Evidence from Chinese State-owned Enterprises,” *Journal of Comparative Economics*. 33: 517-539.

Black, S. and L. Lyuch, 2001. “How to Compete: The Impact of Workplace Practices and Information Technology on Productivity,” *Review of Economics and Statistics*. 83(3): 434-445.

Bresnahan, T., E. Brynjolfsson, and L. Hitt, 2002. “Information Technology, Workplace Organization, and the Demand for Skilled Labor: Firm-level Evidence,” *Quarterly Journal of Economics*. 117(1): 339-376.

Caroli, E. and J. Van Reenen, 2001. “Skill-based Organizational Change? Evidence from a Panel of British and French Establishments,” *Quarterly Journal of Economics.* 116: 1449-1492.

Colombo, M. and R. Mosconi, 1995. “Complementarity and Cumulative Learning Effects in the Early Diffusion of Multiple Technologies,” *Journal of Industrial Economics*. 43(1): 13-48.

Goodwin, B. and T. Schroeder, 1994. “Human Capital, Producer Education Programs, and the Adoption of Forward-pricing Methods,” *American Journal of Agricultural Economics*. 76(4): 936-947.

Helper, S., 1995. “Supplier Relations and the Adoption of New Technology: Results of Survey Research in the U.S. Auto Industry,” NBER Working Paper 5278, National Bureau of Economic Research (NBER), Inc.

Holmstrom, B. and P. Milgrom, 1994. "The Firm as an Incentive System," *American Economic Review*. 84: 972-991.

Hu, W. Y., T. Vukina, and X. Zheng, 2011. *The Role of Risk and Risk-aversion in Adoption of Alternative Marketing Arrangements by the U.S. Farmers*. Raleigh, North Carolina: North Carolina State University.

Ichniowski, C., K. Shaw, and G. Prennushi, 1997. "The Effects of Human Resource Management Practices on Productivity: A Study of Steel Finishing Lines," *American Economic Review*. 87: 291-313.

Key, N., 2005. "How Much Do Farmers Value Their Independence?" *Agricultural Economics*. 33: 117-126.

Lambert, D. and W. Wilson, 2003. "Valuing Varieties with Imperfect Output Quantity Measurement," *American Journal of Agricultural Economics*. 85: 95-107.

Lawrence, J. and G. Grimes, 2001. "Production and Marketing Charateristics of U.S. Pork Producers, 2000," Ames, IA: Iowa State University Staff Paper No.343.

Levinthal, D., 1997. "Adaption on Rugged Landscapes," *Management Science*. 43: 943-950.

MacDuffie, J., 1995. "Human Resource Bundles and Manufacturing Performance: Organizational Logic and Flexible Production System in the World Auto Industry," *Industrial and Labor Relation Review*. 48: 197-221.

Milgrom, P. and J. Roberts, 1990. "The Economics of Modern Manufacturing Technology, Strategy and Organization," *American Economic Review*. 80: 511-528.

Miravete, E. J. and J. C. Pernias, 2006. "Innovation Complementarity and Scale of Producition," *Journal of Industrial Economics*. 54: 1-29.

Mohnen, P. and L. H. Roller, 2005. "Complementarities in Innovation Policy," *European Economic Review*. 49: 1431-1450.

Musser, W., G. Patrick, and D. Eckman, 1996. "Risk and Grain Marketing Behavior of Large-scale Farmers," *Review of Agricultural Economics*. 18(1): 65-77.

Novak, S. and S. Stern, 2009. "Complementarity among Vertical Integration Decisions: Evidence from Automobile Product Development," *Management Science*. 55(2): 311-332.

Pil, F. and J. MacDuffie, 1996. "The Adoption of High Involvement Work Practices," *Industrial*

Relations Review. 47(2): 173-188.

Siggelkow, N., 2002. "Misperceiving Interactions among Complements and Substitutes: Organizational Consequences," *Management Science*. 48: 900-916.

Train, K., 2009. *Discrete Choice Methods with Simulation*. Cambridge: Cambridge University Press.

USDA, 2004. *Organizing the Production and Use of Agricultural Commodities*. Washington, D.C.: United States Department of Agriculture (USDA).

Van Biesebroeck, J., 2007. "Complementarities in Automobile Production," *Journal of Applied Econometrics*. 22: 1315-1345.

Vukina, T., 2003. "The Relationship between Contracting and Livestock Waste Pollution," *Review of Agricultural Economics*. 25(1): 66-88.

Vukina, T., C. Shin, and X. Zheng, 2009. "Complementarity among Alternative Procurement Arrangements in the Pork Packing Industry," *Journal of Agricultural & Food Industrial Organization*. 7(1): Article 3.

美國農民產銷管道之互補性與替代性檢驗*

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使用某一組織模式或實作如果能夠增加（減少）另一種組織模式的邊際報酬則兩種組織模式稱之爲具有互補性（替代性）。本研究探討產銷通路間的相關性並控制農場與農民可觀察到與不可觀察到的異質性，以此檢驗美國農民所使用不同的產銷通路是否具有互補性或替代性的可能。本研究以模擬最大概似法 (simulated maximum likelihood method, SMLE) 估計具有無法觀察到之異質性的機率單元 (Probit) 模型。研究結果顯示不同的產銷通路間具有替代性，此結果在不同的農產品與不同的計量模型設定下都具有相當一致的結果。

關鍵詞：互補性、替代性、非傳統產銷通路

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