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Characteristics of hog producers and how those characteristics affect the rate of adoption of technologies used on the hog industry; evidences in hog producers in United States.

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1. Introduction

Hog production is a vital element of American agriculture and plays key a part of the American diet. The swine industry, has changed on the last decades from small-scale operations and industrial-scale operations on the 1980 to 2000, to nowadays the post industrial era increasing the risk of pathogen movement between and among industrial facilities, and releasing these pathogens to the external environment (Graham et al., 2008). Due to this industrial evolution, the hog industry has developed several technologies. These technologies not only promote biosecurity among hog farms' procedures that prevent a spread of diseases but they have also contributed to production efficiency and genetic improvements.

The introduction and rapid adoption of new technologies used in the hog industry have evolved in the last decades in the areas of nutrition, health, breeding and genetics, reproductive management, housing, and environmental management ("Production Contracts and Productivity in the U.S. Hog Sector on JSTOR," 2015). Intuitively, the adoption behavior of these technologies should not be too surprising. Though, despite the fact that these technologies were created several decades ago, hog producers keep using and adopting them. Besides increase in profitability, the application of these technologies also entails that hog producers consider another type of returns like safety, welfare for pigs and operators, and convenience for operators.

It is complicated to understand how advantages such as safety, convenience, welfare for pigs and operators, and simplicity can affect hog producer's benefits received from adopting these technologies because not all hog producers in the United States have the same preferences. For instance, what may be proper and simple for one hog producer may be different for another hog producer. However, hog producers may have common preferences on the adoption of certain technologies of their choice. Indeed, there are several factors that influence these underlying preferences and they are frequently recognized as important elements on farmers adoption behaviors; such as credit constraint, farm structure or size, human capital, labor supply, and physical environment (Hurley, Mitchell, & Onstad, 2007).

Several studies on understanding the benefits of these technologies provided to hog producers focus on profitability, production, biosecurity, and cost (Fangman & Tubbs, 1997; Foster, Hurt, & Hale; Gerrits et al., 2005; Roca et al., 2006). For instance, Cameron (2000) found that for the establishment of industrialization, production requires the adoption of technologies that decline the risk factor for both animal and human health; furthermore, the success of large scale production depends on the quality of housing and management, level of staff training, and education, and especially on the maintenance of strict biosecurity.

Thus, the research questions for this analysis are the following: Are there any underlying production characteristics that affect the adoption behavior of technologies frequently used in the U.S. hog industry? If they do exist, can they be identified? If they can be identified, does their identification provide useful information? The purpose of this analysis is to assess hog producers' characteristics and how these characteristics affect the rate of adoption of technologies frequently used in the U.S. hog industry. To achieve this goal, we conducted parametric and nonparametric analyzes and we assessed a multinomial logit model and multinomial probit using simulated maximum likelihood and seemingly unrelated multinomial logit.

The contributions of the paper include (i) the formal development of underlying preferences on the adoption the technologies used in the U.S. hog industry in 1995, 2000, and 2005. (ii) intuition about econometric analysis features that not only capture hog producers preferences, but also identifies the possible violation of constant variance and normality assume in parametric models. (iii) evidence of the existence of underlying preferences on the adoption of the technologies and utility of accounting for it. These contributions are important because they provide more refined tools for interpreting the motives underlying consumer behavior, which can help hog farmers better understand core preferences based on hog technology attributes.

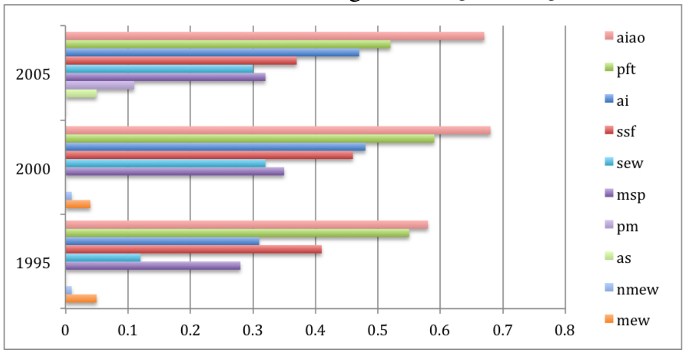
The analysis mainly focuses on the adoption of a bundle of technologies as a group that works well together and is considered complementary to each other; hence, we generated a correlation matrix and then performed a factor analysis on this correlation matrix. This correlation will be an indicator of complementary and substitute technologies. Besides, as these technologies mature, we want to determine how the relationship among technologies changes. In this manner, we can establish which unobservable factors that we are not measuring explain why some farmers are more likely to adopt certain bundles of technologies.

To achieve these objectives, we worked on a survey of subscribers to National Hog Farm Magazine (NHFM) across the United States conducted in years 1995, 2000, and 2005 regarding their adoption behavior of any of the 10 technologies frequently used in the U.S. hog industry. Also, hog producers contributed information regarding their production characteristics and human resources characteristics used on their hog production systems. They provide a variety of information regarding themselves, production structure or size, and physical environment of the operations, including detail information regarding formal evaluation for employees.

This analysis makes inferences in the subpopulation of hog producers that responded to the NHFM survey on years 1995, 2000, and 2005; however, subscriber's response varies drastically between years due to external factors such as the collapse in the pork market in late 1998, which brought huge losses to producers. For instance, the complete data have a total of 5,314 producers responded to the survey conducted by NHFM (3,935 producers in 1995, 674 produces in 2000, and 705 producers in 2005). The collapse of price affected the propensity to respond to survey declining producer's participation on the years 2000 and 2005, which led to missing data and self-selection bias of the sample. We solve the missing data issue based on probabilities weights by weighing the observed data points of each producer in the NHFM sample using propensity score matching. Moreover, we employed bootstrap techniques to measure the accuracy of our estimates to complete our analysis we applied the method of bootstrapping pairs to do bootstrap resampling because it requires fewer assumptions and it is more robust.

We used STATA's principal component analysis command. To determine the number of components to retain we used the Kaiser criterion where we drop all components with eigenvalues under 1.0. We retained components with relatively high determinants loading (greater than 0.3). Using STATA's rotate command we rotated them orthogonally. We performed a principal component analysis by years, because we have panel data for years 1995, 200 and 2005, so as the technologies mature we can see how this relationship of complementarity and substitutability change.

Figure 1: Hog technologies used from 1995-2005, mean percentage



Another issue is that after controlling for factors that we know by the literature that affects technology adoption, there are unobservable factors that we are not measuring that could be explained: why hog producers are more likely to adopt certain bundle of technologies? Hence, differences in each hog producers responded to all factors and unobservable differences among hog producer make possible to run a correlation across individual. Therefore, we assessed a multinomial logit model and multinomial probit using simulated maximum likelihood and seemingly unrelated multinomial logit. This was done to observe which hog farmer characteristics affect the adoption of technologies and how these characteristics vary with observable hog producers and production type differences.

The estimates imply that producers with a higher level of education and low ages are more likely to adopt several bundles of technologies. Large production size is positively correlated with adopting the technologies as bundles. Human capital is a strong factor on the adoption of the technologies as bundles. Because the technologies are complementary, the productivity of one technology is enhanced by the adoption of the other technologies. We find that large farms run by younger and more educated operators are the most likely to adopt multiple technologies.

2. DATA AND METHODS

The data for this analysis are from surveys of subscribers to National Hog Farm Magazine (NHFM) conducted in years 1995, 2000, and 2005. Hog producers in the United States were asked whether they are using any of the 10 technologies itemized in table 6. Single technology is considered as a binary variable taking the value of 1 if the technology is used and 0 otherwise. Also for each survey year, we have eight possible technologies, since in years 1995 and 2000 we have information accessible on Medicated Early Weaning, and Modified Medicated Early Weaning, and only in 2005, producers were questioned regarding they adopted two other technologies, Auto Sorting and Parity Based Management.

A total of 5,314 producers responded to the survey conducted by NHFM from 4 regions on which for this analysis we classified them in the following regions: Midwest (Iowa, Illinois, Indiana, Minnesota, Missouri, North Dakota, Nebraska, Ohio, South Dakota, Wisconsin), North East (Connecticut, Washington D.C., Delaware, Massachusetts, Maryland, Maine, Michigan, New Hampshire, New Jersey, New York, Pennsylvania, Rhode Island, and Vermont), South East (Alabama, Florida, Georgia, Kentucky, Louisiana, Mississippi, North Carolina, South Carolina, Tennessee, Virginia, and West Virginia), and West (Alaska, Arkansas, Arizona, California, Colorado, Hawaii, Idaho, Kansas, Montana, New Mexico, Nevada, Oklahoma, Oregon, Texas, Utah, Washington, and Wyoming).

Abbreviation	**Factor**
Type of facilities	Best described facilities (gestation, farrowing, nursery, and grower/finisher)
Size of production	The average number of pigs and sows in operation
Labor supply	Number of full time employees
Demographic characteristics of producers	Gender, age of the producers
Region	Region of production facilities Midwest, North East, South East, and West
Production-work environment	Information about regarding formal evaluation for employees.
Human Capital	Formal level of education
Production Type	Type of production facilities Nursing or Finishing

Table 1: Factors that may potentially influence hog technologies choices

The hog producers provide a variety of information regarding themselves, production structure or size, and physical environment of their operations, including detail information regarding formal evaluation for employees. In addition, producers were asked specific questions listed in Table 1 were when making any of the hog technology choices. Of specific interest for the objectives of this paper was to determine what producer's characteristics listed in table 1 affect the rate of adoption on the 10 hog technologies frequently used in the U.S. hog industry, such as the size of production, human capital, labor supply, demographic characteristics of producers, and production environment.

Furthermore, this paper analyzed the importance of these characteristics related to observable demographic characteristics of producer, type of facilities, and region. Besides, we want to understand what advantages these technologies can offer to hog producers and how these advantages vary with observable hog producers and production type differences. Since many of these factors and advantages may have different significance and implications to different producers adoption behavior.

Usually, profitability is considered for the majority of Economists to be the most important factor guiding producers decisions. However, this paper goes further and analyzes hog producer's adoption behavior from a different perspective, it considers several factors besides profit and risk that will affect the adoption behavior among producers. In fact, the agricultural adoption literature mentions that several factor besides profitably and risk as important determinants of farmer adoption behavior: credit constraints, farm structure or size, human capital, labor supply, and physical environment. Therefore, in this paper, we focus on production size, human capital, labor supply and physical environment.

Which is why hog producers were asked to select their production size by asking the total number of pigs produce annually and the average number of sows in the operation. Human capital refers to the skills that producers have obtained, for that reason is why we asked hog producers about their formal level of education and if they used a personal computer in managing operations. An important component of adoption behavior is labor supply; it refers a number of full-time employees are used in the production. An important component that might influence adoption behavior would be production work environment; we believed that most organized hog production farms would tend to adopt technologies more frequently. This is why hog producers were asked if they provided to their employees the following: employee's handbook, written job description, work plan and schedule, and formal evaluation procedures. Finally, disparities on physical environment among hog producers is an important factor that influence adoption behavior, which is why hog producers were asked to best describe their facilities (gestation, farrowing, nursery, and grower/finisher), and if they were confinement and environmentally controlled facilities, or not.

	Responses in Percentage					
Size of production						
Number Of Pigs Produced Annually	**1995**		**2000**		**2005**	
Less Than 500	1.65		2.41		0	
500 to 999 in 1990 to 2000/Under 1,000 in 2005	3.61		1.5		8.31	
1,000 to 1,999	22.63		14.14		10.5	
2,000 to 2,999	25.34		14.74		12.39	
3,000 to 4,999	17.99		16.24		14.14	
5,000 to 9,999	16.31		20.3		19.83	
10,000 or more in 1990/10,000 to 14,999 in 1995 to 2005	5.46		9.77		10.93	
15,000 to 24,999	3.58		8.42		8.16	
25,000 Or More in 1995 to 2000/25,000 to 49,999 in 2005	3.43		12.48		7.43	
50,000 to 99,999 in 2005	0		0		3.94	
100,000 or More in 2005	0		0		4.37	
Average number of sows in your operation	**1995**		**2000**		**2005**	
Less Than 50	3.16		5.95		0	
50 To 99 in 1990 to 2000/Less Than 100 in 2005	11.5		5.75		18.57	
100 To 199	42.49		26.98		21.38	
200 To 499	27.97		25.4		20.73	
500 To 999	9.08		16.87		15.77	
1,000 To 1,999	3.46		11.11		11.45	
2,000 or more in 1990/2,000 To 4,999 in1995 and 2005	1.36		5.16		6.7	
5,000 Or More in 1995 to 2000/5,000 to 9,999 in 2005	0.98		2.78		1.73	
10,000 or More in 2005	0		0		3.67	
Labor supply						
Number of full-time employees	**1995**		**2000**		**2005**	
1	47.45		34.59		37.21	
2	24.64		21.51		18.09	
3	11.38		12.21		11.37	
4	5.48		8.14		7.49	
5	2.44		3.78		4.65	
6	1.41		4.65		4.13	
7	0.89		1.45		2.07	
8	1.45		1.45		1.55	
9	0.52		0.58		1.29	
10	0.7		2.33		2.33	
Human Capital						
Education	1995		2000		2005	
Did Not Complete High School	4.03		4.19		4.18	
High School Diploma	33.65		31.08		31.6	
Completed Vocational Technical/School Program	12.49		8.86		12.55	
Completed Junior College Program	6.91		4.83		7.22	
Attended Four-Year College But Did Not Complete	11.31		8.21		9.67	
Four-Year College Degree	27.15		36.23		28.86	
Masters Degree Or Equivalent	3.72		4.67		3.9	
Ph.D. Degree Or Equivalent	0.73		1.93		1.01	
Attended Two Year College But Did Not Complete	0		0		0.14	
Doctor Of Veterinary Medicine (DVM)	0		0		0.87	
	Yes	**No**	**Yes**	**No**	**Yes**	**No**
Personal computer used in managing operations	57.34	42.66	69.43	30.57	62.25	37.25
	1995		2000		2005	
Production Environment	**Yes**	**No**	**Yes**	**No**	**Yes**	**No**
Employees handbook provided	12.79	87.21	22.22	77.78	20.98	79.02
Written job description provided	24.3	75.7	32.67	67.33	26.63	73.37
Work plans, schedule or assignments provided	51.46	48.54	48.99	51.01	50.42	49.58
Formal evaluation procedures	18.11	81.89	23.26	76.74	21.97	78.03

Table 2: Important factors influencing adoption behavior of hog technologies (percent of responses).

Table 2 summarizes the distribution of hog producers and hog production characteristics that affect the rate of adoption on the 10 hog technologies frequently used in the U.S. hog industry. For each one, we have the responses percentage for years 1995, 2000 and 2005. Base on the literature, important determinants of producer's adoption behaviors were classified in the following: size of the production, labor supply, human capital, and production-work environment.

First, the size of production has two variables, number of pigs produced annually and the average number of sows in operation. On graph 2, the variable number of pigs produced annually has increased meaning that the structure of hog production also has changed across time. For instance, in table 2 illustrates hog farms with pig productions of 5000 pigs to 9999 pigs have increased for almost 5 percent from 1995 to 2005, and 10000 pigs to 14999 pigs have almost double from 1995 to 2005. Likewise, for the variable average number of sows in operation, has slightly increased among 1995 to 2005, but not drastically as a number of pigs produced annually. The size and type of production described above indicate that the nature of production and the specialization of hog production have developed across time from breeding operations to finishing operations.

Second, labor supply has a variable number of full-time employees. Graph 4, depicts an increasing trend among 1995 to 2005. Particularly, the percentage of full-time employees increase from about 15% of producer that have full-time employees in 1995, to 40% of producers that have full-time employees in 2000, and to slightly increase in 2005 to about 45% of producers that have full-time employees. Further, we can see this trend on table 2, where the numbers of employees increase as time pass by. For instance, in 1995 the percentage of 5 full-time employees were 2.44%, then this percentage had increased in 2000 and 2005 to 3.78% and 4.65% respectively. Thus, it indicates that hog production has evolved to a slightly more labor intensive across time.

Third, human capital has two variables education and a personal computer used in managing operations. On graph 5 and in our econometric analysis, the variable education was divided into four categories: high school, college, bachelor, and graduate. High school and bachelor degree have the largest percentage for the education variable more than 30 percent and 20 percent respectively. Further, the percentage of the respondents that have a bachelor degree increases as time passes. On the other hand, the variable personal computer used in managing operations, which is a binary variable that takes the value 1 if the producer used a personal computer or 0 otherwise. The percentage of producers that used a personal computer in managing operations is above the 35 percent for the three years, 1995, 2000, and 2005.

Last but not least, production work environment has four variables: employee's handbook provided, written job description provided, work plan and schedule provided, and formal evaluation procedures. They are binary variables that take the value 1 if the producer provided either employee's handbook, written job description, work plan and schedule, or formal evaluation procedures, otherwise they take the value 0. We believe that if production work environment is well organized and employee friendly, it would affect the adoption of new practices, meaning that the most organized hog production would tend to adopt technologies more frequently. Graph 6, represents the distribution of production work environment; where about 45% of the producers provided work plan, schedule, and assignments. Likewise, about 25% of producers provided written job description to their workers. On the contrary, less than the 20% of the producers provided to their employee's handbook and formal evaluation procedures.

	Year 1995 mean/sd	Year 2000 mean/sd	Year 2005 mean/sd
Age	**44.29**	**46.02**	**50.15**
	(11.44)	**(11.27)**	**(11.28)**
male	**0.95**	**0.93**	**0.92**
	(0.21)	**(0.25)**	**(0.27)**
female	**0.04**	**0.05**	**0.07**
	(0.19)	**(0.23)**	**(0.25)**
Midwest	**0.81**	**0.80**	**0.77**
	(0.39)	**(0.40)**	**(0.42)**
Northeast	**0.05**	**0.05**	**0.07**
	(0.23)	**(0.22)**	**(0.25)**
South East	**0.07**	**0.08**	**0.08**
	(0.26)	**(0.27)**	**(0.27)**
West	**0.06**	**0.05**	**0.07**
	(0.24)	**(0.23)**	**(0.25)**

Table 3: Percentage for geographic variables, and demographic characteristics

Producer specific information considered for this analysis was the producer's region and producer's demographic characteristics such as age and gender (see table 3). For the region, producers were asked region of residence on which for this analysis. For this analysis, we classified producer's responses in Midwest, North East, South East, and West. Hog producers with a bigger share of the national hog production are located in the Midwest, with about the 80 percent in 1995 of the United States hog production, with little differences across the two other years. Contrary to the producers from the other three regions, west, northeast, and south, which producers from these regions have a small share of production of United States (see graph 5). For producer's demographic characteristics such as age and gender, we got the following. For the variable age, hog producers were asked how old they are and for gender producers were asked what is your sex. The average age of the hog producer's respondents in 1995 was 44 years old, in 2000 was 46 years old and in 2005 was 50 years old. The gender of the hog producers' respondents is males near 96 percent in 1995, with little differences across 2000 and 2005 (see table 3).

	Year 1995 mean/sd	Year 2000 mean/sd	Year 2005 mean/sd
Num Pigs Prod Annu~y	4.64	5.58	5.84
	(1.69)	(2.06)	(2.39)
Num Sows Operation	3.49	4.09	4.33
	(1.19)	(1.60)	(2.04)
Farrowing Facilities	0.86	0.74	0.64
	(0.35)	(0.44)	(0.48)
Breeding and Gesta~e	0.86	0.73	0.64
	(0.35)	(0.44)	(0.48)
Nursery Facilities	0.86	0.74	0.71
	(0.35)	(0.44)	(0.45)
Grower/Finisher Fa~s	0.91	0.83	0.83
	(0.28)	(0.37)	(0.37)

Table 4: Production Characteristics

Table 4 summarizes production-specific data used for the analysis, for 1995, 2000, and 2005. The average number of pigs produced annually in 1995 was around 4.64 meaning that hog producers reported 2,000 pigs to 5,000 pigs produced annually. The diversity among pigs produced annually for the other two years was almost similar 5.58 and 5.84 respectively. In other words, in 2000 and in 2005 hog producers reported that the number of pig produced annually almost double in those two years to around 5,000 pigs to 9,999 pigs produced annually. However, as time passes the average number of sows in a hog operation did not increase drastically as the average number of pigs produced annually. While hog producers reported in 1995 around 100 sows to 199 sows in an operation (table mean 3.49), in 2000 and 2005 the average number of sows in a hog operation was similar for the two years and in those years the number of sows in a hog operation did not increased by much from 200 sows to 499 sows. (Tables means 4.09 and 4.33 respectively).

Production-specific information considered for this analysis included the following four types of environmental controlled facilities: Breeding and gestation facilities, farrowing facilities, nursery facilities, and grower (finisher) facilities. Producers were asked what types of facilities enlisted in table 4 are used on their hog production, either having the option environmental controlled facilities or not having the facilities at all. These four types of facilities were treated as dichotomous variables choosing the value of 1 if hog producer used them and 0 otherwise. Finally, disparities on physical environment among types of hog productions are summarizing in table 4. It shows the percentage of the four types of facilities. The four types of facilities had decreased drastically from 1995 and 2005. Despite that grower facilities had decreased around 8% from 1995 to 2005, grower facilities has a bigger percent in 2005, 83 %, among the other three facilities, which also they had decreased in larger percentages. For instance, the used of breeding, farrowing, and nursery facilities had decreased drastically from about 86% for the three facilities in 1995 to 64% for breeding and farrowing facilities and 71% for nursery facilities in 2005.

Since hog producers are inclined to adopt several technologies as bundles, chosen technologies are not ordered in any way. Each of the 10 technologies is considered as a binary variable, taking the value of 1 if the technology is used and 0 otherwise. Correlation across individual hog producer's answers is feasible due to their disparities on hog producer responses to whether or no they adopt any of the 10 technologies. Thus, we generated a correlation matrix of the adoption responses of 10 technologies. The correlation matrix of technologies adoption was analyzed using principal components as a way of grouping correlated variables and to identify what is the technologies share in common. So we can see what group of technologies seems to bundle together, this is an indicative that these bundles of technologies is complementarity and potentially can identify substitute technologies, these make possible to estimate a multinomial probit model.

We used STATA's principal component analysis command. To determine the number of components to retain we used the Kaiser criterion where we drop all components with eigenvalues under 1.0. According to Zwick and Velicer components with eigenvalues near zero provide no summarizing power (Zwick, 1986, Comparison of five rules for determining the number of components to retain). We retained components with relatively high determinants loading (greater than 0.3). Using STATA's rotate command we rotated them orthogonally. We performed a principal component analysis by years, because we have panel data for years 1995, 2000 and 2005, so as the technologies mature we can see how this relationship of complementarity and substitutability change.

Another issued is that after controlling for factors that we know by the literature that affects technology adoption, there are unobservable factors that we are not measuring that could be explained: why hog producers are more likely to adopt certain bundle of technologies? Hence, differences in each hog producers responded to all factors and unobservable differences among hog producer make possible to run a correlation across individual. For that matter, the multinomial probit model and multinomial logit model for all 6 factors were estimated jointly using the seemingly unrelated model with STATA's mprobit command and cmp command.

	Artificial Insemination	Split sex feeding	Phase feeding	Multiple site productio n	Segregate d Early Weaning	Medicated Early Weaning	Modified Medicated Early Weaning	All in/All out	Auto Sorting Systems	Parity based Managem ent	Other
Artificial Insemination	1.00										
Split sex feeding	**0.18**	1.00									
Phase feeding	**0.15**	**0.36**	1.00								
Multiple site production	**0.23**	**0.21**	**0.18**	1.00							
Segregated Early Weaning	**0.23**	**0.19**	**0.16**	**0.32**	1.00						
Medicated Early Weaning	0.05	0.05	0.07	0.09	0.02	1.00					
Modified Medicated Early Weaning	0.04	0.06	0.06	0.07	0.04	0.14	1.00				
All in/All out	**0.15**	**0.25**	**0.24**	**0.14**	**0.19**	0.07	0.04	1.00			
Auto Sorting Systems	0.05	0.06	0.05	0.09	0.06	-0.02	-0.01	0.06	1.00		
Parity based Management	0.12	-0.01	0.02	0.09	0.08	-0.02	-0.01	0.04	0.10	1.00	
Other	-0.02	-0.02	-0.03	-0.01	-0.02	-0.01	0.00	-0.04	0.05	0.04	1.00

Table 5: Correlation coefficients of the 10 technologies frequently used in the U.S. hog industry

Table 5 reports correlation coefficients and principal component analysis respectively of 10 hog technologies frequently used in the U.S. hog industry. Both statistical techniques were used to see what group of technologies group together and they were used as indicative that they are complementary technologies, and potentially we can identify substitute technologies. Hence, in the correlation matrix the highest correlation (0.36) exists between phase feeding and split-sex feeding. Also, other technologies seem to group together among these correlations group of technologies that have relatively high correlation are artificial insemination, multiple site production, segregates early weaning, and all in/all out. The principal component analysis allows quantitative exploration of these complementary technologies and potentially can identify for substitutability among technologies.

We used principal component analysis by years 1995, 2000 and 2005 to investigate relationships of complementarity among technological variables. Technological variables with the same pattern of response or positive correlated are associated with a latten variable, which in this case the underlying latent variable is complementarity among technologies or substitutability. Besides, we can understand how this relationship of complementarity and substitutability change as technologies mature . Table 6 reports loadings after rotation for principal component analysis; these loadings represent the weights assigned to each characteristic for the factor of interest. Determinants with relatively high components loading (e.g greater than 0.3) are more strongly associated with the underlying unobservable preferences or characteristics being measured by the factor of interest. To determining the number of components we used the Kaiser criterion where we drop all components with eigenvalues under 1.0. According to Zwick and Velicer components with eigenvalues near zero provide no summarizing power. A component with an eigenvalue greater than 1,0 provides more summarizing power than an original variable (Zwick, 1986). For the principal component analysis, we considered that the two technologies, Auto Sorting and Parity Based Management, were only asked in 2005. Therefore, we have eight possible technologies in each survey year. Then we get the following results:

	1995				2000				2005		
Variable	Complementary	Complementary	Substitutability	Unexplained	Complementary	Complementary	Substitutability	Unexplained	Complementary	Complementary	Unexplained
Artificial Insemination		0.33		0.70		0.68		0.34		0.62	0.41
Split sex feeding	0.58			0.44	0.53			0.49	0.56		0.41
Phase feeding	0.60			0.45	0.60			0.41	0.53		0.46
Multiple site production		0.67		0.38		0.45		0.43		0.49	0.43
Segregated Early Weaning		0.66		0.39		0.57		0.42			0.75
Medicated Early Weaning			0.70	0.44			0.69	0.37			
Modified Medicated Early Weaning			0.70	0.45			0.71	0.36			
All in/All out	0.50			0.59	0.51			0.55	0.47		0.59
Auto Sorting Systems											0.81
Parity based Management										0.55	0.54

Rotated components (blanks are abs(loading)<.3)

Table 6: Principal component analysis by years of the 10 technologies frequently used in the U.S. hog industry

In the year 1995 we can see the relationship of complementarity among the following technologies: for the first bundle of complementarity technologies split-sex feeding, phase feeding, and all in / all out. The second bundle of complementarity technologies among artificial insemination, multiple site production, and segregated early weaning. Last but not least, the bundle of substitutability technologies among medicated early weaning, and modified medicated early weaning.

In the year 2000, the relationship of complementarity did not change and likewise, the components did not vary much, except for artificial insemination, which increases its component from 0.33 to 0.68, comparing to the year 1995. Hence, the first bundle of complementarity technologies among split-sex feeding, phase feeding, and all in / all out. The second bundle of complementarity technologies among artificial insemination, multiple site production, and segregated early weaning. Last but not least, the bundle of substitutability technologies among medicated early weaning, and modified medicated early weaning.

In the other hand, as technologies mature the relationship changed; thus in 2005 the first bundle of complementarity technologies among split-sex feeding, phase feeding, and all in / all out. The second bundle of complementarity technologies among artificial insemination, multiple site production, and party based management. Noted that in 2005 we do not have any bundles of substitutability among technologies.

2.1. PROPENSITY SCORE MATCHING

This study makes inferences in the subpopulation of hog producers that responded to the NHFM survey on years 1995, 2000, and 2005. However, subscriber's response varies drastically between those years due to external factors such as the collapse of the pork market in late 1998, which brought huge losses to hog producers (Drabenstott, 1999). For instance, the complete data have a total of 5,314 producers responded to the survey conducted by NHFM (3,935 producers in 1995, 674 produces in 2000, and 705 producers in 2005). This price collapse affected the propensity to respond to survey declining producer's participation in years 2000 and 2005, which led to missing data and self-selection bias of the sample. Furthermore, when we will make an inference of development of the adoption behavior among hog producers that response to the NHFM survey may be misleading. We solve the missing data issue based on probabilities weights by weighing the observed data points, each producer in the NHFM sample.

Therefore, this research controls for the effects declining producer's participation by choosing as a control group hog producers from the pool of responses to NHFM survey in years 2000 and 2005 respectively closest to responses to NHFM survey in the year 1995 regarding these observables, using propensity score matching (PSM) as a matching approach. Explicitly, PSM balances the distributions of observed covariates between the hog producer's responses to NHFM survey in the year 1995 (treatment group) and hog producer's responses to NHFM survey in years 2000 and 2005 (control group) based on their propensity scores. After matching, hog producers survey responses across time it can be viewed as being drawn from observationally equivalent distributions. (Yu, Hurley, Kliebenstein, & Orazem, 2012). Thus in this way, we addressed self-selection bias on hog producers who response to the survey in 1995 "treated group" and estimates on average how the observed hog producers who respond to the survey in 1995 differ from those who did not respond to the survey in 2000 and 2005. According to Caliendo & Kopeinig, (2008), this parameter is called average treatment effect on the treated (ATT).

2.1.1. Assumptions underlying propensity score matching

Since we have several years and we wanted to compared changes among them we have the following:

TREATED ($D_i = 1$)	CONTROL ($D_i = 0$)
Observations from 1995	Observations from 2000
Observations from 2000	Observations from 2005
Observations from 1995	Observations from 2005

Where subscript i denotes the i^{th}worker in the sample

2.1.2. Multi-probit model

The owners adopt the technologies on this model

$$\mathbf{Y}_{nt} = \beta_{0t} + \beta_{1t} Midwest + \beta_{2t} age + \beta_{3t} age^2 + \beta_{4t} education + \beta_{5t} male + \beta_{6t} Npigs + \beta_{7t} Nsows + \beta_{8t} Nfullemployees$$

$$+\beta_{9t} nursery + \beta_{10t} farrowing + \beta_{11t} bredgest + \beta_{12t} growfinish + \beta_{13t} PCused + \beta_{14t} Handbook + \beta_{15t} JobDescrption$$

$$\mathbf{Y}_{nt} = \beta_{0t} + \beta_{1t} Midwest + \beta_{2t} age + \beta_{3t} age^2 + \beta_{4t} education + \beta_{5t} male + \beta_{6t} Npigs + \beta_{7t} Nsows + \beta_{8t} Nfullemployees$$

$$+\beta_{9t} nursery + \beta_{10t} farrowing + \beta_{11t} bredgest + \beta_{12t} growfinish + \beta_{13t} PCused + \beta_{14t} Handbook + \beta_{15t} JobDescrption$$

$$\mathbf{Y}_{nt} = \beta_{0t} + \beta_{1t} Midwest + \beta_{2t} age + \beta_{3t} age^2 + \beta_{4t} education + \beta_{5t} male + \beta_{6t} Npigs + \beta_{7t} Nsows + \beta_{8t} Nfullemployees$$

$$+\beta_{9t} nursery + \beta_{10t} farrowing + \beta_{11t} bredgest + \beta_{12t} growfinish + \beta_{13t} PCused + \beta_{14t} Handbook + \beta_{15t} JobDescrption$$

Where $t = 1995, 2000, 2005$ & $n = bundels_1, bundels_2, ---, bundels_8$

$$\Pr(Y = 1 \mid X) = \Phi(X'\beta)$$

where Pr denotes probability, and Φ is the Cumulative Distribution Function (CDF) of the standard normal distribution.

$$y_{im}* = \beta m' X_{im} + \varrho_{im}, m = 1, ..., M$$

$$yim = 1$$

$if yim* > 0 and 0 otherwise$

Were $Y_{nt} = 1$ if the n bundles of technologies are adopted, and 0 otherwise.

2.1.3. We wish to measure the treatment effect on the treated

$$E(Y_{n1} - Y_{n0} \mid D = 1, x).E(Y_{n1}|D = 1, x)$$

constructing the counterfactual by matching:

- The probability of being in year 1995 is $Pr(D = 1|x)$

thus

$$P(x_i) = Pr(D = 1|x)$$

where $0 < P(x_i) < 1$

2.1.4. counterfactual mean

$$E(Y_{n0}|D = 1, P(X)) = E(Y_{n0}|D = 0, P(X))$$

3. CONCEPTUAL MODEL

Hog producers adoption decisions on bundle of technologies are assumed to be based upon an objective of utility maximization (Rahm & Huffman, 1984). We defined the adoption of bundle of technology by j, and t where j represents bundles of technologies; for instance, $j = 1$ if hog producers adopted first bundle of complement technologies, $j = 2$ if hog producers adopted second bundle of complement technologies, $j = 3$ if hog producers adopted the third bundle of substitute technologies, and $j = 0$ if hog producer did no adopt any of the three bundle of technologies described above (hog producer stayed with old technologies). Also, t represent time in years when the NHFM survey was conducted $t = 1995, 2000, \&2005$. Note that the components of technology bundle changed across time, so the indexing j and t varies across time. With a non-observed underlying utility function that ranks the ith hog producers' preferences for these technologies bundles by $U\left(\mathbf{C}_{jti}, \mathbf{A}_{jti}\right)$. This utility depends on two vectors, vector $\mathbf{C}_{jt}$ which is a vector of hog producers and production characteristics and attributes of the bundles adopters, and a vector $\mathbf{A}_{jt}$ which is a vector of attributes correlated with technologies bundles. Despite the utility function is unobserved and unavailable, a linear relationship between the utility derivable from a jth technology bundles is assumed to be a function of the vector of observed hog production features X_i such as hog producer's particular characteristics (size of the production, labor supply, human capital, production-work environment, gender, age, and region), characteristics correlated with technology bundles adopted (type of environmental controlled facilities: Breeding and gestation facilities, farrowing facilities, nursery facilities, and grower (finisher) facilities), and zero mean disturbance term e_{jt}

$$U_{jti} = \alpha_{jt}\mathbf{X}_i + e_{jti};\ Where\ j = 0, 1, 2, 3\ ;\ t = 1995, 2000, 2005\ ;\ i = 1, ..., n.$$

$$(1) \qquad U_{jti} = \alpha_{jt} F_i\left(\mathbf{C}_i, \mathbf{A}_i\right) + e_{jti}$$

Assuming that hog producers have rational preferences; thus, they choose technology bundles that provide them the largest utility. Since technology bundles are elements of a superset of a technologies called J (($j = 0, j = 1, j = 2, j = 3 \in J$) where J is the whole group of 10 hog technologies used for this analysis). By definition, a utility function can represent preferences relation

$\succeq$ if, for all $j=0, j=1, j=2, j=3 \in J$: then we have $(j=1) \succeq (j=2) \Longleftrightarrow U_{1ti} \geq U_{2ti}$. In other words, lets suppose that hog producers prefer first bundle of complementarity technologies $(j=1)$ over the second bundle of complementarity technologies $(j=2)$; then, according to definition it can be represent as $(j=1) \succeq (j=2) \Longleftrightarrow U_{1ti} \geq U_{2ti}$. Since, the utilities U_{jti} are real value function and random, the *ith* hog producer will choose the first bundle of complementarity technologies $j=1$ if his decision satisfy completeness $U_{1ti} > U_{0ti}; U_{1ti} > U_{2ti}; U_{1ti} > U_{3ti}$, and transitivity $U_{1ti} > U_{0ti}; U_{0ti} > U_{2ti};$ *and* $U_{2ti} > U_{3ti} \Rightarrow U_{1ti} > U_{2ti}$,*and* $U_{1ti} > U_{3ti}$. The qualitative variable Y_{jti} indexes the adoption decision as follow:

First, Lets suppose that the dependent variable y takes j+1 values $(0,1,....,j)$.

$$(2)\ Y_{ti} = \begin{cases} 1\ if\ j=1 & \Rightarrow \quad U_{1ti} > U_{2ti}; U_{1ti} > U_{3ti}; U_{1ti} > U_{0ti}, \quad \begin{matrix} the\ first\ bundle\ of\ complement \\ technologies\ is\ adopted \end{matrix} \\ 2\ if\ j=2 & \Rightarrow \quad U_{2ti} > U_{3ti}; U_{2ti} > U_{0ti}; U_{2ti} > U_{1ti}, \quad \begin{matrix} the\ second\ bundle\ of\ complement \\ technologies\ is\ adopted \end{matrix} \\ 3\ if\ j=3 & \Rightarrow \quad U_{3ti} > U_{0ti}; U_{3ti} > U_{1ti}; U_{3ti} > U_{2ti}, \quad \begin{matrix} the\ third\ bundle\ of\ substitute \\ technologies\ is\ adopted \end{matrix} \\ 0\ if\ j=0 & \Rightarrow \quad U_{0ti} > U_{1ti}; U_{0ti} > U_{2ti}; U_{0ti} > U_{3ti}, \quad \begin{matrix} did\ no\ adopt\ any\ of\ the\ three\ bundle \\ of\ technologies\ described\ above \end{matrix} \end{cases}$$

For instance, the probability that Y_{it} is equal to one means that the first bundle of technologies is adopted instead of the second bundle, third bundle of technologies, or keep using the old technology $(j=0)$. It can be expressed as a function of independent variables:

Thus, if we let $U_{1ti}, U_{2ti}, U_{3ti}, \in U^{*}_{Jti}$, then

$$(3) \qquad P_i = Pr(Y_{ti} = 1) = Pr\left(U_{\underset{Jti}{*}} > U_{0ti}\right)$$

$$= Pr\left[\alpha_{\underset{Jt}{*}} F_i(\mathbf{C}_i, \mathbf{A}_i) + e_{\underset{Jti}{*}} > \alpha_{0t} F_i(\mathbf{C}_i, \mathbf{A}_i) + e_{0ti}\right]$$

$$= Pr\left[e_{\underset{Jti}{*}} - e_{0ti} > F_i(\mathbf{C}_i, \mathbf{A}_i)\left(\alpha_{0t} - \alpha_{\underset{Jt}{*}}\right)\right]$$

$$= Pr(u_i > -F_i(\mathbf{C}_i, \mathbf{A}_i)\beta)$$

$$= F(X_i\beta)$$

Where X is a $n * K$ matrix of the explanatory variables, β is a $K * 1$ vector of parameter to be estimated $\left(\alpha_{0t} - \alpha_{\underset{Jt}{*}}\right)$, $Pr(.)$ is a probability function, u_i is a random error term $\left(e_{\underset{Jti}{*}} - e_{0ti}\right)$, and $F(X_i\beta)$ is the cumulative distribution function for u_i evaluated at $X_i\beta$. Hence, the probability that ith hog producer adopts any of the three technologies bundles $(j = 1, j = 2, j = 3)$ is the probability that the utility of the old technologies $(j = 0)$ is less than the utility of adopting any of the three technologies bundles, or it is the cumulative distribution F evaluated at $X_i\beta$ where the distribution for F depends on the distribution of the random error term $u_i = e_{1ti} - e_{\underset{Jti}{*}}$ (Rahm & Huffman, 1984). In other words, the probability that a hog producer adopts any of three bundle of technologies $(j = 1, j = 2, j = 3)$ is a function of the vector of explanatory variables and the unknown parameters, and error term.

Besides, the distribution of u_i determines the the distribution of F, so if we assume that u_i from equation (3) is logistic distributed, then F will have a cumulative logistic distribution and then $\hat{\beta}$ is the logit estimator (Wooldridge, 2012). Furthermore, if u_i is logistic distributed then e_{0ti}, e_{1ti}, e_{2ti}, and e_{3ti} are also logistic distributed then a multinomial logit yields a consistent, efficient, and asymptotically logistic estimator[1].

Suppose that the dependent variable y takes j+1 values $(0,1,....,j)$. Then, the multinomial logit model has the following functional form for the probabilities:

$$P\left[y_{it}=j \mid \beta_j,\Sigma\right]=\frac{e^{\beta_j' x_i}}{1+\sum_{k=1}^{J} e^{\beta_k' x_i}};\ for\ j=0,1,2,3,\beta_0=0$$

4. RESULTS

Since we have a sample size $n_{i+}, i=0,1,2,3$ or their interaction. Where the marginal counts are fixed by design, so we have separate $J-$categories multinomial distributions in each of the groups. As we mentioned before each of these distributions has its own set of probabilities parameters $P(Y=j|X=i)=\pi_{j|i}$ as the conditional probability of observing response category j given that a unit is from group i. Therefore in table 7 we assessed a multinomial logit model and multinomial probit using simulated maximum likelihood. This was done to observe which hog farmer characteristics affect the adoption of technologies and how these characteristics vary with observable hog producers and production type differences.

On table 7, we can see the results for the multinomial probit and multinomial logit. We can see that the betas give the signs of the partial effects of each x on the response analysis, and the statistical significance of x is determined by whether we can reject the null hypothesis B=0 . Also, noticed that the pseudoR squared (it is always between 0 and 1), the pseudoR squared suggest the measure of $(1-Lur/Lo)$ where Lur is the log like hood function for the estimated model and Lo is the log like hood function in the model with only an intercept.

For the year 1995, we have the bundle one, bundle two, and the interaction of both. For bundle one, the variables High school, use of PC on managing operations, the number of full-time employees(FTEmp), age, and the number of sows in production, from 2 hundred to 5 thousand sows are highly significant. The variables, high school, age have a positive effect on the adoption of bundle 1. Thus, hog farmers with the at least high school are more likely to affect in the adoption

[1]Note: using probit and logit the results will generally be very similar

Table 7: Results for the multinomial probit and multinomial logit

	Mnomial Lo~t b/se	Mnomial Pr~t b/se
bund1_95		
highSchool	0.346*	0.237
	(0.16)	(0.12)
bachelor	−0.036	−0.025
	(0.17)	(0.13)
WorkPlan	−0.067	−0.059
	(0.13)	(0.10)
EmpHB	−0.040	−0.005
	(0.22)	(0.15)
UsePC	−0.599***	−0.464***
	(0.14)	(0.11)
NursF	0.691	0.493
	(0.46)	(0.30)
GFF	−0.404	−0.220
	(0.29)	(0.20)
FTEmp	−0.118**	−0.144***
	(0.04)	(0.02)
Age	0.019**	0.017***
	(0.01)	(0.00)
male	−0.244	−0.191
	(0.30)	(0.23)
Midwest	−0.272	−0.204
	(0.17)	(0.13)
from1hto2hsows	−0.437	
	(0.29)	
from2hto5hsows	−0.905**	−0.361*
	(0.34)	(0.17)
from5hto1ksows	−1.454***	−0.656**
	(0.43)	(0.21)
from1kto2ksows	−1.326**	
	(0.48)	
from2kto5ksows	−2.430*	
	(1.11)	
from3kto5kpigs	−0.167	−0.148
	(0.23)	(0.17)
from5kto10kpigs	−0.276	−0.215
	(0.26)	(0.18)
from10kto15kpigs	−0.195	−0.128
	(0.41)	(0.25)
from15kto25kpigs	−0.034	
	(0.42)	
Constant	0.233	−0.171
	(0.65)	(0.42)
bund2_95		
highSchool	0.053	0.052
	(0.28)	(0.17)
bachelor	−0.055	−0.052
	(0.29)	(0.17)
WorkPlan	−0.305	−0.220
	(0.24)	(0.14)
EmpHB	−0.441	−0.273
	(0.42)	(0.22)
UsePC	−0.554*	−0.459**
	(0.24)	(0.15)
NursF	−0.121	−0.070
	(0.50)	(0.31)
GFF	−1.639***	−0.914***
	(0.37)	(0.24)
FTEmp	−0.014	−0.004
	(0.01)	(0.01)
Age	0.059***	0.038***
	(0.01)	(0.01)
male	−0.327	−0.281
	(0.45)	(0.28)
Midwest	−0.635*	−0.361*
	(0.26)	(0.16)
from1hto2hsows	−1.242**	
	(0.39)	
from2hto5hsows	−1.034	−0.032
	(0.54)	(0.25)
from5hto1ksows	−1.433*	−0.503
	(0.69)	(0.28)
from1kto2ksows	−2.522**	
	(0.82)	
from2kto5ksows	−2.554**	
	(0.84)	
from3kto5kpigs	−1.258*	−0.630*
	(0.50)	(0.27)
from5kto10kpigs	−1.128*	−0.525*
	(0.49)	(0.27)
from10kto15kpigs	−0.736	−0.058
	(0.69)	(0.33)
from15kto25kpigs	−1.055	
	(0.80)	
Constant	−0.159	−0.934
	(0.85)	(0.49)
bund1_2_95		
highSchool	0.000	0.000
	(.)	(.)
bachelor	0.000	0.000
	(.)	(.)
WorkPlan	0.000	0.000
	(.)	(.)
EmpHB	0.000	0.000
	(.)	(.)
UsePC	0.000	0.000
	(.)	(.)
NursF	0.000	0.000
	(.)	(.)
GFF	0.000	0.000
	(.)	(.)
FTEmp	0.000	0.000
	(.)	(.)
Age	0.000	0.000
	(.)	(.)
male	0.000	0.000
	(.)	(.)
Midwest	0.000	0.000
	(.)	(.)
from1hto2hsows	0.000	
	(.)	
from2hto5hsows	0.000	0.000
	(.)	(.)
from5hto1ksows	0.000	0.000
	(.)	(.)
from1kto2ksows	0.000	
	(.)	
from2kto5ksows	0.000	
	(.)	
from3kto5kpigs	0.000	0.000
	(.)	(.)
from5kto10kpigs	0.000	0.000
	(.)	(.)
from10kto15kpigs	0.000	0.000
	(.)	(.)
from15kto25kpigs	0.000	
	(.)	
Constant	0.000	0.000
	(.)	(.)
bund1_00		
highSchool	−0.111	−0.033
	(0.50)	(0.25)
bachelor	0.122	0.017
	(0.49)	(0.25)
WorkPlan	−0.665	−0.371
	(0.43)	(0.21)
EmpHB	0.811	0.502
	(0.56)	(0.28)
UsePC	−0.509	−0.309
	(0.43)	(0.22)
NursF	−1.009	−0.364
	(0.97)	(0.48)
GFF	0.109	−0.175
	(0.95)	(0.41)
FTEmp	−0.198	−0.118
	(0.17)	(0.06)
Age	0.085***	0.048***
	(0.02)	(0.01)
male	−0.642	−0.359
	(0.79)	(0.41)
Midwest	−0.283	−0.148
	(0.48)	(0.25)
from1hto2hsows	−0.281	
	(0.85)	
from2hto5hsows	−1.506	−0.806*
	(1.00)	(0.33)
from5hto1ksows	−0.222	−0.193
	(1.19)	(0.38)
from1kto2ksows	0.501	
	(1.27)	
from2kto5ksows	−14.712	
	(2659.99)	
from3kto5kpigs	0.814	0.354
	(0.63)	(0.33)
from5kto10kpigs	0.597	0.380
	(0.78)	(0.36)
from10kto15kpigs	−0.273	0.011
	(1.15)	(0.49)
from15kto25kpigs	−0.764	
	(1.26)	
Constant	−4.331**	−2.593***
	(1.64)	(0.77)

of the bundle one of the technologies. Likewise, as the age of the hog farmers increase they are more likely to adopt bundle one in the year 1995. On the contrary, in the year 1995 as the use of PC on managing operations, a number of full-time employees, and the number of sows in production, from 2 hundred to 5 thousand sows increase there is a less likely to adopt the bundle one in the year 1995.

On the other hand, for the bundle 2 in year 1995, the variables use of PC on managing operations, grower and finisher facilities, age, midwest, the number of sows in production, from one hundred to two hundred sows, and the number of pigs in production, from three thousands to five thousands pigs are highly significant. Most of the variables have negative effect in the adoption of bundle 2; however, variable age of the hog farmers increase they are more likely to adopt bundle two in the year 1995.

For the other two years 2000 and 20015 and for bundle one and two and the interaction of them, age and number of full time employees are the variable that is highly significant at 99 percent and hog farmers that are older and have large number of full time employees are more likely to adopt the bundles in the three years.

bund2_00		
highSchool	−0.299	0.026
	(0.71)	(0.33)
bachelor	0.309	0.211
	(0.59)	(0.29)
WorkPlan	−0.828	−0.327
	(0.53)	(0.25)
EmpHB	0.504	0.359
	(0.60)	(0.29)
UsePC	−0.157	−0.056
	(0.59)	(0.29)
NursF	−1.599*	−1.108**
	(0.69)	(0.37)
GFF	−2.036**	−1.069**
	(0.70)	(0.34)
FTEmp	0.003	0.006
	(0.01)	(0.01)
Age	0.023	0.018
	(0.02)	(0.01)
male	0.478	0.111
	(1.16)	(0.56)
Midwest	−0.345	−0.283
	(0.55)	(0.26)
from1hto2hsows	−16.757	
	(1112.98)	
from2hto5hsows	−2.766*	−0.603
	(1.14)	(0.42)
from5hto1ksows	−1.700	−0.314
	(1.18)	(0.42)
from1kto2ksows	−0.292	
	(0.93)	
from2kto5ksows	−0.836	
	(1.02)	
from3kto5kpigs	1.867	0.442
	(1.26)	(0.43)
from5kto10kpigs	1.353	0.469
	(1.13)	(0.44)
from10kto15kpigs	−0.802	−0.488
	(1.47)	(0.61)
from15kto25kpigs	−0.199	
	(1.02)	
Constant	−0.510	−1.038
	(1.67)	(0.83)
bund1_2_00		
highSchool	−0.111	−0.055
	(0.23)	(0.15)
bachelor	0.129	0.071
	(0.21)	(0.14)
WorkPlan	−0.392*	−0.228
	(0.18)	(0.12)
EmpHB	0.426	0.342*
	(0.22)	(0.15)
UsePC	0.430	0.235
	(0.24)	(0.15)
NursF	−0.850*	−0.577*
	(0.39)	(0.26)
GFF	−0.954**	−0.748***
	(0.31)	(0.21)
FTEmp	0.011*	0.008*
	(0.01)	(0.00)
Age	0.028***	0.022***
	(0.01)	(0.01)
male	−0.004	−0.024
	(0.42)	(0.27)
Midwest	0.309	0.171
	(0.23)	(0.15)
from1hto2hsows	−0.203	
	(0.53)	
from2hto5hsows	0.308	0.024
	(0.58)	(0.22)
from5hto1ksows	0.527	0.095
	(0.58)	(0.21)
from1kto2ksows	0.869	
	(0.52)	
from2kto5ksows	0.509	
	(0.55)	
from3kto5kpigs	−0.567	−0.399
	(0.43)	(0.24)
from5kto10kpigs	−0.002	−0.014
	(0.39)	(0.22)
from10kto15kpigs	−0.018	0.014
	(0.44)	(0.24)
from15kto25kpigs	−0.130	
	(0.38)	
Constant	−1.915*	−1.135**
	(0.81)	(0.44)

bund1_05		
highSchool	−0.000	0.046
	(0.48)	(0.24)
bachelor	−0.408	−0.224
	(0.55)	(0.27)
WorkPlan	0.047	−0.065
	(0.43)	(0.22)
EmpHB	0.531	0.343
	(0.60)	(0.31)
UsePC	0.167	−0.042
	(0.47)	(0.23)
NursF	−0.242	0.007
	(1.20)	(0.61)
GFF	0.544	0.000
	(1.17)	(0.48)
FTEmp	−0.446	−0.238*
	(0.25)	(0.10)
Age	0.060**	0.036***
	(0.02)	(0.01)
male	−0.814	−0.527
	(0.78)	(0.40)
Midwest	−0.725	−0.352
	(0.48)	(0.25)
from1hto2hsows	−0.005	
	(0.84)	
from2hto5hsows	−1.151	−0.639
	(1.05)	(0.34)
from5hto1ksows	−1.743	−0.986
	(1.48)	(0.54)
from1kto2ksows	0.309	
	(1.46)	
from2kto5ksows	−12.898	
	(2238.23)	
from3kto5kpigs	0.135	0.037
	(0.67)	(0.34)
from5kto10kpigs	0.550	0.239
	(0.81)	(0.39)
from10kto15kpigs	1.328	0.671
	(1.32)	(0.60)
from15kto25kpigs	−14.760	
	(2178.71)	
Constant	−3.892*	−2.153*
	(1.90)	(0.86)
bund2_05		
highSchool	1.310**	0.548*
	(0.47)	(0.24)
bachelor	0.571	0.170
	(0.49)	(0.25)
WorkPlan	−0.934*	−0.462*
	(0.37)	(0.20)
EmpHB	0.354	0.275
	(0.46)	(0.24)
UsePC	0.020	−0.084
	(0.41)	(0.21)
NursF	−1.512**	−0.889**
	(0.54)	(0.32)
GFF	−2.461***	−1.346***
	(0.51)	(0.28)
FTEmp	0.004	0.008
	(0.01)	(0.00)
Age	0.067***	0.039***
	(0.02)	(0.01)
male	0.266	0.127
	(0.70)	(0.42)
Midwest	−0.100	−0.158
	(0.40)	(0.22)
from1hto2hsows	−3.093***	
	(0.85)	
from2hto5hsows	−0.760	0.412
	(0.77)	(0.37)
from5hto1ksows	−1.002	−0.237
	(0.89)	(0.34)
from1kto2ksows	−1.520*	
	(0.69)	
from2kto5ksows	−2.154**	
	(0.77)	
from3kto5kpigs	−1.849*	−0.887*
	(0.87)	(0.43)
from5kto10kpigs	−2.366**	−1.094**
	(0.80)	(0.42)
from10kto15kpigs	−1.044	0.021
	(0.83)	(0.36)
from15kto25kpigs	−1.546	
	(0.92)	
Constant	−1.344	−1.657*
	(1.21)	(0.67)

bund1_2_05		
highSchool	0.130	0.049
	(0.22)	(0.15)
bachelor	0.118	0.059
	(0.21)	(0.14)
WorkPlan	-0.367*	-0.193
	(0.18)	(0.12)
EmpHB	0.234	0.373*
	(0.22)	(0.15)
UsePC	0.219	0.181
	(0.23)	(0.14)
NursF	-0.928*	-0.669*
	(0.42)	(0.28)
GFF	-0.379	-0.408
	(0.35)	(0.23)
FTEmp	0.010*	0.010**
	(0.00)	(0.00)
Age	0.056***	0.039***
	(0.01)	(0.01)
male	-0.370	-0.238
	(0.38)	(0.25)
Midwest	0.706**	0.356*
	(0.24)	(0.15)
from1hto2hsows	-1.852***	
	(0.45)	
from2hto5hsows	-0.329	0.116
	(0.48)	(0.22)
from5hto1ksows	0.045	0.078
	(0.48)	(0.20)
from1kto2ksows	0.494	
	(0.40)	
from2kto5ksows	0.264	
	(0.43)	
from3kto5kpigs	-1.057*	-0.738**
	(0.43)	(0.24)
from5kto10kpigs	-1.088**	-0.642**
	(0.38)	(0.23)
from10kto15kpigs	-0.558	-0.131
	(0.42)	(0.23)
from15kto25kpigs	-0.422	
	(0.34)	
Constant	-2.447***	-1.878***
	(0.74)	(0.44)
R-sqr	0.147	
dfres	160	128
BIC	6104.4	5998.3

* p<0.05, ** p<0.01, *** p<0.001

In table 8, we can see the results for the Seemingly unrelated multinomial probit. The following variables number of full-time employees, nursery facilities, age, education, and the number sows from two hundred to five hundred in production are highly are highly significant for the bundle two for the year 1995. Likewise, for bundle 2 in the year 2000 and 2005, the variables number of full-time employees, nursery facilities, and education are highly significant at 99%.

The estimates imply that producers with a higher level of education and high ages are more likely to adopt several bundles of technologies. Large production size is positively correlated with adopting the technologies as bundles. Human capital is a strong factor on the adoption of the technologies as bundles. Because the technologies are complementary, the productivity of one technology is enhanced by the adoption of the other technologies. We find that large farms run by younger and more educated operators are the most likely to adopt multiple technologies.

Table 8: Seemingly unrelated multinomial probit

```
Mixed-process regression                        Number of obs     =       1739
                                                Wald chi2(80)     =     437.37
Log likelihood = -2480.8882                     Prob > chi2       =     0.0000

 ( 1)  [bund1_95]_cons = 0
```

bundles	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
bund1_95						
_cons	0	(omitted)				
bund2_95						
WorkPlansSchedule	-.1463193	.1440609	-1.02	0.310	-.4286734	.1360348
EmployeesHandbook	-.1595592	.2254285	-0.71	0.479	-.601391	.2822725
education	.0491124	.0365011	1.35	0.178	-.0224286	.1206533
PC_used_managing_operations	.0091922	.1489205	0.06	0.951	-.2826867	.301071
Number_full_time_employees	.1498667	.0242373	6.18	0.000	.1023625	.1973709
nursery	-1.190601	.3102697	-3.84	0.000	-1.798719	-.5824837
age	.0190863	.0058897	3.24	0.001	.0075427	.0306299
male	-.190712	.2867613	-0.67	0.506	-.7527538	.3713298
from2hto5hsows	.1169357	.1580594	0.74	0.459	-.1928551	.4267265
from3kto5kpigs	-.3953021	.2141869	-1.85	0.065	-.8151006	.0244964
_cons	-.9925202	.5144744	-1.93	0.054	-2.000871	.0158311
_outcome_1_3						
WorkPlansSchedule	.0234061	.100925	0.23	0.817	-.1744033	.2212156
EmployeesHandbook	-.0242638	.1522116	-0.16	0.873	-.322593	.2740655
education	.1029286	.0263953	3.90	0.000	.0511947	.1546625
PC_used_managing_operations	.5153049	.1091304	4.72	0.000	.3014132	.7291967
Number_full_time_employees	.1490114	.0236796	6.29	0.000	.1026003	.1954225
nursery	-.4289573	.2736048	-1.57	0.117	-.9652128	.1072982
age	-.0206785	.0044514	-4.65	0.000	-.0294031	-.0119538
male	.1991547	.2289641	0.87	0.384	-.2496067	.6479162
from2hto5hsows	.33024	.1093352	3.02	0.003	.115947	.5445329
from3kto5kpigs	-.0411313	.1320454	-0.31	0.755	-.2999356	.217673
_cons	.3404864	.4168384	0.82	0.414	-.4765018	1.157475

bund1_00						
WorkPlansSchedule	-.2585679	.2177687	-1.19	0.235	-.6853867	.168251
EmployeesHandbook	.4163416	.3016039	1.38	0.167	-.1747912	1.007474
education	.0832825	.0543663	1.53	0.126	-.0232735	.1898386
PC_used_managing_operations	.1960924	.2231949	0.88	0.380	-.2413615	.6335463
Number_full_time_employees	.051998	.0565901	0.92	0.358	-.0589166	.1629125
nursery	-.7031588	.5233647	-1.34	0.179	-1.728935	.3226172
age	.0260296	.0084896	3.07	0.002	.0093904	.0426689
male	-.1773066	.4178909	-0.42	0.671	-.9963578	.6417446
from2hto5hsows	-.2547293	.2498259	-1.02	0.308	-.744379	.2349204
from3kto5kpigs	-.0019925	.2897505	-0.01	0.995	-.569893	.565908
_cons	-2.473933	.8170881	-3.03	0.002	-4.075397	-.8724701
bund2_00						
WorkPlansSchedule	-.2689509	.2446275	-1.10	0.272	-.748412	.2105101
EmployeesHandbook	.3695552	.2932621	1.26	0.208	-.205228	.9443385
education	.1651784	.0664498	2.49	0.013	.0349392	.2954176
PC_used_managing_operations	.3434926	.2848672	1.21	0.228	-.214837	.9018221
Number_full_time_employees	.1542893	.0241097	6.40	0.000	.1070351	.2015435
nursery	-2.066783	.3448542	-5.99	0.000	-2.742685	-1.390881
age	-.0001632	.0107571	-0.02	0.988	-.0212467	.0209202
male	.1448028	.5237431	0.28	0.782	-.8817148	1.17132
from2hto5hsows	.1331119	.2934766	0.45	0.650	-.4420916	.7083154
from3kto5kpigs	.0348715	.352983	0.10	0.921	-.6569625	.7267055
_cons	-1.388941	.8184805	-1.70	0.090	-2.993133	.2152516
_outcome_1_6						
WorkPlansSchedule	-.186532	.1292881	-1.44	0.149	-.4399321	.066868
EmployeesHandbook	.3492981	.1744888	2.00	0.045	.0073064	.6912898
education	.1116997	.0338181	3.30	0.001	.0454174	.177982
PC_used_managing_operations	.7680184	.1544986	4.97	0.000	.4652067	1.07083
Number_full_time_employees	.1545553	.0237201	6.52	0.000	.1080647	.2010458
nursery	-1.431408	.2842452	-5.04	0.000	-1.988518	-.8742975
age	.0002979	.005635	0.05	0.958	-.0107465	.0113423
male	.2742553	.2991388	0.92	0.359	-.3120459	.8605565
from2hto5hsows	.3218953	.1424619	2.26	0.024	.0426751	.6011155
from3kto5kpigs	-.4953682	.1924163	-2.57	0.010	-.8724972	-.1182393
_cons	-.9946291	.4980393	-2.00	0.046	-1.970768	-.01849

bund1_05						
WorkPlansSchedule	-.0039401	.2184218	-0.02	0.986	-.4320389	.4241588
EmployeesHandbook	.4180276	.3059156	1.37	0.172	-.181556	1.017611
education	.0101265	.0558914	0.18	0.856	-.0994186	.1196716
PC_used_managing_operations	.445021	.233935	1.90	0.057	-.0134831	.9035251
Number_full_time_employees	-.1101231	.0988997	-1.11	0.266	-.3039629	.0837166
nursery	-.7677969	.5082882	-1.51	0.131	-1.764024	.2284298
age	.0197222	.0088431	2.23	0.026	.00239	.0370544
male	-.347351	.4002038	-0.87	0.385	-1.131736	.4370341
from2hto5hsows	-.1353933	.244128	-0.55	0.579	-.6138754	.3430888
from3kto5kpigs	-.0374164	.2845193	-0.13	0.895	-.5950639	.5202311
_cons	-1.644909	.7842042	-2.10	0.036	-3.181921	-.107897
bund2_05						
WorkPlansSchedule	-.4086554	.1929451	-2.12	0.034	-.7868209	-.0304899
EmployeesHandbook	.3729648	.2416048	1.54	0.123	-.100572	.8465016
education	.009641	.0483777	0.20	0.842	-.0851775	.1044595
PC_used_managing_operations	.373176	.2070502	1.80	0.071	-.032635	.778987
Number_full_time_employees	.1567923	.0238206	6.58	0.000	.1101048	.2034797
nursery	-2.296735	.3011387	-7.63	0.000	-2.886956	-1.706514
age	.0177522	.0077986	2.28	0.023	.0024673	.0330372
male	.1211003	.4021797	0.30	0.763	-.6671575	.9093581
from2hto5hsows	.1100963	.2240724	0.49	0.623	-.3290774	.5492701
from3kto5kpigs	-.3503274	.3224015	-1.09	0.277	-.9822227	.2815679
_cons	-.8416994	.6339987	-1.33	0.184	-2.084314	.4009152
_outcome_1_9						
WorkPlansSchedule	-.1948926	.1269003	-1.54	0.125	-.4436127	.0538274
EmployeesHandbook	.3709536	.17253	2.15	0.032	.032801	.7091062
education	.1032101	.0329063	3.14	0.002	.0387149	.1677053
PC_used_managing_operations	.6872034	.1465135	4.69	0.000	.4000422	.9743646
Number_full_time_employees	.1577723	.0237038	6.66	0.000	.1113137	.2042308
nursery	-1.316609	.2848531	-4.62	0.000	-1.874911	-.7583071
age	.0184325	.0054821	3.36	0.001	.0076878	.0291773
male	-.0275194	.2702306	-0.10	0.919	-.5571616	.5021228
from2hto5hsows	.0173672	.1444938	0.12	0.904	-.2658355	.3005698
from3kto5kpigs	-.3754473	.1905575	-1.97	0.049	-.7489331	-.0019615
_cons	-1.416259	.4818687	-2.94	0.003	-2.360704	-.4718132

5. DISCUSSION

The analysis in this paper mainly focuses on the adoption of a bundle of technologies as a group that works well together and is considered complementary to each other. Besides, as these technologies mature, we want to determine how the relationship among technologies changes. In this manner, we can establish which unobservable factors that we are not measuring explain why some farmers are more likely to adopt certain bundles of technologies. Thus, producers with a higher level of education, type of facilities pre-stablished in the hog farm and older are more likely to adopt several bundles of technologies. Large production size is positively correlated with adopting the technologies as bundles

It is also interesting to note the interaction of production structure, size, and physical environment of the operations is one of the most relevant underlying factors that hog farmers consider on the adoption and continue use of technologies . Besides, a higher level of education and high ages production size, and physical environment of the operations (nursing and finish facilities) are factors that strongly influence on the adoption of bundles of technologies. Other researchers have referred to as biosecurity among hog farms' procedures, convenience, and flexibility as an important determinant that hog farmers considered on the adoption of new technologies. Also, the bundles of technologies investigate in this study contribute to production efficiency, biosecurity, convenience for producers, and managerial improvements.

However, this study explores only a limited set of characteristics that could be influencing hog producer decisions on adopting bundles of technologies. Future research could expand on this list in an effort to obtain a complete picture. Future research might also focus on other characteristics and methods in an effort to determine the benefits that factor such as increased profitability and hog production, and decreased costs provide to hog producers.

6. CONCLUSION

In conclusion, technological advantages have led to dramatic and widespread in hog meat production over the last 20 years, advances that have had broad and mostly positive implication for hog producers. Producers with higher level of education and low ages are more likely to adopt the technologies. Large production size are positive correlated with adopt the technologies as bundles. Human capital is a strong factor in the adoption of the technologies as bundles. Also complementarity among technologies in large bundles is contributing to a form of returns to scale that is leading to increasing growth in average farm size. Because the technologies are complementary, the productivity of one technology is enhanced by the adoption of the other technologies. We find that large farms run by younger and more educated operators are the most likely to adopt multiple technologies.

7. GRAPHS

Figure 2: Number of pigs produced annually

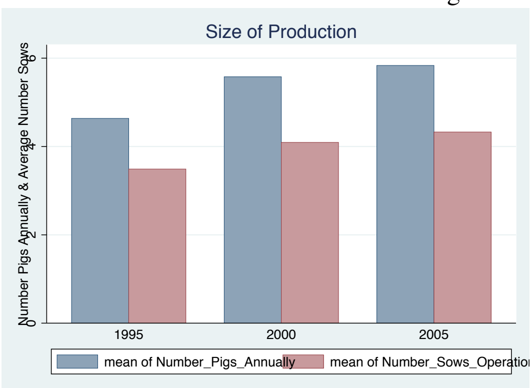


Figure 3:

Figure 4: Labor supply (full-time employees)

Figure 5: Human capital (education and used of personal computer)

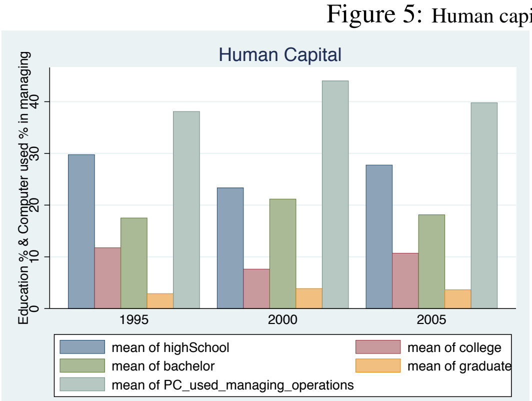
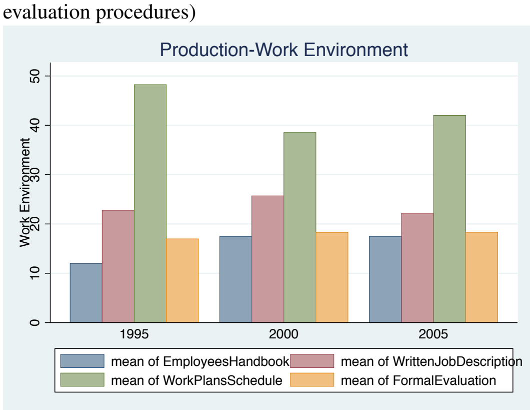


Figure 6: Work environment (employee's handbook provided, written job description provided, work plan and schedule provided, and formal evaluation procedures)



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