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The Adoption of Technologies and Structural Change in the Hog Industry: Evidence from United States.

Part I

Introduction

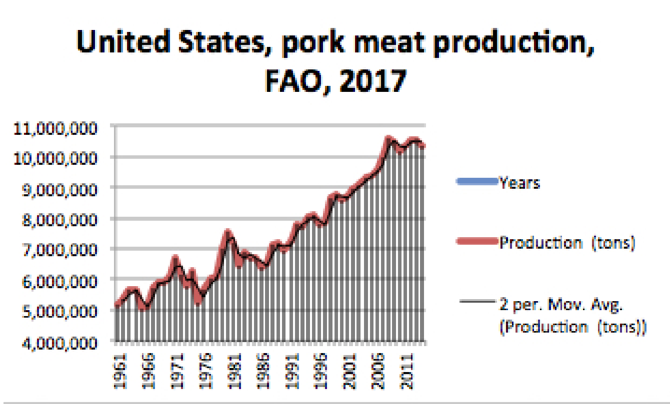
Chapter 1

Introduction

Hog production is a vital element of US agriculture and pork is a main part of the American diet. In the last decades, swine production has changed in United States from small-scale operations to industrial-scale operations (figure 1.1.) These industrial scale operations rely on confinement production, which increases the risk of pathogen movement through the swine heard 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 that not only promote biosecurity among hog farms-procedures but they have also contributed to market structural changes that led to production efficiency and genetics improvements in the industry. During the 1950's, considerable concern about vertical integration in agriculture developed; further, Dirks and Fienup in their 1965 article predicted that advancing technology and inter commodity competition will virtually insure increased size and specialization in hog production, narrowing margins per pig that eliminated many small hog producers [Dirks and Fienup1965].

Figure 1.1: Pork Meat Production



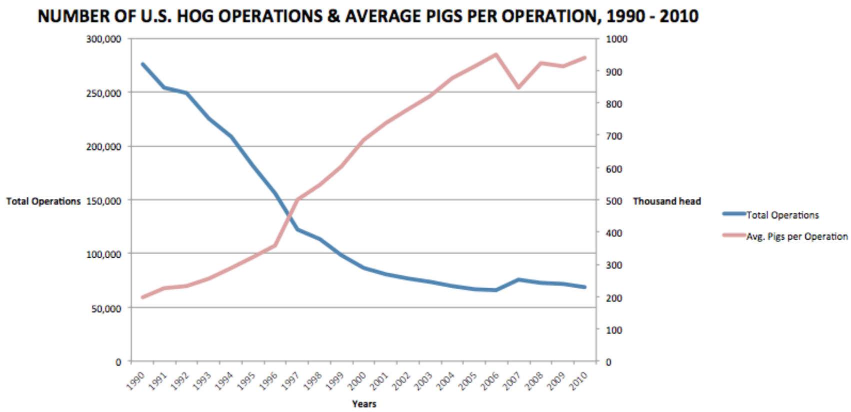
Indeed, the introduction and rapid adoption of new technologies used in the hog industry have drastically evolved in the last decades in the areas of nutrition, health, breeding and genetics, reproductive management, housing, and environmental management [Key and McBride2003]. These technical changes allowed changes within the structure of the commercial family farm [Dirks and Fienup1965]. Several studies on understanding the benefits of these technologies provided to hog producers focus on profitability, biosecurity, and cost [Fangman and Tubbs1997, Foster et al., Gerrits et al.2005, Roca et al.2006]. Despite the fact that these technologies were created several decades ago, hog producers keep using and adopting them even without solid indication of increase in profit, production, or cost reduction.

Thus, it suggest that hog producers also consider other types of non-monetary concerns such as safety, welfare for pigs and operators, and convenience for operators [Cameron2000]. For instance, Cameron (2000) found that for the establishment of industrialized, production requires the adoption of technologies that decreases 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.

It is complicated to understand how advantages such as safety, convenience, welfare for pigs and operators, and simplicity can affect hog producer's benefits from adopting these technologies because not all hog producers in the United States have the same preferences. For instance, what may be suitable and easy for one hog producer may be different for another hog producer. According to Hurley, Mitchell, & Frisvold (2010), these concepts are not neutrally defined and depend on unique tastes and preferences [Hurley et al.2010]. However, this ambiguity does not reduce the fact that hog producers may have underlying preferences on the adoption of specific technologies of their choice. Indeed, several factors influence these underlying choices, 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 et al.2007]. According to Parvan (2011), fixed costs are often a primary barrier to adoption. Hence, spreading fixed costs over a larger farm may be one explanation for the observed positive association between farm size and propensity to adopt, so the underlying factor is that farm size may act as a proxy for other socio-economic indicators such as access to credit because the larger farm has more collateral value.

Indeed, swine production has changed in the United States from small-scale operations to industrial-scale operations. According to the 1994 USDA report from 1990 to 2010, the number of hog operations in the U.S. had decreased from around 280,000 to around 60,000; however, the average number of pigs per operations increased from around 250 pigs per operations to around 950 pigs per operations, (figure 1.2.).

Figure 1.2: Number of U.S. hog operations and Average pigs per operation, 1990 - 2010



Source: USDA — Hogs and Pigs Report through 1994; Farms, Land in Farms and Livestock Operations 1995-2011, 2012 Census of Agriculture 2012

The purpose of this analysis is to better understand hog producer's characteristics and how they relate to the adoption of the technologies frequently used in the U.S. hog industry. Furthermore, the goal of this paper is to determine how the relationships of complementarity among technology adoption, labor demand,

and farm operation size evolved between 1995 and 2005. These associated patterns allow us to understand the U.S. hog industry evolution throughout the last 20 years and to what degree these complementarity relationships have developed as these technologies matured. Also, to understand variation in technology adoption in U.S. hog production as it relates to producers, operations, and technology characteristics.

To achieve these objectives, we use 1995 and 2005 U.S. hog farmer survey data from the National Pork Producers Council-National Hog Farmer magazine (NPPC-NHF). Where we first assess the effect of farmer characteristics on the adoption of production technologies, management and information technologies, and operation size using a seemingly unrelated regression model. Then we run a factor analysis on the correlation error matrix to explore complementary relations between technology adoption and operation size, and how these evolved between 1995 and 2005.

In the next sections, we discuss the data used for this analysis. Subsequently, we described an initial examination of the relationship between adoption of technologies and producer's behavior as well as the empirical model used in this research. Here, we exhibit the results of the descriptive statistics of the independent and dependent variables, the multi-equation mixed models coefficient estimates, the correlation error matrices, and factor loadings and uniqueness results for these correlation error matrices. We further show our findings and conclusions, where estimating the hog producers adoption behavior is not straightforward process since it is a dynamic process in which as hog technologies mature they impacted on structural changes in the hog industry.

Part II

DATA

Chapter 2

DATA

We analyze the relationship between technology adoption, farm size, and other socio economic factors using survey data from the National Pork Producers Council-National Hog Farmer magazine (NPPC-NHF). The four-page questionaries were addressed to pork producers, and employees across the United States in 1990, 1995, 2000, and 2005 [Hurley et al.2005]. The survey in 1990 had a relevant information related to socio economic factors, average salaries, types of operations and production levels of owners/employers; however, in 1990 there was no information related to technology use. As a result, we dropped survey information for 1990.

In late 1998, meat packers were not bidding up the prices of hogs, Large pork meat supplies had provoked slaughterhouse overflow that led a precipitous decline in hog prices at the pig farmers and the meat packers levels. This market collapse devastated thousands of people who had staked their lives on hogs [Barboza1998]. Therefore, in 2000 the survey response decreased drastically due to these external factors which caused a political upheaval from the hog producers to National Pork Producers Council. It also arouses concerns that the survey response for that year were no representative. Therefore, this analysis makes inferences only in the random sample of a subpopulation of hog producers that responded to the (NPPC-NHF) survey on years 1995 and 2005.

The subscribers had contributed information regarding their production characteristics and human resources characteristics (worker demographics, past experience on hog farms, job tenure, and education and attributes of each worker's farm), production structure or size, technology usage, and physical environment of the operations, including detail information regarding formal evaluation of employees.

NPPC-NHF survey asked producers if they are currently using any of the *technologies* described below. A single technology was considered as a binary variable taking the value of 1 if the technology was used and 0 otherwise. The technologies examined in this study are artificial insemination (AI), split-sex feeding (SSF), phase feeding (PF), multiple site production (MSP), segregated early weaning, medicated early weaning, or modified medicated early weaning. Subscribers were asked if a computer (PC) was used to manage the operation. It also asked, if the employees were provided with handbooks, written job descriptions, or work plans, and if employees were formally evaluated.

For manageability, we combine the following variables: segregated early weaning, medicated early weaning, and modified medicated early weaning into a single measure of early weaning (EW) technologies. Also, provision of either employee handbooks, written job descriptions, work plans, or formal evaluations is considered to indicate the use of formal management technologies (MT). They are binary variables that take the value one 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.

The purpose of this analysis was to assess how characteristics like region, education, gender, and age relate to the adoption of any of the five technologies (AI, SSF, PF, MSP, and EW), the use of computers for managing operations, managerial technologies, size of production, and labor supply. Hence of specific interest for the objectives of this paper is to explain to what extent these hog technologies and farm size bundle together after controlling for the different exogenous factors described above.

First, we exhibit summary information on the dependent variables of interest for our analysis. There were *seven technologie*s involved in the surveys that were available to hog farmers in 1995 and 2005. The techniques are used to improve gene pool (AI), target nutrition programs (PF, SSF), curb disease spread (MSP,) and increase output (EW). Still, only in 2005, producers were questioned regarding they adopted two other technologies, Auto Sorting (AS) and Parity Based Management (PBM) [Yu and Orazem2014]. Thus we focus on the available technology in both 1995 and 2005.

Our hypothesis is that certain hog technologies are complementary between themselves, the used of managerial technologies, the type of pig farm specialize production stages, size of operation, and labor demand. Certainly, according to Hurley, Kliebenstein, and Orazem besides improvements in production technologies, improvements in organizational structure helps firms allocate resources more efficiently.[Hurley et al.1999]. Remarkably, we assert that pig producers seek bundles of technologies that maximize their profits given their type of pig farm specialization and size.

The type and labor intensity of particular technologies would be associated with the adoption of specific *managerial activities*; for instance, artificial insemination requires specialized knowledge and skills and the use of work plans and formal evaluations would be necessary to increase the efficacy of this technology. In other words, if a production work environment uses several administrative techniques, it would affect the adoption of new practices, meaning that the most organized hog production would be more likely to adopt certain technologies.

Personal computer used in managing operations is a binary variable that takes the value 1 if the producer used a personal computer or 0 otherwise. We consider computers as technological innovation since they have contributed to the development of the swine industry. For instance, computers reduce the amount of labor required to maintain production and financial records [Hurley et al.1999].

*Size of productio*n was measured using two variables: number of pigs produced annually and the average number of sows in an operation. Several factors influence the role of farm size in technology adoption; such, as risk attitudes and the stochastic relationship of returns per pig head or unit of production [Just and Zilberman1983]. Size of production variables described above indicate the nature of production and the specialization of hog production over time. Also, this farm size increase might have several benefits for economies of scale. Therefore, we want to test if the size of production affects technology adoption.

An important component of adoption behavior is *labor demand*; it refers to the number of full-time employees used in the hog production. Certain technologies might require more full-time employees, while others might not. On the other hand, certain techniques demanded less full-time employees with specialized skills to implement them. For instance, artificial insemination requires specific skills and requires additional employees. Some technologies may be feasible only in large operations, whereas others are equally effective regardless of firm size. For example, multiple-site production requires greater annual hog production and more full-time employees to support [Hurley et al.1999].

Second, we exhibit summary information on the independent variables (*exogenous variables*) of interest for our analysis. For this analysis, we consider education as an exogenous factor. Consequently, we asked hog producers about their formal level of *education;* specifically, the variable education was divided into four categories: high school, some college, bachelor, and graduate. *Education* is usually described as a learning process and is frequently employed as an indicator to human capital; such as, formal education (years of schooling) and informal education (age, experience, etc.). Schulz [Schultz and Schultz1982] named the human farm capital as farm entrepreneurs, and their entrepreneurial ability of farmers have spurred capacity to perceive, interpret, and respond to new events.

Age is another exogenous factor that we consider for this analysis. On the technology adoption decision, age, matters. It influences in which technology is developed; also, it depends on who the users is and it can have a substantial impact on a given acceptability to that user [Morris and Venkatesh2000]. For instance, older farmers have less time to recoup any fixed costs of learning how to use a new technology compared to young farmers.

Gender was studied as exogenous factors on the adoption of technologies. According to Venkatesh, men's technology usage decisions were more strongly influenced by their perceptions of usefulness. In contrast, women were more strongly influenced by perceptions of ease of use and subjective norm, although the effect of subjective norm diminished over time [Venkatesh and Morris2000].

The variable *region* is another exogenous factor that we used as an instrument of control. Since each region has particular characteristics, the location must have a significant effect on the adoption of new technologies. The significant effect that a grower's regional location has on the likelihood of adoption indicates the need to take into account regional differences when considering technologies adoption [D'Emden et al.2006].

Producers were asked state of residence. We classified producer's responses as follows: 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) [Hurley et al.1999].

Part III

Methods

Chapter 3

Methods

For this analysis, we used STATA's cmp command which is a system of the seemingly unrelated equations program to assess the effects of diverse exogenous hog producer and operation characteristics on the adoption of any of the five technologies, the use of computers, managerial technologies, size of production, and labor demand. The exogenous hog features are the region, education, gender, and age. As a result, we obtained a system of equations that are developed on the *classical linear regression model* with *normally distributed errors* and these errors might be correlated, sharing a multidimensional distribution [Roodman2009].

Further, the seemingly unrelated regression model assumes that hog farmers maximize their expected utility (farmers pick the most profitable technology bundle), farmer's characteristics are heterogeneous (different bundles are selected due to heterogeneous farmer and farm operation characteristics), and that there is underlying dynamic process of learning that affect the adoption of these technologies (Some of these were observed, while others were not observed).

$$max\ U = E\left(\pi_i\left(Technology\ Adoption,\ \ Operation\ Size,\ Labor\ Demand \mid Production\ Characteristics\right)\right)$$

$$= E\left(\pi_i\left(\overbrace{AI,\ SSF,\ PF,\ MSP,\ EW,\ PC,\ MT},\ \overbrace{NS,\ NP},\ \overbrace{FTE} \mid \overbrace{Region,\ Education,\ Gender,\ Age}\right)\right)$$

We obtained a system of equations (mixed model) that are developed on: The *classical probit regression model*, interval regression model, and truncated regression model; all of them with *Normally Distributed Errors. The Seemingly Un-*

related Equations (S.U.R.) system of 10 equations are define with the following latent variables:

$$Y^*_{i,j,t} = \beta_{0,j,t} + X_{i,j,t}\beta_{j,t} + \sum_{k \epsilon F} \ell_{j,k,t}\omega_{j,k,t} + \varepsilon_{i,j,t}$$

For $j \in \{AI,\ SSF,\ PF,\ MSP,\ EW,\ PC,\ MT,\ NP,\ NS,\ FTE\} = J$ where $\mathbf{X}_{i,t}$ is a vector of control variables for survey respondent i in year t (1995 or 2005); $\beta_{j,t}$ is a conformable parameter vector; $F = \textit{common unobservable characteristics}$, $\ell_{j,k,t} = \textit{factors loadings}$; $\varepsilon_{i,j,t}$ is a mean zero error with the vector of errors $\varepsilon_{i,t}$ having the correlation matrix R_t; $\mathbf{J}$ includes the technologies artificial insemination (AI), split sex feeding (SSF), phase feeding (PF), multiple site production (MSP), early weaning (EW), personal computer (PC), and management technologies (MT); and $\mathbf{J}$ also includes firm size measures in terms of the number of pigs produced annually (NP), average sow herd side (NS), and the number of full-time employees (FTE). These are defined as latent variables because the technology variables were recorded as indicator variable equal to one if the technology was used on the farm or 0 otherwise. Alternatively, measures for the number of pigs produced annually and average sow heard size were categorical, and the measure for the number of full-time employees was truncated from above and below. Given these latent variables, the observed survey responses are

$$y_{i,j,t} = \begin{cases} 1\ for & y^*_{i,j,t} \geq 0 \\ 0 & otherwise \end{cases} \quad for\ j \in \{AI,\ SSF,\ PF,\ MSP,\ EW,\ PC,\ MT\} \tag{3.1}$$

Equations 3.1 are probit regression models, this model implicates two normalizations. It normalize location by setting 0 as the cut point and because it is no longer possible to determine the scale of $y^*_{i,j,t}$, the model normalizes to $\sigma^2 = 1$ [Roodman2009].

Equations 3.2 and 3.3 are interval regression models for the latent variables. It generalizes the interval regression models by slicing the continuum into a finite set of ranges, each corresponding to range of number of pigs produced annually (NP) and to range of the average number of sows in an operation (NS) [Roodman2009]. Assume that $y_{i,NP,t}$ and $y_{i,NS,t}$ can achieve $J = 8^{th}$ outcomes, $O_1, ..., O_8$. Use the known ascending sequences of cut points $c_1, ..., c_{J-1}$ to define the regions into which $y^*_{i,NP,t}$ and $y^*_{i,NS,t}$ fall then the link function is:

$$y_{i,NP,t} = \begin{cases} 1\ for\ 1,000 & \geq y^*_{i,NP,t} & > 0 \\ 2\ for\ 2,000 & \geq y^*_{i,NP,t} & > 1,000 \\ 3\ for\ 3,000 & \geq y^*_{i,NP,t} & > 2,000 \\ 4\ for\ 5,000 & \geq y^*_{i,NP,t} & > 3,000 \\ 5\ for\ 10,000 & \geq y^*_{i,NP,t} & > 5,000 \\ 6\ for\ 15,000 & \geq y^*_{i,NP,t} & > 10,000 \\ 7\ for\ 25,000 & \geq y^*_{i,NP,t} & > 15,000 \\ 8\ for & \geq y^*_{i,NP,t} & > 25,000 \end{cases} \tag{3.2}$$

$$y_{i,NS,t} = \begin{cases} 1\ for\ 0 & \geq y^*_{i,NS,t} & \\ 2\ for\ 100 & \geq y^*_{i,NS,t} & > 0 \\ 3\ for\ 200 & \geq y^*_{i,NS,t} & > 100 \\ 4\ for\ 500 & \geq y^*_{i,NS,t} & > 200 \\ 5\ for\ 1,000 & \geq y^*_{i,NS,t} & > 500 \\ 6\ for\ 2,000 & \geq y^*_{i,NS,t} & > 1,000 \\ 7\ for\ 5,000 & \geq y^*_{i,NS,t} & > 2,000 \\ 8\ for & \geq y^*_{i,NS,t} & > 5,000 \end{cases} \tag{3.3}$$

Equations 3.4 is a regression that was truncated from above 99 and below 0 for measure for the number of full-time employees. The model posits lower and upper truncation $99 > y^*_{i,FTE,t} > 0$. For generality, they can take the value $-\infty$ or ∞ respectively, but the likelihood must be normalized by the total probability over the observable range. In this way, we exclude observations with dependent variables outside of the range of bellow 0 and above 99 number of full-time employees then the link function is:

$$y_{i,FTE,t} = \begin{cases} 0 & for\ 0 \geq & y^*_{i,FTE,t} & \\ 99 & for & y^*_{i,FTE,t} & \geq 99 \\ y^*_{i,FTE,t} & for\ 99 > & y^*_{i,FTE,t} & > 0 \end{cases} \tag{3.4}$$

Stata's cmp command uses simulated maximum likelihood to obtain estimates of $\beta_{j,t}$ and R_t for $j \in \mathbf{J}$ and $t \in \{1995, 2005\}$ assuming the vector of errors $\varepsilon_{i,t}$ are distributed multi-variate normal with mean zero and correlation R_t.

The likelihood ratio test was used to compare if there were variations between the coefficients and correlation error matrices for the pooled model (years 1995 and 2005 together) versus the two years separately. Our null and alternative hypotheses are:

$$H_0 : \begin{cases} \beta_{j,1995} = \beta_{j,2005} \\ R_{1995} = R_{2005} \end{cases} \quad for\ all\ j$$

$$H_1 : \begin{cases} \beta_{j,1995} \neq \beta_{j,2005} \\ R_{1995} \neq R_{2005} \end{cases} \quad for\ all\ j$$

Table 3.1: Likelihood Ratio Test

Model	**Obs**	**ll(null)**	**ll(model)**	**df**	**AIC**	**BIC**
Year 1995 & 2005 Model	4055	-44782.04	-43858.28	228	88172.57	89610.72
Year 1995 Model	3363	-34912.5	-34455.84	138	69187.69	70032.33
Year 1995 Model	692	-7709.729	-7543.798	138	15363.6	15990.06

LR chi2(48) = 3717.28; Probability > chi2 = 0.0000

Table 3.1 gives the model choice summaries; the likelihood ratio statistic yields a χ^2 value of 3717.28 with 48 degrees of freedom for a $p-value$ that is less than 0.001, so we rejected the null hypothesis meaning that there is variations between the coefficients and correlation error matrices on the separated models, between years 1995 and 2005.

After controlling the exogenous characteristics (region, education, gender, and age) used on the seemingly unrelated regression (S.U.R) model we determine complementarity relationships among the latent variables $y^*_{i,j,t}$ (hog technology, labor demand, and farm operation size). These associated patterns allow us to understand the U.S. hog industry evolution throughout the last 20 years and to what degree these complementarity relationships have developed as these technologies matured. Therefore, we run a factor analysis on the sample correlation error matrix ($\mathbf{R}$) obtained from the two S.U.R models for data interpretation to find features that are important for explaining correlation error matrix.

We used STATA's factor analysis command "factormat" using the "pf" which specifies that the principal-factor method be used to analyze the correlation matrix (are computed using the squared multiple correlations as estimates), and "pcf" which specifies that the principal-component factor method be used to analyze the correlation matrix [StataCorp2009].

$$\underset{(\rho\,x\,1)}{\mathbf{X}-\mu} = \underset{(\rho\,x\,m)}{\mathbf{L}}\underset{(m\,x\,1)}{F} + \underset{(\rho\,x\,1)}{\varepsilon}$$

Where $\mathbf{X} = (X_1, \ldots.., X_p)^{'}$ is a random vector with mean μ and correlation matrix $\mathbf{R}$, $\mathbf{L} =$ denotes the matrix of factor loadings (loadings of common factor), $F =$denotes the vector of latent factor scores (scores of common factor), and $\varepsilon =$ denotes the vector of latent error terms (specific factor).

For the principal-factor method, we applied Factor Analysis to the sample correlation matrix $\mathbf{R}$ where $\mathbf{R} - \psi = \mathbf{LL}^{'}$. Where $\hat{\psi}_j$ [1] are the initial of the specific variance [Helwig et al.2012].

For the principal components solution for factor analysis, the parameters of interest are the factor loadings $\mathbf{L}$ and specific variances on the diagonal of ψ for $m < p$ common factors, the PCA solution estimates $\mathbf{L}$ and ψ as L and Ψ as $\hat{L} = \left[\lambda_1^{1/2}\nu_1, \lambda_2^{1/2}\nu_2, \ldots..., \lambda_m^{1/2}\nu_m\right]$ and $\hat{\psi}_j = \sigma_{jj} - \hat{h}_j^2$. Where the eigenvalue decomposition of $\Sigma = \vee \wedge \vee'$, and $\hat{h}_j^2 = \sum_{k=1}^{m} \ell_{jk}^2$ is the estimated communality of the $j-th$ variables [Helwig et al.2012].

[1] $\hat{\psi}_j = \frac{1}{r^{jj}}$ $\left(where\ r^{jj}\ is\ the\ diagonal\ of\ \mathbf{R^{-1}}\right)$

Part IV

Results

Chapter 4

Results

We first present on table 4.1 the results of the descriptive statistics of the independent variables used for this analysis. Second, table 4.2 and 4.3 report the descriptive statistics of the dependent variables. Fourth, tables 4.4 - 4.5 reports the seemingly unrelated regression models coefficient estimates (absolute t-statistics in parentheses) for each exogenous characteristic. Also, we report in tables 4.6 and 4.7 correlation error matrices for years 1995 and 2005 obtained from the seemingly unrelated regression models and then on tables 4.8 - 4.12 we reported the factor loadings and uniqueness results for 1995 and 2005 of the factor analysis for the correlation error matrix.

4.1 Descriptive statistics

Table 4.1: Mean (standard deviation) for hog producer's region, and demographic characteristics variable (exogenous variables)

	1995	2005
Midwest	0.81	0.78
	(0.39)	(0.42)
Northeast	0.05	0.07
	(0.23)	(0.25)
South__East	0.07	0.08
	(0.26)	(0.27)
West	0.06	0.07
	(0.24)	(0.25)
college	0.18	0.17
	(0.38)	(0.38)
bachelor	0.26	0.28
	(0.44)	(0.45)
graduate	0.04	0.06
	(0.20)	(0.23)
age	44.29	50.15
	(11.44)	(11.28)
gender (female)	0.041	0.067
	(0.19)	(0.25)
Observations	3372	695

Table 4.1 summarizes the distribution of hog producers's demographic characteristics for years 1995 and 2005. The exogenous variables listed are the following region, education, gender, and age. For our analysis, the region variable was classified as the Midwest, North East, South East, and West. Hog producers' responses with a bigger share of the national hog production were located in the Midwest, with about the 80 percent in 1995 and 2005 of the United States. Contrary to the producers from the other three regions, North East, South East, and West, which they had a small share of hog production in the United States. The variable education was divided into three categories college, bachelor, and graduate. Bachelor degree has the largest percentage for the education variable more than 25 percent. In 2005, the percentage of respondents that have a bachelor degree slightly increased as time passes. The average age of hog producer's respondents was 44 years old in 1995 and 50 years old in 2005, which suggests the industry is not attracting new young producers. In 2005, the gender prevalence of hog producers' respondents were males, near 96 percent, while in 2005 still significant share of pig farmers' respondents were males too, near 93 percent.

Table 4.2: Mean (standard deviation) for the use of hog technologies, labor demand, managerial technologies, and use of computers (dependent variables).

	1995	2005
Full-time employees (FTE)	1.66	4.89
	(5.86)	(25.98)
Artificial Insemination (AI)	0.31	0.47
	(0.46)	(0.50)
Split Sex Feeding (SSF)	0.41	0.37
	(0.49)	(0.48)
Phase Feeding (PF)	0.55	0.53
	(0.50)	(0.50)
Multiple Site Production (MSP)	0.28	0.32
	(0.45)	(0.47)
Early Weaning (EW)	0.17	0.30
	(0.38)	(0.46)
Personal Computer (PC)	0.54	0.57
	(0.50)	(0.49)
Managerial Technologies (MT)	0.35	0.42
	(0.48)	(0.49)
Observations	3372	695

Tables 4.2 and 4.3 report the descriptive statistics for the dependent variables. First, table 4.2 shows that the number of full-time employees had an increased trend from 1995 to 2005. Expressly, the average of full-time employees increases from about 1.66, in 1995 to an average of full-time staff of about 4.89, in 2005. Note, the increase in the demand for full-time employees almost double from 1995 to 2005.

Second, table 4.2 shows the variable personal computer used in managing operations. The average of hog farmers that used a personal computer in managing operations is above the 54 percent for the two years, 1995 and 2005, but it was not a large difference between both years. Third, table 4.2 describes the hog technologies used for this analysis; the set of reproduction and nursing techniques (AI, MSP, and EW) were highly adopted, and in 2005 they show a substantial increase of 51.6 percent, 14.3 percent, and 43.3 percent, respectively[1]. Alternatively, we can see that the probability of adoption for the set of growing technologies (split-sex feeding (SSF), and phase feeding (PF)) have slightly decreased as time passes. Last but not least, managerial techniques had about 35 percent of the producers offered managerial technologies in 1995. In 2005, we saw a 7 percent point increase of the use of managerial techniques.

[1] $100 * (.47 - .31)/.31 = 51.6$ % for AI, $100 * (.32 - .28)/.28 = 14.3$ % for MSP, and $100 * (.30 - .17)/.30 = 43.3$ % for EW

Table 4.3: Mean (standard deviation) for size of production (dependent variables).

	1995	2005
Number Pigs Annually, lower and upper levels		
0 - 1000	0.05	0.15
1000 - 2000	0.24	0.18
2000 - 3000	0.26	0.13
3000 - 5000	0.18	0.14
5000 - 10000	0.16	0.18
10000 - 15000	0.05	0.12
15000 - 25000	0.04	0.10
Number Sows, lower and upper levels		
0 - 100	0.15	0.23
100 - 200	0.44	0.27
200 - 500	0.29	0.25
500 - 1000	0.09	0.20
1000 - 2000	0.02	0.05
2000 - 5000	0.00	0.00

The size of production has two variables, number of pigs produced annually and the average number of sows in operation. The summary statistics for those two variables are reported in table 4.3. In 1995, a significant share of the number of pigs produced annually was reported from 2,000 to 5,000 pigs range. In 2005, there were significant increases in small proportions at the lower pig ranges (0-1000) and top end pig range (10,000 to 25,000) suggesting a bifurcation apart from the middle (1000 to 5,000). However, in 2005 a large share of producers were still growing from 1,000 to 2,000 pigs.

For the variable average number of sows in operation, in 1995 about 44 percent of hog producers had an average 100 to 200 sows in operations, and about 30 percent had an average 200 to 500 sows in operations. In 2005, the distribution of the number of sows in operation was more spread from a range of 100 to 1,000 sows. Table 4.3, records that around 30 percent of hog producers had a share of 100 to 200 sows and 200 to 500 sows in operations. Also, the proportion of producing an average of 500 to 1000 sows increased from about 9 percent, in 1995, to 20 percent, in 2005.

4.2 Regression Results

For our econometric analysis, we assess the effects of diverse exogenous hog producer characteristics (region, education, gender, and age) on the adoption of any of the five technologies (AI, SSF, PF, MSP, and EW), the use of computers, managerial technologies, size of production, and labor demand using the Seemingly Unrelated Regression model. Tables 4.4 - 4.5 reports the regression results for the models first for 1995 and second for 2005 clustered on five sets of columns corresponding to each response technology.

Table 4.4: Regression Table; Coefficient Estimates and standard errors (absolute t-statistics in parentheses) for the Seemingly Unrelated Model

	Artificial Insemination		Split sex feeding		Phase feeding		Multiple Site Production		Early Weaning	
Exogenous Variables	1995	2005	1995	2005	1995	2005	1995	2005	1995	2005
Northeast	-0.172	-0.00346	-0.0291	-0.264	-0.172	-0.418*	-0.285**	-0.269	-0.367**	-0.178
	(-1.65)	(-0.02)	(-0.30)	(-1.33)	(-1.78)	(-2.13)	(-2.60)	(-1.36)	(-2.80)	(-0.89)
South_East	0.0744	0.543**	-0.325***	-1.039***	-0.413***	-1.028***	-0.132	0.0590	-0.131	-0.784***
	(0.81)	(3.07)	(-3.69)	(-4.42)	(-4.83)	(-5.08)	(-1.41)	(0.31)	(-1.27)	(-3.30)
West	0.256**	0.101	-0.320***	-0.329	-0.304***	-0.744***	-0.400***	-0.405	-0.206	-0.227
	(2.82)	(0.60)	(-3.43)	(-1.61)	(-3.35)	(-3.65)	(-3.83)	(-1.84)	(-1.82)	(-1.09)
Some College	0.257***	0.195	0.162**	0.354*	0.110	0.299*	0.183**	0.345*	0.280***	-0.0969
	(4.10)	(1.60)	(2.68)	(2.56)	(1.81)	(2.16)	(2.92)	(2.57)	(4.04)	(-0.68)
Bachelor	0.406***	0.505***	0.349***	0.262*	0.361***	0.383**	0.160**	0.267*	0.237***	0.0238
	(7.52)	(4.94)	(6.64)	(2.26)	(6.77)	(3.27)	(2.89)	(2.32)	(3.87)	(0.20)
Graduate	0.550***	0.429*	0.271*	0.112	0.458***	0.689**	0.272*	0.283	0.350**	0.322
	(4.80)	(2.18)	(2.39)	(0.49)	(3.99)	(3.00)	(2.32)	(1.35)	(2.75)	(1.48)
Gender (female)	0.281*	0.152	-0.243*	0.170	-0.312**	-0.250	-0.0179	0.133	-0.211	0.119
	(2.53)	(0.90)	(-2.14)	(0.87)	(-2.81)	(-1.26)	(-0.15)	(0.69)	(-1.53)	(0.60)
Age	-0.0121***	-0.0127***	-0.00924***	-0.00323	-0.0195***	-0.0221***	-0.00974***	-0.00924*	-0.00760**	-0.00278
	(-5.86)	(-3.31)	(-4.75)	(-0.73)	(-10.00)	(-4.98)	(-4.74)	(-2.12)	(-3.26)	(-0.61)
Intercept	-0.158	0.421*	0.109	-0.220	0.949***	1.161***	-0.172	-0.0368	-0.699***	-0.305
	(-1.64)	(2.09)	(1.19)	(-0.94)	(10.23)	(4.99)	(-1.78)	(-0.16)	(-6.44)	(-1.28)

t-statistics in parentheses; $*\rho < 0.05$, $**\rho < 0.01$, $***\rho < 0.001$

Table 4.5: Regression Table; Coefficient Estimates and standard errors (absolute t-statistics in parentheses) for the Seemingly Unrelated Model

	Personal Computer		Formal Management		Number Of Pigs		Number of sows		Number Full-time employees	
Exogenous Variables	1995	2005	1995	2005	1995	2005	1995	2005	1995	2005
Northeast	-0.190*	-0.177	0.129	-0.0982	707.6	-2032.3	33.70	31.68	0.0597	-6.291
	(-1.97)	(-0.95)	(1.31)	(-0.56)	(1.67)	(-1.19)	(0.80)	(0.12)	(0.09)	(-1.15)
South_East	0.0347	0.200	0.651***	0.868***	5261.0***	10165.6***	355.7***	1230.2***	4.457***	26.86***
	(0.40)	(1.06)	(7.44)	(5.15)	(13.70)	(5.87)	(9.53)	(4.81)	(8.16)	(5.72)
West	-0.0129	0.0460	0.147	0.323	1424.2***	-735.0	104.9**	201.5	1.420*	8.366
	(-0.14)	(0.24)	(1.63)	(1.85)	(3.58)	(-0.42)	(2.68)	(0.76)	(2.42)	(1.64)
Some College	0.233***	0.615***	0.264***	0.307*	775.3**	1926.5	46.81	136.2	0.168	4.169
	(3.88)	(4.55)	(4.32)	(2.49)	(2.94)	(1.58)	(1.79)	(0.73)	(0.42)	(1.14)
Bachelor	0.527***	0.598***	0.430***	0.475***	1587.7***	3404.1**	151.8***	716.5***	2.470***	12.76***
	(9.90)	(5.30)	(8.11)	(4.59)	(6.88)	(3.28)	(6.68)	(4.59)	(7.20)	(4.18)
Graduate	0.848***	1.052***	0.630***	0.863***	2089.4***	7901.2***	260.2***	579.9*	2.393***	13.95*
	(7.07)	(4.53)	(5.61)	(4.23)	(4.23)	(4.00)	(5.40)	(1.97)	(3.32)	(2.49)
Gender	-0.0341	0.0698	0.0398	-0.0559	181.9	-991.0	49.21	109.0	0.149	2.690
	(-0.31)	(0.37)	(0.36)	(-0.32)	(0.38)	(-0.57)	(1.04)	(0.41)	(0.21)	(0.52)
Age	-0.0187***	-0.0227***	-0.00290	-0.00994*	-32.50***	-145.2***	-2.564**	-17.70**	0.0366**	-0.0426
	(-9.53)	(-5.30)	(-1.47)	(-2.54)	(-3.85)	(-3.75)	(-3.07)	(-3.02)	(2.89)	(-0.37)
Intercept	0.733***	1.014***	-0.464***	0.0725	5277.1***	15230.6***	294.3***	803.3**	-3.936***	-12.45*
	(7.95)	(4.51)	(-4.95)	(0.35)	(13.17)	(7.48)	(7.43)	(2.61)	(-6.41)	(-2.04)

t-statistics in parentheses; $*\rho < 0.05$, $**\rho < 0.01$, $***\rho < 0.001$

First, the variable region has the following subset of variables Northeast, Southeast, and West. In 1995 hog producers from Northeast region were less likely to adopted multiple-site production and early weaning technologies and the odds ratio of using a personal computer in their management operation was negative. Also, in 2005, hog producers from this region were less likely to adopt Phase feeding technology.

Pig farmers from Southeast region were less likely to choose Split-sex feeding, and Phase feeding technologies in 1995; moreover, used of these technologies decreased in 2005. The dependent variables that were more likely to adopt were formal managerial techniques where their probability of adoption increased in 2005. The odds ratio of choosing the artificial insemination technology was highly significant in 2005, contrary to 1995. The following set of dependent variables that are highly significant in both years, 1995 and 2005, are the number of pigs, number of sows, and number full-time employees. More specifically, as time passed hog producer from Southeast region increased their average size of production relative to the midwest region. For instance, the average number of pigs, number of sows, and number full-time employees in 1995 were 5261, 356, and 4.5 respectively, see table 4.5. While, in 2005 we saw an increase in the size of production of about 93 percent for the number of pigs, 245 percent for the number of sows, and about 504 percent on the demand of full-time employees [2].

For swine producers from the west region in 1995, the odds ratio of adopting split-sex feeding and multiple site production technologies was highly significant and negative. Also, farmers from the west region were less likely to adopt the phase feeding technology in years 1995 and 2005. However, in 1995 the likelihood of choosing the artificial insemination technology was highly significant and positive for producers from this region. In 1995, the average number of pigs, number of sows, and number full-time employees in 1995 were highly relevant and with 1424.2 number of pigs, 104.9 number of sows, and 1.4 for the demand of full-time employees, see table 4.5.

The exogenous variable education contains the following subset of variables some college, bachelor, and graduate. In 1995 and 2005, hog producers with college degrees were more likely to adopt the following technologies: split-sex feeding, multiple site production, personal computer, formal management.

[2] $100 * (10165.6 - 5261)/5261 = 93$ % for number of pigs, $100 * (1230.2 - 355.7)/355.7 = 245$ % for number of sows, and $100 * (26.86 - 4.45)/4.45 = 504$ % for demand of full-time employees

Furthermore, the odd ratio of adopting these technologies had increased in 2005. In 1995, the likelihood of adopting artificial insemination and early weaning technologies were positive and highly significant for hog producers with college degrees. In 2005 the phase feeding technique was positive and highly significant. In 1995, the average number of pigs that hog producers with college degrees was about 775.3 pigs produced annually, see table 4.5..

The variable bachelor level was a reliable determinant of the adoption of technologies. Besides the early weaning technique that was highly significant only in 1995, all the dependent variables were highly significant in both years. Also, in 2005, we saw a substantial increase in the number of pigs produced annually and the number of sows in operations.

In 1995, hog producers with a graduate level of education were more likely to adopt the split-sex feeding, multiple site production, and early weaning technologies compared to hog producers with only high school degrees. In 1995 and 2005, the following set of technologies were more likely to be adopted by hog producers with a graduate level of education: artificial insemination, phase feeding, use a personal computer, and formal management when compared to hog producers with only high school degree. In both years, the number of pigs produced annually, number of sows in operations, and demand for full-time employees were highly significant. Moreover, producers with graduate degree level increased their size of production in 2005 to a 278 percent, and 123 percent for the number of pigs and number of sows respectively, likewise, labor demand grow to a 483 percent [3].

In our regression results table, the variable gender refers to females. In 1995 female hog producers were less likely to adopt the split-sex feeding and phase feeding, but odds of adopting the artificial insemination technology were positive.

The variable age has a negative sign on all of its coefficient except for the variable number full-time employees. Thus, we can infer that a year increase in hog producer decreases the odds of adopting any technology. Indeed, in years 1995 and 2005, younger pig farmers were more likely to use the following set of technologies artificial insemination, phase feeding, multiple site production, personal computer, and formal management techniques. Likewise, younger hog farmers tend to have larger sizes of production, and the number of pig and sows

[3] $100*(7901.2-2089.4)/2089.4 = 278$ % for number of pigs, $100*(579.9-260.2)/260.2 = 123$ % for number of sows, and$100*(13.95-2.39)/2.39 = 483$ % for demand of full-time employees

had increased as time passed. Plus only in 1995, younger pig farmers were more likely to adopt the phase feeding and early weaning technologies. Contrary to all the coefficients in 1995, age has a positive effect on the number full-time employees; in other words, older hog farmers demand larger amounts of full-time employees.

4.3 Correlation analysis R

The correlation error matrix captures the unobservable factors that are systematically affecting the adoption process of technological innovation, size of production, and labor demand. Tables 4.6 and 4.7, reports correlation error matrices for years 1995 and 2005, the bolded values represent highly significant and positive correlation.

Table 4.6: Correlation Error Matrix for 1995

	A I	SSF	PF	MSP	EW	PC	MT	NP	NS	NE
A I	1									
SSF	**0.28**	1								
PF	**0.24**	**0.50**	1							
MSP	**0.23**	**0.23**	**0.19**	1						
EW	**0.30**	**0.29**	**0.27**	**0.46**	1					
PC	**0.35**	**0.28**	**0.25**	**0.22**	**0.24**	1				
MT	**0.35**	**0.23**	**0.19**	**0.24**	**0.26**	**0.37**	1			
NP	**0.31**	**0.36**	**0.16**	**0.32**	**0.31**	**0.31**	**0.46**	1		
NS	**0.36**	**0.21**	**0.12**	**0.29**	**0.25**	**0.26**	**0.39**	**0.76**	1	
NE	**0.28**	**0.18**	**0.11**	**0.23**	**0.20**	**0.23**	**0.45**	**0.52**	**0.68**	1

The correlation error matrix for the year 1995 tell us that some the dependent variables are slightly positively correlated and some are highly positively correlated. For instance, the technologies split sex feeding, and phase feeding are highly positively correlated ($\rho_{PF,SSF} = 0.5011$). The early weaning and multiple site production technologies are positively correlated ($\rho_{EW,MSP} = 0.4632$). We can see a positive correlation between the dependent variables that indicate the size of hog farm with the response variable management activities ($\rho_{NP,MA} = 0.4616$). Also, 1995 the number of sows and number of pigs in operation had a high positive correlation. These positive correlations motivate us to infer that in 1995 the average farm size growth, managerial activities, and adoption of these new technologies, reveals the increase in productivity growth and the beginning of the structural change in the hog industry.

Table 4.7: Correlation Error Matrix for 2005

	A I	SSF	PF	MSP	EW	PC	MT	NP	NS	NE
A I	1									
SSF	0.09	1								
PF	0.12	**0.67**	1							
MSP	**0.63**	**0.32**	**0.41**	1						
EW	**0.27**	**0.24**	**0.24**	**0.4**	1					
PC	**0.59**	**0.27**	**0.31**	**0.46**	**0.33**	1				
MT	**0.73**	**0.19**	**0.16**	**0.53**	**0.29**	**0.63**	1			
NP	**0.66**	**0.29**	**0.19**	**0.55**	**0.38**	**0.54**	**0.67**	1		
NS	**0.9**	0.06	0.07	**0.52**	**0.22**	**0.52**	**0.71**	**0.69**	1	
NE	**0.78**	0.13	0.14	**0.57**	**0.23**	**0.60**	**0.88**	**0.65**	**0.76**	1

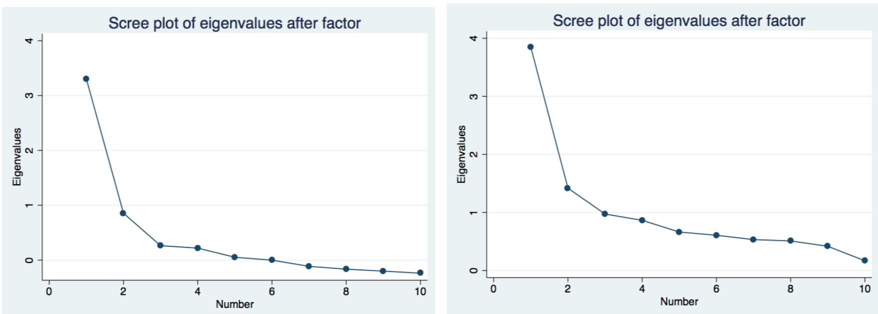
The correlation error matrix for the year 2005 tells us that a few of the dependent variables are slightly positively correlated and most of them are highly positively correlated. For instance, the artificial insemination technology is highly positively correlated with the used of managerial activities, use of computer on operations, ($\rho_{AI,MA} = 0.73$) and ($\rho_{AI,PC} = 0.59$), and it is strongly correlated with the number of sows and the number of employees, ($\rho_{AI,NS} = 0.9$) and ($\rho_{AI,NE} = 0.78$) respectively. Likewise, the multiple site production technology is highly positively correlated with the use of managerial activities ($\rho_{MSP,MA} = 0.53$), and correlated with the number of sows and pigs, and the number of employees: ($\rho_{MSP,NS} = 0.52$) , ($\rho_{MSP,NP} = 0.55$) , and ($\rho_{AI,NE} = 0.56$). Also, the use of personal computer is highly positively correlated with the response variables described before, see table 4.7. The correlation between size of hog farm and management activities is positive and higher ($\rho_{NP,MT} = 0.67$). Further, in 2005 the number of sows and number of pigs in an operation, and the number of sows and number of full-time employees had a higher positive correlation than in year 1995, ($\rho_{NP,NS} = 0.69$) and ($\rho_{NS,NE} = 0.76$).

Comparing the two years correlation values, it reveals an structural change in hog production that promote specialization. However, it is ambiguous to determine what underlying factors had an impact on the development of the swine industry from 1995 to 2005. Consequently, we ran a factor analysis on the samples correlation error matrix obtained from the two S.U.R models for 1995 and 2005. Where latent with the same pattern of response are associated as complements.

4.4 Factor Analysis

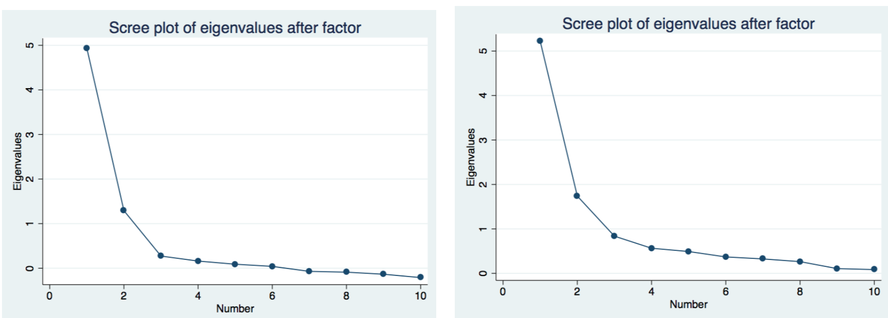
To determine the number of factors to preserve we used scree plots for 1995 and 2005 factor analyses, see figures 4.1 and 4.2. The scree depicts the magnitude of an eigenvalue λ_i (proportion of variance) versus number of factors i. The eigenvalues are ordered from largest to smallest and to determine the number of factors, we look for a bend in the scree plot [Zwick and Velicer1986].

Figure 4.1: Scree Plots for 1995 factor analysis Principal-Factor method, and Principal-Component Factor method



An elbow or bend occurs in the scree plot in figure 4.1 for both factors analysis methods principal factor and principal component factor method, in both cases, we retained at about $i = 2$ and in the scree plot in figure 4.2 at about $i = 2$. For the scree plots, we can see that eigenvalues after λ_2 for 1995 and λ_2 for 2005 are relatively small and about the same size. For the two methods principal factor and principal component, the two first factors summarize the total sample variance in 1995 and the two first factors summarize the total sample variance in 2005.

Figure 4.2: Scree Plots for 2005 factor analysis Principal-Factor method, and Principal-Component Factor method



Tables below, report factors after promax rotation and varimax rotation for the year 1995 and 2005, the promax rotation is an oblique rotation method that clarifies the interpretation of the solution and also we presented the correlation matrix of the common factors and varimax rotation which is and orthogonal rotation.

The estimated factor loadings and uniqueness for 1995 are displayed in table 4.8, and the cob-web plot of these factor loadings are shown as a visual presentation in figure 4.3-4.5. The portion of variance of the $j-th$ variables that is explained by the m common factors is called communality of the $j-th$ variables [Helwig et al.2012]:

$$\underbrace{\sigma_{jj}}_{Var(X_j)} = \underbrace{h_j^2}_{communality} + \underbrace{\psi_j}_{uniqueness}$$

where σ_{jj} is the variance of the X_j, $\mathbf{X_j} = (X_1, ..., X_p)'$ is a random vector with mean μ and correlation matrix $\mathbf{R}$, h_j^2 [4] is the communality of X_j, ψ_j is the specific variance of X_j (uniqueness). Therefore, we choose the method that has the lowest uniqueness (ψ_j) and the variance explained by common factors. In both years 1995 and 2005, the factor analysis principal component factor method with varimax rotation have the lowest uniqueness comparing with the other two models, so we choose this method to draw our conclusions.

The variables with most substantial loadings in factor 1 are the number of sows, number of pigs, and number of full-time employees and the variables with slight weight in factor 1 are formal management, artificial insemination, and multiple site production.

Factor 1, will be attributed to the large size of farms that requires vast labor demand and had farrow-to-feeder operations on which pigs were farrowed and then fed to a feeder pig weight of about 30-80 pounds. However, this group hog farmers had rarely used computer on managerial operations and had no yet adopted split sex feeding, phase feeding, early weaning technologies, in 1995.

The latent variables with most substantial loadings in factor 2 are formal management, personal computer, artificial insemination, multiple site production, split sex feeding, phase feeding, and early weaning technologies and the variable with sparse weight is the number of pigs. Also, notice highly substantial loadings in formal management and used computer on managerial operations, but negative

[4] $h_j^2 = \left(\mathbf{LL}''\right)_{jj} = \ell_{j1}^2 + \ell_{j2}^2 + ... + \ell_{jm}^2$

small loading for number of full-time employees.

Factor 2, will be attributed to small size pig farms that used information management technologies and are in the business of wean-to-finish operation. In which weanlings (10-20 pounds) are obtained from outside the operation either then fed to a feeder pig weight of about 30-80 pounds or then finished to a slaughter weight of 225-250 pounds. However, factor 2 might also call farrow-to-finish factor; since it has some variables that are used in farrowing operations.

In conclusion, the factor analysis principal component factor method with varimax rotation tell us that there were a group of hog farmers that had large size of productions especially large number of sows that demand large quantities of labor, and management techniques but were laggards in terms of adopting split-sex feeding, phase feeding, early weaning technologies. These hog producers farrowed their piglets and then fed to a feeder pig weight of about 30-80 pounds and then market some of their pigs (30-80 pounds) or piglets to the small size pig farms that early adopted information management technologies and were in the business of wean-to-feed-to-finish operation to a slaughter weight of 225-250 pounds.

Table 4.8: Factor Loadings, Uniqueness, and Correlation Matrix of the Common Factors for the year 1995

	Method of Estimation								
	Principal Factor			**Principal Factor**			**Principal Component Factor**		
	Promax Rotation			**Varimax Rotation**			**Varimax Rotation**		
Variables	**Factor 1**	**Factor 2**	**Uniqueness**	**Factor 1**	**Factor 2**	**Uniqueness**	**Factor 1**	**Factor 2**	**Uniqueness**
Number of sows	**0.94**	-0.12	0.23	**0.87**	0.08	0.23	**0.89**	0.07	0.20
Number Of Pigs	**0.76**	0.09	0.35	**0.78**	0.23	0.35	**0.81**	0.21	0.30
Full-time employees	**0.78**	-0.09	0.47	**0.72**	0.07	0.47	**0.82**	0.02	0.32
Formal Management	**0.43**	0.24	0.65	**0.51**	**0.30**	0.65	**0.62**	0.28	0.54
Personal Computer	0.14	**0.42**	0.74	**0.30**	**0.41**	0.74	**0.33**	**0.49**	0.66
Artificial Insemination	0.22	**0.39**	0.71	**0.36**	**0.40**	0.71	**0.41**	**0.45**	0.63
Multiple Site Production	0.14	**0.40**	0.75	0.29	**0.40**	0.75	**0.32**	**0.48**	0.67
Early Weaning	0.05	**0.53**	0.69	0.26	**0.50**	0.69	0.26	**0.60**	0.57
Split sex feeding	-0.07	**0.67**	0.60	0.19	**0.60**	0.60	0.15	**0.73**	0.45
Phase feeding	-0.21	**0.68**	0.66	0.06	**0.58**	0.66	-0.03	**0.77**	0.41

bold numbers represent abs(loading)>.3

Correlation Matrix								
Factors	Factor1	Factor2	Factors	Factor1	Factor2	Factors	Factor1	Factor2
Factor1	1		Factor1	1		Factor1	1	
Factor2	0.5695	1	Factor2	0	1	Factor2	0	1

The estimated factor loadings and uniqueness for 2005 are in table 4.9, and the cob-web plot of these factor loadings are shown as a visual presentation in figure 4.4.

The variables with substantial loadings on factor 1 are the number of sows, artificial insemination, and multiple site production technologies. Also, variables with less substantial loadings on factor 1 are number of pigs, number of full-time employees, personal computer, and early weaning.

This factor represents the group of large pig farmers that had specialized in the farrow to wean operations and had adopted and specialized in artificial insemination, multiple site production, and early weaning technologies. In the farrow to wean operations, pigs are farrowed and then sold or removed after an early weaning at a mass of about 10-20 pounds [Key and McBride2007]. Comparing to hog producers in 1995, this type of hog production demanded fewer amounts of full-time employees, had less number of pigs, and used more personal computers in 2005. Comparing the first factor in 1995 with the first factor in 2005, these hog farmers had specialized in the farrow to wean operations. They had advanced skills in the used of artificial insemination, multiple site production, and early weaning technologies.

Factor 2 has a reasonably heavy loadings for used of personal computers, and number of pigs. This second factor might be labeled as a wean-to-feeder producers on which weanlings (10-20 pounds) are obtained and then fed to a feeder pig weight of about 30-80 pounds. This wean-to-feeder operations had a large number of pigs, but were laggards in terms of adopting wean-to-feeder technologies.

Also, notice less but positive substantial loadings in number of pigs and used of personal computer. Factor 2 might be labeled as feeder-to-finish producers which pigs are obtained from outside the operation, and then terminated to a slaughter weight of 225-300 pounds. This hog producers had fully adopted technologies that are frequently used in wean-to-finish operations, such as multiple site production, early weaning, split sex feeding, and phase feeding technologies.

Table 4.9: Factor Loadings, Uniqueness, and Correlation Matrix of the Common Factors for the year 2005

	Method of Estimation								
	Principal Factor			**Principal Factor**			**Principal Component Factor**		
	Promax Rotation			**Varimax Rotation**			**Varimax Rotation**		
Variables	**Factor 1**	**Factor 2**	**Uniqueness**	**Factor 1**	**Factor 2**	**Uniqueness**	**Factor 1**	**Factor 2**	**Uniqueness**
Number of sows	**0.96**	-0.18	0.19	**0.90**	-0.01	0.19	**0.91**	-0.03	0.18
Number Of Pigs	**0.70**	0.15	0.39	**0.73**	0.27	0.39	**0.78**	0.25	0.33
Full-time employees	**0.93**	-0.07	0.19	**0.89**	0.09	0.19	**0.91**	0.07	0.17
Formal Management	**0.87**	0.00	0.24	**0.86**	0.15	0.24	**0.88**	0.12	0.21
Personal Computer	**0.57**	0.24	0.51	**0.62**	**0.33**	0.51	**0.68**	0.33	0.44
Artificial Insemination	**0.96**	-0.11	0.16	**0.92**	0.06	0.16	**0.92**	0.04	0.15
Multiple Site Production	**0.50**	**0.37**	0.45	**0.59**	**0.44**	0.45	**0.63**	**0.46**	0.39
Early Weaning	0.20	**0.32**	0.80	0.28	**0.35**	0.80	**0.30**	**0.45**	0.70
Split sex feeding	-0.14	**0.79**	0.45	0.07	**0.74**	0.45	0.05	**0.87**	0.25
Phase feeding	-0.15	**0.83**	0.40	0.07	**0.77**	0.40	0.05	**0.88**	0.22

bold numbers represent abs(loading)>.3

Correlation Matrix								
Factors	Factor1	Factor2	Factors	Factor1	Factor2	Factors	Factor1	Factor2
Factor1	1		Factor1	1		Factor1	1	
Factor2	0.4239	1	Factor2	0	1	Factor2	0	1

The group of big producers had changed their production structure, in 2005. Factor 1 in both years represent a group of large size of producers that had divided from farrow-to-finish operations, in 1995, to small segments operations such as farrow-to-wean and farrow-to-feeder and lightly focus on feeder-to-finish production stage. Hence, each specific hog production stages required an appropriate kind of technologies, and the requirements of labor, use of computer and managerial techniques depends on the nature of the production stage specialization.

Factor 2 in 2005 depicts a group of pig farmers that did not have a large number of sows, but have specialized in feeder-to-finish production stage. A large number of piglets from the wean-to-feeder production stage was sent to the feeder-to-finish production stage. Note, that this group of farmers does not need specialized of farrowing technologies; instead, their feeder pigs were obtained from outside the operation, either purchased or placed under contract and then finished to a slaughter weight of 225-250 pounds. Comparing with the first correlated group in 2005, these hog farmers have smaller sizes of productions, but also had changed their production structure from farrow-to-finish operations to wean-to-feeder and feeder-to-finish production stage, in 2005.

The cob-web plot of the factor loadings for years 1995 and 2005 are shown in the figures below, we used the factor loadings after a promax factor rotation. The diagrams represent adoption patterns of hog technologies decision and structural changes of hog farms from 1995 to 2005. Indeed, the structural change in the last two decades in the swine industry, and it has promoted a steady increase in hog production. The following latent variables loadings were used to formed the cob-web plot: artificial insemination, split-sex feeding, phase feeding, multiple site production, early weaning, personal computer, managerial activities, the number of pigs, the number of sows, and the number of full-time employees

Figure 4.3: Cob-web plots of factor loadings after varimax rotation for 1995 and 2005.

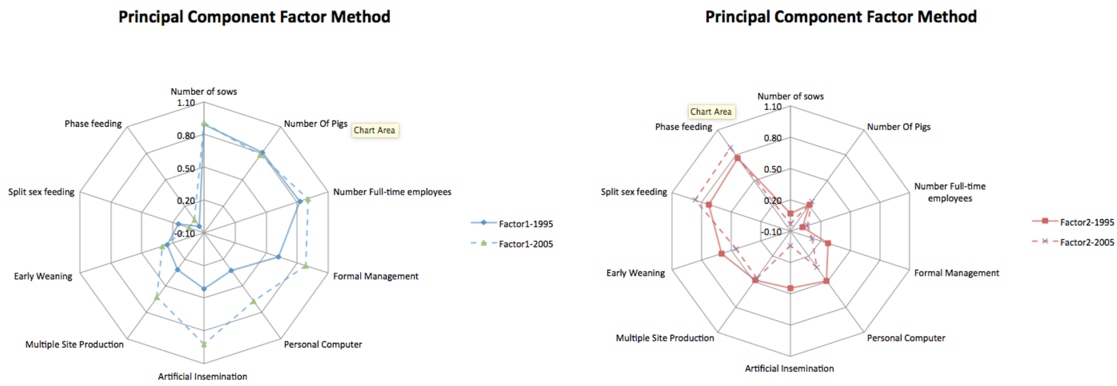


Figure 4.4: Cob-web plots of factor loadings after promax rotation for 1995 and 2005

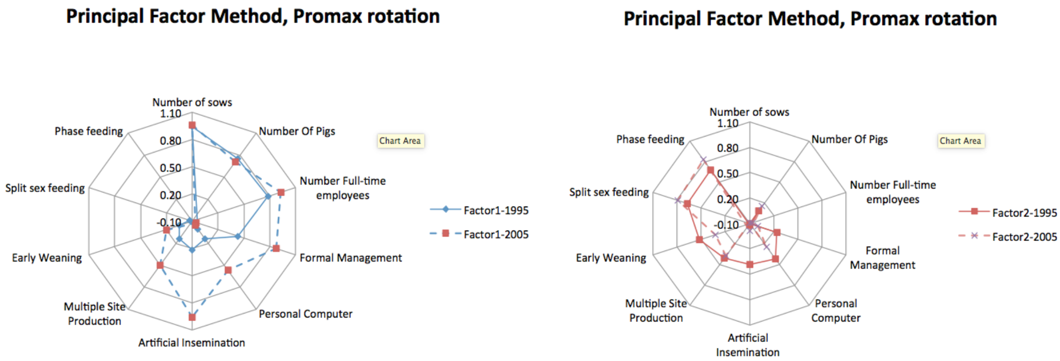
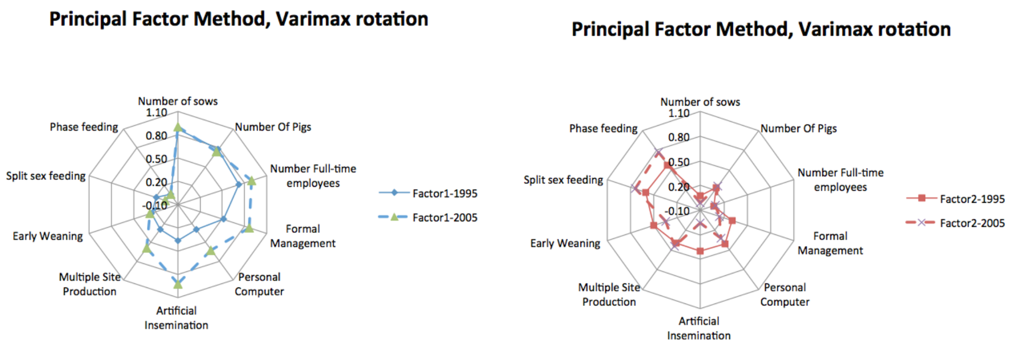


Figure 4.5: Cob-web plots of factor loadings after varimax rotation for 1995 and 2005.



Part V

Discussion

Chapter 5

Discussion

Technologies development could be a cumbersome process from researching and designing to implementing and helping these technologies to transition to markets. Also, the selection process and use of the new technologies could be a complicated and costly process to farmers. Furthermore, these adoption and development processes can be influenced by changes in demand, changes in the dynamic of economic conditions, changes in the technology supply mix, or an increase of the variability and uncertainty from both supply and demand of these technologies.

The adoption decision could be either simple or elaborate judgment to a farmer. The former could imply a single technique such as a sustainable crops rotation with legumes, which most farmers might view it as a low advanced technology, but the chemistry behind the process of nitrogen fixation is extensive and complicated. The latter could imply a strategic and tactical decision concerning resource allocation that influence the day-to-day operational decisions like the adoption of artificial insemination that requires not only specialized knowledge and skills but also needs administrative techniques.

Level of education is an important factor that influences the adoption of technologies. Indeed, education is considered as the entrepreneurial ability of farmers have spurred capacity to perceive, interpret, and respond to new events [Schultz and Schultz1982]. Education is usually described as a learning process and is frequently employed as an indicator to human capital; such as, formal education (years of schooling) and informal education (age, experience, etc.).

Also, age is another exogenous factor that we consider for this analysis.

On the technology adoption decision, age, matters. It influences in which technology is developed; also, it depends on who the users is and it can have a substantial impact on a given acceptability to that user [Morris and Venkatesh2000]. For instance, older farmers have less time to recoup any fixed costs of learning how to use a new technology compared to young farmers.

Recalled that our factor analysis results have shown that the swine production in the United States evolved from a few large to medium size hog producers that adopted multisite strategies, considered as early adopters, in 1995; to numerous small, medium, and large size hog producers that fully executed multisite production management strategies, in 2005. Diversification and specialization on different swine life cycles production such as farrow - weaning, weaning - feeder, and feeder - finish production levels has become a widely implemented by large to small commercial pig operations in 2005.

However, what other potential factors had influenced on the development of the swine industry? Also, what other factors besides profitability and the exogenous ones recognized in this analysis hog producers considered before adopting any technology? Most formal studies of technological adoption and structural changes in agriculture have framed resources allocation regarding farm size and nature of production, so we discussed the following:

First, while swine farming is a necessary step in the whole chain of the hog production, stock of hog farm inputs and transformation of hog outputs into consumer goods have become to dominate the economy of the hog industry [Lewontin1998]. Consequently, vertical integration had not only being influenced by the new technologies development, but it had impacted the swine industry developments. Changes in hog production concerning vertical integration led the extension of specialization on the swine production life cycles (farrow - weaning, weaning - feeder, and feeder - finish). These vertical integrations in the swine industry were possible due to advances in the fixed reproductive cycle on pigs to shortening hogs production life cycle.

Further, the extended periods and production intensification for pigs are hard to control because production operations are spatially large, economies of scale are difficult to achieve past the medium-scale enterprises, and the risks from natural events will always exist. These factors have spurred sizable multinational agri-food businesses promoting vertical integration among them with farmers where the contract hog producer buys nothing, sells nothing, nor makes any decisions about the physical process of transformation. The farmer does own some of the means of production, land, and buildings, but has no control over the labor process or the alienated product [Lewontin1998].

Nevertheless, vertical integration provides contract hog producers to have a more regular source of income, diminished their risk of production, marketing, and pricing uncertainty. According to, [Lewontin1998], vertical integration is possible by a technical linking of the inputs and outputs, the dual function of a single capital enterprise as both the monopsonist purchaser of outputs and the provider of critical contributions and a contract mechanism that links farmer into the loop of inputs and outputs.

Second, biosecurity measurements prevent entrance of infection into a pig farm and control the spread of diseases within farms. According to [Baker2011], these measures differ among hog farms due to the geographic location, proximity to other pig farms, epidemiological situation of the zone, type of swine operation, and level of technology adoption.

Adoption of biosecurity technologies not only promotes animal welfare, improved efficiency, and profitability for the pork producer, but also raise consumer acceptability of the quality and safety of the meat supply. For instance, the early weaning technologies have led to the evolution of the multisite production strategy since this technique decreases the transfer of growth-depressing pathogens to offspring and has improved pig performance in herds with low or high levels of endemic pathogens [Main et al.2004]. Hence, hog producer considers biosecurity technologies due to reducing the transmission of a virus from new animals and improves pig performance.

Third, acknowledging the relation of technologies adoption and farm size, given that the technology choice is endogenous and from our correlation error matrix results (tables 4.6 and 4.7), we ascertained that the adoption technologies is a function of the nature of farm type production (produce sows, piglets, or finish pigs), fixed cost related to the kind of production, and size of production. In " Science under scarcity: principles and practice for agricultural research evaluation and priority setting" the authors claim that large farms tend to adopt new technologies first and this probably results from their economies of size in obtaining information about those technologies, their additional experience and education, and a greater ability to absorb risk [Alston et al.1995]. For instance, in our analysis we had shown that the probability of adoption of the following technologies split-sex feeding, phase feeding, and multiple site production rose as the number of pigs produced annually increased. Likewise, the reproduction and nursing technologies are highly adopted and positively correlated with sizable average number of sows in operation.

Yet, our findings also show that the medium to small size hog farmers have also acquired and integrated on the multisite strategy production and specialized in singular stages of hog production, in 2005. The degree of adoption of the hog technologies use on different stages of production have several entanglements to consider. For example, according to [Just and Zilberman1983], the flexibility of adoption versus non-adoption has additional implications for the relationship of intensity of adoption and farm size, particularly when adoption involves fixed costs, whether fixed costs of adoption are high or low and whether the returns under old and new technologies are highly correlated or not. Indeed, the adoption and productivity of one technology may be enhanced by the employment of other technologies previously established. Furthermore, the uncertainty diminishes over time through the acquisition of experience and information, and the production function itself may change as adopters become more efficient in the application of the technology [Parvan2011].

Part VI

Conclusion

Chapter 6

Conclusion

There's no doubt that technological advantages have enhanced production efficiency in the hog industry in the United States. Nevertheless, before the acquisition of a technology hog producers ask whether it is appropriate for their production systems, and the strength of the new technology depends on the ability to learn how to use it. Additionally, hog producers have to consider the fixed cost of the new technology as well as a fixed investment of time for learning, locating and developing markets, and training hired labor. These fixed expenses tend to discourage adoption by small farms and thus play an important role in the relationship of farm size and adoption [Just and Zilberman1983].

In conclusion, the results of this analysis suggest that the adoption of technologies related to multisite swine production that promotes biosecurity and enhanced production efficiency has become a broadly implemented strategy in commercial hog production. Hog farmers production decisions are guided by indirect benefits such as increments of biosecurity, safety, convenience, as well as profitability, yields, and cost.

To sum up, the level of education is an important factor in the adoption of hog technologies. Some college degrees increases the likelihood of adopting the following technologies: Artificial insemination, phase feeding, early weaning. The variable bachelor level was a determinant of the adoption of all the technologies, in both years. In 2005, we saw a substantial increase in the number of pigs produced annually and the number of sows in operations. Also, hog producers with a graduate level of education were more likely to adopt the following technologies: Split-sex feeding, multiple site production, early weaning technologies. Producers with graduate degree level increased their size of production in 2005 to a 278 percent, and 123 percent for the number of pigs and number of sows respectively, likewise, labor demand grow to a 483 percent.

Also, age is an important factor in the adoption of technologies, younger hog farmers were more likely to adopt hog technologies, and they are more likely to have larger sizes of production. However, older hog farmers are more likely to demand larger amounts of full-time employees.

The interaction between vertical integration, production size, and farm type production previously established are some of the relevant underlying factors that hog farmers consider on the adoption of technologies. Besides, a higher level of education and lower ages, managerial practices, and physical environment; such as, nursing and finish facilities are factors that strongly influence the adoption of technologies.

Some researchers in the hog industry have referred biosecurity among hog farms' procedures, convenience, and flexibility as an essential determinant that hog farmers considered on the choice of new technologies. Most formal studies propose that the fixed cost of the new technology as well as the time investment for learning the technique, and training hired labor as essential factors on the adoption of new technologies. We also concluded that vertical integration had not only influence the adoption of technologies that shorten swine production life cycles, but it had also impacted the production structure on the swine industry in United States.

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