Exploring the Effect of Disease Outbreaks on Farm Structure Change: A Dynamic Analysis for the Canadian Pig Industry

Zheng, Yanan ; Goddard, Ellen W. ; Qiu, Feng

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Abstract

Over the past four decades, the Canadian pig industry has experienced significant structural change with a dramatic decrease in the number of pig farms and an increase in pig numbers per farm (defined as type 1 structural change). This study aims to investigate whether pig diseases (including porcine reproductive respiratory syndrome (PRRS), porcine circovirus associated disease (PCVAD), and porcine epidemic diarrhea (PED)) have played a role in structural change in the Canadian pig industry. Given that most structural change analysis focuses on structural change at the national level, we are interested in assessing whether examining the influences on structural change at a national level over- or under-estimates the impacts of key economic factors when heterogeneous responses across the disaggregated census division (CD) level are considered. From CD level data, we find 69% of the CDs across the country experienced structural change with decreases in both pig farm number and total pig numbers (defined as type 2 structural change). From national level analyses, the regression results present pig disease outbreaks did negatively affect farm structure adjustment. By comparing each factor's coefficients derived from the CD (type 1 and type 2 structural change) and the national level analyses, our study detects significant underestimation of the impacts of individual explanatory factors on farm structure at the national level and suggests the necessity to conduct analyses at the disaggregated level for a better understanding for policy analysis purposes.

Key words: Canadian pig industry, Census division (CD), Pig diseases, Porcine epidemic diarrhea (PED), Porcine circovirus associated disease (PCVAD), Porcine reproductive respiratory syndrome (PRRS), Type 1 structural change, and Type 2 structural change

1. Introduction

Structural change in agriculture is the adjustment of a sector to multiple influences that have impacts on farm operations and is often characterized by a dramatic decrease in farm numbers and a rapid increase in average farm size (Goddard et al., 1993). Since structural change might have significant influences on the efficiency of farming and equity of farmers (Buttel et al., 1990), it has been investigated by many researchers trying to understand the forces underlying structural change (e.g., Ahearn et al., 2005; Ben Arfa et al., 2015; Eastwood et al., 2010; Huffman and Evenson, 2001; Syrquin, 2010; Tonini and Jongeneel, 2009).

Our empirical setting is the Canadian pig industry, which has experienced dramatic structural change with a significant decrease in the number of pig farms (from 55,765 to 8,402) and an increase in average pig numbers per farm (from 177 head per farm to 1,677 head per farm) over the period from 1981 to 2016. In total, the industry produced approximately 4.2 million more pigs in 2016 as compared to 1981 (Statistics Canada, 1982; Statistics Canada). In the agricultural economics literature, such changes are usually attributed to the realization of scale economies with increased farm size (Gervais et al., 2008; Komirenko, 2015). Accompanying the increase in the national average number of pigs per farm, pig production has also changed to become more specialized. Farms have moved away from the traditional farrow-to-finish operations to specialization on a single phase of production, which may allow lower per unit production costs. According to the Agricultural Division of Statistics Canada, the proportion of the pig farms that were farrow-to-finish operations decreased from 45% in 1981 to 23% in 2016. However, not every census division (CD) in Canada followed the national trend with a decrease in pig farm numbers and an increase in total pig numbers. Using CD level data, we find about 69% of the CDs across the country experienced another type of structural change with

decreases in both pig farm numbers and total pig numbers over the same time period (Statistics Canada, 1982; Statistics Canada). This implies that in some geographic regions, the industry expanded in spite of the declining farm numbers, while in other regions the industry shrank in terms of reduction in total pig numbers.

In a wide range of studies discussing an industry's structural transformation and the factors contributing to it, technology adoption, market condition, and institutional factors such as policy implementation have been comprehensively identified, with most of them focusing on the national level analyses (e.g., Chilonda and Van Huylenbroeck, 2001; Happe et al., 2011). In the Canadian pig industry context, factors including mandatory country of origin labelling (COOL) in U.S., feed price changes, and technology improvements (e.g., Brisson, 2015; Rude and Unterschultz, 2013) have been extensively discussed. Although a multitude of economic factors have been identified for the analysis of changing farm structure, the impact of disease outbreaks on a livestock industry's structural change has rarely been documented. From an economic point of view, an investigation into the role of pig diseases in an industry's structural change is critical in the sense that the diseases have caused losses of billions of dollars to the Canadian pig industry (Office of Audit and Evaluation, 2015). As a greater proportion of farrow-to-finish farms reported seeing clinical signs of pig diseases than those with single-phase production (Young et al., 2010), the pig industry may have restructured their production and become more specialized to stop pathogen transmission among pigs at different life stages, especially from the older pigs to the younger and more susceptible piglets.

Our study adds a new dimension to research on structural change in livestock industry by examining the effects of animal diseases. The objective of this study is to identify the impacts of different economic factors on the sector's structural change at a national level and compare that

to the impacts across different provinces and CDs. Our focus is on investigating how pig diseases (including porcine reproductive respiratory syndrome (PRRS), porcine circovirus associated disease (PCVAD), and porcine epidemic diarrhea (PED)) have affected structural change in the Canadian pig industry while controlling for the effect of other key explanatory variables.

Our study contributes to the literature in two different ways. First, we contribute to the literature on structural change in the livestock industry by specifically examining how disease outbreaks might play a role in an industry's structural change. Among the studies that investigate how the livestock industry has evolved across years (e.g., Kazukauskas et al., 2013; Rude and Unterschultz, 2013), the literature that empirically investigates the impact of disease is still in its infancy. Second, we contribute to the literature on structural change in agriculture by first examining the structural change at a national level and comparing that to to the sector's different patterns of structural change across different regions. Through running a national level regression and a set of separate regressions that allow for the estimation of the same parameter across different types of structural change and provinces, our study may help identify whether examining the influences on structural change at a national level over- or under-estimates the impacts of key economic factors when the heterogeneous responses across the disaggregated CDs are considered.

The remainder of this paper is structured as follows. In section 2 some background on pig disease outbreaks in Canada and a brief overview of the relevant literature on structural change in agriculture are provided. In section 3 the data and the economic variables incorporated are described, and in section 4 the empirical methodology is discussed. Results and discussions are presented in section 5, while section 6 concludes.

2. Background

2.1 Pig Disease Outbreaks and Disease Prevention in Canada

The Canadian pig industry is currently plagued by three major pig diseases including PRRS, PCVAD, and PED. These three diseases are host specific and capable of infecting only pigs (Pitkin et al., 2009). PRRS, also called blue ear disease, is a contagious viral disease affecting all stages of pig production (Lunney and Chen, 2010). It was first recognized in the late 1980s in North America and is currently the most expensive endemic disease in the pig industry (Kappes and Faaberg, 2015; MacDougald, 2013). In Canada, the annual economic losses caused by PRRS were estimated to be CAD$130 million dollars (Mussell, 2010). Also known as post-weaning multi-systemic wasting syndrome (PMWS), PCVAD has long been a major threat to the Canadian pig industry since its initial detection in the province of Saskatchewan in the early 1990s (Harding, 2007). From 2004 through 2009, the economic impact of PCVAD on the Canadian and North American pork industries was estimated at $560 million dollars (eBiz Professionals Inc., 2010). PED, the most recent emerging pig disease in Canada, was first confirmed in a swine herd in southern Ontario in January 2014 (Kochhar, 2014). The initial detection of PED in the U.S. was in Iowa in May 2013 and it quickly spreads to 32 states by the end of September 2014 (ESFA Panel on Animal Health and Welfare, 2014). Because of PED's quick spread in the U.S. and the fact that Canada and the U.S. share extensive borders, PED quickly became a great concern for Canadian pig farmers. Since its first detection, PED has killed millions of pigs and cost the industry hundreds of $millions (CBCnews, 2016).

To control the introduction, persistence, and spread of pathogens, vaccination has been employed with the aim to develop an immunity to protect animals from clinical diseases. PRRS vaccine was first introduced to Canadian pig farmers in 1997, and two types of PRRS vaccine

are now commercially available in Canada (Canadian Food Inspection Agency). One is a modified-live virus vaccine and the other is a killed virus vaccine. PCVAD vaccine was first available in Canada in 2006 (Canadian Food Inspection Agency). It has been proved by many empirical studies as very effective in reducing the severity and incidence rate for pigs of different ages (Genzow et al., 2009; O'Neill et al., 2011). For PED, vaccines are predominant in Asian countries, but not in America (ESFA Panel on Animal Health and Welfare, 2014). So far, there's no commercial vaccine available in Canada to prevent PED. In 2015, the University of Saskatchewan's Vaccine and Infectious Disease Organization-International Vaccine Centre reported the development of a new vaccine that is a prophylactic aimed at preventing the disease, and field testing in Manitoba and Saskatchewan is underway (Vanraes, 2015).

By 2006 when the PCVAD vaccine was first available in Canada, Canadian pig producers requested aid and access to vaccines from the provincial and the national governments to help them control PCVAD outbreaks. In response to producers' requests for help, Agriculture and Agri-Food Canada (AAFC) announced a contribution of $76 million for the establishment of Control of Disease in the Hog Industry (CDHI) programming in 2007 to combat disease and enhance prosperity and stability in the pig sector (Office of Audit and Evaluation, 2015). This program was delivered in two phases. Phase 1 catered to the provision of financial assistance to pig farmers for the detection and mitigation of PCVAD (specifically for diagnosing tests and vaccination). In Phase 2, CDHI supported the development of an industry-led framework to achieve long-term health and stability of the Canadian pig herd through biosecurity, research and long-term disease risk management solutions. This national program was wound up in 2015.

2.2 Literature Review on Structural Change in Agriculture

Structural change can be defined in various ways as it consists of both organizational and institutional changes (Goddard et al., 1993). Among others, the most common definition refers to the long-term persistent change in the sectoral composition of the aggregate indicators for the economy (Syrquin, 2010). In the specific literature regarding structural change in agriculture, there are many alternatives to it and researchers often assess the changes in farm size, farm number, ownership, asset value, technology use, operating and marketing arrangements (Knutson et al., 1998; Welsh, 1996). Most of the emphasis has been placed on analyzing the changes in farm number and farm size (Ahearn et al., 2005; Ben Arfa et al., 2015; Stanton, 1993).

Numerous factors could affect farm structure adjustment. In general, the factors can be divided into internal and external determinants that would lead to different producer decisions on farm operation, which finally drive the sector to the current state. Internal factors are those pertaining to the characteristics of farms (e.g., farm type and land tenure arrangements) and farmers (e.g., demographic characteristics), while external factors refer to the situation in which pig farming occurs. In particular, external factors encompass market conditions (input and output price), institutional factors (government policies and the organization of agricultural extension system), biophysical factors (disease incident itself and the factors that determine their occurrences (e.g., weather)), and technology. This conceptual framework was adapted from various studies examining the decisive factors for structural change in agriculture (Breustedt and Glauben, 2007; Chilonda and Van Huylenbroeck, 2001; Happe et al., 2011).The purpose of listing the causative factors is to identify and analyze how they might be associated with structural change in agricultural production. Further variable descriptions and explanations on these causative factors are presented in section 3.2.

Because structural change can be defined in different ways, a broad range of methods has been applied to examine the forces behind an industry's structural change and to predict the trends of structural change in the future. For the purpose of the present study, we restrict our attention to the studies that define structural change as farm number and farm size changes. Of all relevant empirical methodologies used, they can be categorized into three methodological approaches: 1) Simulation models; 2) Markov models; and 3) Econometric models. The criterion for selecting the method are its suitability for data type and the model's explanatory power.

Simulation models aim to investigate the ex ante impacts of some economic factors such as policy changes on the industry's structural change by simulating farm size changes under different factor conditions (e.g., Viaggi et al., 2011). Markov models try to retrieve the specific patterns of structural change from historical experiences and to predict future adjustments by estimating the probability of farm movement from one state to another over time (e.g., Zimmermann et al., 2009). Econometric models, on the other hand, are used to assess the factors that actually affect change in farm structure, and such approaches can be carried out using either panel, time series, or cross section data (e.g., Ahearn et al., 2005; Goetz and Debertin, 2001). A large share of the literature falls within this third category. Another reason that econometric framework is preferred by researchers to deal with the analysis of farm structural change is it allows some sort of statistical validation of the results (Landi et al., 2016).

Among the studies addressing the impacts of different economic determinants on changes in farm structure, the vast majority of them conducted their analyses at the national level (e.g., Rude and Unterschultz, 2013), which may neglect heterogeneities in structural change in different regions (something to be examined in this study). Take the Canadian pig industry as an example, the U.S. COOL might have had especially significant impacts on pig operations in

Ontario and Manitoba because of their stronger integration with the US and the proximity of their pig farms to the border (Office of Audit and Evaluation, 2015). Some other studies analyzed structural change using individual farm accountancy data, however, these studies usually use producer survey results from a single year or two years and lack the ability to assess the trends of structural change across long time periods (e.g., Bustos et al., 2013). The rest of the studies employed regional level data (e.g, county or state level) to account for the regional heterogeneities and to cover longer time periods (e.g., Goetz and Debertin, 2001). Our study analyzes the Canadian pig industry's structural change at both the national level and the CD level to meet the objectives of: 1) assessing the Canadian pig industry's structural change at both the CD level and the national or country level to capture possible regional differences regarding the sector's structural change and to examine how regional changes deviate from the structural change at the national level; 2) examining how pig diseases have affected structural change in the industry while controlling for the effect of other key explanatory variables; and.

3. Data and Variable Description

3.1 Data Source

This study employs two datasets to describe pig operation (i.e., number of pigs and number of farms reporting pigs) in Canada covering the period from 1981 to 2016. The first one is a time series dataset (by year) constructed at the national level, while the second dataset is a panel one (by census year) constructed at the CD level. Both datasets are from Statistics Canada.

Farm characteristics (by CD and country level) regarding land tenure/ownership, operational arrangement, production type, computer usage in pig farming and farmer characteristics (by CD and country level) including operators' age, gender, and off-farm status

are census data obtained from Statistics Canada. Since census data are only available from Statistics Canada every five years, we assume farm and farmer characteristics are constant between census years for the national level analyses. The spatial boundary file is also from Statistics Canada for the calculation of land area (by CD and country level) (Statistics Canada, 2017b). Annually estimated Canadian population is collected from Statistics Canada (2017c). Human population by CD is extracted from the National Household Survey (NSH), which is also conducted every five years and is coincidental with the timing of the Census of Agriculture Survey, available through the CHASS Data Center from the University of Toronto. Land area and human population are collected for the derivation of human population density.

The number and location of the federally inspected slaughter plants for each year are available from the Market Analysis section of AAFC. For the location of the agricultural universities and veterinary institutions, we collect the data by browsing all of the research institutions (including all campuses) and extracting those that provide agricultural education and veterinary services for each year. Provided by the locations, distance variables (i.e., from the centroid of each CD to the nearest slaughter plant and agricultural university) are created using ESRI ArcGIS software version 10.3.

Prices of hogs (index 100 hogs), corn, and barley are of monthly frequency. These price series are collected from Statistics Canada and are available at the provincial and national level (Statistics Canada, 2017d). To remove the impacts of inflation, all price series are deflated to real levels using the Consumer Price Index (CPI),base year 2002 (Statistics Canada, 2017e) . Weather data including temperature is also of monthly frequency and is collected from the Department of Environmental and Natural Resources from Government of Canada (2017). Since empirical analyses are conducted at both the national and the CD levels, summaries of the data's level of

availability and variable definitions are presented in Table 1 and 2. Descriptive statistics are shown in Appendices.

3.2 Economic Variables

3.2.1 Internal Factors

Farm characteristics

1) *Availability of slaughter plants.* The availability of slaughter plants is an important determinant of farm structure. Farmers tend to benefit from buyer competition in their localities, and they are more likely to have larger herds given the lower transportation costs and higher profitability. As the plants becoming less available and the transportation costs becoming higher, farmers might choose to downsize their operation or even exit. The national model measures the availability of slaughter plants by the number of plants in Canada. For the CD level analyses, the distance (in kilometers) from the centroid of the CD to the nearest federally inspected slaughter plant is used to measure the availability.
2) *Farm number.* Number of farms in a region is often incorporated to assess the persistence of the industry's adjustment behavior (Glauben et al., 2006). Farm numbers could contribute to the industry's transition in two directions. On one hand, larger farms could be more efficient on a per unit cost of production basis. As farm numbers decreases, farm size might increase to realize scale economies (Duffy, 2009). On the other hand, some operators might choose to have smaller farms to meet the needs of niche and local markets (Maynard and Nault, 2005) and to compete against the larger operators who are able to achieve economies of scale. Niche is defined in our study as a production system that does not follow a standard commodity-based approach to pork production and handles differentiated pork products with

higher market prices (Gooch, 2007), and niche pork products could be organic or antibiotic free. For the relationship between farm size and farm numbers, no prior expectation is assumed as previous studies' results regarding the relationship have been ambiguous.

3) *Farm production type.* Given that specialization can lead to economies of scale with increased output and lower per unit production cost, farms with single-phase production tend to be bigger, and on the contrary, farrow-to-finish farms tend to be smaller. Another reason for farrow-to-finish operations tending to be smaller is they have a higher risk of being infected with disease (Young et al., 2010), and the high mortality rate resulting from disease outbreaks leads to smaller farm size. In our study, we measure the percentage of farrow-to-finish units in each CD and in Canada to investigate how the change in production type might have affected the structure of farms, and a negative relationship between the "farm production type" variable and farm size is expected.
4) *Family farm*[1]. Farm structure can also be affected by operational arrangement (family farm in our case). One contributor to this impact is the availability of successors. The family farm sector is highly related to intergenerational succession (Pesquin et al., 1999), and Gale (1994) pointed out succession played an important role in farm structure. When a successor was present, the operator would have an incentive to expand farms for next generation (Chilonda and Van Huylenbroeck, 2001). Another contributor is the improved labor-saving technologies, which have helped reduce the labor-to-capital ratio greatly. When a family farm is not willing to lay off members, they are somewhat forced to expand production. Such a situation is particularly relevant to farmers in Hutterite colonies in Canada. The percentage

[1] Family farm is defined as an operation where an individual or members of a family owns the majority of the corporation shares (Statistic Canada, 2014). Available at: https://www.statcan.gc.ca/ca-ra2006/gloss-eng.htm .

of family farms in each CD and in Canada is derived, and no expectation is assumed as farmers may face different situations regarding succession and family employment.

5) *Human population density.* Farmlands in more population-dense areas are usually subject to competition for alternative use. Due to the scarce land resources and the higher opportunity costs of land use in more population-dense regions, increases in population density are more likely to be associated with reduced farm size (Ricker-Gilbert et al., 2014). We employ population density per kilometer in each CD and in Canada to investigate the relationship.
6) *Land tenure/ownership.* Land tenure, indicating the extent of land ownership, has long been considered as a factor affecting farm structure (Daloğlu et al., 2014; Key and Roberts, 2003). Some studies suggested farmers may expand their operation by renting additional land (e.g., Gallacher, 2010). Other studies found operators who owned all their land expanded operation more than those that owned only a share of farmland (e.g., Key and Roberts, 2003). In our study, land tenure is measured by the percentage of farms that leased land from the government and/or other farm operators for pig farming in each CD and in Canada. No expectation is assumed for the sign of the coefficient on the "land tenure" variable.

Farmer characteristics

1) *Farmer's age.* The impact of farm operators' age on farm structure is ambiguous. One set of literature suggested younger farmers tended to be more business focused and were more likely to pursue long-term goals and to expand production (Kim et al., 2005). Another set of studies claimed farmer's age was positively related to the size of the farm (e.g., Sumner and Leiby, 1987) because age was usually associated with effective interest rates. Older farms are less risky and older farm operators tend to have more wealth. Therefore, the lower costs of

borrowing would encourage older farmers to run larger farms. In this study, age is measured by the farm operators' average age in each CD and in Canada.

2) *Farmer's gender*. Operator's gender can also be included as a contributor to the sector's structural change. Male and female farmers would make different decisions as they have different tendencies of risk taking. An overwhelming number of studies suggested men are more inclined to take risks than women are (Byrnes et al., 1999; Harris et al., 2006). For studies looking at the agricultural sector, Akimowicz et al (2013) found men tended to run larger farms in southwestern France. All else being equal, Ferjani et al (2015) found farms operated by a woman were more likely to exit than farms operated by a man. In our study, gender is captured by the percentage of male operators in every CD and in Canada.
3) *Farmer having no-off farm work.* The operator's off-farm work status also relates to farm structure change. When farmers spend more time working off-farm, they would have less time for on-farm working. These farmers tended not to expand production as labor may not be perfectly mobile. Key and Roberts (2003) confirmed this with the finding that operators who farmed as a primary occupation increased the size of their operation 8-20% more than did operators for whom farming was not their primary occupation. However, many researchers claimed that off-farm income could serve as a stabilizer for farm income volatility and may positively affect farm size (Glauben et al., 2006; Mishra and Goodwin, 1997). In the Canadian context, Kimhi (2000) found farmers' exit probability decreased with off-farm work. The percentage of farmers who had no off-farm work (by CD and Canada) is analyzed in this study.

3.2.2 External Factors

Market Conditions

The profitability of farming, usually measured by output and/or input prices, has been documented by many researchers as one of the causes of structural change (e.g., Breusted and Glauben, 2007, Dolev and Kimni, 2010). Because prices play a central role in production decision (Tomek and Kaiser, 2014), farmers have been shown to be very responsive to the changing prices by adjusting the size of operation. Evenson and Huffman (1997) found farmers would expand production in reaction to a decrease in input price. Barley and corn are the common feed grains for pigs in Western and Eastern Canada, respectively. In our study, market condition is depicted by the hog feed price ratio, and a high price feed ratio is expected to positively impact pig production. As the ratio increases, farm operators would earn more and might be more motivated to invest more money into their farm operation. Since the Census of Agriculture questionnaires often contain questions relating to the production status from January, one year before census year, to the data collection date[2], we take the monthly average of the price series during this time period. For the national level analyses, we take the annually average of the price series.

Institutional Factors

The institutional setting in which livestock farmers operate encompasses government intervention and the organization of agricultural extension system (e.g., access to information, veterinary and extension services) (Chilonda and Van Huylenbroeck, 2001). For domestic

[2] Census data collection date varies across census years. It was June 3rd for the census years of 1981 and 1986, June 4th for the year of 1991, May 14th for the year of 1996, May 15th for the year of 2001, May 16th for the year of 2011, and May 10th for the year of 2016.

programs taking the form of government payments, several empirical studies found high subsidy payments slowed down structural change in agriculture because they led to increased profitability that discouraged farmers from exiting or leaving from their status quo (e.g., Breustedt and Glauben, 2007). Foreign policies implemented by trading partners would also have influences on domestic farm operation. For example, Rude et al (2016) found evidence showing the mandatory COOL in the U.S. had significantly affected U.S./Canada hog trade flows.

The 2002 U.S. Farm Bill announced the provision of COOL that originally required retail-level labeling for pork by country of origin to begin in 2004 (Jones et al., 2009), and the removal of COOL was in March, 2016 (AMS-LPS-16-0002). This study examines the impact of U.S. COOL by creating time dummies covering the period of its implementation. For the national level analyses, the "COOL" variable takes the value of one from 2004 to 2016, and zero otherwise. For the CD level analyses, the "COOL" variable takes the value of one from 2006 census to 2016 census, and zero otherwise. In terms of the impact of COOL, it made Canadian pigs less attractive to the U.S. buyers and forced a considerable number of pigs to remain in Canada (Economics Research Group-University of Guelph, 2010), and this would lead to a positive impact. However, the impact could be also negative as farmers may expect the possibility of future trade to be very low. As a result, they reduced the size of their farms. There might exist a peculiarity for Manitoba. From 2006 to 2015, Manitoba implemented a hog barn moratorium for environmental reasons (Manitoba Agriculture, 2008; Manitoba Pork, 2015), and the presence of the hog barn moratorium may offset or exaggerate the impact of the U.S. COOL.

For the organization of the agricultural extension system, it may be related to farmers' access to know-how, consulting service, and veterinary personnel. The institutional environment in which the farmers operate is an important explanatory variable as it sets transaction costs and

affects the availability and quality of the service (Chilonda and Van Huylenbroeck, 2001). For example, Ahearn et al (2005) detected a positive relationship between extension and farm size. Gallacher (2010) also detected farm size is correlated to access to information-providers. The availability of extension service and veterinary personnel is captured by the number of research institutions in each year for the national level analysis. For the CD level analyses, its availability is measured by the travel distance (in kilometers) from the centroid of a CD to the nearest research institution. We expect the availability of agricultural extension system to positively affect farm structure.

Biophysical Factors

Biophysical factors consist of disease incident itself and the factors that determine their occurrence (e.g., weather) (Putt et al., 1987). For animal diseases themselves, their occurrences would negatively affect farm production and incur extra costs for disease management and prevention. When diseases are present, farm operators need to adjust their farm structure to control the spread of disease and to absorb the additional production costs. In our study, the impacts of PRRS and PCVAD outbreaks are captured by time dummies. From the Fall of 2003 to the Winter of 2006, both Animal Health Laboratory (AHL) at the University of Guelph (Guelph, Ontario) and the Ministère de l'Agriculture, des Pêcheries et de l'Alimentation (MAPAQ, Quebec) detected an increase in the frequency of reported lesions associated with PRRS (Carman et al, 2011; MAPAQ). For PCVAD, concurrent with a shift of genotype (Poljak et al., 2010), dramatic increase in its outbreaks occurred in the period from the Fall of 2004 to the Winter of 2008. The reason that we suddenly had frequent and severe problems during the period of 2003 to 2008 is we were dealing with new and more virulent isolates of the viruses

(Carman et al, 2011; MAPAQ). In our study, we create a dummy variable, which takes the value of one from 2003 to 2008 and zero otherwise to examine the impacts of PRRS and PCVAD outbreaks on the industry's structural change at the national level. The CD level regressions employ a time dummy taking the value of one for 2006 census and zero otherwise.

For PED, since it was first detected in January 2014, we create a time dummy, which takes the value of one from 2014 to 2016 and zero otherwise, to denote the presence of PED on the Canadian pig farms. For the CD level analyses, we create another dummy, which takes the values of one for 2016 census. Since PED has been only found in the provinces of Ontario, Quebec, and Manitoba (Alberta Pork, 2016), this variable is only included in the regressions of these three provinces. Disease variables are expected to negatively affect farm structure given the increased mortality and morbidity rates.

For the determinants of disease occurrences, one important determinant is climate factor. PRRS virus survival is optimal when temperature is cold and when ultra-violet light exposure is low, and pathogen would be inactivated in high temperature (Albina, 1997). The "Temperature range" variable (i.e. the subtraction of lowest temperature from the highest one) is created with the examination of all climate stations in Canada. Western Canada is known for its extreme weather, we thus expect no relationship or a positive one as pathogen would not be able to survive if the temperature is too extreme. For Eastern Canada, we expect a negative relationship between the "temperature range" variable and farm size.

Technology

Another determinant that has been suggested in many studies as an explanatory factor for structural change is technology, and these studies have confirmed the positive relationship

between farm size and technology innovation (e.g., Chand et al., 2011; Sheng et al., 2015). New technologies have been pushing considerable changes upon agriculture, because they help farm operators realize scale economies with increased output and significant decreases in per unit production costs (Chavas, 2001). This scale increasing effect facilitates structural transformation in agriculture characterized by increasing farm size and declining farm number (Reimund et al., 1981). Instead of using a time dummy capturing the trends of technology improvement, our study uses the percentage of computer usage for pig farming in each CD and in Canada as the measure. A positive relationship between the "technology" variable and farm size is expected.

4. Empirical Methodology

To investigate whether the influences on structural change at the national level over- or under-estimates the impacts of key economic factors when the heterogeneous responses across the disaggregated CDs are considered, we proceed in two steps. First, an ordinary least square (OLS) regression of Canadian average pig farm size on various economic factors discussed in section 3.2 is estimated to investigate how those factors affect the industry's structural change over the period from 1981 to 2016 . Second, we estimate a set of random effects generalized least squares (GLS) regressions to investigate to what extent the different factors affect the industry's structural change across different patterns of structural change and different provinces. Comparisons are made to indicate how the impacts of the economic pressures vary at the regional level and the national level.

In our study, structural change is examined from the standpoint of farm size (i.e. average number of pigs per farm) change. As illustrated in section 3.2, farm characteristics (F), farmer

characteristics (FM), market conditions (M), institutional factors (I), biophysical factors (B), and technology (T) all have the possibility to play a role in the industry's structural change.

4.1 National Level Analysis

We first estimate an OLS regression model to examine what factors have affected the Canadian pig industry's structural change, and the equation used to examine the relationships between farm structure and various economic factors is:

$$Y_t = \delta + \gamma_1 Y_{t-1} + \gamma_2 F_t + \gamma_3 F_t + \gamma_4 M_t + \gamma_5 I_t + \gamma_6 B_t + \gamma_7 T_t + \varphi_t \quad (1)$$

where F_t, FM_t, M_t, I_t, B_t, and T_t are defined above, Y_t is the national average pig farm size in the t^{th} year, term δ is the constant, terms γ_1 - γ_7 are the explanatory variables' coefficients, and φ_t is the residual that captures the unobserved characteristics affecting farm structure.

4.2 Census Division Level Analysis

Next, we conduct the empirical analyses at the CD level and employ the CD's average farm size as the measure of farm structure. The same explanatory variables employed in the national level analysis are used in the CD level analyses to detect the presence of estimation deviation. The effects of various factors on farm structural change are estimated by random effects GLS model, and the equation is specified as:

$$y_{it} = \alpha + \beta_1 y_{it-1} + \beta_2 F_{it} + \beta_3 FM_{it} + \beta_4 M_{it} + \beta_5 I_{it} + \beta_6 B_{it} + \beta_7 T_{it} + \mu_i + \varepsilon_{it} \quad (2)$$

where term α is a constant, terms β_1- β_7 are the coefficients of the independent variables, term μ_i is the between-CDs error, and term ε_{it} is the within-CDs error.

When using geographical data to estimate regression models, the residuals tend to be spatially autocorrelated. Spatial autocorrelation is addressed by employing a clustering approach, which assumes the residuals are correlated within a certain geographic cluster but uncorrelated across the clusters. Census agricultural regions (CAR), which are composed of groups of adjacent CDs (Statistics Canada, 2015), are used in our study to define clusters.

Because there exist heterogeneity in the types of structural change in different CDs, we divide CDs into two groups to investigate how various factors contribute to the different types of structural change in the Canadian pig industry. The first group consists of CDs that underwent structural change with a decrease in pig farm number and an increase in total pig number over the period from 1981 to 2016 (type 1 structural change), and the second group includes CDs that experienced structural change with decreases in both pig farm number and total pig number over the same time period (type 2 structural change).

In agricultural economics, regional dummies are usually incorporated to depict the impact of different regions. Instead of using provincial dummies to control for the factors that are common within the same province, our study conducts the empirical analyses for each province separately. The reason, provided by Weiss (2006), claims that the impact of a certain independent variable on structural change depends not only on the value of the variable itself, but also on the level of other explanatory variables. Such an explanation also confirms the necessity of separately analyzing different types of structural change. A disadvantage associated with running regressions provincially is a waste of econometric estimation efficiency as we now have fewer data points for each regression.

Another reason for doing the empirical analyses provincially is the three pig diseases examined in our study are not reportable or immediately notifiable diseases in Canada. Because

of this, PRRS, PCVAD, and PED are managed by each province with different codes of practice for the care and handling of pigs. In addition, pig disease outbreaks are relatively more common in Eastern Canada. The reasons that pig diseases are more prevalent in Eastern Canada include: 1) the diversity of the disease genotypes is more pronounced in the Eastern provinces (Brar et al., 2011; Brar et al., 2015); and 2) pig farming in the Eastern provinces is more geographically concentrated with higher pig density, which increases the possibility of pig infection (Dewey, 2000). Thus, it would be more appropriate and informative to examine how pig diseases have affected farm structural change in each province.

All regression models are estimated using Stata 14 statistical software. Given the explanatory variables employed in our study are of different units of measurement, standardized coefficients are derived after running the regressions to account for the differences in units of measurement of the explanatory variables. Post-estimation, we conduct several tests for heteroscedasticity and autocorrelation to ensure the adequacy of the models.

5. Results and Discussion

In this section, two sets of results are reported. The first set of results presents how various economic factors affect the national level farm structural change. The second set of results describes how those same economic variables may contribute to the different patterns of structural change across regions.

5.1 National Level Analysis

The estimation results for the impacts of various economic factors on the nationally average farm size are presented in Table 3. Lagged farm size explains most of the variation in the

current farm structure. The disease variables suggest pig diseases did negatively affect farm structure. During the period with dramatic increase in PRRS and PCVAD cases, each farm on average raised 1 fewer pig. With the presence of PED, each farm on average raised 45 fewer pigs. Such results are not surprising as the high mortality and morbidity rates resulting from disease outbreaks would lead to smaller farm size. Surprisingly, we find the U.S. COOL has no significant impact on national farm size. In addition, we find no evidence showing hog feed price ratio affects farm structure change. The insignificance of hog feed price ratio may be explained by the increasing use of contracts because they may decouple hog supply from output and input prices (McEwan and Duffy, 2006). Agriculture and Agri-Food Canada (2005) reported about 90% of pigs are sold using marketing contracts and 10% through the spot market. In terms of other external factors, as expected, technology improvement positively contributed to farm expansion. The availability of agricultural extension has had a positive impact on farm size due to the lower transaction costs and higher quality of services associated. A positive relationship between the "temperature range" variable and farm size is detected.

In addition to the external factors, internal ones including farm and farmer characteristics are also found to have significant impacts on farm structure. The regression results show the availability of slaughter plants does positively influence farm structure change, and this may be attributable to the lower transportation costs associated with the buyer competition in the localities. The negative relationship between the "farm production type" variable and farm size implies that farrow-to-finish farms tend to be smaller. One reason for farrow-to-finish operations tending to be smaller is provided by Young et al (2010) claiming farrow-to-finish farms have a higher risk of being infected with disease, especially from the older pigs to the younger and more susceptible piglets. The high mortality rate resulting from disease outbreaks further leads to

smaller farm size. Older farmers and farmers who have no off-farm work tend to expand their pig farms. On the other hand, farmers who rent additional land for pig farming are found to be less likely to expand their farms. No relationship is detected between farm size and number of farms within the region. As mentioned earlier, farm number could contribute to the industry's transition in two different directions. One is a negative contribution to realizing scale economies, and another is a positive one to meet the needs of high-priced niche markets. These two contradictory effects might offset each other and lead to the coefficient's insignificance.

After running the regression, standardized coefficients are derived and also listed in Table 3. A one standard deviation increase in the availability of agricultural extension would lead to 0.499 standard deviation increase in the average farm size. The other variables listed in the table can also be explained similarly. Among the determinants examined, we find lagged farm played the most important role in the determination of current farm size, followed by technology and farm production type. Technology innovation is found to have positively influenced farm structure, while a negative relationship between the "farm production type" variable and farm structure is detected

5.2 Census Division Level Analysis

5.2.1 Western Canada

The estimation results for the province of British Columbia (BC), Alberta (AB), Saskatchewan (SK), and Manitoba (MB) are presented in Table 4-7, accordingly. All CDs in BC experienced type 2 structural change. Five CDs in MB experienced type 2 structural change, so this study make empirical analyses for MB on the CDs that underwent type 1 structural change. For the provinces of AB and SK, the left column presents the results for CDs that underwent type

1 structural change, and the right column displays the results for CDs that went through type 2 structural change.

The regression results show farm size in AB, SK, and MB was not affected by the dramatic increase in PRRS and PCVAD outbreak during the period from 2003 to 2006. This is unsurprising as Batista (2007) also stated fewer disease incidents were seen in the Canadian prairies. However, farm size in BC was negatively impacted. On average, each pig farm in BC raised 48 fewer pigs.

The U.S. COOL is found to have had no impact on the size of farms in AB and SK on the CDs that experienced type 2 structural change. For farms in the CDs that are categorized as having type 1 structural change, we find farm size increased when COOL was in place. This could be attributable to the reduced export of Canadian pigs to the U.S. market. The insignificance of the "COOL" variable for the MB regression might be explained by the presence of hog moratorium, which was implemented for environmental reasons from 2006 to 2015. If there had been no restrictions on hog barn expansion, we might have expected COOL to have had a positive impact on farm size in MB.

The hog feed price ratio has had positively affected farm size. Technology, measured by the extent of computer usage for pig farming, has facilitated farm expansion, and it is shown CDs that underwent type 1 structural change were affected more by technology improvement. This is unsurprising as the CDs that are categorized as having type 1 structural change are dominated by large pig farms with mean farm size being 1433 head per farm, and these large farms have great potential to take advantage of technology innovation. For the CDs that are categorized as having type 2 structural change, their mean farm size is 262 head per farm. The coefficients on the

"temperature range" variable are either insignificant or possessing positive signs. Such results confirmed our expectation that extreme temperature would not negatively affect farm size

For internal factors, we find being located a further distance from the slaughter plant and agricultural extension (i.e., the unavailability of slaughter plants and agricultural extension) is found to have discouraged farm expansion, which could be attributed to the higher transportation costs and the unavailability of extension advice. For those who live nearby research institutions or have college/university students working on their farms, they may know more about technology and gain disease treatment information more quickly. A negative relationship between human population density and farm size is found, given the higher opportunity costs of land use and possible negative feedback from people living in population dense areas. We do not find any evidence showing family farms' tendencies for farm expansion in Western Canada. A positive relationship between farm size and farm number is detected in the BC regression, while no relationship is detected for the rest of the Western provinces.

Farm size path dependency is also detected with the past farm size explaining most of the variation in the current farm size. As expected, a negative relationship between the "farm production type" variable and farm size is detected, and this implies that farrow-to-finish farmers are more likely to have smaller farms. In terms of the effects of farmer characteristics, male farmers in BC and AB are found to be more likely to expand farm operation. In the province of SK, female operators are found to be more likely to expand their farms. In general, older farmers in Western Canada seem to be more likely to operate larger pig farms.

5.2.2 Eastern Canada

The estimation results for the province of Ontario (ON) and Quebec (QC) are shown in Table 8 and 9, respectively. For the impact of disease outbreaks, structure of the farms located in the CDs that underwent type 1 structural change were affected more by PRRS and PCVAD outbreak, while the structure of the farms located in the CDs that underwent type 2 structural change were affected more by PED outbreak. We find the U.S. COOL did affect farm structure in ON. For the CDs that underwent type 1 structural change, each farm on average raised 271 more pigs. The undesirability of Canadian pigs in the U.S. market forced a great number of pigs to be raised and slaughtered in Canada. For the CDs that went through type 2 structural change, however, we found each farm on average raised 66 fewer pigs. With the presence of COOL, some farmers possibly had low expectation on future trade, so they chose to reduce farm size. For the province of QC, the U.S. COOL has had no impacts on the structure of farms. Unlike ON and MB which have specialized in exports of pigs that end up being slaughtered in the U.S., QC is specialized in pork exports (Jeddy, 2011), and this may explain the differences in COOL impacts. Technology adoption has encouraged farm operators to expand their production.

Like Western Canada, being located far away from the slaughter plant and agricultural extension has discouraged farm expansion. A negative relationship between farm size and the "farm production type" variable is present. The coefficients on the "human population density" variables possess negative signs and imply farm size have decreased in more population dense areas. Farms located in the CDs that underwent type 1 structural change were more affected by technology innovation. Unlike Western Canada, a negative relationship between the "temperature range" variable and farm size is detected, and this is consistent with our expectation as pathogen survival is optimal when temperature is cold but not too extreme

(Albina, 1997). For the impact of hog feed price ratio, we find farmers in the Eastern provinces were relatively not price sensitive. Younger and male pig farmers in ON seemed to be more likely to have larger pig farms, while it is the older farmers in QC who tended to run larger farms. In QC, family farms are detected to be more likely to expand their production.

The derived standardized coefficients indicate the current farm structure has been more significantly and positively affected by past farm performance (i.e. lagged farm size). In terms of other internal factors, farm operator's age and production type also have had large roles in farm size change. For external determinants, technology and disease outbreaks are found to have great impacts on farm structure adjustment. In particular, technology innovation has encouraged farm expansion, while disease outbreaks have discouraged the expansion of farm operation.

The estimation results indicate pig diseases did affect the Canadian pig industry's structural change. For the CDs that went through type 1 structural change, we find during the period reporting dramatic increase in PRRS and PCVAD outbreak incidents, only farm structure in the Eastern provinces was severely affected. In terms of those that underwent type 2 structural change, only BC from Western Canada was affected. Eastern Canada was significantly affected by PED outbreaks. The reason that the CDs underwent type 1 structural change were affected more by PRRS and PCVAD is due to the strong connection between farm size and these two diseases. The CDs that are categorized as having type 1 structural change are denominated by large pig farms, which are associated with higher pig densities and are more likely to get infected with PRRS and PCVAD. The reason that CDs experienced type 2 structural change were more affected by PED is these divisions are dominated by relatively small pig farms. Unlike PRRS and PCVAD cases, the connection between farm size and PED prevalence is tenuous. Rather, it's the intermediaries such as birds who play a significant role in PED transmission (McWilliams,

2014). With small farms having relatively poor biosecurity levels (e.g., no screens installed), they are at very high risks of getting infected. Moreover, our results suggest pig diseases have played a more significant role in the structure of farms in Eastern Canada, which is in accordance with previous literature claiming pig diseases are more prevalent in Eastern provinces (e.g., Dewey, 2000; Brar et al., 2015).

6. Conclusion

The results of our study provide useful evidence of the impact of pig diseases on the Canadian pig industry's structural change. Both the national level and the CD level analyses suggest pig disease outbreaks did negatively affect the Canadian pig industry's structural change. However, not every region was negatively impacted. In particular, we find pig diseases have played a more significant role in Eastern Canada. During the period with dramatic increases in PRRS and PCAVD outbreaks (2003-2008), pig farms located in the CDs that are categorized as having type 1 structural change in ON raised on average 232 fewer head of pigs per farm. For farms in QC, each farm on average raised 167 fewer head of pigs. In the province of British Columbia, the average farm size decrease was 48 head per farm. Speaking of the impact of the PED outbreak (2014-2016), farms located in CDs that are categorized as having type 2 structural change in ON raised on average 33 fewer head per farm, while farms located in CDs that are categorized as having type 2 structural change in QC raised on average 1,006 fewer head per farm.

Heterogeneity in structural change across different regions does exist, and the comparison of the scenarios regarding structural change at the national and the CD levels shows a strong difference in the determinants of farm structure change. When we conduct the empirical analyses

at the national level, the results exhibit significant underestimations of the economic factors, as suggested by the standardized coefficients. Some economic variables such as the U.S. COOL were detected as an important determinant of farm structure adjustment at the CD level, but the same variable is found to have had no impact on farm structural change at the national level. Farm and farmer characteristics such as farmer's age and farm production type are included as control variables in the model specification, and we also detect their heterogeneous influences on farm structure change with different levels of analyses.

Given the negative impact of pig diseases on the Canadian pig industry's structural change, our findings demonstrate the potential of government programs to assuage the negative impact. Instead of promoting a national program, which can neglect heterogeneity in the situations faced by the pig farmers in different regions, regional programs are highly recommended with the incorporation of regional specific characteristics into policy development to prevent and control the spread of pig diseases. In addition, we encourage the establishment of programs with the aim to improve biosecurity levels, especially in the regions that experienced type 2 structural change, as those regions are dominated by small pig farms and our national level results suggest PED has great impacts on farm structure change.

By comparing the impacts of various economic factors on the sector's structural change across different regions at the CD level and on the industry's structural change at a national level, we find one-size-fits-all programs are not appropriate due to the heterogeneity in the pig sector. Farm transition policies and assistance programs should be developed to align with the values and needs of different farm and farmer groups. The findings of this study imply the necessity of investigating the industry's structural change with the differentiation of types of structural change and regions to have a better understanding on how various factors affect farm

structure change. In our case, analyses at the disaggregated level easily help us identify the regions where pig diseases have been important and could assist both governments and pig producers to make policies and decisions that are pertinent to their situations.

Several limitations are associated with the present study. The first is in utilizing time dummies to examine the impact of pig diseases on the Canadian pig industry's structural change. Time dummies could only help gauge farm size changes for the period with dramatic increases in disease incidents, but not for the rest of the time. More detailed data on disease evolution are needed to examine how disease outbreaks have influenced farm structure across time and to improve the estimation of the effects. In addition, the timing of vaccines development and the timing of government support for vaccine delivery could also be included. Second, due to the data protection rules from Statistics Canada, disaggregated level analyses were conducted at the CD level, which fails to account for the farm specific differences. Moreover, reduced estimation efficiency is resulted as our study segregates the types of structural change and the provinces to detect heterogeneity. If farm accountancy level data is available, future study could be conducted using this new dataset with improved estimation efficiency. At last, factors such as pig disease outbreaks in the U.S. should also be included as determinants as Canada and the U.S. share borders and have extensive trade relationships.

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Table 1. Data Definition (National Level)

Variables	Definition
Dependent variable	
Farm Size (C)	The nation's average number of pigs per farm
Independent variable	
Availability of agricultural extension (C)	The number of research institutions
Availability of slaughter plant (C)	The number of slaughter plants
COOL implementation (D)	Time dummy indicating the implementation of U.S. COOL
Disease variables	
Dramatic increase in PRRS and outbreak (D)	Time dummy indicating the dramatic increase in PRRS and PCVAD cases
PED outbreak (D)	Time dummy indicating the presence of PED
Family farm (C)	% of family farms in Canada
Farm number (C)	Number of pig farms in Canada (in 000's)
Farm production type (C)	% of farrow-to-finish-units in Canada
Farmer having no off-farm work (C)	% of farmers who have no off-farm work in Canada
Farmer's age (C)	The average age of the farmers in Canada
Farmer's gender (C)	% of male operators in Canada
Hog feed price ratio (C)	The ratio of the market hog price in dollars per 100 pounds to the price of feed per bushel
Human population density (C)	Population density per square kilometer in Canada
Lagged farm size (C)	Last census year's average number of pigs per farm in Canada
Land tenure/ownership (C)	% of farms that rent land from government or others for hog farming in Canada
Technology (C)	% of farms using computers for farm business in Canada
Temperature range (C)	The range of temperature (in °C) in Canada (all climate stations considered)

Table 2. Data Definition and Level of Availability (Census Division Level)

Variables	Definition
Provincial level data	
COOL implementation (D)	Time dummy indicating the implementation of U.S. COOL
Disease variables	
Dramatic increase in PRRS and outbreak (D)	Time dummy indicating the dramatic increase in PRRS and PCVAD cases
PED outbreak (D)	Time dummy indicating the presence of PED
Hog feed price ratio (C)	The ratio of the market hog price in dollars per 100 pounds to the price of feed per bushel
Census Division level data	
Dependent variable	
Farm Size (C)	The census division (CD)'s average number of pigs per farm
Independent variable	
Availability of agricultural extension (C)	Distance (in km) from the centroid of the CD to the nearest research institution
Availability of slaughter plant (C)	Distance (in km) from the centroid of the CD to the nearest slaughter plant
Family farm (C)	% of family farms within the CD
Farm number (C)	Number of pig farms within the CD
Farm production type (C)	% of farrow-to-finish-units within the CD
Farmer having no off-farm work (C)	% of farmers who have no off-farm work within the CD
Farmer's age (C)	The average age of the farmers within the CD
Farmer's gender (C)	% of male operators within the CD
Human population density (C)	Population density per square kilometer within the CD
Lagged farm size (C)	Last census year’s average number of pigs per farm within CD
Land tenure/ownership (C)	% of farms that rent land from government or others for hog farming within the CD
Technology (C)	% of farms using computers in farm business within the CD
Temperature range (C)	The range of temperature (in °C) within the CD (all climate stations considered)

Table 3. Estimates of the Impacts of Various Factors on Farm Size, Canada.

	Coeff	Std.dev	SC
Availability of agricultural extension (C)	0.499***	112.079	-0.003***
Availability of slaughter plant (C)	0.959	3.659	0.013
COOL implementation (D)	10.661	45.222	0.009
Disease variables			
Dramatic increase in pig disease outbreak (D)	-0.602*	30.175	0.001*
PED outbreak (D)	-45.43*	40.841	-0.021*
Family farm (C)	-0.947**	7.706	-0.031**
Farm number (C)	-3.348	4.683	-0.084
Farm production type (C)	-1.464***	2.83	-0.044***
Farmer having no off-farm work (C)	0.427**	6.404	0.003**
Farmer's age (C)	3.302*	3.302	0.015*
Farmer's gender (C)	-2.656	6.223	-0.126
Hog feed price ratio (C)	-0.166	1.027	-0.004
Human population density (C)	82.282	667.827	0.051
Lagged farm size (C)	0.874***	0.145	0.859***
Land tenure/ownership (C)	-39.388	151.237	-0.04
Technology (C)	2.097*	9.846	0.095*
Temperature range (C)	2.371*	1.746	0.016*
Constant	437.193	503.502	
R_Squared		0.9	

Table 4. Estimates of the Impacts of Various Factors on Farm Size, British Columbia.

	Type 2 structural change		
	Coeff	Std. dev	SC
Provincial level data			
COOL implementation (D)	77.262*	52.017	0.182*
Dramatic increase in PRRS and outbreak (D)	-48.371*	33.912	-0.077*
Hog feed price ratio (C)	3.326*	2.376	0.184*
Census Division level data			
Availability of agricultural extension (0.5≤ d <1km) (D)	-7.249*	4.594	-0.075*
Availability of slaughter plant (d ≥ 5km) (D)	3.692	21.579	0.038
Availability of slaughter plant (4 ≤ d < 5km) (D)	-4.115	17.225	-0.007
Availability of slaughter plant (3 ≤ d < 4km) (D)	-19.175	21.978	-0.033
Availability of slaughter plant ((2 ≤ d < 3km) (D)	-22.826	18.025	-0.038
Availability of slaughter plant (1 ≤ d < 2km) (D)	-29.840*	17.983	-0.061*
Family farm (C)	0.422	0.648	0.029
Farm number (C)	0.432***	0.104	0.123***
Farm production type (C)	0.464*	0.243	0.057*
Farmer having no off-farm work (C)	0.02	0.09	0.004
Farmer's age (age ≥ 50) (D)	10.709*	6.482	0.021*
Farmer's age (45≤ age <50) (D)	-17	16.474	-0.039
Farmer's gender (C)	0.184*	0.127	0.028*
Human population density (C)	-0.119***	0.027	-0.086***
Lagged farm size	0.932***	0.027	0.883***
Land tenure/ownership (C)	0.087	0.305	0.005
Technology (C)	0.032	0.297	0.005
Temperature range (C)	-0.608	0.881	-0.037
Constant	-125.952	104.156	
R_Squared		0.9	

Table 5. Estimates of the Impacts of Various Factors on Farm Size, Alberta.

	Type 1 structural change			Type 2 structural change		
	Coeff	Std. dev	SC	Coeff	Std. dev	SC
Provincial level data						
COOL implementation (D)	1543.946*	944.529	0.492*	160.745	278.801	0.162
Dramatic increase in PRRS and outbreak (D)	-634.278	588.835	-0.138	107.362	259.202	0.074
Hog feed price ratio (C)	20.404*	12.967	0.169*	3.281	2.538	0.086
Census Division level data						
Availability of agricultural extension (d ≥ 2km) (D)	-998.737*	574.135	-0.23*	135.761	348.53	0.099
Availability of agricultural extension (1≤ d < 2km) (D)	-57.155	185.514	-0.019	-454.727*	244.959	-0.427*
Availability of slaughter plant (C)	-200.584***	52.637	-0.114***			
Availability of slaughter plant (d ≥3km) (D)				114.968	118.796	0.079
Availability of slaughter plant (2.5≤ d < 3km) (D)				-587.584	622.674	-0.449
Availability of slaughter plant (2≤ d <2.5km) (D)				-263.978***	73.519	-0.17***
Availability of slaughter plant (1 .5≤ d <2km) (D)				-28.166	209.056	-0.013
Availability of slaughter plant (1≤ d < 1.5km) (D)				100.727	93.038	0.086
Availability of slaughter plant (0 .5≤ d <1km) (D)				-4.657	172.719	-0.004
Family farm (C)	-4.932	5.805	-0.065	0.054	5.16	0.002
Farm number (C)	1.323	1.274	0.197	0.001	0.059	0.001
Farm production type (C)	7.335	11.596	0.092	0.335	3.282	0.005
Farmer having no off-farm work (C)	-5.835	5.328	-0.086	8.813	9.548	2.819
Farmer's age (C)	113.984***	16.571	0.375***	-13.396**	5.65	-0.548**
Farmer's gender (C)	1.93	3.456	0.032	2.479***	0.779	0.127***
Human population density (C)				-5.584	4.483	-0.376
Human population density (p ≥4) (D)	-236.725	317.16	-0.057			
Human population density (2≤ p <4) (D)	-412.895	319.335	-0.135			
Human population density (1< p <2) (D)	-292.004	298.545	-0.064			
Lagged farm size	-0.028	0.129	-0.028	0.379**	0.153	0.371**
Land tenure/ownership (C)	1.81	3.387	0.02	-5.599	3.934	-0.194
Technology (C)	25.793***	6.712	0.554***	6.214***	2.067	0.241***
Temperature range (C)	22.333***	4.551	0.064***	-6.461	19.083	-0.421
Constant	-6545.872	2325.416		723.374	127.777	
R_Squared		0.9			0.8	

Table 6. Estimates of the Impacts of Various Factors on Farm Size, Saskatchewan.

	Type 1 structural change			Type 2 structural change		
	Coeff	Std. dev	SC	Coeff	Std. dev	SC
Provincial level data						
COOL implementation (D)	385.93	881.532	0.131	31.166	20.333	0.045
Dramatic increase in PRRS and outbreak (D)	636.986	1093.696	0.143	127.253	197.694	0.136
Hog feed price ratio (C)	11.533	14.169	0.109	5.591***	0.018	0.217***
Census Division level data						
Availability of agricultural extension (C)				130.520***	25.822	0.205***
Availability of agricultural extension (d ≥1km) (D)	-733.327**	287.413	-0.233**			
Availability of agricultural extension (0.5≤ d <1km) (D)	401.5	275.104	0.139			
Availability of slaughter plant (C)	43.713	92.23	0.027	-14.441	20.441	-0.034
Family farm (C)	-2.727	10.953	-0.033	-0.383	3.499	-0.02
Farm number (C)	-1.463	1.49	-0.177	0.058	0.136	0.049
Farm production type (C)	8.505	6.137	0.117	-2.638***	0.242	0.171***
Farmer having no off-farm work (C)	0.181	2.991	0.004	2.375*	1.607	0.13*
Farmer's age (C)	69.854**	27.316	0.347**	4.277	0.032	0.112
Farmer's gender (C)	-7.733***	2.648	-0.155***	0.643	0.322	0.056
Human population density (C)				-0.116**	0.049	-0.025**
Human population density (2≤ p <2.5) (D)	641.687	566.672	0.2			
Human population density (1.5≤ p <2) (D)	-672.311***	217.326	-0.205***			
Human population density (1≤ p <1.5) (D)	-426.829**	209.614	-0.144**			
Lagged farm size	0.241**	0.106	0.225**	0.733***	0.04	0.687***
Land tenure/ownership (C)	2.512	5.94	0.036	-2.736***	0.984	-0.182***
Technology (C)	19.883***	7.576	0.486***	3.439***	0.07	0.329***
Temperature range (C)	37.261	58.925	0.122	4.163***	1.575	1.009***
Constant	-6328.652	4639.631		-1048.073	276.361	
R_Squared		0.8			0.8	

Table 7. Estimates of the Impacts of Various Factors on Farm Size, Manitoba.

	Type 1 structural change		
	Coeff	Std. dev	SC
Provincial level data			
COOL implementation (D)	-166.248	366.995	-0.038
Disease variables			
Dramatic increase in PRRS and outbreak (D)	263.929	474.231	0.055
PED outbreak (D)	-1245.513*	938.194	-0.2*
Hog feed price ratio (C)	14.104*	10.531	0.082*
Census Division level data			
Availability of agricultural extension (d ≥1.5km) (D)	-157.26	187.945	-0.037
Availability of agricultural extension (1≤ d <1.5km) (D)	-223.315	218.832	-0.043
Availability of slaughter plant (C)	179.168	162.213	0.044
Family farm (C)	0.239	7.767	0.002
Farm number (C)	0.445	0.42	0.027
Farm production type (C)	-11.046*	7.053	-0.09*
Farmer having no off-farm work (C)	4.372	4.861	0.034
Farmer's age (C)	40.354***	14.077	0.092***
Farmer's gender (C)	0.926	2.344	0.011
Human population density (D) (d ≥ 10)	-26.155	324.104	-0.005
Human population density (D) (3 ≤ p < 10)	-91.92	159.817	-0.02
Human population density (D) (2 ≤ p < 3)	-104.566	155.517	-0.022
Lagged farm size	1.255***	0.291	0.97***
Land tenure/ownership (C)	-2.725	3.564	-0.019
Technology (C)	8.287*	4.87	0.135*
Temperature range (C)	17.696	13.927	0.058
Constant	-3484.285	1634.7	
R_Squared		0.9	

Table 8. Estimates of the Impacts of Various Factors on Farm Size, Ontario.

	Type 1 structural change			Type 2 structural change		
	Coeff	Std. dev	SC	Coeff	Std. dev	SC
Provincial level data						
COOL implementation (D)	271.158**	123.335	0.177**	-65.874*	38.306	-0.115*
Disease variables						
Dramatic increase in PRRS and outbreak (D)	-232.414**	97.883	-0.104**	68.552	42.593	0.085
PED outbreak (D)	-360.106	229.078	-0.161	-32.662*	37.05	-0.036*
Hog feed price ratio (C)	4.933	6.568	0.055	3.339*	2.545	0.1*
Census Division level data						
Availability of agricultural extension (C)				8.564	8.625	0.052
Availability of agricultural extension (d ≥0.5km) (D)	-72.379	140.285	-0.041			
Availability of agricultural extension (0.25≤ d <0.5km) (D)	47.93	27.471	0.032			
Availability of slaughter plant (C)	-31.944	26.313	-0.023			
Availability of slaughter plant (d ≥3m) (D)				-123.768***	39.918	-0.131***
Availability of slaughter plant (2≤ d <3km) (D)				-57.789**	25.732	-0.077**
Availability of slaughter plant (1≤ d < 2km) (D)				-84.457***	28.763	-0.14***
Availability of slaughter plant (0 .5≤ d <1km) (D)				-63.847***	13.222	-0.096***
Family farm (C)	1.053	2.541	0.027	0.957	0.816	0.054
Farm number (C)	0.157	0.183	0.069	-0.026	0.032	-0.02
Farm production type (C)	-7.778**	3.097	-0.166**	-0.634**	0.269	-0.053**
Farmer having no off-farm work (C)	9.343*	5.412	0.112*	0.201*	0.411	0.021*
Farmer's age (age ≥ 50) (D)	-14.423	138.917	-0.005	-28.953***	6.799	-0.042***
Farmer's age (45≤ age <50) (D)	-46.565***	17.996	-0.031***	-27.267***	8.441	-0.051***
Farmer's gender (C)	0.549***	0.21	0.015***	0.343*	0.12	0.04*
Human population density (C)				-0.150*	0.084	-0.092*
Human population density (p ≥ 50) (D)	-21.734	33.517	-0.011			
Human population density (40 ≤ d < 50) (D)	-86.735**	39.294	-0.055**			
Human population density (30 ≤ d < 40) (D)	-71.037***	21.686	-0.045***			
Lagged farm size	0.830***	0.185	0.698***	1.035***	0.036	0.87***
Land tenure/ownership (C)	3.362	5.085	0.041	0.525	0.332	0.044
Technology (C)	3.917*	2.1	0.171*	1.079***	0.387	0.128***
Temperature range (C)	-9.608***	1.87	-0.061***	-1.054	1.829	-0.029
Constant	198.678	521.452		45.974	143.565	
R_Squared		0.9			0.8	

Table 9. Estimates of the Impacts of Various Factors on Farm Size, Quebec.

	Type 1 structural change			Type 2 structural change		
	Coeff	Std. dev	SC	Coeff	Std. dev	SC
Provincial level data						
COOL implementation (D)	-76.745	132.75	-0.036	536.821	544.848	0.299
Disease variables						
Dramatic increase in PRRS and outbreak (D)	-167.472*	116.216	-0.054*	-266.013	463.347	-0.102
PED outbreak (D)	-194.451	209.704	-0.064	-1005.585**	448.753	-0.377**
Hog feed price ratio (C)	-4.561	8.456	-0.032	-16.258	12.5	-0.134
Census Division level data						
Availability of agricultural extension (C)	-43.817	64.015	-0.035			
Availability of agricultural extension (1.2≤ d <2.4km) (D)				-215.383	193.761	-0.082
Availability of agricultural extension (0.6≤ d <1.2km) (D)				-137.007	132.87	-0.07
Availability of agricultural extension (0.4≤ d <0.6km) (D)				52.366	132.76	0.023
Availability of agricultural extension (0.2≤ d <0.4km) (D)				-162.044	130.103	-0.087
Availability of slaughter plant (C)	-116.746*	84.263	-0.047*	295.368	233.872	
Family farm (C)	-0.76	4.565	-0.015	6.883*	4.404	0.218*
Farm number (C)	-0.165*	0.113	-0.016*	3.149***	0.873	0.168***
Farm production type (C)	1.289	2.892	0.001	-3.957*	2.61	-0.002*
Farmer having no off-farm work (C)	-0.326	2.162	-0.305	2.501	1.801	2.163
Farmer's age (45≤ age <50) (D)	243.995**	121.6	5.383**	-157.962	193.629	-5.24
Farmer's age (age ≥50) (D)	51.465	80.515	0.017	-161.739	129.575	-0.071
Farmer's gender (C)	2.191	2.621	0.057	-0.062	1.306	-0.002
Human population density (C)				0.117	0.219	0.017
Human population density (p ≥180) (D)	-191.887	177.286	-0.041			
Human population density (90≤ p <180) (D)	8.732	104.924	0.003			
Human population density (60≤ p <90) (D)	-57.906	219.585	-0.016			
Human population density (30≤ p <60) (D)	-207.181*	126.82	-0.066*			
Human population density (20≤ p <30) (D)	-110.411	185.403	-0.042			
Human population density (10< p <20) (D)	-139.903	141.899	-0.063			
Lagged farm size (C)	0.966***	0.102	0.79***	0.420***	0.147	0.39***
Land tenure/ownership (C)	-3.596**	1.688	-0.052**	6.354**	3.154	0.125**
Technology (C)	5.007**	2.058	0.096**	2.921*	2.099	0.089*
Temperature range (C)	1.546	9.718	0.05	-26.564***	9.981	-1.083***
Constant	287.088	847.115	1.433	2253.899**	1086.362	14.595**
R_Squared		0.8			0.7	

Appendices

Appendix 1. Descriptive Statistics, Canada

	Mean	Std. dev	Min	Max
Dependent variable				
Farm Size	853.611	596.698	177	1851
Dependent variable				
Availability of agricultural extension (C)	82.639	3.870	75	88
Availability of slaughter plant (C)	36.417	7.915	26	50
Family farm (C)	28.068	19.696	1.39	60.14
Farm number (C)	23.146	15.011	7.03	55.77
Farm production type (C)	35.683	17.796	0.52	56.06
Farmer having no off-farm work (C)	68.748	4.100	63.08	77.25
Farmer's age (C)	43.194	2.765	39	49
Farmer's gender (C)	54.796	28.354	2.87	73.49
Hog feed price ratio (C)	30.690	13.953	12.06	71.88
Human population density (C)	3.342	0.371	2.74	3.99
Lagged farm size (C)	808.778	586.188	159	1851
Land tenure/ownership (C)	20.811	0.605	19.62	21.44
Technology (C)	44.861	27.111	0	77
Temperature range (C)	92.247	4.001	85.7	105.5

Appendix 2. Descriptive Statistics, British Columbia

	Type 2 structural change			
	Mean	Std. dev	Min	Max
Dependent variable				
Farm Size	82.8705	205.776	4	1272
Dependent variable				
Availability of agricultural extension (0.5≤ d <1km) (D)	2.732	2.123	0.11	8.90
Availability of slaughter plant (d ≥ 5km) (D)	0.122	0.329	0	1
Availability of slaughter plant (4 ≤ d < 5km) (D)	0.144	0.352	0	1
Availability of slaughter plant (3 ≤ d < 4km) (D)	0.137	0.345	0	1
Availability of slaughter plant ((2 ≤ d < 3km) (D)	0.230	0.422	0	1
Availability of slaughter plant (1 ≤ d < 2km) (D)	0.194	0.397	0	1
Family farm (C)	7.237	13.935	0	100
Farm number (C)	64.158	58.650	7	446
Farm production type (C)	26.079	25.353	0	100
Farmer having no off-farm work (C)	40.532	36.551	0	100
Farmer's age (age ≥ 50) (D)	0.201	0.403	0	1
Farmer's age (45≤ age <50) (D)	0.331	0.472	0	1
Farmer's gender (C)	63.705	31.013	0	100
Hog feed price ratio (C)	35.479	11.391	14.08	48.22
Human population density (C)	46.393	149.925	0.23	873.35
Lagged farm size	70.672	124.732	0	956
Land tenure/ownership (C)	10.626	12.211	0	50
Technology (C)	28.468	30.385	0	100
Temperature range (C)	65.135	12.601	37.10	88

Appendix 3. Descriptive Statistics, Alberta

	Type 1 structural change				Type 2 structural change			
	Mean	Std. dev	Min	Max	Mean	Std. dev	Min	Max
Dependent variable								
Farm Size	1381.911	1533.940	38	8993	418.304	485.376	4	2687
Dependent variable								
Availability of agricultural extension (d ≥ 2km) (D)	0.143	0.353	0	1	0.143	0.353	0	1
Availability of agricultural extension (1≤ d < 2km) (D)	0.429	0.499	0	1	0.286	0.456	0	1
Availability of slaughter plant (C)	1.871	0.871	0.69	3.96				
Availability of slaughter plant (d ≥3km) (D)					0.125	0.334	0	1
Availability of slaughter plant (2.5≤ d < 3km) (D)					0.161	0.371	0	1
Availability of slaughter plant (2≤ d <2.5km) (D)					0.107	0.312	0	1
Availability of slaughter plant (1 .5≤ d <2km) (D)					0.054	0.227	0	1
Availability of slaughter plant (1≤ d < 1.5km) (D)					0.214	0.414	0	1
Availability of slaughter plant (0 .5≤ d <1km) (D)					0.196	0.401	0	1
Family farm (C)	20.250	20.348	0	100	13.857	16.5215	0	72
Farm number (C)	215.000	228.815	8	1239	377.321	374.266	15	1682
Farm production type (C)	56.214	19.303	0	100	49.161	18.799	0	100
Farmer having no off-farm work (C)	64.000	22.720	0	100	65.821	19.861	0	100
Farmer's age (C)	46.107	5.049	39.40	65	45.592	7.654	0	67
Farmer's gender (C)	74.500	25.140	0	100	76.224	76.127	0	285
Hog feed price ratio (C)	33.234	12.681	11.67	48.40	33.234	12.681	11.67	48.40
Human population density (C)					22.578	32.667	0.97	120.65
Human population density (p ≥4) (D)	0.161	0.371	0	1				
Human population density (2≤ p <4) (D)	0.446	0.502	0	1				
Human population density (1< p <2) (D)	0.125	0.334	0	1				
Lagged farm size	1105.054	1505.443	26	8993	362.482	475.515	4	2687
Land tenure/ownership (C)	0.304	0.464	0	1	38.536	16.809	0	100
Technology (C)	43.071	32.972	0	100	36.500	31.605	0	100
Temperature range (C)	74.577	4.425	65.80	84.50	72.570	4.986	63.60	81.50

Appendix 4. Descriptive Statistics, Saskatchewan

	Type 1 structural change				Type 2 structural change			
	Mean	Std. dev	Min	Max	Mean	Std. dev	Min	Max
Dependent variable								
Farm Size	1088.387	1416.655	39	6158	286.268	312.382	10	1253
Dependent variable								
Availability of agricultural extension (C)					0.779	0.490	0.28	1.70
Availability of agricultural extension (d ≥1km) (D)	0.274	0.450	0	1				
Availability of agricultural extension (0.5≤ d <1km) (D)	0.387	0.491	0	1				
Availability of slaughter plant (C)	2.227	0.875	1.10	3.97	1.197	0.739	0.36	2.81
Family farm (C)	12.452	17.319	0	67	10.982	16.535	0	100
Farm number (C)	176.887	171.654	22	750	259.125	262.413	22	1322
Farm production type (C)	61.774	19.408	0	100	54.786	20.266	0	100
Farmer having no off-farm work (C)	72.274	33.952	0	100	69.125	17.123	33	100
Farmer's age (C)	47.363	7.045	29	71	44.861	8.164	0	69
Farmer's gender (C)	79.952	28.375	0	100	77.196	27.045	13	100
Hog feed price ratio (C)	38.473	12.119	11.97	52.14	38.473	12.119	11.97	52.14
Human population density (C)					20.676	66.525	1.66	380.04
Human population density (2≤ p <2.5) (D)	0.258	0.441	0	1				
Human population density (1.5≤ p <2) (D)	0.242	0.432	0	1				
Human population density (1≤ p <1.5) (D)	0.339	0.477	0	1				
Lagged farm size	798.803	1323.728	27	6158	236.146	292.752	10	1253
Land tenure/ownership (C)	39.194	20.106	0	83	43.286	20.809	0	88
Technology (C)	40.516	34.658	0	100	31.161	29.852	0	100
Temperature range (C)	75.235	4.647	66.40	86.70	75.725	5.173	67.00	86.50

Appendix 5. Descriptive Statistics, Manitoba

	Type 1 structural change			
	Mean	Std. dev	Minimum	Maximum
Dependent variable				
Farm Size	1829.457	2096.471	81	13483
Dependent variable				
Availability of agricultural extension (d ≥1.5km) (D)	0.405	0.493	0	1
Availability of agricultural extension (1≤ d <1.5km) (D)	0.207	0.407	0	1
Availability of slaughter plant (C)	0.812	0.510	0.10	2.41
Family farm (C)	17.276	17.051	0	67
Farm number (C)	126.224	126.965	5	592
Farm production type (C)	43.362	17.056	0	76
Farmer having no off-farm work (C)	66.733	16.321	0	100
Farmer's age (C)	46.043	4.755	37.00	60.80
Farmer's gender (C)	77.302	24.270	0	100
Hog feed price ratio (C)	36.804	12.257	14.77	49.58
Human population density (D) (d ≥ 10)	0.259	0.440	0	1
Human population density (D) (3 ≤ p < 10)	0.310	0.465	0	1
Human population density (D) (2 ≤ p < 3)	0.250	0.435	0	1
Lagged farm size	1304.097	1620.469	48	9424
Land tenure/ownership (C)	41.922	14.500	0	88
Technology (C)	45.802	34.190	0	100
Temperature range (C)	72.306	6.927	38	87

Appendix 6. Descriptive Statistics, Ontario

	Type 1 structural change				Type 2 structural change			
	Mean	Std. dev	Min	Max	Mean	Std. dev	Min	Max
Dependent variable								
Farm Size	986.361	746.041	96	2901	250.779	268.231	4	1736
Dependent variable								
Availability of agricultural extension (C)					0.971	1.637	0.06	8.73
Availability of agricultural extension (d ≥0.5km) (D)	0.222	0.419	0	1				
Availability of agricultural extension (0.25≤ d <0.5km) (D)	0.542	0.502	0	1				
Availability of slaughter plant (C)	0.970	0.527	0.15	2.2				
Availability of slaughter plant (d ≥3m) (D)					0.088	0.283	0	1
Availability of slaughter plant (2≤ d <3km) (D)					0.147	0.355	0	1
Availability of slaughter plant (1≤ d < 2km) (D)					0.267	0.444	0	1
Availability of slaughter plant (0 .5≤ d <1km) (D)					0.203	0.403	0	1
Family farm (C)	23.000	19.085	0	66	10.221	15.050	0	100
Farm number (C)	370.278	329.653	35	1481	150.885	207.478	4	1255
Farm production type (C)	47.306	15.949	18	73	45.378	22.506	0	100
Farmer having no off-farm work (C)	65.194	8.920	40	88	54.876	28.458	0	100
Farmer's age (age ≥ 50) (D)	0.069	0.256	0	1	0.189	0.392	0	1
Farmer's age (45≤ age <50) (D)	0.500	0.504	0	1	0.447	0.498	0	1
Farmer's gender (C)	72.042	20.015	24	100	71.346	31.421	0	100
Hog feed price ratio (C)	25.025	8.305	13.38	35.76	25.025	8.305	13.38	35.76
Human population density (C)					118.445	165.041	0.67	1127.89
Human population density (p ≥ 50) (D)	0.153	0.362	0	1				
Human population density (40 ≤ d < 50) (D)	0.319	0.470	0	1				
Human population density (30 ≤ d < 40) (D)	0.333	0.475	0	1				
Lagged farm size	740.028	627.416	39	2662	212.832	225.554	4	1141
Land tenure/ownership (C)	42.250	9.095	22	61	36.005	22.246	0	100
Technology (C)	45.139	32.529	0	93	33.212	31.747	0	100
Temperature range (C)	58.225	4.747	49.60	75.00	64.263	7.271	44	89.2

Appendix 7. Descriptive Statistics, Quebec

	Type 1 structural change				Type 2 structural change			
	Mean	Std. dev	Min	Max	Mean	Std. dev	Min	Max
Dependent variable								
Farm Size	1312.565	1018.507	13	7582	1033.776	870.653	6	5439
Dependent variable								
Availability of agricultural extension (C)	0.725	0.822	0.06	3.66				
Availability of agricultural extension (1.2≤ d <2.4km) (D)					0.126	0.332	0	1
Availability of agricultural extension (0.6≤ d <1.2km) (D)					0.272	0.446	0	1
Availability of agricultural extension (0.4≤ d <0.6km) (D)					0.183	0.388	0	1
Availability of agricultural extension (0.2≤ d <0.4km) (D)					0.314	0.465	0	1
Availability of slaughter plant (C)	0.479	0.406	0.07	2.85	0.560	0.504	0.03	3.81
Family farm (C)	25.523	19.773	0	100	27.845	27.614	0	100
Farm number (C)	71.065	96.944	3	635	35.340	46.436	1	311
Farm production type (C)	34.007	19.502	0	95	33.669	26.607	0	100
Farmer having no off-farm work (C)	73.610	22.472	0	150	68.924	28.879	0	100
Farmer's age (45≤ age <50) (D)	0.122	0.328	0	1	0.178	0.384	0	1
Farmer's age (age ≥50) (D)	0.281	0.450	0	1	0.319	0.467	0	1
Farmer's gender (C)	71.833	26.327	0	100	71.953	31.794	0	100
Hog feed price ratio (C)	24.572	7.231	12.81	35.76	24.572	7.231	12.81	35.76
Human population density (C)					89.747	123.222	0.84	600.38
Human population density (p ≥180) (D)	0.050	0.219	0	1				
Human population density (90≤ p <180) (D)	0.101	0.301	0	1				
Human population density (60≤ p <90) (D)	0.086	0.281	0	1				
Human population density (30≤ p <60) (D)	0.119	0.324	0	1				
Human population density (20≤ p <30) (D)	0.187	0.391	0	1				
Human population density (10< p <20) (D)	0.302	0.460	0	1				
Lagged farm size (C)	1011.515	832.907	13	4694	853.243	807.652	3	4123
Land tenure/ownership (C)	24.574	14.785	0	75	21.127	17.123	0	100
Technology (C)	42.558	33.093	0	100	39.314	35.500	0	100
Temperature range (C)	64.342	5.085	37.50	79.00	64.784	5.638	44	82