An Economic Analysis of Wheat Variety Selection in Kansas, 1990-2016

by

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Abstract

From 1990 to 2016, the Kansas wheat varieties with milling and baking quality rated as "Less Desirable" accounted for 22% of all wheat acres planted, compared with 36% during the period 1974 to 1993. Thus, wheat producers have selected wheat varieties with lower end-use quality over time. Regression analysis was used to identify and quantify the determinants of planted wheat varieties in Kansas over the time period 1990 to 2016. The results show that Kansas wheat producers make variety decisions primarily based on relative yield and previously planted varieties. Wheat producers also consider the end-use qualities on test weight and milling and baking quality. There were more varieties planted in 1990-2016 than during the 1974-1993 period, and producers have planted with a greater emphasis on yield than other production characteristics.

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Chapter 1 - Introduction and Objectives

Kansas is the largest wheat producing State in the United States of America. The wheat produced in Kansas comprises nearly one-fifth of all wheat grown in the USA. Kansas has approximately 60,000 farmers, and 20,000 of those farmers plant wheat.

Kansas wheat producer variety choice is affected by many things, including relative yield, yield stability, and diseases or insects' resistance. For many years, Kansas has served as being part of the global bread basket, owing to its vast volume of wheat that is used for baking. Nalley, Barkley and Chumley (2008) noted that wheat is the staple crop produced in Kansas. The usages of the wheat are varied, including making bread, biscuits and other baked goods, and for livestock feed.

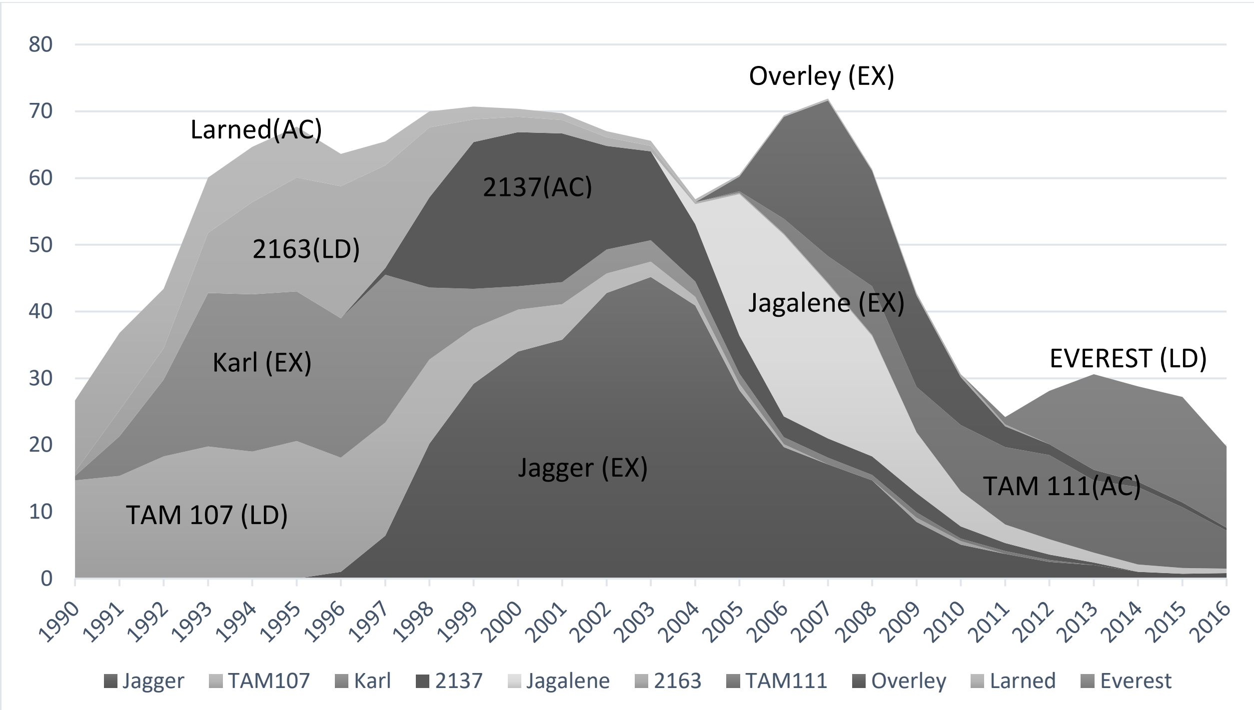
Barkley and Porter (1996) sought to identify the determinants that influence variety selection among farmers in Kansas and emphasized the need to find out why some wheat varieties with "Exceptional" milling and baking qualities were not widely planted in Kansas. The same question has been raised here to determine whether there have been any changes since Barkley and Porter (1996) was published.

The main objective of this study is to identify and quantify the relationship between the planted Kansas wheat varieties, relative yield, yield stability, variety age, production characteristics, and end-use qualities from experimental plots. Special emphasis will be placed on variety relative yield and yield stability and how they affect acreage planted in the nine crop-reporting districts in Kansas. In this study, we focused on the dryland winter wheat varieties. What causes farmers to choose a certain wheat variety? Are there reasons that farmers plant the varieties that were chosen last year? Farmers depend mainly on published data about a variety from last year before making such a decision. There are many wheat varieties available, and each of them have unique characteristics.

The main finding from the time period of 1990 to 2016 is that the production characteristics showed a decreasing quality over time which might indicate that the overall quality characteristics have decreased since 1974-1993. For end-use qualities, the test weight quality became more important in the purchase of wheat varieties, although the milling and baking qualities is still a major component on making variety decisions. The results show that the farmers chose wheat varieties that were “Acceptable” on milling and baking quality instead of “Exceptional.” In 1990-2016, 43 percent of the planted wheat acres in Kansas were seeded to wheat varieties with milling and baking qualities ranked as “Acceptable.” Only 22 percent of the wheat varieties rated as “Less Desirable” were planted. Figure 1 shows the ten leading wheat varieties planted in Kansas during the time period of 1990 to 2016. A variety can be quite commonly used when it is first introduced. However, its popularity decreases gradually and disappears. The varieties Jagger, Karl, Overley, and Jagalene have “Exceptional” milling and baking qualities; TAM107, Everest and 2163 (no longer in use) have “Less Desirable” milling and baking qualities; and 2137, TAM 111, and Larned have “Acceptable” milling and baking qualities. Which, compared six leading wheat varieties in the period 1974 to 1993, only Karl and Eagle had an “Exceptional” rating (Barkley and Porter 1996). The varieties Newton, Larned, and Scout were rated as “Acceptable,” and the TAM 107 was rated as “Less Desirable” (Barkley and Porter 1996).

This study updates the data and statistical methods used since the study of Barkley and Porter (1996). The literature review will provide information on wheat varieties. The theoretical model is used to derive the empirical models. The empirical models were developed from economic theory to analyze the main factors of influence on wheat variety decisions. In this study, we focus on all winter wheat varieties, together with a discussion of the implications of the regression results.

Figure 1. Ten Leading Percent Seeded Acres of Kansas Wheat Varieties, 1990-2016



Note: The ranking for three categories:

EX=Exceptional Quality; usually large kernels; high protein content; very good milling, mixing, and commercial bread baking performances.

AC=Acceptable Quality; milling and baking attributes are acceptable, but not outstanding for all properties and may have minor defects.

LD=Less Desirable Quality; one or more serious quality defects.

Source: Kansas Performance Tests with Winter Wheat Varieties 1990-2016.

Chapter 2 - Literature Review

In this chapter, variety selection and the determinants of variety selection among farmers in Kansas will be examined in detail. The study sought to identify what made a certain wheat variety preferable over others. Several peer reviewed journals will be analyzed in line with the available statistics. The study will mainly discuss the state of Kansas, a leading state of wheat production for many decades. Wheat is a major source of income for approximately 20,000 farmers.

2.1: The Importance of Variety Selection for Wheat Farmers

Variety selection remains an important and timely issue among wheat farmers. Wheat varieties determine their agricultural productivity and profitability in the long run. Some of the major factors that many producers consider is the expected yield from a certain variety. The price for the end product, wheat, is what determines the farmers' willingness to grow a certain wheat variety.

2.2: What Does Variety Selection Entail?

Variety selection entails identification of the best and the most reliable variety. A reduction in yield would ultimately discourage farmers from such a variety of wheat. Barkley et al. (2010) note that the exercise of wheat variety selection is not a one-time decision. It continues over time; as higher yielding wheat varieties continue to be developed (p. 40). Hence, a seed profiling exercise is recommended for many farmers as they seek to determine the strengths and weaknesses of a certain variety (Barkley and Porter, 1996). Gwirtz et al. (2007) note that with time, farmers and agricultural firms have sought to improve the quality of wheat varieties to suit the preferred quality of end product for bakers and millers. It is thus important to determine the major factors that farmers consider when choosing a wheat variety. According to Clark et al. (1922), "the choice of varieties for given conditions and purposes, therefore, usually is given careful consideration by growers" (p. 1).

Farmers depend on advice from government sources as well as private agricultural firms and extension before selecting a variety. Barkley (1997) revealed that breeding was one of the strategies that would be used to constantly improve the seed variety of wheat planted in Kansas.

2.3: Related Literature

Farmers in other regions such as Washington state also consider these quality of wheat varieties (Washington Wheat Facts, 2015). Barkley and Porter (1996) revealed that "grain variety selection has been considered by previous researchers as the adoption of new technology or as the purchase of a profit maximizing input to the production process." Researchers sought to determine the factors that cause farmers to choose a certain seed variety over others (Barkley et al., 2010., Cox et al., 1988, Guth et al., 2017, and Lesser and Kolady, 2011). A farmer's choice of seed variety is dependent on their most preferred end product or outcome. In the next section, the thoughts of other researchers and scholars on the same topic will be analyzed.

2.3.1: Factors that Determine Wheat Variety Selection among Kansas State Farmers

Several agricultural firms stock a wide range of seeds depending on their yielding potential, maturity time, and disease resistance to allow farmers to choose, that which suits them the most. For instance, the Kansas Agricultural Experiment Station (KAES) conducts a scientific seed profiling exercise to determine the varieties that have the best characteristics and the ones that have a good end product. Barkley et al. (2010) also observe that other private firms also developed wheat varieties. These firms include Agripro, West Bred, and many others which conduct research and improve the existing varieties of wheat grains. They provide products with detailed data on the available varieties, their needs in terms of rainfall and overall climate that is suitable for them.

Farmers are more likely to choose a variety of wheat that will assure them of high returns with minimal expenses as a great number of wheat farmers in Kansas have farming as their major source of income. They also consider other factors such as the variety's demand for rainfall, the type of soil that supports them besides general climatic conditions that are ideal for such a wheat variety. First, changes in climate can affect productivity a great deal. Other challenges associated with wheat farming include diverse soils that may not support all varieties of wheat. Hence, wheat breeders attempt to develop wheat varieties that can counter such challenges. Farmers have tried out different wheat varieties through rotation to determine the best variety that is suitable for their soils. Many of them have centered their wheat farming activities to wheat varieties that withstand challenges such as fluctuating climatic conditions and lack of sufficient rainfall to sustain their crops until harvest.

2.3.2: Selecting a Wheat Variety

One of the major activities associated with wheat farming in Kansas is selection of a wheat variety. Wheat producers consider some factors as they influence their expenses in the line of production (Barkley et al., 2010). Dealers of agricultural inputs should possess knowledge to advise farmers accordingly. The following considerations are universal to wheat farmers in Kansas.

i. *Dependability of a Wheat Variety*: When choosing a wheat variety, farmers would prefer a wheat variety that is reliable even in adverse weather conditions among other misfortunes that may confront them. Hence, wheat farmers in Kansas are more likely to settle for a wheat variety that they can depend on as agriculture may be their main source of income. Cox et al. (1988) are of the opinion that genome improvement of the existing varieties of wheat grown in Kansas would improve its dependability.

A wheat variety's selection may change with time, especially due to emergence of new varieties that may be more ideal for farmers. Sometimes, older varieties may go through a chain of improvements to make them better. Agricultural research institutions could continue to advise farmers on the best available options during a planting season for them to make sound decisions when it comes to variety selection. Research is ongoing to develop the best wheat varieties that are suitable for the soil as well as climatic conditions of Kansas.

Maturity Time: The time that a wheat variety takes to mature is an important consideration for farmers. A wheat variety that matures within a short time or medium time is more preferable. Sometimes, varieties that take too long to mature cannot sustain the economic activity of farmers. Moreover, taking too long in the fields could mean that extreme weather conditions might strike and damage the wheat in the fields (Nalley and Barkley, 2010). Their major targets are mainly millers and bakers (Barkley et al., 2010).

ii. *A Winter Hardy Wheat Variety:* Very cold temperatures can damage wheat and lead to losses to farmers. A variety that is not susceptible to damage due to very cold temperatures would be the most ideal (Guth et al., 2017). Therefore, the rating of a variety in terms of its winter hardiness should count when making a decision on which wheat variety to grow (K-State Research & Extension, 1997). Considering the extremely cold temperatures during winter, hardiness among wheat varieties determines which wheat varieties which farmers may decide to plant in a particular season.

iii. *Ability to tolerate Soil Acidity:* Soil acidity is another issue in agriculture in the State of Kansas. Soils are gradually becoming more acidic considering the recurrent use of nitrogen laced fertilizers. Therefore, acid levels in these soils continue to rise (Barkley et al., 2010).

If a farmer's soil is highly acidic, it would be wise for them to select a wheat variety that can withstand acidic soils without much effect to the crop's stability in the long run. At the moment, there is no permanent solution for soil acidity as farmers continue to use fertilizer. The need to use fertilizers to improve soil fertility has further escalated the acidic levels in most wheat fields in Kansas State as farmers use them almost every season (K-State Research & Extension, 1997). Wheat varieties that can cope with acidic soils would, be the best variety in areas where the soils are overly acidic. Noteworthy is the fact that soil acidity affects the productivity of some wheat varieties which are not suited to cope with high acid levels. However, researchers noticed that by adding lime increases soil pH (reduces acidity), adds calcium (Ca) and/or magnesium (Mg), and reduces the solubility of Al and Mn in the soil. Regardless of whether it is powdered, prilled, or fluid, lime is usually applied to the soil surface and either left on the surface or incorporated (Anderson et al., 2013).

Disease Resistance: Diseases translate into losses. Therefore, farmers have to be wary of the diseases that afflict various varieties of wheat and their ability to resist diseases. Diseases have a number of effects to wheat farmers. They reduce the volume and quality of yields besides the test weight (Lesser and Kolady, 2011). Although farmers cannot satisfactorily address the threat of wheat diseases, too many diseases could lead to huge losses (K-State Research & Extension, 1997). Manageable diseases could not really have much effect on the yield volume. Farmers ought to choose a variety that can resist diseases or that that can be managed with ease without much impact on the cost of production. Diseases such as the seed smut may be managed through ways such as using disease free seed from certified seed handlers and use of seeds that have been treated using fungicides (De Wolf and Shroyer, 2017).

iv. *Ability to Resist Pests:* Pests are a menace that affects wheat farming in Kansas. Pest infested crops can translate into huge losses for farmers. For farmers in Kansas, pest resistance should be a major consideration.

A wheat variety that is prone to pests is not ideal for wheat producers. First, such a variety could be too costly to eliminate these pests. Secondly, pests reduce the quality of the harvest; thus, the product may be rejected in the market translating into losses. The Kansas State Research and Extension Institute has statistics of wheat varieties that have the best ability to resist pests (K-State Research & Extension, 1997). Unfortunately, these varieties may not be the best in terms of yield. The farmer is thus left to make a decision over whether to risk on yield over pest resistance and vice versa. Wheat varieties such as Everest and WB Redhawk are deemed as being the best in terms of pest resistance.

v. *Yield:* The higher the yield, the higher the revenues, hence, farmers must select a wheat variety that assures them of substantial yields. Barkley and Porter (1996) for the time period 1974-1993 rated wheat yields as the major consideration for many wheat farmers. A productive variety of wheat that has a host of other desirable characteristics such as shorter maturity time, winter hardiness, disease and pest resistance among others are ideal for many wheat farmers. A study published by the Oklahoma

Cooperative Extension Service (2010) reveals that farmers select the best variety in terms of yield coupled with other desirable traits such as a variety assures them of good prices.

2.4: The Relationship between Variety Selection and End Use Quality

Wheat variety characteristics selected by farmers are characterized by end use quality. The findings of many studies on wheat farming in Kansas support the fact that end use qualities as well as related factors such as yield, pest resistance and winter hardiness among others were the core considerations in variety selection (Nalley et al., 2008). However, many prefer the variety that assures them of high yields, as they have wheat farming as their major source of revenue. Some of the available varieties do not provide the best quality for miller and barkers. Barkley and Porter (1996) observed that farmers consider a number of economic parameters particularly that of high yields. Unfortunately, the best-yielding varieties may have low qualities that millers and bakers prefer (p. 8). What could drive some producers away from planting such varieties would be lack of market for their wheat variety. Millers and bakers depend on various wheat varieties for their purposes. In line with this, many of them conduct a profiling analysis of the wheat varieties before wheat variety selection. Just like the target customers, farmers also have to consider what their customers demand and produce it in large volumes. Thus they may adopt variety that is termed as being the best mainly by millers and bakers as they are a category that provides a ready and stable market for their wheat (Barkley and Porter, 1996). Therefore, for many years, wheat farmers in Kansas have expressed interest in planting wheat varieties that millers and bakers prefer most. Barkley and Porter (1996) note that "over the past decades, wheat breeders have developed varieties characterized by high milling and bread-baking qualities" (p. 1). Both public and private agricultural research organizations contribute to the overall productivity of wheat through constant improvement of the available varieties. These organizations conduct research to determine the genomes that would breed a strong and reliable wheat variety.

Agricultural research institutions have also conducted several studies on wheat varieties with an aim of improving its yield as well as its desirable traits. Essentially, almost all wheat varieties in Kansas have gone through a number of improvements through research and technology (Guzman et al., 2016). For many years, there has been a gradual improvement in wheat production in Kansas. Barkley et al. (2010) attribute this to the gradual improvement of yields due to improved farming practices coupled with improved varieties of wheat. Farmers have also adopted better farming practices such as use of fertilizer to increase production.

Varieties are different in terms of their yield, disease and pest resistance. Therefore, farmers seek wheat varieties that have a combination of desirable factors in reliable levels for them to counter challenges such as winter, drought, diseases and pests. They consider the strengths and weaknesses of various wheat varieties before planting it. K-State Research & Extension (1997) stated that "high yield potential should not be the only yardstick for varietal selection and probably is not the most important criterion since many factors influence the actual yield in the bin" (p. 7). There are instances where a farmer may have to go for a variety that can cope with unpredictable weather conditions over yield.

2.5: Adoption of Technology among Farmers

Sunding and Zilberman (2001) and Lee (2005) consider adoption of seed variety as being a form of technology adoption. Adoption of technology in Kansas has been fueled by agricultural research institutions and agribusinesses which encourage it among farmers. These institutions may come up with seed varieties that researchers may prefer as well as other farming mechanics that could aid them improve their varieties. However, many of producers would adopt one aspect of technology at a time. They would be at ease to adopt another aspect of technology if they find it suitable. Sunding and Zilberman (2001) observe that adoption of technology in farming is not a new phenomenon for many farmers. Unfortunately, some may still be reluctant to adopt new technology until they are assured that it has substantial benefits. Ideally, farmers will only be willing to adopt technologies that prove to be most profitable. If the price of that technology remains constant, farmers will be willing to keep using that technology for longer and vice versa (Lee, 2005). Much of the literature that exists on adoption of technology in farming emphasizes the use of the hybrid seed varieties. Many farmers adopt new farming technologies only if they have considered all the factors and have been satisfied that it would maximize their profits.

Chapter 3 - Theoretical Model

Barkley et al. (2010) provide a foundation to develop the theoretical model led in this study. Several other studies on wheat selection have been considered as part of secondary information for the study. The important studies of Carlton (1979), Barkley and Porter (1996), Dahl et al. (2004), Detlefsen and Jensen (2004) were critical sources of secondary information for this study. The neoclassical input characteristic model fits with the demands of this study (Ladd and Martin, 1976). The model gained support from other scholars such as Melton et al. (1994). The model has been used to determine the degree of demand for certain wheat varieties depending on important factors such as end use qualities, yield stability and other agronomic factors. According to the provisions of this model, a wheat farmer is interested in maximizing expected profits from wheat farming, E (π). The wheat output (Q_w) is assumed to be a normal distribution where Q_w ~ N (E (Q_w), σ^2). E (Q_w) is the mean of wheat output, and σ^2 is the variance. According to Barkley and Porter (1996), and Barkley et al. (2010), it is possible to derive a profit maximization equation in equation (1).

(1) $E(\pi) = P_w E(Q_w) - W_i X_i - K'Z - \lambda[var(Q_w)]$.

In the equation, P_w refers to the price of wheat while X_i is the i^{th} wheat variety. The variable W_i, is the cost of seeds, Z is a vector of other inputs, and K is a vector denotes the prices of other inputs. The cost of a yield's variability, denoted by the symbol (λ), is assumed to linearly increase with an output's variability (σ^2) noted by Carlton (1979); Barkley and Porter (1996); and Barkley et al. (2010).

Wheat output is always synonymous with wheat characteristics as shown in the following equation: q_{ij} (j=1,….n). This shows the value of j^{th} characteristic in each unit of a seed variety i.

Hence, q_j represents the value of the j^{th} characteristic utilized during the production of Q_w, as represented in equation 2:

(2) $Q_w = f\ (q_{.1}, q_{.2}, q_{.n};$ Z).

In the equation, it is assumed that other inputs from seed variety (Z) are exogenous during the variety selection exercise. Barkley and Porter (1996), and Barkley et al. (2010) assumed that when purchased seed variety, *ex ante,* cost was assumed to be exogenous. *Ex post,* define unanticipated production cost is denoted by λ. During the variety selection process, differences in cost remain unknown. Some examples of these costs include the cost of harvesting and drying wheat and purchasing fungicides. This call for an analysis in relation to characteristics of each variety is shown in equation (3).

(3) $w_i = P_w \Sigma_j [\partial \mathrm{E}(Q_w) / \partial q_{.j}] (\partial q_{.j} / \partial x_i) - \lambda \Sigma_j (\partial \sigma^2 / \partial q_{.j}) (\partial q_{.j} / \partial x_i)$

Where $\partial q_{.j} / \partial x_i = q_{ij}$.

Barkley and Porter (1996) and Barkley et al. (2010) pointed out that the value marginal product of each of the variety characteristics embodied in a given wheat variety is equal to the price of the seed wheat, and with the variable costs associated with that variety. Moreover, they conducted a study to justify that the demand of a certain variety (X_i) is determined by prices (P_w and W_i), variety variability costs (λ_i), and production characteristics (q_{ij}), as follows:

(4) $X_i = X_i(P_w, W_i,\ \lambda_i, q_1, q_2, \ldots q_n)$ for all i=1,…m.

Barkley and Porter (1996) note this simplifying assumption since they could not find data on seed prices. Seed prices are assumed to identical regardless of varieties. Stakeholders in the Kansas wheat farming industry stipulate that there are no differences in prices of wheat due to varieties. According to Barkley et al. (2010), the only differences noted are fueled by geographical availability. According to Dahl et al. (2004), "the opinion that trade practices are influenced by cost of seeds depending on variety. Consequently, even if these data were available, their effect would not affect the results" (p. 319).

The empirical model of wheat variety selection is specified in the following section against this theoretical framework.

Chapter 4 - Empirical Model

The model used to estimate the wheat variety selection for Kansas farmer is based on a method developed by Barkley and Porter (1996). The central source of this study is from the *Kansas Performance Tests with Winter Wheat Varieties*, published annually by KAES at Kansas State University.[1] In our model, these data are at the district level and cover the time period of 1990 to 2016.[2] We focused on one single location in each district. All yield data are for dryland hard winter wheat. Because we only considered the percent seeded acres of wheat in Kansas, we simplified the notations, the subscript i that denotes the wheat variety, the subscript j that denotes the crop-reporting district, and the subscript t that denotes the time period. However, more new varieties released over time will replace the old, low-yielding varieties, and it collected from repeated surveying of same varieties over various year. Therefore, we also have unbalanced, pooled cross-section, time-series data. We have applied the model to the cross-section data of 46 varieties and 604 observations.[3]

Table 1 provides an overview of the variables used in regressions from 1990 to 2016. It reports the mean, standard deviation, minimum, and maximum values for all variables including the fixed effects variables we used in the regression. The lagged percent seeded acres for a given variety's mean is 9.7 with range in 0.1 percent to 69.8 percent. For variety age, the oldest wheat variety is 31 years old.

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[1] *Kansas Performance Tests with Winter Wheat Varieties* publications provided data for each variety, included Percent Seeded Acres, milling and baking qualities, and resistance to diseases.

[2] The year of 1989 is included in the study to obtain the lagged value of the variables in the model. Due to precipitation and resulting diseases, data from the Colby location at 2015 were missing and omitted from the study.

[3] The total of 604 district-level observations are different from the state data in Figure 1.

Table 1. Summary Statistics of Kansas Wheat Variety Study Variables, 1990-2016

Variable	Mean	Std. Dev.	Min	Max	Year	Mean	Std. Dev.	Min	Max
PCACRE(t-1)	9.702	10.544	0.100	69.800	1990	0.048	0.215	0	1
Variety Age	7.612	4.294	2.000	31.000	1991	0.054	0.227	0	1
RELYLD(t-1)	1.006	0.119	0.430	1.486	1992	0.029	0.167	0	1
CVYLD(t-1)	0.319	0.136	0.018	0.739	1993	0.003	0.055	0	1
Public	0.514	0.500	0.000	1.000	1994	0.009	0.095	0	1
Production Characteristics					1995	0.110	0.102	0	1
Maturity	2.616	1.353	1.000	7.000	1996	0.012	0.109	0	1
Maturity Square	8.674	7.958	1.000	49.000	1997	0.020	0.139	0	1
Straw Strength	3.829	1.238	1.000	9.000	1998	0.038	0.191	0	1
Winter Hardy	4.134	1.804	1.000	9.000	1999	0.029	0.167	0	1
Leaf Rust	6.757	2.174	1.000	9.000	2000	0.020	0.139	0	1
Stem Rust	3.574	1.514	1.000	8.000	2001	0.015	0.122	0	1
Hessian Fly	6.431	2.500	1.000	9.000	2002	0.018	0.134	0	1
Wheat Streak Mosaic	6.456	1.460	4.000	9.000	2003	0.029	0.167	0	1
Soil Borne Mosaic	2.790	2.813	1.000	9.000	2004	0.032	0.175	0	1
End-Use Qualities					2005	0.036	0.187	0	1
Test Weight	3.353	0.913	1.000	5.000	2006	0.042	0.201	0	1
Milling Quality	2.156	0.506	1.000	3.000	2007	0.015	0.122	0	1
District					2008	0.018	0.134	0	1
North West	0.142	0.349	0	1	2009	0.053	0.224	0	1
West Central	0.174	0.379	0	1	2010	0.086	0.281	0	1
South West	0.097	0.296	0	1	2011	0.073	0.260	0	1
North Central	0.131	0.338	0	1	2012	0.094	0.292	0	1
Central	0.136	0.343	0	1	2013	0.076	0.264	0	1
South Central	0.112	0.315	0	1	2014	0.056	0.230	0	1
North East	0.050	0.218	0	1	2015	0.054	0.227	0	1
East Central	0.068	0.252	0	1	2016	0.032	0.175	0	1
South East	0.091	0.287	0	1					

Note: Production Characteristics and Test Weight are rated on a scale of 1 to 9, with 1 being the best.
Maturity rated on scale of 1 to 9, 1 is earliest.
Milling Quality is rated on a scale of 1 to 3 with 1 being the lowest.
Source: Kansas Performance Tests with Winter Wheat Varieties 1990-2016.

In the subsequent multiple regression analysis, $PCACRE_{ijt}$, the dependent variable is the percentage seeded acres to each variety. Which also is the dependent variable (X_{ijt}) from the theoretical model. Farmers have the option choose either retain the seeds from last year to be planted in the following year or purchasing new seeds to plant. Many farmers in Kansas retain seeds for roughly three years before they purchased new wheat seeds (Porter and Barkley, 1996). Owing to this, a lagged dependent variable ($PCACRE_{ij,t-1}$) is included in this empirical model.[4]

As previous studies (e.g. Barkley et al., 2010; Barkley and Porter 1996) have shown, the variety yield average and coefficient of variation also have to be taken into account when producers make wheat variety selections. Thus, relative yields and yield stability are included in the model. Relative yields ($RELYLD_{ij,t-1}$), it was calculated by the ratio of variety *i*'s yield in district *j* to the district mean yield for each year *t*. This variable accounts for differences in weather among other growing conditions across locations and years. Yield stability, which means risk, was measured using $CVYLD_{ij,t-1}$, which is the coefficient of variation of yields calculated across all locations in the same year. Those two variables are the lagged value based on the fact that farmers are making decision in this year based on the information from previous year.

A previous study (Barkley and Porter, 1996) of wheat variety selection has shown that variety age has to be taken into account when making variety selection. There was a need to identity the patterns in adoption of varieties. Hence, we included the variety age variable, using it to refer to the years that a certain variety has existed since its introduction.

In Barkley and Porter's (1996) study, they pointed out that individual producers' wheat prices depend on market price and the price adjustment of transportation costs. They also noted some other factors that determine wheat prices, such as dockage, test weight, baking and milling qualities, and protein content. Since transportation cost and physical grading qualities are assumed exogenous, and these two factors are not vary across variety, wheat prices are assumed homogeneous across all varieties (Barkley and Porter, 1996). In their analysis, they used test

[4] We also tried to include a second lagged variables (t-2) but it reduced the observation to one-half.

weight and milling and baking qualities as the price determinants, and they noticed that those two variables vary across seed varieties.

Determinants for P_w in the variety selection is function of the test weight (*Test Weight*) and milling and baking qualities (*Milling Quality*). Data on these variables came from the 1990 - 2016 state-level *Kansas Performance Tests with Winter Wheat Varieties*. However, the two characteristics were no variation across the district (*j*). In our model, we updated the varieties with newest reporting rating. The relationship is shown in equation (5):

$$(5) \qquad (P_w)_{it} = f\ (Test\ Weight_{it}, Milling\ Quality_{it}).$$

According to Barkley and Porter (1996) and Hill (1990), test weight is the "measure of grain density and is included in the U.S. grade standards for many grains as an indicator of quality" (p. 223). The test weight is graded in pounds per bushel. However, in this study, the variables were in KAES grade, where 1 denoted the BEST and 9 represented the POOREST. Parcell and Stiegert (1998) noted another determinant when they found the protein content was related to the wheat price. How protein content in wheat impacts wheat variety selection is shown in the mill quality variable. The influence of milling and baking qualities of wheat varieties was accessed through expert opinion in regard to the exact qualities in a year (Barkley and Porter, 1996). The qualities that were emphasized during ranking from best to poorest included loaf volume and milling and baking qualities. Later, in 1991, the three qualities were referred to as "relative milling and baking quality." These qualities were also ranked in three categories, namely:[5] Exceptional

[5] The ranking for three categories: EX=Exceptional Quality: usually large kernels; high protein content; very good milling, mixing, and commercial bread baking performances. AC=Acceptable Quality: milling and baking attributes are acceptable, but not outstanding for all properties and may have minor defects. LD=Less Desirable Quality: one or more serious quality defects.

Quality, Acceptable, and Less Desirable. In our study, we denote one for Less Desirable Quality, two for Acceptable Quality, and three for Exceptional Quality.

Many wheat seed dealers did not have complete and comprehensive records of the cost on wheat seeds, and the cost for the same wheat variety are vary across seed dealer and locations.[6] We used a binary variable to denote publicly distributed varieties besides zero for private varieties and one for public varieties ($Public_{it}$).[7] Previous literature (Nalley et al., 2008) noted that, in varietal selection, the publicly release varieties planted better than private varieties. They also noticed that Kansas has shown a rapid increase in the adoption of private varieties. Moreover, they wrote that the continuing coexistence of public and private varieties demonstrates that wheat seeds from both types of program are economically viable, and yields of each type of variety are extensively planted (Nalley et al., 2008). In addition, according to Barkley and Porter (1996), the public varieties have lower prices than private varieties; thus, the cost of seed relationship is defined in Equation (6):

(6) $w_i = w_i(Public_{it})$.

Farmers seek wheat varieties that have a combination of desirable factors in reliable levels for them to counter challenges such as winter, drought, diseases and pests. Each individual wheat variety has been given a rating of one to nine on relative production characteristics and with rating, it can tell farmers how well the variety resists specific disease or insects. Those desirable factors may affect the varietal decision, namely production characteristics,[8] which are rated on scale from

[6] Actual cost of wheat seeds is a relatively small component of total variable costs, thus we omitted the actual seeds cost in the study.

[7] *Public* is referring to the wheat varieties is released by a public research university such as Kansas State University, Texas A&M, University of Nebraska, etc.

[8] *Production characteristics*: Maturity; Maturity Square; Straw Strength; Winter Hardy; Leaf Rust; Stem Rust, Hessian Fly; Wheat Streak Mosaic, and Soil Borne Mosaic.

1 (best quality) to 9 (poorest quality). An exception to this scale was maturity, which was ranked from 1 (earliest) to 9 (latest). Production characteristics data were also from *Kansas Performance Tests with Winter Wheat*. Ratings are reported annually, we updated these ratings within wheat verities with the newest rating. The production characteristics are included in the model are list in the detail in below.

1. Maturity: A wheat variety that matures within a short time or medium time is more preferable. Moreover, taking too long in the fields could mean that extreme weather conditions might strike and damage the wheat in the fields (Nalley and Barkley, 2010). Maturity can provide valuable information due to unpredictability of the weather. Later-maturing varieties are less like to be damaged by a freeze than early-maturing varieties.
2. Squared maturity is included to capture nonlinearity.
3. Straw Strength: related to the variety’ ability to resist lodging, which is the ability of stems to withstand the effects of wind and rain. Wheat varieties with difference in straw strength do exist, but a plant can still experience lodging due to root lodging regardless of how strong the straw is (Porter, 1994; Stoskopf, 1981).
4. Winter Hardiness: the essential characteristics for winter wheat is winter hardiness, the ability to resist cold weather. Therefore, the rating of a variety in terms of its winter hardiness should count when making a decision on which wheat variety to grow (K-State Research & Extension, 1997). Moreover, noted by Cook and Veseth (1991) varieties with a better winter hardiness rating tend to have lower yields.
5. Leaf rust, a fungus disease. Severe early infections can cause significant yield losses, mainly by reducing the number of kernels per spike, test weights, and kernel

quality (Prescott et al. 1986). It can be controlled by foliar fungicides or by using resistant varieties (De Wolf and Shroyer, 2017)

6. Stem rust, a fungus disease. If infection occurs during the early crop stages, the effects can be severe: reduction in tillering and losses in grain weight and quality (Prescott et al., 1986). Sharma (2012) pointed out that stem rust was considered the most feared disease in various parts of the world due to its rapid spread at critical stages of wheat grain production. The way to control this disease are application of foliar fungicides, using early maturing varieties, and utilizing resistant varieties (De Wolf and Shroyer, 2017).
7. The Hessian fly is often ranked as the most important insect pest in winter wheat production. If the hessian fly is responsible for the lodging, larvae or pupae will be present on the stems when the leaf sheaths are carefully stripped away to expose the stems (Whitworth et al., 2009). Sowing winter wheat late, crop rotation, and plowing under stubble containing fly eggs soon after harvest, or plant resistant varieties (Martin et al., 1976).
8. Wheat streak mosaic is one the most economically devastating wheat disease in Kansas and the Great Plains. It is a disease primarily of winter wheat. Three ways to control the spread: removal of volunteer wheat; avoid early planting; and plant resistance varieties (Martin et al., 1976).
9. Soil Borne Mosaic, which can persist in the soil for all extended period of time. Wheat soil borne mosaic is a viral disease of wheat. It is frequently reported in counties in the eastern two-thirds of Kansas. Symptoms of wheat soil borne mosaic include a mosaic of small “green islands” on a pale-yellow background. The disease

often occurs in patches within a field and wheat varieties susceptible to the disease may be significantly shorter than healthy plants in the same field (De Wolf, 2010).

Substitution of equations (5) and (6) into equation (4), plus the Variety Age and the lagged dependent variable, a regression model of the trends in demand for varieties of wheat (*i*) in each district (*j*) at year *t*:

(7) $$PCACRE_{ijt} = \alpha + \beta_1\ (PCACRE_{ij,t-1}) + \beta_2\ (Variey\ Age_{it}) + \beta_3\ (RELYLD_{ij,t-1})$$
$$+\beta_4\ (CVYLD_{ij,t-1}) + \beta_5\ (Public_{it}) + \beta_6\ (Test\ Weight_{it})$$
$$+\beta_7\ (Milling\ Quanlity_{it}) + \gamma' Q_{it} + \delta_j + u_{ijt}.$$

where Q represents the vector of state-level production characteristics, δ is the fixed effects, and u represents the error margin.

Chapter 5 - Results

Based on the nature of the unbalanced cross-section and time series data, the study utilized feasible generalized least squares regression model. This model will generally yield better estimates than ordinary least square under heteroscedasticity and serial correlation (Wooldridge, 2012). Instead of R-Square, in the model, the Wald-Chi Squares is reported to capture model statistical significance (McDowell, 2013). The test can be used for a model that including those binary variables. For all regression results, to show how our dependent variable of percent seeded acres of variety "*i*" at districts "*j*" in time "*t*" is affected by independent variables.

5.1 Wheat Variety Regression Results with District Fixed Effects

The regression results are shown in Table 2. The Wald-Chi Square is highly significant. The regression used district data from nine Kansas crop-reporting districts. The district fixed effects were estimated to determine whether the vector of fixed effects contributed to the overall model.

In the regression output, the district fixed effect variables are included. The Central district is excluded due to avoid perfect collinearity. The eight districts (NorthWest, NorthEast, NorthCentral, WestCentral, EastCentral, SouthEast, SouthWest,) are compared with the (omitted) Central district. The WestCentral district planted more varieties with small percent seeded acres and the EastCentral plant fewer varieties on more percent seeded acres compared with Central district.

Table 2. Wheat Variety Regression Results with District Fixed Effects, 1990-2016

Variables	Coef.	Std.Err.
Intercept	-10.660***	1.557
PCACRE(t-1)	0.761***	0.019
Variety Age	-0.422***	0.030
RELYLD(t-1)	8.163***	0.491
CVYLD(t-1)	-1.157**	0.412
Public	1.592***	0.327
Production Characteristics		
Maturity	-0.091	0.422
Maturity Square	-0.106	0.057
Straw Strength	-0.208**	0.074
Winter Hardy	0.073	0.080
Leaf Rust	0.234***	0.053
Stem Rust	0.866***	0.086
Hessian Fly	0.051	0.051
Wheat Streak Mosaic	0.533***	0.107
Soil Borne Mosaic	0.299***	0.060
End-Use Qualities		
Test Weight	-0.802***	0.161
Milling Quality	1.222**	0.424
Districts		
North West	-0.374	0.429
West Central	-1.002**	0.383
South West	0.456	0.422
North Central	0.274	0.362
South Central	0.431	0.403
North East	-0.151	0.352
East Central	1.040**	0.369
South East	0.524	0.550
Number of Observations	604	
Wald Chi Square	125046.300***	
Prob>chi2	<0.01	

Note: Dependent Variable: percent seeded acres of variety i in district j at year t.
Production Characteristics and test weight variable are rated from 1 (best) to 9 (poorest), Maturity is rated from 1 (earliest) to 9 (latest) and Milling Quality is rated from 1 (Less desirable) 2 (Acceptable) 3 (Exceptional).
* $p<0.05$, ** $p<0.01$, *** $p<0.001$

Source: Kansas Performance Teats with Winter Wheat Varieties 1990-2016.

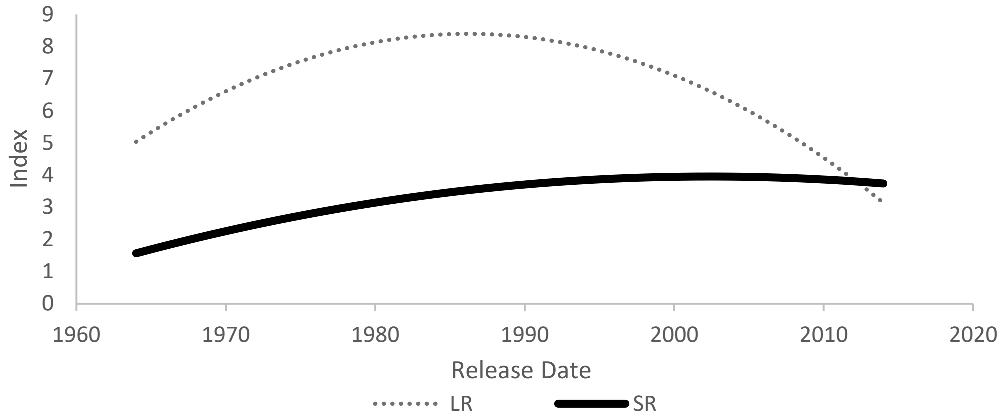
The lagged percent seeded acre variable's coefficient was positive and statistically significant at the one percent level. The reasons could be that most producers use the seed wheat for the following year, which has come from the portion they saved last year. The strategy of saving wheat from the current year for the coming planting is a common practice. This is driven by the fact that if producers do not own adequate wheat seeds for planting coming year, they are forced to pay the prices in the market to acquire the seeds (Barkley and Porter, 1996). If the percent seeded acres last year increased by one unit, the percent seeded acres this year increased by 0.761, holding all else constant. This is shows that 76 percent of the last year seeded for the wheat variety is retained in the next year.

The negative value of the variety age reflects that the farmer prefer to plant the newer variety rather than the older variety, since the newer variety may have better characteristics in resistance to disease or insect or higher potential yield than the old varieties. However, it will take time for farmers to adjust to plant new wheat varieties. The relative yield variable's coefficient was statistically significant at the one percent level and positive, which shows that this variable is an important part in wheat variety selection, and the producers relied more on past production of wheat variety. When the relative yield increase by one unit, the percentage of seeded acre for the current year will be increased by 8.163, holding all else constant. Farmers are also looking at yield stability when they make decision in regard to seeds options. The higher value of the yield stability, the lower is the reliability of the wheat variety. When the yield stability increased by one unit, the percent seeded acres in current year will decrease by 1.157, holding all else constant. The positive estimated coefficient on the Public (qualitative measure of price) shows that the farmers' preference for public brands is higher than for private wheat brands. The coefficient of this variable implies that farmers choose public varieties over private ones by 1.592, holding all else constant. The estimated coefficient on public is 1.592 compared with Barkley and Porter (1996) is 3.104, this result may be associated with the fact that public varieties indicate lower prices compared to the private. However, there will be competition between wheat varieties released by public and private since the estimators on public compared with Barkley and Porter (1996) is much smaller. If the sign of the coefficient changed from positive to negative, that would tell us that the farmers preferred private wheat varieties over the public wheat varieties which this is not the case here.

The production characteristic results (rated on a scale of 1 is best to 9 is poorest, except for maturity 1 is earliest) differ from the previous research by Barkley and Porter (1996) and it is estimated that most of them demonstrated a negative coefficient on production characteristics, statistically different from zero. However, most of the production characteristics have positive coefficients and are highly significant at the one percent level (statistically different from zero). It might be that the characteristics were not yearly factors. Those production characteristics may depend on time and climate changes. Some years those may be high, some years those might be low, just like Barkley and Porter (1996) found in Hessian Fly characteristics coefficient is also positive and significant. Another reason why those production characteristics may have become positive over time is because the wheat price is high enough to cover the chemicals the producer will use to stop disease or insects in 1990 to 2016. The more produced, the higher profits they received in order to cover the lost from the disease or insect affection in the timeframe from 1990 to 2016. If the wheat variety with higher rating on production characteristics (the higher rating means less tolerant/resistant to diseases and insects), the producers will still choose this variety because the variety has higher potential yield. For example, the variety Everest, has excellent yield potential, and lower performance on wheat streak mosaic disease. However, this variety has been the most planted variety in the state for several years.

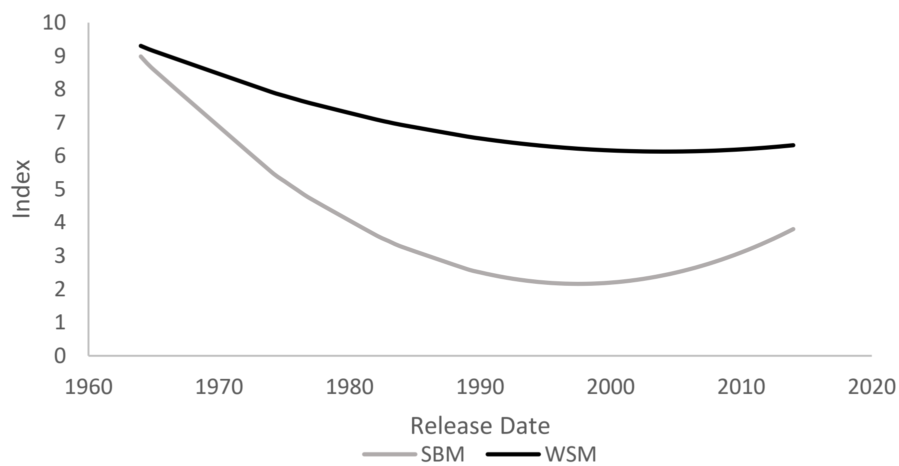
Figures 2 to 4 are scatter plots with smoothed lines, the regression line expresses a mathematical relationship between the independent variable (release date and release date squared) and dependent variable (leaf rust, stem rust, straw strength, wheat streak mosaic, and soil borne mosaic). It's expressed as a quadratic curve. Figure 2 shows that leaf rust and stem rust resistance have improved over time due to a negative nonlinear relationship. Figure 3 shows the wheat streak mosaic and soil borne mosaic have a positive relationship with release date. Figure 4 shows the straw strength variable has positive relationship with release date. The estimators on the leaf rust, stem rust, wheat streak mosaic, and soil borne mosaic have positive sign and statistically significant at the one percent level (different from zero), with increase numerical value by one in those variables (the rating of those variables increased by one), the percent seeded acres will increase by 0.234, 0.087, 0.533, and 0.299, holding all other constant. Straw strength's coefficient remains negative and statistically significant at the five percent level, with increase numerical value of this variable by one unit, the percent seeded acres will decreased by 0.074, holding all else constant. Hessian fly and winter hardy variables have positive coefficients in the regression results, and maturity, maturity square have negative coefficients, but all of them are insignificant (not statistically different from zero). Hessian fly's coefficient being insignificant may be because it depends on the plant date and locations. Winter hardy is insignificant might due to climate conditions, some years perform highly and some years do not. Maturity is the rated on one (earliest) to nine (latest) characteristic. Because the weather is hard to predict, some wheat varieties with early maturity quality will be more damaged by a freeze than other later maturity varieties.

Figure 2. Leaf Rust and Stem Rust Indexes, 1990-2016



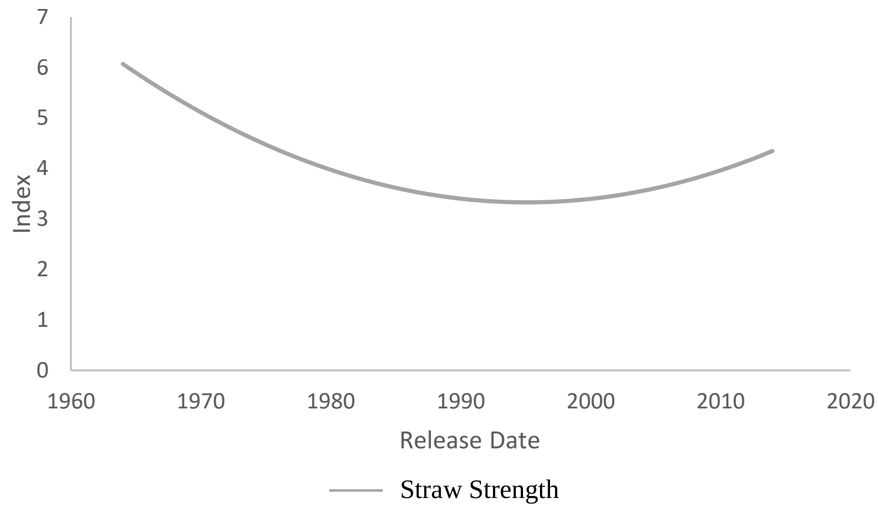
Note: Leaf Rust (LR) and Stem Rust (SR) were rated from 1 (BEST) to 9 (POOREST).
The regression line expresses a mathematical relationship between the independent variable (release date and release date squares) and dependent variables (Leaf Rust and Stem Rust).
It's expressed as a quadratic curve. Scatter plot with smooth lines.
Source: Kansas Performance Tests with Winter Wheat Varieties 1990-2016.

Figure 3. Wheat Streak Mosaic and Soil Borne Mosaic Index, 1990-2016



Note: Soil Borne Mosaic (SBM) and Wheat Streak Mosaic (WSM) were rated from 1 (BEST) to 9 (POOREST).
The regression line expresses a mathematical relationship between the independent variable (release date and release date squares) and dependent variables (Soil Borne Mosaic and Wheat Streak Mosaic).
It's expressed as a quadratic curve. Scatter plot with smooth lines.
Source: Kansas Performance Tests with Winter Wheat Varieties 1990-2016.

Figure 4. Straw Strength Index, 1990-2016



Note: Straw Strength rated from 1 (BEST) to 9 (POOREST).
The regression line expresses a mathematical relationship between the independent variable (release date and release date squares) and dependent variable (Straw Strength).
It's expressed as a quadratic curve. Scatter plot with smooth lines.
Source: Kansas Performance Tests with Winter Wheat Varieties 1990-2016.

The impact on end-use quality also changed compared to the results from Barkley and Porter (1996) in their research, they found only the milling and baking quality is significant, but in this study, we found the test weight also became significant. The test weight can be interpreted as price discount in the wheat production and it became important component with negative impact on percent seeded acres (lower number rating better performance on test weight), statistically different from zero at the one percent level. It means with test weight of wheat variety decrease (increase numerical value of test weight rating), it will decrease percent seeded acres by 0.802, holding all other constant. Milling and baking quality is indicated as price premium (Barkley and Porter, 1996). The coefficient on milling and baking qualities is positive, statistically different from zero at the five percent level. If milling and baking quality increased by one unit (better rating of milling and baking qualities), the percent seeded acres will increase by 1.222, holding all else constant. The end-use qualities results show the evidence to supported that the producers prefer to plant more of the wheat variety with better performance on test weight and milling quality, if the variety they choose has similar yield potential compare to other variety with lower performance on end-use qualities. In the study, we used these two variables to be the price determinants in the variety selection, better performance on the end-use qualities better profit farmers can get.

5.2 Wheat Variety Regression Results without District Fixed Effects

The simple regression which does not include district fixed effects, is recorded in Table 3. The Wald-Chi Square is highly significant. This is lower than Wild-Chi Square in Table 2. We can see the results without district fixed effects.

Comparing the results in Table 3 with Table 2, the model results without district fixed effects are qualitatively similar to the regression results with district fixed effect. Except the estimated coefficient signs of maturity square that were changed from insignificant to statistically significant at the five percent level in production characteristics. This might be because the maturity square is correlated with district. When we excluded the district fixed effects in regression, it is statistically significant at the five percent level. If maturity square is rated on the scale increased by one unit, the percent seeded acres in the current year will decrease by 0.148, holding all other factors constant. The significant level of straw strength is changed from five percent to one percent level. The level of significance of yield stability is also increased from the five percent to one percent level. Positive and highly statistically significant coefficients included lagged percent seeded acres, relative yield, public, leaf rust, stem rust, wheat streak mosaic, soil borne mosaic and milling and baking quality. Negative and highly significant coefficient are variety age, yield stability, straw strength and test weight. The statistically significance of straw strength is increased from the five percent to the one percent level.

Comparing the results in both with district fixed effects and without district fixed effects, there are not many differences across the models.

Table 3. Wheat Variety Regression Results without District Fixed Effects, 1990-2016

Variables	**Coef.**	**Std.Err.**
Intercept	-11.040***	1.146
PCACRE(t-1)	0.783***	0.015
Variety Age	-0.429***	0.027
RELYLD(t-1)	9.379***	0.359
CVYLD(t-1)	-1.736***	0.338
Public	2.052***	0.286
Production Characteristics		
Maturity	0.175	0.359
Maturity Square	-0.148**	0.050
Straw Strength	-0.269***	0.068
Winter Hardy	0.073	0.065
Leaf Rust	0.162***	0.035
Stem Rust	0.849***	0.062
Hessian Fly	0.022	0.041
Wheat Streak Mosaic	0.598***	0.076
Soil Borne Mosaic	0.202***	0.036
End-Use Qualities		
Test Weight	-0.896***	0.138
Milling Quality	1.151**	0.361
N	604	
Wald Chi Square	56112.510***	
Prob>chi2	<0.01	

Note: Dependent Variable: percent seeded acres of variety i in district j at year t.
Production Characteristics and test weight variable are rated from 1 (best) to 9 (poorest), Maturity is rated from 1 (earliest) to 9 (latest) and Milling Quality is rated from 1 (Less desirable) 2 (Acceptable) 3 (Exceptional).
* p<0.05, ** p<0.01, *** p<0.001
Source: Kansas Performance Teats with Winter Wheat Varieties 1990-2016.

5.3 Wheat Variety Regression Results with Year Fixed Effects

The regression results of year fixed effects variables are recorded in Table 4. The Wald-Chi Square is highly significant. Several significant coefficients sign are changed from positive to negative. These coefficients include: leaf rust, hessian fly, and wheat streak mosaic. The coefficients sign changed might because they had some correlation with these year fixed effects. If some years there was an major yield loss due to those diseases, the variety with better resistance will become more valuable than other variety with less tolerant on the diseases.

The significant level of coefficient variance and public are not statistically different from zero at the ten percent level. All the production characteristic variables' coefficients are statistically significant at one percent level, except the coefficient of maturity statistically significant at the ten percent level, and maturity square is not statistically different from zero at the ten percent level. For end-use qualities, the test weight the sign and significant level remains same, but the milling and baking quality become not statistically different from zero at the ten percent level with negative sign.

By adding a year dummy, we excluded the year of 2016; we compared how other years will be affected by excluding 2016. Year of 1990 to 2006 are statistically significant at the one percent level, except 1993, and 2007 to 2015 are not statistically different from zero at the ten percent level, and year of 1996 the significant level is at the five percent.

Table 4. Wheat Variety Regression Results with Year Fixed Effects, 1990-2016

Variables	Coef.	Std.Err.	Year	Coef.	Std.Err.
Intercept	1.251	1.787	1990	3.349***	0.557
PCACRE(t-1)	0.753***	0.017	1991	3.584***	0.584
Varity Age	-0.354***	0.020	1992	3.227***	0.658
RELYLD(t-1)	6.973***	0.740	1993	3.011	2.138
CVYLD(t-1)	-0.321	0.994	1994	8.785***	1.432
Public	0.064	0.353	1995	5.653***	0.991
Production Characteristics			1996	2.417**	0.840
Maturity	-0.668*	0.322	1997	3.858***	0.882
Maturity Square	-0.008	0.046	1998	4.055***	0.739
Straw Strength	0.311***	0.070	1999	5.063***	0.775
Winter Hardy	0.370***	0.096	2000	3.782***	0.927
Leaf Rust	-0.252***	0.064	2001	4.495***	1.013
Stem Rust	0.813***	0.067	2002	5.055***	0.785
Hessian Fly	-0.241***	0.049	2003	4.916***	0.830
Wheat Streak Mosaic	-0.495***	0.108	2004	5.245***	0.845
Soil Borne Mosaic	0.461***	0.049	2005	4.799***	0.813
End-Use Qualities			2006	2.999***	0.830
Test Weight	-0.621***	0.144	2007	2.211	1.141
Milling Quality	-0.595	0.486	2008	-1.011	0.802
N	604		2009	0.269	0.579
Wald Chi Square	153495.100***		2010	0.601	0.550
Prob>Chi2	<0.01		2011	0.302	0.505
			2012	-0.664	0.481
			2013	0.475	0.519
			2014	-0.752	0.559
			2015	-0.299	0.305

Note: Dependent Variable: percent seeded acres of variety i at district j in year t.
Production Characteristics and test weight variable are rated from 1 (best) to 9 (poorest), Maturity is rated from 1 (earliest) to 9 (latest) and Milling Quality is rated from 1 (Less desirable) 2 (Acceptable) 3 (Exceptional).
* p<0.05, ** p<0.01, *** p<0.001
Source: Kansas Performance Teats with Winter Wheat Varieties 1990-2016.

5.4 Wheat Variety Regression Results with District and Year Fixed Effects

The regression results of district and year fixed effects are recorded in Table 5. The Wald-Chi Square is highly significant. The result with fixed effect of districts and year will compare with the Table 2. Several significant coefficients sign are changed compare with Table 2. These coefficients include: straw strength, leaf rust, hessian fly, and wheat streak mosaic. For eight district fixed effects, we excluded the central district. For year fixed effects, we excluded year of 2016 to avoid perfect collinearity.

The estimated coefficients of yield stability and public are not statistically different from zero at the ten percent level. For production characteristics, straw strength variable's coefficient is positive but not statistically different from zero at the ten percent level. The winter hardy variable's coefficient is positive, and statistically significant at the five percent level. The negative signs of coefficients on leaf rust, hessian fly, and wheat streak mosaic are statistically significant at the one percent level, the stem rust and soil borne mosaic are positive signs and significant at the one percent. The end-use qualities, the milling and baking qualities is not statistically different from zero at the ten percent level.

For district fixed effects, compared with Central district, the coefficient of the WestCentral is statistically significant at the one percent level with negative sign means more wheat varieties planted with small percent seeded acres. The coefficient of the SouthCentral is statistically significant at the ten percent level with negative sign suggesting that more wheat varieties planted with small percent seeded acres. The coefficient of the NorthEast is significant at the five percent level with negative sign suggesting that more wheat varieties planted but small percent seeded acres. The coefficient of year of 1990, 1991, 1992, 1994, 1995, 1997, 1998, 1999, 2000, 2001, 2002, 2003, 2004, 2005, and 2006 are statistically significant at one percent level. The coefficient of year 1996 and 2014 are statistically significant at the ten percent level, and the coefficient of year 2006 is statistically significant at the five percent level, all those compared with year of 2016.

Table 5. Wheat Variety Regression Results with District and Year Fixed Effects, 1990-2016

Variables	Coef.	Std.Err.	Year	Coef.	Std.Err.
Intercept	3.608	-2.365	1990	3.375***	0.596
PCACRE(t-1)	0.712***	0.021	1991	3.823***	0.666
Variety Age	-0.335***	0.022	1992	2.850***	0.684
RELYLD(t-1)	6.277***	0.841	1993	2.514	2.138
CVYLD(t-1)	-0.083	0.984	1994	8.252***	1.478
Public	0.237	0.381	1995	5.535***	1.045
Production Characteristics			1996	1.940*	0.934
Maturity	-0.680	0.407	1997	3.232***	0.943
Maturity Square	-0.011	0.060	1998	3.439***	0.795
Straw Strength	0.169	0.092	1999	4.487***	0.819
Winter Hardy	0.256**	0.098	2000	3.482***	0.962
Leaf Rust	-0.415***	0.094	2001	4.070***	1.040
Stem Rust	0.858***	0.080	2002	4.825***	0.820
Hessian Fly	-0.263***	0.058	2003	4.437***	0.863
Wheat Streak Mosaic	-0.586***	0.136	2004	4.710***	0.894
Soil Borne Mosaic	0.525***	0.052	2005	4.291***	0.859
End-Use Qualities			2006	2.418**	0.890
Test Weight	-0.574***	0.149	2007	2.043	1.108
Milling Quality	0.224	0.525	2008	-1.622	0.837
Districts			2009	-0.460	0.635
North West	-0.311	0.403	2010	-0.317	0.644
West Central	-1.400***	0.315	2011	-0.433	0.609
South West	0.376	0.572	2012	-1.238	0.633
North Central	-0.490	0.263	2013	-0.095	0.641
South Central	-0.714*	0.324	2014	-0.752	0.667
North East	-1.122**	0.351	2015	-0.223	0.329
East Central	-0.253	0.338			
South East	0.069	0.332			
N	604				
Wald Chi Square	31685.420***				
Prob>Chi2	<0.01				

Note: Dependent Variable: percent seeded acres of variety i at district j in year t.
Production Characteristics and test weight variable are rated from 1 (best) to 9 (poorest),
Maturity is rated from 1 (earliest) to 9 (latest) and Milling Quality is rated
from 1 (Less desirable) 2 (Acceptable) 3 (Exceptional).
* $p<0.05$, ** $p<0.01$, *** $p<0.001$
Source: Kansas Performance Teats with Winter Wheat Varieties 1990-2016.

Chapter 6 – Implications and Conclusions

This empirical model is specified to determine whether yield stability, relative yield, production characteristics and end-use qualities were used in wheat producers' decisions (percentage of wheat acres to each variety) to select wheat varieties in Kansas, 1990 to 2016. The model showed similar results to previous study (Barkley and Porter, 1996). Kansas wheat producers relied more on the wheat varieties they choose last year and relative yields than in previous time periods, and they still emphasize saving wheat from last year rather than purchasing the new seed from this year. So, most likely for Kansas wheat varieties, a lot of the same wheat varieties will be planted in the following year. The producers have placed a strong emphasis on past production, relative yield, yield stability, and variety age.

Farmers care about the production characteristics due to statistically significant level, but the interesting implication in this study is that farmers will choose a productive variety of wheat that a host of not desirable characteristics such as less tolerant in soil borne mosaic. The results may support that Kansas producers care more about potential yield on wheat variety. Other reasons may because the wheat price is high in 1990 to 2016. The farmers can manage with ease without much impact on the cost of production. With some of the wheat varieties which have high rating on these production characteristics, farmers are still planting these wheat varieties, such as variety Everest. However, the production characteristics are important to farmers based on some of the variables that are statistically significant.

According to Barkley and Porter (1996), wheat producers in Kansas are taking milling and baking qualities into account while considering which wheat varieties they are going to plant. The results on end-use quality suggest that the farmer considers test weight as well as considering the milling and baking qualities of wheat varieties. The result on the end-use qualities, the milling and baking industries may still not be receiving the highest quality wheat. Barkley and Porter (1996) noted that for industry to want to have high quality of end-use they could increase the premiums or develop more varieties with high yield and high milling and baking qualities. Farmers care about the end-use qualities but not as much as yields and past production choices. For farmers who are trying to maximize the profit, they would like to choose the wheat variety with higher yield rather than considering the end-use qualities. Economic considerations lead many farmers to plant higher- yield varieties, some of them are characteristics by better performance on test weight and milling and baking quality.

Farmers in Kansas in times 1990-2016 were only considering high yield potential wheat varieties than considering better quality on the production characteristics. Future research should carry out in order to find out the reason why the production characteristics showed a decreasing quality over this time periods. For wheat breeders, they will need continue develop high yielding, with better performances on end-use quality, like Jagalene. It will leads farmers to plant higher yield wheat varieties with better performance on end-use qualities in order to take advantage on price premium.

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