Weather Cycles, Production Yields and Georgia's Muscadine Market

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Selected Paper prepared for presentation at the American Agricultural Economics Association Annual Meeting, Portland, OR
July 29-August 1, 2007

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Abstract

This paper looks at the relationship between weather, crop yield, and market price of muscadines using a dynamic panel data that spans from the 2000 to 2005 and across the state of Georgia. We use a Generalized Methods of Moments technique to estimate the impact of weather on the price of muscadines with the yield per acre as the instrumented variable. The results suggest that there is a relationship between the price and weather for muscadines, which provide important implications for the potential relevance of a weather derivative for muscadine production.

Key Words: muscadines, weather cycles, price, production yields, Georgia, Generalized Method of Moments

We would like to acknowledge Sue Boatwright, Charles Cowart, Pam Knox, and Gerard Krewer for their indispensable assistance on this paper.

I. Introduction

In recent years, in terms of planted acreage, grapes have become one of the prominent fruit crops in the United States. It has grown from 5,912,350 tons in 1995 to 5,960,900 tons in 2004 (Trade Data & Analysis, 2004). Within the United States California, New York and Washington lead the way with grape production; however, other states, such as Georgia, are starting to become major players in grape industry.

Georgia's aggregate grape yield has grown from 8.89 million pounds in 2000 to 11.22 million pounds in 2005, resulting in a 26% increase in production within a 6 year period. The majority of the increase in production has been due primarily to the increase in demand of muscadine grapes and to the suitable growing climate for muscadines. Specifically the species *Muscadinia* thrive in Georgia's climate.

Where the rest of the world only can produces a variety of grapes in *Euvitis*, which include Concord and Niagara species, southeastern United States is a region where the muscadines have the benefit of having a niche grape market. Thus, measuring the impact of weather on Muscadine grape production yields and prices is essential to the continued growth of Georgia's 40 year old infant industry.

Muscadines have recently become more popular than *Euvitis* grape cultivation in Georgia for a variety of reasons. Recently published articles emphasize its health benefits such as its role as inhibitors of carcinogens, cholesterol-reduction, and improvement in joint inflammation through inherent agents such as antioxidants, phenolic acid, and trans-resveratol. (Quick, 2004; Yi, 2006; Gog, 2007; Core, 2006). This resulted in an increase in demand for muscadines, making it imperative that those stochastic events that affect yield and price be investigated.

Using data obtained from the University of Georgia Extension Center this paper analyzes the impact of weather on prices through production yields. The objective of this paper is to measure the weather effects on Georgia production yields and the resulting effect on muscadine market prices in the southeastern market throughout the state of Georgia. By regressing weather trends (through a Generalized Methods of Moments model (GMM)) on vineyard yields and market prices, (1) a more thorough insight of the effects of weather on the market price, and (2) and the significance of the relationship of Georgia's impact on the southeastern market can be determined.

Through this analysis, the effects of weather on prices can be used to determine the relevance of weather based crop insurance, which thereby help to reduce risk and encourage muscadine cultivation in Georgia. This analysis is not only of use for farmers and insurers in Georgia, but also to other southeastern states (North Carolina, Tennessee, Alabama, etc.) producing muscadines. The results of this paper indicate that there is some relationship between weather and prices (via production yields). As one of the primary producers of muscadines in the United States, Georgia's influence on the market will surely affect the prices and production in other states therefore the effects of weather on Georgia's prices and production will, in turn, affect other muscadine producing states.

The paper is structured as follows. The succeeding two sections will review the current literature on weather's influence on muscadine and grape production and weather's link to prices. Section IV discusses the dynamic panel data analyzed in this study, which is followed by a discussion on the methodology, particularly the use of Generalized Method of Moments (GMM) to fix the heterogeneity inherent in the model. Section VI discuss the results and section VII concludes.

II. Weather's Effect on Grape and Muscadine Production

The April 2007 late frost and the subsequent speculation on its impact on fruit prices demonstrates the relevance of weather on everyday life. This is even more true for those crops without international producers. While fruits such as apples, oranges, and even grapes that can be imported from other states not affected by the extreme weather fluctuations or through international imports, something so specific as muscadines are more vulnerably affected by such changes. Interestingly, muscadine supply does not have a fallback on an out-of-state source (other than those in the southeast) or country to rely on for supply in the event of a serious adverse weather situation such as the late frost occurrence earlier this year (Goggins, 2007).

The link between production and weather for crops has been studied through many research articles (Matthews et al, 1988; Bergqvist et al, 2001; Proebsting et al, 1980; Chen et al, 2005). The two most prominent areas in researching this topic are economics and agronomy. The majority of muscadine literature has generally been written by agronomists who are looking at specific case studies and experiments that test how weather affects production. For instance Folwell et al (1994) uses a log-log functional form to estimate harvest yields of concord grapes. The dependent variable in his model was five measurements of flower clusters between late March and early September with the independent variables composing of: the number of clusters per vine, the natural log of year t and one weather variable, the lowest December temperature for that growing season. This study, in the yield estimates of concord grapes, was limited by its use of only four weather stations in the state of Washington. However, there are some problems with the weather inclusion as the stations were not located in all the sections of Washington that produce concord grapes and the data were not contiguous. In addition, they only used one weather variable that did not capture the growing season, or even the winter season, accurately. The results found that the December variable was not significant.

Temperature plays an important role in the development of on crops, since drastic low temperatures can cause a significant decrease in the health of the muscadine buds and vine. It is thus touted as the quintessential "supreme controller of plant life" (Oliveira, 1998). There is a base temperature that is required for bud break and flowering, and while this base temperature is different for muscadines versus other grapes Oliviera's (1998) study of *Vitis vinifera* still provides useful information that can be applied to muscadines. Oliveira in his article concludes that the air temperature has a significant effect on bud breaking and flowering. If the grapevine cannot reach the base temperature early enough then there will be an effect on bud break and flowering. Some of the weather variables noted by this and others studies were chilling days, days that fell below ten degrees and rainfall(Oliveira, 1998; Kovacs et al, 2003).

As witnessed this year, a late frost can be extremely detrimental to fruit production where countless crops of Georgia, South Carolina, North Carolina and all the way to West Virgina and Texas were devastated (Goggins, 2007). Late frosts are especially harmful as the grapes have, due to the warming weather preceding the frost, come out of their protective dormant stage and are therefore susceptible to cold weather (Cowert, 2007; Kovacs et al, 2003).

There is a paucity of literature on weather's influence on muscadine production. Moreover the majority of literature available on muscadine production is outdated. There is a real need for researchers to conduct and publish recent information on muscadine production. This is especially urgent as muscadines gain prominence in the natural health market due to the high levels of resveratol found in muscadine wine. Goldy (1988), one of the few articles available, reports on how different yield components correlate to muscadine yield. The yield components examined were flower and fruit number, fruit set, and fruit weight. Significance was exhibited for all the variables except for fruit weight. This indicated that encouraging the development of flower and flower cluster will potentially result in a greater yield. Basiouny et al (2001) provides the most comprehensive look at muscadine from rootstock to harvest and everything in between through a collection of articles. Basiouny et al. looks at the connection between weather and flower/flower clusters. A connection between last year's weather and this year's flower/flower clusters is found. This, along with the correlation between number of flower/flower clusters and yields, provides fertile ground for researching the link between weather and prices.

III. The Link Between Weather and Prices

The literature available on linking weather affects on price changes in grapes ranges from limited to nonexistent for muscadines. However, a small number of articles exist linking weather to wine prices. Lecocq et al. (2006) is one of the most recent to publish a study examining the relationship between wine prices and weather. In their study they look at whether using local weather stations significantly differs from using a regional weather station in Bordeaux when regressing wine prices and weather. Their results indicate that while the local stations do better, it is not significantly better. The region Bordeaux can be compared to a state county in the United States. An interesting conclusion by both models (local vs. regional weather stations) establishes that a relationship exists between the rainfall recorded and the wine prices. Specifically there is a negative relationship between the amount of rain and the price of wine. A simple log-linear model was used to compute the regression.

Another popular method of testing the relationship between wine and prices is through the use of hedonic pricing methods. Haeger (2005) uses this method and concludes that pinot noir prices are mainly decided by temperature and precipitation. Jones (2001) is more specific in his findings as warm dry summers result in a better quality Bordeaux Crus Classes, which, in turn, result in higher prices.

As visible by the lack of available research on linking weather to prices, this is an area that has a lot of room for exploration. While trying to tie weather to prices would be difficult for the main crops (cotton, grain, corn, etc.), it is a workable (and needed) estimation for a niche crop that does not have external competition. This is ever more relevant as global warming (and therefore the changes in weather patterns) become a growing concern and therefore increases farmers' risk.

IV. Data

The data collected and utilized in the paper are : (1) production yields, (2) weather patterns, (3) and prices for muscadines. The data ranges from the fiscal years of 2000 through 2005 and is separated into four categories: (a) combined, (b) wine/juice, (c) fresh/table, and (d) u-pick. The combined data is all of the three succeeding categories combined. The production data for each category is summed together, while the price data is averaged over the three categories at the county level. The wine/juice, fresh/table, and u-pick all have separate production and price data for each producing county. The datasets for categories "b" to "d" are from the years 2001-2005, while category "a" is from 2000-2005. Categories "b" to "d" could not be broken down into the three categories for 2000. All the categories use unbalanced, dynamic panel data. (See Table 1 for the summary statistics)

Initially, production data was collected from several vineyards throughout Georgia, such as *Still Pond Vineyard and Winery*, and *Paulk Vineyards*. Unfortunately, due to the lack of an adequately large enough sample of grower information, the data used in this study is limited to that which was collected from the University of Georgia Agricultural Extension Service. One of the hurdles found with using this data is that the Georgia county extension officers sometimes categorized muscadine and grapes synonymously. This leads to the data as sometimes being labeled as muscadines or grapes, when in fact they are referring both to muscadines. However, muscadines only grow under 1600 feet elevation in Georgia, whereas the major *Euvitis* grape grown in Georgia, vinifera, can only grow above 1600 feet elevation due to Pierce's Disease. Pierce's Disease has been a debilitating problem for wine growers in the south (where the disease originated) and recently has spread to California. Since the disease "spreads slowly at higher elevations" and is rampant under 1600 feet, we were able to isolate those counties that produce muscadines and those that produce vinifera (Omahen, 2005). Muscadines have a natural resistance to Pierce's Disease.

The price data was also obtained from the University of Georgia extension service and presents the prices for categories (b) table, (c) wine/juice, and (d) u-pick. The weather variables collected are from Georgia State Climatology Office and the Georgia Automated Environmental Monitoring Network of the College of Agricultural and Environmental Sciences of the University of Georgia. Thirty-six weather stations were used to collect the data. If a county did not have its own weather station, temperatures and rainfall would be averaged for the county from nearby weather stations (where the county would be in the middle of the two weather stations).

The counties that were used for the production and price data met two requirements: (1) the county had produced muscadines for at least three of the six years and (2) had more than 1 acre of commercial production in muscadines. Unfortunately these two requirements reduced our dataset from 60+ counties to 40+ counties. Although the reduction in data drastically reduced our degrees of freedom, we felt that using those counties that did not meet the aforementioned requirements would affect the accuracy of the model.

Some limitations on the data are the lack of grower specific information such as:

irrigation use, fertilizer use, pesticide use, IPM, etc. These data were not available as finding and receiving information from all growers in the 40+ counties was not possible.

V. Methodology

A Generalized Method of Moments IV Model (GMM) is used instead of a 2 Stage Least Squares (2SLS) approach due to the prevalent heteroskedasticity, which was determined by the use of the Pagan and Hall (1983) test. With the use of the GMM heteroskedastic-consistent estimator ($\hat{S}$) of the covariance matrix of the moment, conditions can be found (Hansen, 1982; Wooldridge, 2001; Alfaro, 2007; Baum, 2006).

$$\hat{S} = \frac{1}{N} \sum_{i=1}^{N} \hat{u}_i^2 Z_i' Z_i \quad (1)$$

A GMM approach allows for more efficient use of the information in the moment conditions, and also provides for a robust standard error estimation. It has been acknowledged that the GMM model is not dependent on using first-stage functional form and that the first differenced equation can have poor sample properties in terms of statistical tests and precision (Angrist, 2001; Bun, 2007).

The Model

To estimate the GMM model a log-nonlinear function was used. This model was chosen to conform with the current literature available on muscadine production as well muscadine growers' testimonies. The null hypothesis is that there is no effect between weather and prices (via production) whereas the alternative hypothesis is that there is a relationship between weather and prices.

The first equation used in this study is based on market price and tests the affect of Georgia production on the market price. The second equation determines the affect of weather and its correspondence with production cycles, and illustrate the affects of weather on muscadine prices. It is hypothesized that market price is dependent on Georgia's yields. Our analysis will determine if there is a significant correlation between weather, production yields and price.

Equation 1

$$LMP = \beta_0 + \beta_1 LGY + \beta_2 LNCY \quad (2)$$

LMP is Log of Georgia Counties's Market Price

LGY is Log of Georgia Counties's Yields

LNCY is Log of North Carolina's Yields

Equation 2

$$LGY = \beta_0 + \beta_1 LYR^2 + \beta_2 HR^2 + \beta_3 LCD + \beta_4 DD + \beta_5 LC \quad (3)$$

GY is Log of Georgia County's Yields

LYR is Last Year's Yearly Rainfall

HR is This Year's Harvest Rainfall

LCD is Last Year's Chilling Days

DD is for Years Where the Disease Effect was Abnormally High

LC is whether the county is inland or coastal

In the first equation, the instrumented variable is the log of Georgia counties' yields with the log of North Carolina's yields included as a variable to help counter any substitution effect that may have arisen in the muscadine market. More information is being sought on influencing factors on Georgia's market prices for muscadines.

In the second equation, the excluded instruments for the LGY were the weather variables. These variables were chosen based on the literature available on muscadine production, as well as testimonials from local Georgia growers. The yield at harvest time is dependent on how many blooms and bloom clusters are on the vine. The number of clusters and buds are determined from the previous year's weather and in particular, with regard to the number of chilling days in the previous winter and the amount of rainfall from the previous year. During the actual flowering, maturation, and harvest time rain plays an important role, as too much rain can cause black rot, fungus, and mold to develop on the fruits thereby significantly reduce yields (Basiouny, 2001; Cowart, 2007). Late frosts also play an important role in the yield totals. However, due to the lack of late frosts in the dataset this variable was omitted from the equation. It would have been be interesting to see how the late frost in early 2007 will affect muscadine production, unfortunately, this data is not yet available.

This model will be run four times. The first run will use a compiled dataset of overall production and average prices. Next, the data set will be broken down into wine/juice, table/fresh, and u-pick production and prices. The compiled dataset has 183 observations broken down into 44 counties. The wine/juice muscadine dataset has 37 observations broken down into 16 counties; the table/fresh muscadine data set has 36 observations broken down into 15 counties; and the u-pick muscadine data set has 81 observations broken down into 32 counties

VI. Empirical Results

All Muscadine Categories Combined

The first column of Table 2 shows the results for the combined (wine/juice, table, and u-pick) muscadine dataset. Yield per acre is positively and significantly correlated with price per pound. North Carolina yield is also positively and significantly correlated with price per pound, implying that North Carolina production may complement, instead of substitute, Georgia's production.

North Carolina yield coefficient of .452 (p-value .008) supports the theory that North Carolina serves as a complement for Georgia in muscadine production. The fact that North Carolina serves as a complement for Georgia indicates an overall growth in demand for the muscadine market. This may be in part due to the growing demand for muscadines, not only in the south, but also in the northeast as well. This theory is supported by the fact that there has been more intense growth in the last 5 years than there has been for the previous 35 years combined (Cowart, 2007). One of the major buyers, outside of the south, is Hunts Point Market in New York, where the muscadine taste not only appeals to migrated Southerners, but also to international foreigners who identify with familiarity in the muscadine flavor (Cowart, 2007).

Of course the increase in demand can also be witnessed through the yield per acre coefficient (.556, p-value .019) where there is a positive relationship between prices and yield. This indicates that even though yield may increase, demand is growing at a faster rate thereby raising prices as well. This is supported by the overall increase in production in muscadines in Georgia with a growth of 86% in the last 10 years.

Of course this model looks at the combination of all three of the muscadine categories and uses an average price over the three categories to estimate the model. A better understanding of the muscadine situation in Georgia may be obtained through the analysis of each category separately.

Table Muscadines

The analysis of table muscadine production also exhibits a positive and significant correlation between yield per acre and price per pound, however, the North Carolina yields are not statistically significantly with price per pound. This may be due to the fragile nature of fresh/table muscadines' sensitivity to time and temperature after harvesting and thereby are not able to be imported into the state.

Muscadine fruits bind strongly to their vines. During harvest this resistance to removal often results in tears in the tough skin. Due to these skin abrasions, the shelf life of muscadines is reduced to only a few days. Not only is time an issue for the muscadines, but transportation would also be difficult due to the pressure on the muscadines during travel which would encourage spoilage. Any rotten muscadines in the shipment would cause otherwise healthy fruit to accelerate in its decay. Due to these limitations, fresh muscadine production is localized to the surrounding communities and therefore North Carolina muscadines cannot be considered either a complement or substitute for Georgia's muscadines. These results can be seen on Table 2, Column 2.

The positive coefficient (.455, p-value .039) between yield per acre and price per pound suggests that demand for fresh/table muscadines is growing. This is due in part to the new literature on the health benefits of the muscadine fruit from the high levels of antioxidants and resveratol. However, since most of the beneficial nutrients are larger due to the high concentrations of the juice, the muscadine wine/juice industry has been having the more growth than any of the other muscadine categories.

Wine/Juice Muscadines

Wine/juice muscadine production shows a slightly different picture. While both North Carolina yields and the yield per acre are statistically significant, yield per acre is negatively related to price per pound. North Carolina yields are still positively related to price per pound, once again, supporting the idea that North Carolina production is a complement to Georgia's production. These results can be seen in Table 2, Column 3.

The negative relationship between Georgia's yield coefficient (-1.09, p-value .07) and the price might be due to the greater increase in muscadine wine production than actually demanded by the market. Muscadine wine production has increased recently due to some large farms converting completely to wine/juice production, due to rising labor costs. When harvesting wine/juice muscadines a mechanical harvester can be used. However, for fresh/table muscadines, hand harvesting is required to reduce harvest damage to the fruit and thereby keep the muscadine as intact as possible.

While the North Carolina yield coefficient (3.26, p-vale .019) it is still positive and therefore a complement to Georgia's market price, the conversion of table/fresh muscadines into wine muscadines has increased at a faster rate than demand. However, it will be interesting to see how this relationship changes once the larger farms are more stabilized and price is regressed on production without any conversions.

U-Pick Muscadines

U-pick muscadine production is the only model that does not have any significant correlation. This may be due to the fact that u-pick prices would be governed by a different set of variables than the wine or table grapes. Among other factors location seems to potentially influence u-pick prices would consider whether the farm was located in a high traffic location, urban versus rural areas, etc. These results can be seen on Table 2, Column 4.

VII. Conclusion

Muscadines are a fast growing niche market in the United States. While muscadines used to be a predominantly southeastern phenomenon, northern states are starting to appreciate their benefits and unique flavor. With this increase in demand, there has been an overall increase in production. To ensure the viability of this new niche market, stochastic factors such as weather need to be further examined. What is even more important is how sensitive prices are to weather among the difference categories of muscadines: fresh/table, juice/wine, and u-pick. The analysis can help farmers decide what category of muscadine they want to cultivate to maximize their revenues and farm income.

The results of this study will allow farmers to prepare for any loss when poor weather strikes. More importantly this allows them to look at the normal disturbances of weather and not only the rare late frost. As the years studied (2000-2005) did not have any extremely unusual weather, this study reflects on the everyday analysis. This information could also be used for weather derivatives and crop insurance to set the basis for insurance products.

The study provides important insight into weather variables and their effect on prices. There are three main conclusions that can be drawn about the economic relationships: (1) weather is a factor in determining Georgia's price of muscadines, (2) overall, demand is growing faster than production, and (3) muscadines are not governed by the 'law of one price'. The analysis of the impact of weather on prices indicates that mild weather increases the price of muscadines. This is mainly due to an increase in demand alongside with the increase in production. Even though this study has useful implications, it is far from plenary. There are limitations in this paper due to the lack of data in: irrigation use, fertilizer use, pesticide practices, and a limited cross-sectional and time-series sample.

Further research could be done on the link between the recent increase in demand, and the new literature on muscadine's health benefits. Another area for future research could be for the insurance market and discovering the optimal levels for crop insurance. This paper has many applications and its benefits span many markets and users. The conclusions on the positive correlation between weather's impact on prices should be further analyzed and improved on to generate further benefit for all those impacted.

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Variable	Mean	Std. Dev.	Min	Max
LMP	-.368	.262	-1.609	.322
(Log of Georgia's Market Price)				
LGY	8.421	.447	6.214	9.393
(Log of Georgia Yields)				
LNCY	.132	.135	-.150	.250
(Log of North Carolina Yields)				
LYR	43.773	8.419	24.210	64.340
(Last Year Total Rainfall)				
HR	11.211	5.518	0	50.410
(This Year Harvest Rainfall)				
LCD	10.627	7.813	0	33
(Last Year Chilling Days)				
DD	.168	.375	0	1
(Disease Dummy)				
LC	.261	.440	0	1
(Land/Costal)				

Table 1: Combined Summary Statistics

Variable	Combined	Table/Fresh	Wine/Juice	U-Pick
D.LYP	.556**	.457**	-1.091*	-.035
(Differenced Log of Georgia Yields)	(.237)	(.222)	(.603)	(.416)
LNCY	.452***	-.352	3.263**	.006
(Log of North Carolina Yields)	(.170)	(.344)	(1.395)	(.475)
Constant	-.443***	-.329***	-1.439***	-.247***
	(.034)	(.060)	(.282)	(.086)
* 90% **95% ***99%				

Table 2: Coefficients Table

Major Muscadine Counties In Georgia