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Selection of Peach Varieties and the Role of Quality Attributes

Timothy A. Park and Wojciech J. Florkowski

Timely adoption of new varieties is critical to profitable peach production, and peach quality is a primary factor driving adoption. An adoption model for peach varieties is estimated, incorporating grower evaluations of peach quality. The model identifies the impact of farm characteristics such as the farmer's quality preferences, on-farm agronomic and orchard conditions, as well as geographic effects in Georgia peach-growing regions. The relative impact of the key external and internal peach quality attributes on adoption is assessed. Decisions on new varieties are influenced by the age distribution of the orchard, information which can be used in targeting new varieties to growers.

Key words: count data, peach variety adoption, robust standard errors

Introduction

Leading peach cultivars change rapidly in Georgia production patterns, reflecting a continuing demand for new cultivars by growers. Selecting a profitable cultivar at the right time is an important factor determining success or failure in peach production. Growers aspire to bring a cultivar into production at the height of its popularity and to eliminate it before its popularity wanes. Thus, new varieties are generally phased out and replaced by superior varieties over a 20-year period (Savage).

Okie notes that timely adoption of new varieties is critical to profitable peach production, and peach quality is a primary factor in growers' decisions. Attention to quality is reflected in the implementation of cultural practices, harvesting procedures, post-harvest handling, grading, packing, on-farm storage, and transportation. Peach varieties have limited shelf lives in retail outlets and each variety has a short and well-defined production season. Consequently, multiple varieties are needed to provide a steady supply of fruit from April to September across a range of microclimates and marketing regions in the Southeast.

Demand by Georgia growers for peach varieties is revealed in the increasing numbers of cultivars grown over time. The 10 leading cultivars accounted for 78% of total trees in 1957, but by 1995 the top 10 cultivars accounted for only 53% of the total. Increased diversity in choices of peach varieties occurred in conjunction with a decline in peach tree numbers of almost 57%, from 4.31 million trees in 1957 to 1.84 million in 1995 (Hubbard et al.). Georgia growers are moving toward planting more varieties even as

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Timothy A. Park is associate professor, University of Georgia, Athens, and Wojciech J. Florkowski is professor, Georgia Station, University of Georgia, Griffin, GA.

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the total number of trees declines, highlighting the importance of identifying the key factors that influence farmers' adoption decisions.

Production requirements also promote the adoption of a portfolio of peach varieties. Varieties are harvested at different times, and operations such as girdling, thinning, irrigation, fertilization, and spraying are performed in sequence. Growers plant varieties that ripen over the season to allow efficient use of input resources such as labor crews, packing, and storage facilities. Growers choose an optimal combination of peach cultivars, all having desirable marketing characteristics and specifically selected to follow a planned pattern of ripening dates.

Horticulturists and peach breeders at U.S. Department of Agriculture (USDA) research sites, university, and private breeding programs continue to develop new varieties, recognizing the importance of targeting quality features to meet grower needs. Consumer demand plays a joint role, influencing peach breeding programs and stimulating rapid acceptance of new varieties by growers (Okie)—suggesting a close linkage between consumer demand for quality and grower adoption patterns.

Peach breeders have expressed extreme concern about declining numbers of south Georgia orchards, pointing to the stymied development of a "peach belt" growing region which could stretch across the lower U.S. coastal plains from North Carolina to Texas. Reduced peach production in the Southeast has been linked to a lack of regional varieties requiring only a moderate number of chill hours (Rahn). LaRue and Johnson emphasize the importance of identifying region-specific quality features to aid in promoting the adoption of new peach varieties.

In this study, we develop a model of adoption decisions, taking into account the number of chosen varieties by a grower is a discrete, integer value. The model incorporates grower evaluations of peach quality and evaluates the relative impact of the key external and internal peach quality attributes. The econometric specification examines how the number of adopted varieties depends on farm-level and geographic effects unique to Georgia peach production regions. The model separately identifies the impact of farm characteristics such as the farmer's quality preferences, on-farm agronomic and orchard conditions, as well as economic constraints facing individual growers.

Economic Decision Model of Variety Adoption

Following Sah and Zhao, who note the importance of accounting for the integer and discrete nature of economic decisions, the number of peach varieties adopted by farmers is defined as a nonnegative integer variable, denoted as N. Peach quality is a primary factor in the adoption decision by growers, as quality can greatly improve growers' revenues even in an average crop year. While quality and performance attributes of new varieties are assessed prior to adoption in field trials, profitability is not directly observed by farmers until after adoption, cultivation, and marketing over a number of years.

The grower chooses a portfolio of N varieties over time, where the random variable n represents the number of peach varieties which are profitable and meet grower quality expectations, and $N \geq n \geq 0$. The probability that the variety is profitable is an independent event with probability (p) bounded by zero and one. The probability that n out of N chosen varieties will be profitable is represented by the binomial density:

(1) $$B(n, N, p) = \binom{N}{n} p^n (1 - p)^{N-n}.$$

The grower's utility from the n profitable peach varieties, $U(n)$, depends on the expected returns from the adopted varieties, where the utility function is increasing and concave in n. The grower's expected utility in choosing the N varieties with a given probability that the variety will be profitable is denoted by $U(N, p)$, or:

(2) $$U(N, p) \equiv \sum_n B(n, N, p) U(n).$$

Based on the farmer's assessment of available peach cultivars, the largest optimal number of varieties to hold is denoted as $n(p)$, and the grower's indirect utility for this decision is $V(p)$:

(3) $$V(p) \equiv \max_n U[n, p] \equiv U[n(p), p].$$

The primary objective is to identify factors that influence the adoption decision, a decision based on the grower's expectations about the returns to new varieties. Forming the discrete equivalent of the first derivative, adoption occurs if the grower's expected marginal utility $U_N(N, p)$ from the jth variety is positive, i.e.,

(4) $$U_N(N, p) \equiv U(N + 1, p) - U(N, p) > 0.$$

The optimality conditions can be solved to give the grower's demand for new varieties, $N_i(p, M)$, where M represents a grower's current income level. Given the grower's profit expectations, the set of adopted varieties is defined as:

(5) $$PeachVar = \left[i \mid N_i(p, M) > 0 \right],$$

where *PeachVar* is the number of adopted varieties. The model for the number of adopted varieties is driven by the variables in the indirect utility function in combination with individual farm-level factors and regional agronomic variables which influence the expected profitability of peach production. Survey information from peach growers provides the number of adopted varieties for each grower, and a count data model is specified for the adopted varieties.

Model Specification and Estimation

The model developed in equation (5) is estimated using a Poisson regression, recognizing that the number of adopted peach varieties is recorded as count data (Greene). The Poisson regression model assumes that y, given $\mathbf{x}$, has a Poisson distribution with conditional mean $\mu(\mathbf{x}) \equiv E(y \mid \mathbf{x})$:

(6) $$f(y \mid \mathbf{x}) = \frac{\exp[-\mu(\mathbf{x})]\,[-\mu(\mathbf{x})]^y}{y!}, \quad (y = 0, 1, \ldots),$$

where $y!$ is y factorial. The parametric model for $\mu(\mathbf{x})$ is $\exp(\beta'\mathbf{x})$, where y is the count variable for each farmer, $\mathbf{x}$ contains the variables influencing the adoption decision, and β represents the estimated coefficients.

Following Wooldridge, the variance assumption in the Poisson generalized linear model (GLM) is adopted:

$$\text{(7)} \qquad \mathrm{Var}(y\,|\,\mathbf{x}) = \sigma^2 E(y\,|\,\mathbf{x}),$$

where the variance-mean ratio for the Poisson distribution can be any positive constant, $\sigma > 0$. Wooldridge demonstrates that the Poisson quasi-maximum likelihood estimator (QMLE) is asymptotically normal and efficient in the class of all QMLEs in the linear exponential family of distributions. The Poisson QMLE is more efficient than nonlinear least squares and many other QMLEs including the negative binomial model. We report the fully robust standard errors which are valid under any conditional variance assumption. The estimated model accounts for the fact that all growers adopted at least one variety, so the count variable is truncated at one.

Let $PeachVar_{ij}$ measure the number of adopted peach varieties by farmer i in region j. The statistical model separately identifies the impact of farm characteristics such as the farmer's quality preferences, on-farm agronomic and orchard conditions, and economic constraints facing individual growers. Regional effects account for larger scale agronomic and climatic conditions, as well as preferences for quality features which vary across distinct geographically concentrated growing areas in Georgia:

$$\text{(8)} \qquad PeachVar_{ij} = \exp\left[\beta'\mathbf{x}\right] = \exp\left[\delta_0 + \delta'\mathbf{F}_{ij} + \gamma'\mathbf{R}_j\right],$$

where the parametric model from equation (6) is now specified. The vector of relevant farm-level variables is $\mathbf{F}_{ij}$, $\mathbf{R}_j$ denotes the fixed effects for key Georgia production regions, and the estimated parameters are δ and γ.

Variable Description and Sample Design

Data from the ninth Georgia *Commercial Peach Tree Inventory*, conducted in 1995 (Hubbard et al.), were used in model specification. Information from 106 commercial peach growers was gathered on the number of trees by age and variety, market channels utilized, and quality measures valued by growers. Each identified commercial grower was mailed a questionnaire, followed by a second mailing to nonrespondents. Remaining nonrespondents were then contacted either by telephone or in person. Questionnaires were obtained from 95% of the total growers in the three main Georgia peach-growing regions. Data provided by 28 growers located in north Georgia, 31 in central Georgia, and 35 in south Georgia were used in model development after deleting surveys with missing data, for an overall response rate of 89% (94 growers).[1]

Definitions of the variables and summary statistics are presented in table 1, and are discussed here. The number of cultivars (*NUMVAR*) reported by each farmer confirms the adoption of multiple varieties of peach trees by growers. About 38% of farmers adopted five or fewer varieties, while 22% of orchards utilize 16 or more varieties. The average number of varieties held by Georgia peach growers is approximately nine.

[1] Information on the geographic districts can be referenced from the maps found in the Hubbard et al. report, *Commercial Peach Tree Inventory and Prospectus*, available online at http://www.ces.uga.edu/pubs/PDF/RR-650.PDF.

Table 1. Variable Description and Summary Statistics (sample size = 94 growers)

Variable	Description	Unit of Meas.	Value	Min.	Max.
NUMVAR	Number of planted varieties	Mean (S.D.)	9.30 (8.41)	1	36
	Percentage of respondents planting:				
	▸ 5 or fewer varieties	%	38		
	▸ 6 to 15 varieties	%	40		
	▸ 16 to 25 varieties	%	12		
	▸ 26 or more varieties	%	10		
INTRATT	Index ranking the importance of four internal attributes in choosing peach varieties (juicy flesh, split pit, pit does not separate from the fruit, and absence of internal bruises)	Mean (S.D.)	12.78 (4.98)	4	20
EXTRATT	Index ranking the importance of eight external (shape) attributes in choosing peach varieties (size, overall shape, consistency of shape, maturity, absence of decay, presence of high color, firmness, and absence of visible bruises)	Mean (S.D.)	28.97 (10.08)	8	40
FINCSAM	Farmer plans to increase or maintain orchard size	%	68	0	1
PCTIRRG	Percentage of trees that are irrigated	%	39	0	1
RETINDEX	Index ranking the importance of returns in decisions to grow peaches (profitability of peaches relative to alternative crops, value of peaches as long-term investment, role of stable returns in growing and peach variety decisions)	Mean (S.D.)	8.37 (4.10)	3	15
RESINDEX	Index ranking the importance of resource availability in decisions to grow peaches (availability of machinery, farm workers, and farmland)	Mean (S.D.)	7.70 (3.72)	3	15
CHANCONC	Measure of marketing channel concentration—percentage of growers marketing to one outlet	%	55	0	1
	Percentage of respondents using:				
	▸ commercial packing (inspected shipments)	%	4		
	▸ field-run sales	%	25		
	▸ retail sales	%	26		
YRHERF	Diversification index across years (Herfindahl measure)	Mean (S.D.)	0.36 (0.33)	0	0.92
NUMCOMP	Number component of Herfindahl diversification index	Mean (S.D.)	0.47 (0.35)	0	0.94
DISTCOMP	Distribution component of Herfindahl diversification index	Mean (S.D.)	−0.07 (0.11)	−0.50	0.00
CENTRAL	Producer is located in central Georgia	%	33	0	1
SOUTH	Producer is located in south Georgia	%	37	0	1

Farm-Level Measures Influencing Adoption

The importance of external quality characteristics (*EXTRATT*) and attributes in a farmer's choice of peach varieties was recorded in an index of eight measures. Farmers rated the importance of each quality attribute on a 1–5 scale, where 1 = not important and 5 = very important. The external quality index had a mean of 28.97 on a scale ranging from 8 to 40. The index of shape attributes was formed based on size, overall shape, consistency of shape, maturity, absence of decay, presence of high color, firmness, and absence of visible bruises.

Table 2. Grower Quality Preferences and Peach Orchard Characteristics

	Respondent Rankings (%) for External (E) and Internal (I) Quality Attribute Categories (External rating scale = 0–40; Internal rating scale = 0–20)							
	Ranking Range		Ranking Range		Ranking Range		Ranking Range	
Description	E = 0–10	I = 0–5	E = 11–20	I = 6–10	E = 21–30	I = 11–15	E = 31–40	I = 16–20
Number of Varieties Adopted by Farmers (%):								
0 to 5 varieties	22	25	5	12	23	25	50	38
6 to 15 varieties	13	13	0	8	19	30	68	49
16 to 25 varieties	10	10	0	0	0	40	90	50
26+ varieties	0	0	0	0	0	100	100	0
Farmer's Location by Region of State (%):								
North Georgia	11	11	3	11	11	28	75	50
Central Georgia	13	13	0	10	26	48	61	29
South Georgia	23	26	3	6	14	26	60	42

Note: The values represent percentages in each category. For example, the last two entries in the first numeric row of the table indicate that 50% of farmers who adopted 0–5 varieties rated external quality attributes at the highest level (between 31–40 on a scale of 40 for the eight-item *EXTRATT* index), and 38% of farmers who adopted 0–5 varieties rated internal quality attributes at the highest level (between 16–20 on a scale of 20 for the four-item *INTRATT* index).

Evaluations of peach quality characteristics which could influence adoption decisions were formed based on four taste, texture, and internal attributes (*INTRATT*) ranked by each farmer: juicy flesh, split pit, a pit that does not separate from the fruit, and the absence of internal bruises. The average score was 12.78 on a maximum scale of 20. Labovitz shows that the correlation between an ordinally scaled measure (such as the internal quality index measure) and the "correct" intervally scaled measure is very high as long as the number of levels in the ordinal scale exceeds 15. This standard for establishing the validity of a constructed index is met for the variables formed from the peach inventory survey.

Cross-tabulations (table 2) of the external quality rankings and the number of adopted varieties indicate that growers who place the highest value on quality tend to adopt more varieties. Across each level of adoption, external quality measures achieved a greater proportion of responses in the highest ranking categories as compared to ranking for the internal quality attributes. A similar pattern is apparent in regional preferences for quality. As observed from the survey data reported in table 2, external attributes dominate internal taste and texture in adoption of peach varieties. The attribute rankings reflect the diversity among producers and across regions in assessing peach quality characteristics. The econometric model evaluates the impact of the rankings on variety adoption decisions by farmers.

Establishing a commercial peach orchard is a long-term operation and investment, where the first three years following tree planting are devoted to the development of trees for early production. Trees normally attain full bearing capacity about their fifth year in south and central Georgia, and in their sixth year in north Georgia, with production continuing for 15 to 30 years. The impact of a farmer's long-term planning horizon and goals in establishing peach orchards may influence adoption patterns. Farmers who plan to increase or maintain the size of their orchards provide a base for estimating long-run demand for new peach varieties. Statistical results for the dichotomous variable *FINCSAM* (table 1) reveal that 68% of farmers have a long-term commitment to peach production.

Slightly more than one-third (39%) of commercial peach trees in Georgia were irrigated, and the percentage of irrigated trees varied across the production districts. Growers in the southern and central districts tend to allocate irrigation to younger trees in order to establish the trees and bring them into production. The shorter life span of trees in these districts encourages the application of irrigation to lower production risk associated with periodic droughts. The variable measuring the percentage of trees irrigated by each grower (*PCTIRRG*) is incorporated to control for regional sources of risk.

Expected economic returns affect the decision to grow peaches and the adoption of new varieties. Growers evaluated the importance of economic factors such as the profitability of peaches relative to alternative crops, the value of peaches as a long-term investment, and the role of stable returns in growing and peach variety decisions. The variable *RETINDEX* is an index of growers' ratings of these three factors, with each rating ranging from 1–5 and higher values indicating greater importance of returns in grower decisions.

The role of input availability in influencing adoption decisions was measured by an index derived from survey responses. Three factors are incorporated into the *RESINDEX* measure which consists of farmer evaluations of the availability of machinery, farm workers, and farmland in the decision to produce peaches.

Desired quality features of peaches differ across marketing channels, and farmers who target their production to one outlet typically adopt varieties with quality features favored by that market channel. Farmers who are focused on one market have a precisely defined set of quality features to consider. Georgia growers market peaches through four main channels: (*a*) inspected shipments for commercial packing, (*b*) field-run sales (which are packed directly by the grower from the field), (*c*) retail sales, and (*d*) processing. A measure of marketing channel concentration (*CHANCONC*) was formed as a dichotomous measure when total reported peach production was grown and marketed through a single marketing channel. As reported in table 1, about 55% of growers indicated their production was allocated to one channel, and over 51% of growers specialized in either field-run sales or retail sales.

The year of adoption for each variety provides insight into the timing of adoption decisions over the life cycle of the orchard. The age distribution of peach trees in each grower's orchard measures the diversification of peach variety adoptions over time. Survey information on the number of trees planted each year is used to calculate the share of trees adopted in each year and the age distribution of trees across each year.

The diversification measure is used to address two questions related to adoption of new varieties. First, how frequently do growers introduce new varieties into their orchards as measured by the number of years in which a variety is adopted? Second, how many trees do growers consider planting in any given year once the adoption decision is made? The intensity of the adoption decision is measured by the share of trees planted in a given year. For example, peach growers may tend to concentrate the number of trees planted in discrete sets of years, or plan to spread out the number of trees planted across a range of years. A diversification measure is calculated to assess the relative impact of these decisions in the adoption of new peach varieties.

A measure of diversification in variety adoption is based on the Herfindahl index, defined as $d = 1 - \Sigma s_i^2$, where s_i for each orchard is the share of the orchard trees which were adopted in the ith year. Because the years in which trees were adopted ranged from 1955 to 1995, the shares reflect the dynamics of adoption of trees over a period of 41 years. A decomposition of the Herfindahl index is used to address the properties of the diversification decision described above (Gollop and Monahan):

$$d = \left[1 - \frac{1}{y}\right] + \sum_i \left[\frac{1}{y^2} - s_i^2\right]. \tag{9}$$

The first term in brackets is the number component (*NUMCOMP*), reflecting the number of different years y in which a producer adopted a new variety. The diversification index increases with the number of different years in which a new variety was adopted. A producer who adopts a complete set of varieties for the orchard in a single year attains a number component of 0. A farmer who adopts new varieties over a range of four years has a number component of 0.75. Higher values of the number component measure how farmers diversify the orchard's age distribution by adopting varieties over time.

The second element in (9) is the distribution component (*DISTCOMP*), representing how the age composition of the orchard is distributed across years. Consider two farmers who have adopted varieties in two separate years. One orchard has an age distribution with an equal proportion of adoptions in each year, or $s_i = ½$, for a distribution index of 0. Another farmer adopted 90% of the orchard's trees in year 1 and allocated the remaining 10% of the orchard to year 2. This farmer's distribution index is −0.57, as higher negative values indicate an increasingly unequal distribution of trees adopted across years. Given the decision to adopt a variety, the distribution component indicates the portion of orchard holdings which would be devoted to the new variety. The distribution component, combined with information on the current size of each grower's orchard, provides an indicator of the number of new trees growers would demand in any given year.

The distribution component of the index shows that an increasingly unequal distribution of adoptions over time decreases the Herfindahl index. The distribution component is negative and smaller in absolute value than the number component (table 1). An increasingly unequal product distribution reduces the negative distribution term in absolute value. Decomposition of the year diversification index into its number and distribution components yields values of 0.47 and −0.07, respectively, for Georgia peach producers, with relatively stable values reported across the three regions.

Based on findings reported in the *Commercial Peach Tree Inventory*, Hubbard et al. commented on the striking difference in maturity dates for adopted varieties across the three peach-growing regions in Georgia. South Georgia growers attempt to exploit their climatic advantage over growers located to the north by capturing their share of the early domestic fresh peach market. In contrast, producers in the northern region balance their cultivars among the early, mid-season, and late cultivars. Among leading peach cultivars, early-maturing cultivars comprised 46% of total trees in central Georgia and 76% in south Georgia. Late-maturing cultivars accounted for 38% and the early-maturing cultivars represented 34% of total trees in north Georgia.

Unobserved fixed effects are included to control for factors that are constant within each of the three main peach production regions in Georgia. The fixed effects control for the impact of climatic variables, agronomic characteristics, and other unobserved regional differences influencing the adoption of new varieties. To capture the regional effects, dichotomous variables are used for the three main Georgia peach-producing regions: *NORTH*, *CENTRAL*, and *SOUTH*.

Model Evaluation and Interpretation

Parameter estimates and asymptotic standard errors for the portfolio of adopted peach varieties are presented in table 3. Estimates from the model based on the diversification measure (*YRHERF*) alone are shown aligned with the results which decompose the diversification measure into its underlying number and distribution components (*NUMCOMP* and *DISTCOMP*). Elasticity estimates for the continuous variables and marginal effects for discrete changes in the index variables (Greene) are based on the model containing the number and distribution components. The marginal effects measures allow for discrete changes in a given variable so that the impact of specific unit increases in the indices of external and internal quality rankings by growers can be evaluated. For continuous variables, the elasticity can be evaluated by computing the impact of a 1% change in an explanatory variable. Asymptotic standard errors are obtained using the delta method (Greene).

We test for the impact of unobserved heterogeneity in estimation of the count data model (Mullahy). If unobserved factors that influence the adoption decision are correlated with the measured explanatory variables, parameter estimates for the count data model based on maximum likelihood, nonlinear least squares, or other standard methods are biased and inconsistent.

The potential impact of endogeneity in the orchard grower's decisions on the diversification in variety adoption across years (*YRHERF*) is investigated. Unobserved factors influencing the decisions on the age distribution of peach trees by each grower may be correlated with the number of adopted varieties. Key determinants of variety adoption not explained by the model include factors such as a grower's inherent propensity to try new peach cultivars or attempts to develop a market niche by promoting new varieties. These unobserved factors may be positively correlated with the grower's decisions on the optimal age distribution of peach trees in the orchard and timing of new variety adoption. The estimated coefficients on the number and distribution components would be biased upward.

A two-stage QMLE approach examines the impact of endogeneity in count data models (Wooldridge). The instrumental variables, apart from the other explanatory variables defined in equation (8), include factors to explain the farmer's decisions influencing the age distribution of the orchard, but which have no direct effect on the number of peach varieties. These variables include the farmer's production decisions on other crops including grains, beef cattle, vegetables, pecans, and row crops. The percentage of farm income generated by sales of these alternative enterprises is elicited in the peach inventory survey. A linear reduced form for *YRHERF* is estimated, and the residuals from the estimated model are included in the set of regressors for the count data model. Testing the null hypothesis that *YRHERF* is exogenous is based on the t-statistic of the coefficient of the residual. These results indicate *YRHERF* is exogenous, with a t-statistic of -1.141.

Based on the findings of this analysis, readily available information on the age distribution of orchards is a valid indicator to identify growers who are prepared to adopt new

Table 3. Count Data Model Results for Adopted Peach Varieties (sample size = 94 growers)

Explanatory Variable	Coefficient Value	Unrestricted Model Coefficient Value	Elasticities/ Marginal Effects[a]
CONSTANT	1.397*	1.278*	
	(4.074)	(3.848)	
INTRATT	-0.043	-0.041	-0.379*
	(-1.693)	(-1.669)	(-3.087)
EXTRATT	0.031*	0.029*	0.265*
	(2.257)	(2.148)	(3.975)
FINCSAM	0.461*	0.454*	4.207*
	(2.681)	(2.739)	(5.041)
PCTIRRG	0.340*	0.325*	3.009*
	(4.290)	(2.225)	(4.124)
RETINDEX	-0.008	-0.002	
	(-0.364)	-(0.097)	
RESINDEX	-0.015	-0.031	
	(-0.646)	(-1.381)	
CHANCONC	-0.406*	-0.330*	-3.055*
	(-2.826)	(-2.346)	(-4.347)
YRHERF	1.080*		
	(8.950)		
NUMCOMP		1.203*	0.525*
		(5.096)	(9.363)
DISTCOMP		-0.652	-0.048*
		(-1.074)	(-1.996)
CENTRAL	-0.097	-0.083	-0.771
	(-0.562)	(-0.506)	(-0.937)
SOUTH	-0.268	-0.277	-2.562*
	(-1.529)	(-1.650)	(-3.055)

Notes: An asterisk (*) denotes statistical significance at the 0.05 level. Numbers in parentheses are asymptotic standard errors, obtained using the delta method.

[a] Elasticities and marginal effects are based on the discrete-change results from column 3. For continuous variables, the elasticity is evaluated by computing the impact of a 1% change in an explanatory variable. For the index variables, the marginal effects measures allow for a discrete change in a given variable so that the impact of a one-unit increase can be evaluated.

varieties and to assess the significance of this relationship. Ongoing inventories of peach growers should continue to gather age distribution information to target adoption of new varieties.

Interpretation of Results

Quality rankings by growers have statistically significant impacts on adoption decisions, reinforcing the importance of identifying and marketing new peach varieties meeting grower preferences (table 3). The coefficient on the measure of internal peach quality attributes (*INTRATT*) indicates varieties with lower measures of perceived quality defects are adopted more frequently by growers. Quality defects measured by fruit taste, texture, and peach pit characteristics contribute to decreases in adopted varieties. The marginal effect for this index measure suggests a new variety must show a decrease in the internal quality defects rating by 2.64 units (or 1/0.379) to induce growers to adopt a new variety.

The external attributes measure (*EXTRATT*) had a positive and significant impact on variety choices by farmers. Hubbard et al. documented specific external traits favored by growers across regions. The authors found that absence of decay was an attribute favored by the greatest proportion of growers in north and south Georgia. In central Georgia, absence of decay, absence of visible bruises, and size as large as possible were tied as the leading attributes rated important or very important. In each district, the absence of visible bruises was considered the most important attribute. If the grower's ranking of the external quality in the adoption decision increases by 3.77 units, an additional variety will be adopted.

The econometric model for variety choice (*NUMVAR*) reveals results not apparent in the raw survey responses. The estimates from the econometric model linking quality to number of adopted varieties suggests a different ranking in the factors influencing actual grower decisions. Specifically, the marginal effects suggest internal attributes (*INTRATT*) have a stronger impact on growers' acceptance of peach varieties than the external quality measures (*EXTRATT*).

Other findings from the model align with expectations. Farmers who plan to increase or maintain the size of their orchards (*FINCSAM*) tend to adopt more varieties. The number of adopted varieties is also positively influenced by the irrigation choices of farmers (*PCTIRRG*). These indicators can be readily tracked by extension agents and allow for targeting of new varieties to farmers who are more likely to adopt added varieties.

The year diversification measure (*YRHERF*) was positive and significant, implying growers who spread their adoption patterns across more years consider an expanded set of peach varieties. Analysis of the *YRHERF* variable highlighted two components which influence diversification by growers in variety adoption. As discussed earlier, we test whether these two components of the Herfindahl diversification variable—the number and distribution elements (*NUMCOMP* and *DISTCOMP*)—have an equal impact on adoption decisions. A Wald test rejects the restriction that the coefficients on the components are equal; the calculated χ^2 statistic of 98.26 exceeds the critical value for a $\chi^2_{[1]}$ variable of 3.84 at the 95% confidence level.

The results from the unrestricted model (table 3, column 3) confirm that orchard growers holding varieties which are spread out over a range of years (*NUMCOMP*) adopt a greater number of peach varieties. The number component has a positive impact on adoption. The distribution component has a negative and insignificant effect on adoption decisions. The effects of the number and distribution components are obscured by neglecting the decomposition of the diversification index. Growers who commit to plant a larger number of trees in any given year tend to adopt fewer varieties over time.

Decomposing the diversification measure addresses an important issue in variety choice: the relative impact of the year component and distribution component in peach adoption. Evaluating the elasticities reveals the number effect is significantly larger than the distribution effect. A 1% change in the number of adoption years (*NUMCOMP*) induces a 0.525% increase in the number of adopted varieties—an effect which is more than 10 times larger in absolute value than the elasticity for the distribution effect (*DISTCOMP*) at −0.048 (table 3).

Table 4. Predicted Peach Variety Adoptions Associated with Changes in Explanatory Variables

	Probability of Adoption Event (%)			
	Central Georgia		South Georgia	
Description	5 Varieties	10 Varieties	5 Varieties	10 Varieties
Base Probability[a]	9.20	9.90	14.29	5.80
Internal Quality Attributes (*INTRATT*):				
Minus 1 on Attribute Index[b]	10.33	9.05	15.16	5.01
Minus 5 on Attribute Index	14.53	5.59	17.34	2.52
External Quality Attributes (*EXTRATT*):				
Plus 1 on Attribute Index[b]	8.42	10.45	13.63	6.38
Plus 5 on Attribute Index	5.52	12.11	10.65	8.81

[a] Base probability denotes the probability (in percentage terms) of adopting the number of varieties evaluated at the mean values of the explanatory variables.

[b] Plus 1 or minus 1 denotes a one-unit change in the explanatory variable while holding other variables constant at their mean values. For internal quality attributes, the measure represents a unit decrease in the internal quality defects index.

Decisions on new varieties are driven primarily by the grower's desire to shift the age distribution of the orchard by replacing older varieties. In addition, decisions to make large-scale adoptions of new trees have a smaller relative impact. This decomposition between timing and scale is important to assess. LaRue notes that growers may face constraints in obtaining an adequate supply of varieties if nurseries are sold out or if insufficient trees were budded to fill an unexpected surge in orders from growers. The distribution component is not statistically significant in constraining growers' choices of new varieties. Peach breeders who are interested in getting growers to adopt more varieties could target growers who adopt across a wider set of years. This information is readily available from the Georgia *Commercial Peach Tree Inventory* (Hubbard et al.), and could be used by extension specialists to identify these growers.

Predicting Peach Adoptions from the Model

The count data model is used to predict the probability that a specific number of varieties will be adopted by a grower, conditional on the farm and regional characteristics included in the model. In table 4, two scenarios are illustrated for the predicted probabilities of growers adopting 5 or 10 varieties. A complete analysis would compute the adoption probability for any integer value, information which could be used to target growers with specific characteristics when advising on or marketing new varieties.

The base probability computes the probability of the events (5 and 10 adoptions) at the mean values of the explanatory variables. The case of a central Georgia producer who markets through one outlet (*CHANCONC* = 1) and who plans to maintain or increase the size of the orchard (*FINCSAM* = 1) is considered. To allow a comparison across regions, the probability effects for a south Georgia producer are also calculated. Compared to the central Georgia grower, the probability of five varieties being adopted by the south Georgia producer is higher at 14%, with a large decline to less than 6% for the probability of 10 varieties. The central Georgia grower shows stability in the adoption probabilities for these events (5 and 10 varieties). These results demonstrate the flexibility of the model, as extension advisors and peach breeders can observe regional differences in the number of varieties growers would consider for their orchards.

A useful experiment is to compute the probability of adoption if peach breeders can establish that a new variety has improved quality attributes which are preferred by growers. Assume breeders develop a new variety which scored one level higher on the external attribute index. The external attribute index (*EXTRATT*) weights key quality measures monitored by growers, such as size, shape, maturity, absence of decay, presence of high color, firmness, and absence of visible bruises. The probability that a central Georgia peach grower would adopt five varieties after a 1-unit increase in the external quality index is 8.42%. A 5-unit improvement decreases the 5-level adoptions to 5.52%, but increases the likelihood of adopting 10 varieties by 2.21 percentage points from the mean probability for the sampled growers.

Decreases in quality defects lead to a higher probability of adoption by central Georgia producers. The probability a grower will adopt five varieties increases by more than 5 percentage points with a 5-unit decrease in the internal quality defects index. As shown by these shifts in predicted adoption probabilities, growers respond more to efforts aimed at mitigating poor internal quality measures of peaches than from improvements in external quality attributes.

Additional applications of the predicted probabilities could be computed by examining the impact of changes in other explanatory variables appearing in the model. Predicted probabilities could be computed for individual farmers, given information about the age distribution of their peach orchards and their quality ratings.

Conclusions and Future Work

In this study, the adoption decision for new crop varieties is modeled in an integer choice framework leading to the econometric specification based on a count model for the peach varieties grown by Georgia producers. The model incorporates grower evaluations of peach quality and assesses the relative impact of external and internal peach quality attributes that influence adoption. The econometric specification examines how the number of adopted varieties depends on farm-level and geographic effects unique to Georgia peach production regions. The model separately identifies the impact of farm characteristics such as the farmer's quality preferences, on-farm agronomic and orchard conditions, and the importance of economic factors facing individual growers.

Quality rankings by growers are found to have statistically significant impacts on adoption decisions, reinforcing the importance of identifying and marketing new peach varieties which meet grower preferences. The econometric model highlights two findings related to quality. First, growers who place the highest value on quality tend to adopt more varieties, as external attribute measures had a positive and significant impact on variety choices by farmers. The elasticity estimates reveal a stronger impact by internal and taste attributes on a grower's demand for peach varieties than the impact produced by the external measures. The results also suggest a limited role for the two index measures of expected economic returns and input availability constraints in targeting adoption patterns among growers. Additional information on costs of peach production and orchard establishment, as well as measures of farm-level income from peach markets, could be elicited from farmers in the Georgia *Commercial Peach Tree Inventory* survey to strengthen the economic model.

A key variable which emerges is the impact of the age distribution of trees in the farmer's orchard as a factor in the decision to plant a new variety. The diversification measure suggests growers who spread their adoption patterns across more years consider an expanded set of peach varieties. Decisions on new varieties are influenced by the grower's desire to shift the age distribution of the orchard by replacing older varieties. Information on the age distribution of orchards is available from surveys and can be monitored by extension field experts for individual growers. The information is useful in targeting new varieties to growers who may be most prepared to try a new variety, given the current age distribution of trees in their orchards.

In spring 2000, peach breeders released Gulfprince, a new peach variety for the southeastern region. The Gulfprince peaches represent a shift away from the current industry standard to pick peaches while still firm and ship them before softening occurs. Through the use of on-farm orchard conditions, complemented with growers' quality concerns as identified in the adoption model, growers may be targeted who are most prepared to consider new varieties and adapt management practices to allow the new varieties to prosper.

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References

Gollop, F. M., and J. L. Monahan. "A Generalized Index of Diversification: Trends in U.S. Manufacturing." *Rev. Econ. and Statis.* 73(1991):318–30.

Greene, W. H. *Econometric Analysis*, 4th ed. Upper Saddle River NJ: Prentice-Hall, 2000.

Hubbard, E. E., W. J. Florkowski, T. A. Park, and H. J. Witt. *Commercial Peach Tree Inventory and Prospectus*. Experiment Station Res. Rep. No. 650, University of Georgia, College of Agricultural and Environmental Sciences, 1998. Online. Available at http://www.ces.uga.edu/pubs/PDF/RR-650.PDF.

Labovitz, S. "The Assignment of Numbers to Rank Order Categories." *Amer. Sociological Rev.* 35(1970): 515–24.

LaRue, J. H. "Propagation and Nursery Practices." In *Peaches, Plums, and Nectarines: Growing and Handling for Fresh Market*, eds., J. H. LaRue and R. S. Johnson, pp. 12–15. Pub. No. 3331, Coop. Ext. Ser., Div. of Agr. and Natural Resour., University of California, Oakland, 1989.

LaRue, J. H., and R. S. Johnson, eds. *Peaches, Plums, and Nectarines: Growing and Handling for Fresh Market.* Pub. No. 3331, Coop. Ext. Ser., Div. of Agr. and Natural Resour., University of California, Oakland, 1989.

Mullahy, J. "Instrumental Variable Estimation of Count Data Models: Applications to Models of Cigarette Smoking Behavior." *Rev. Econ. and Statis.* 79(1997):586–93.

Okie, W. R. *Handbook of Peach and Nectarine Varieties: Performance in the Southeastern United States and Index of Names.* Agriculture Handbook No. 714, U.S. Department of Agriculture, Byron GA, 1998.

Rahn, D. "The Dawning of the Perfect Peach." *Research Reporter* [University of Georgia] 26(Summer 1997):4–9.

Sah, R. K., and J. Zhao. "Some Envelope Theorems for Integer and Discrete Choice Variables." *Internat. Econ. Rev.* 39(1998):623–34.

Savage, E. F. "History of the Georgia Peach Industry." Unpub. manuscript, Exp. Sta., University of Georgia, College of Agriculture, 1983.

Wooldridge, J. W. *Econometric Analysis of Cross-Section and Panel Data.* Cambridge MA: The MIT Press, 2002.