AN ABSTRACT OF THE DISSERTATION OF

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Title: Essays on Nursery Labor, Sales Contracts, and Price Discovery

Abstract approved:

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Oregon's nursery and greenhouse industry has ranked the first in the State's agricultural for 18 years. The majority of nursery sales from the Pacific Northwest come from Oregon. Due to data limitations, empirical study of the Oregon nursery industry is rare. The present dissertation consists of three essays that analyze the demand and supply of inputs and outputs and the relationship between producers and retailers in the Oregon nursery industry.

Chapter 2 identifies the major factors affecting farm labor supply and demand and evaluates their relative importance in the Oregon nursery industry from 1991 to 2008. Empirical results show that border control effort doesn't have an influential role in labor supply, while the Oregon and Mexican minimum wage do. It is because of the substantial gap between the U.S. and Mexican economies, reflected for an example in the minimum wage gap, which attracts a continual flow of immigrants. Risk of border apprehension is not great enough to prevent the flow. Increases in Oregon minimum wage is more effective than border apprehension policies in boosting the average wage and in reducing the number of hours that illegal immigrants work in the nursery sector.

Chapter 3 investigates producers' and retailers' choices of, and reactions to, various contract types in the Oregon nursery industry from 2005 to 2010. As new and fast-growing retailers in the industry, big-box stores are less likely than independent retailers to make pre-order contracts with the producer. However, once a pre-order contract is chosen, big-box stores demand more days of pre-order interval than independent retailers do. Transactions with independent retailers exhibit – on average over the sample range – scale economies and scope diseconomies. Boosting per-transaction revenue scale and the number of species sold to big-box stores enhances transaction efficiency.

Chapter 4 examines the interaction between supply and demand in Oregon nursery products. The result indicates that the production and transaction costs are major drivers on the supply side, while transportation costs and consumer demand for nursery products play important roles on the demand side. At the genus level, the supply elasticities of coniferous plants are larger than those of deciduous plants, which in turn are higher than those of flowering plants. The demand elasticities are the lowest in coniferous trees followed by deciduous plants, then flowering plants. Price discounts on plants with high demand elasticities would significantly boost sales and enlarge the market, while those on plants with low demand elasticities would have less sales impact. Empirically, patenting seems to bring no direct signs of greater profitability. The wholesale nursery may wish to reconsider the pricing and marketing policies of its patented plants to differentiate them more effectively from its non-patented plants.

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Essays on Nursery Labor, Sales Contracts, and Price Discovery

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Cheng Li

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I understand that my dissertation will become part of the permanent collection of Oregon State University libraries. My signature below authorizes release of my dissertation to any reader upon request.

Cheng Li, Author

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Chapter 1 : Introduction

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Foreign-born labor, sales contracts, and price discovery are three important areas of agricultural economics. The Oregon nursery provides an interesting background from which to study these topics. I address each of them in the following three chapters.

Labor's importance to agriculture is well known, as is the large proportion of foreign-born workers in the agricultural workforce. Rapid expansion of foreign-born workers in the low-skilled sectors of the agricultural labor market has impelled both legal and illegal U.S. immigration to the front rank of policy debate. In particular, the interaction between potential immigrants' relocation decisions, growers' production decisions, and government policy choices has become crucial to the formulation and implementation of immigration policy reform. However, immigration policy impacts on labor supply, demand, and local wage rate remain inconclusive. In chapter 2, I focus on the nursery industry—one of the more labor-intensive in agriculture—as a case in point. The objective has been to answer three questions: (1) What are the major factors in agricultural labor supply? (2) What are the major drivers of agricultural labor demand? (3) What are these factors' relative contributions to labor supply and demand? A new and carefully constructed quarterly dataset of 93 Oregon nurseries during the 1991-2008 period is used in the empirical study.

The nursery industry consists of wholesale nurseries – which I will call the producers – and their customers, namely retail nurseries, landscapers, garden centers, and big-box stores. Marketing practices of nursery growers include sales to repeat customers, negotiated sales, brokerage sales, contract sales, and export sales. Pre-order contracting is an important marketing practice as a risk management tool (Hodges, A., M. Palma, and C. Hall, 2009). Compared with a spot market transaction, pre-order contracts reduce the producer's inventory and market risk, while providing retailers with purchase discounts. Based on retailer and payment type, nursery contracts are divided into four groups in chapter 3: single-order contracts using pay-by-order, single-order contracts using pay-by-scan, annual contracts using pay-by-order, and annual contracts using pay-by-scan. The goal is to analyze producers' and retailers' choices of, and reactions to, various contract types in the Oregon nursery industry. Data on contract and retailer characteristics were provided by a large Oregon wholesale nursery during the 2005 – 2010 period.

A critical characteristic distinguishing nursery products from many other agricultural crops is the high degree of product differentiation. Enormous product diversity arises from combinations of variety, plant material, and plant size. A representative nursery wholesaler may produce as many as 500 varieties of coniferous trees, deciduous trees, broadleaf evergreens, shrubs, Japanese Maples, ornamental, perennial, and annual plants. Chapter 3 is the first research to systematically examine the interaction between supply and demand among highly differentiated nursery products. Data were collected from a variety of sources, including the Oregon Association of Nurseries, the invoices of a representative nursery company, and the Oregon Employment Department. The objectives are to: (a) study the interaction among the major drivers of nursery supply and demand in an industry of high product differentiation; and (b) draw management implications on the basis of the estimated supply and demand elasticities.

Chapter 2 : Immigration and Agricultural Labor Market in Oregon Nursery Industry

Cheng Li

Introduction

The U.S. agricultural labor market has experienced structural changes in the last fifty years, from family farmworkers to hired farmworkers and from domestic farmworkers to foreign-born farmworkers. Immigrants play an increasingly important role in this transition since, based on the report *The National Agricultural Workers Survey*[1], 78 percent of all crop workers were foreign-born in fiscal years 2001-2002 and 53 percent of all respondents lacked legal status to work in the U.S. There is a long-standing immigration policy debate regarding the laws surrounding immigrant farmworkers, including the Immigration Reform and Control Act of 1986 (IRCA), agricultural guest-worker program, non-immigrant agricultural worker program (H-2A), Agricultural Job Opportunity Benefits and Security Act of 1998 (AgJOBS), and Comprehensive Immigration Reform Act of 2006 (CIRA). However, the effectiveness and enforcement of immigration policy are doubtful because of the rapidly expanding numbers of illegal foreign-born workers. Relationships among farmworkers, producers, and government are reciprocal and partly contradictory. For example, strict border control will limit immigration across the border and reduce the availability of agricultural workers, while loose border control will expand illegal immigration, boosting the social cost of education and health care.

The Oregon nursery provides an interesting background from which to study the effect of immigrants on the agricultural labor market because Oregon's nursery and greenhouse industry has ranked the first in the State's agriculture for 18 years, and a large proportion of Oregon nursery workers are from Mexico (*Oregon Nursery and Greenhouse Survey 2007*). Compared to beef, hogs, and poultry industries, many jobs in the nursery sector are labor-intensive and physically demanding. In Oregon nursery, greenhouse, and floriculture production, the share of labor among all production expenses was 49.2% in 2007 (Britsch 2010). However, these low-paid, high mobility, exacting, and tedious agricultural jobs are less attractive for domestic workers than non-agricultural jobs are. Therefore immigrants, even lacking documents, fill the gap between high demand from growers and low supply from domestic workers.

The objectives are to: (1) specify the factors affecting the farm labor supply, such as immigration policies, minimum wage policy, and labor demand from other industries employing low-skilled workers; (2) identify the factors affecting the farm labor demand, such as important input and plant prices; and (3) evaluate the relative importance of labor supply and demand drivers. To this end, a theoretical model is conducted to analyze the interaction between the relocation decisions of immigrants, production decisions of growers, and policy choices of government. I compile a unique dataset covering quarterly working hours and wages of 93 nurseries from 1991 to 2008. Based on the theoretical analysis, a simultaneous equation system is estimated to evaluate the effects on labor working hours and wages of immigration policies, the minimum wage gap, and labor demand in other low-skilled industries.

Literature Review

Analysis of agricultural labor supply and demand combines labor economics, migration theory, and immigration policy. Regarding labor supply, because most agricultural workers are foreign-born and seasonal employed, they make choices not only between leisure and labor but also between moving and staying. Evers et al. (2005) observe that 239 estimates of labor supply elasticities ranged from -0.24 to 2.79, with the mean of 0.24. They show that the large variation in the estimates stems from variations in gender, participation rates, and country fixed effects. Some researchers assess migration reasons on the basis of individual characteristics, such as gender, education, age, marriage status, and legal status, to determine which person finds it worthwhile to migrate to a new location (Perloff et al., 1998). Surprisingly, Perloff et al. find that unauthorized workers are more likely to migrate within the U.S. than authorized workers are because unauthorized workers gain more from migrating than do citizens and green-card holders. They also conclude that if the earnings of seasonal agricultural workers rise by 10% in a new U.S. location, the probability of migrating rises by slightly more than 1%. Migration probability is inelastic to income increases because of high moving costs. Other researchers, for example Hanson and Spilimbergo (1999), emphasize the importance of social and economic factors in workers' migration decisions. They analyze the effects of macroeconomic conditions such as real wage, unemployment rate, and minimum wage, on illegal immigration. In accounting for macroeconomic conditions and immigration policy, they find that border apprehension rate, implying illegal immigration effort, is strongly positively correlated with border patrol enforcement and that shrinking the U.S. – Mexico wage gap would reduce illegal Mexican immigration. Kochhar (1992) and Card (2001) argue the impacts of labor immigration on domestic wage rates and labor supply depend on the patterns of labor migration generated by substitution and income effects. The former effect boosts the migration because wages and thus wealth utility rise, while the latter effect reduces migration since marginal utility of wealth falls as workers increase their consumption flows. If the substitution effect dominates, the domestic labor supply falls in response to migrant inflow. Otherwise, immigration would increase the domestic labor supply. Empirical analysis supports the argument that immigrant inflows reduce employment among low-skilled natives by one to three percentage points because the substitution effect dominates the income effect (Card 2001).

On the demand side, producers' employment decisions have also been widely discussed in the economic literature. The labor demand function is derived from a production function that describes how growers use technology to produce goods and services (Borjas, 2010). Growers then decide how to allocate labor, capital, and material to maximize profit. Espey and Thilmany (2000) summarize 84 estimated farm labor demand elasticities, ranging from 0.22 to -4.42. The mean elasticity is -0.74, and over 85% range from 0 to -1.5. The average long run elasticity is -1.11 and the average short run elasticity is -0.60, indicating that in the long run, farm labor demand is more elastic than in the short run.

Borjas (2003), Ottaviano and Peri (2006), and Bodvarsson et al. (2008) estimate the effects of immigration on wages. Overall immigration reduces wages by 3 to 4 percent, but the impact differs by the worker's education, work experience, and ethnicity. Immigration impact on U.S.-born workers with at least a high school degree is actually positive because immigrants are imperfect substitutes for this group. Jaeger (2008) employs a regional input-output model of Oregon to evaluate the effect of "No Match" immigration rules[2] on the Oregon economy. These rules include fines or criminal prosecution of firms hiring illegal workers, which might affect firms' incentives to hire illegal workers. Jaeger estimates that the rule will result in a loss of 7.7% of Oregon's workforce in the short term and 6.5% in the long term. The departure of Oregon's undocumented workers will not reduce the unemployment rate because there is a mismatch in skills, education, location, and willingness-to-work between undocumented workers and Oregon's unemployed.

Kannan (1988), Wilkinson (1970), and Katz et al. (1992) have analyzed labor supply and demand simultaneously. However, it is not common to assess international agricultural immigration issues in a labor supply and demand framework. With a rich data set, I am able in the present chapter to examine such issues that have been inadequately treated in the earlier literature. First, I establish general equilibrium in the labor market by specifying supply and demand factors simultaneously. Because supply and demand quantities depend on each other, estimates of supply and demand elasticities would be biased if either supply or demand were ignored. Second, I combine migration theory into a labor supply and demand framework to examine the effect of immigration on the agricultural labor market. Third, I assess the effects of social and economic factors on migration, with consequent important policy implications.

The Theoretical Model

Roback (1982) develops a general equilibrium model in which both labor and capital are assumed completely mobile across cities. Wages and rents are determined by the interaction between the equilibrium conditions of workers and firms. I modify this model by assuming that the costs of changing locations are not zero and that workers are identical in skill and different in immigration costs and accessible amenities. Wage rates and working hours are determined by the interaction between the equilibrium conditions of labor supply and demand. Work locations are assumed to differ by socio-economic characteristics, industry characteristics, and local amenities.

Quantity Determination on the Supply Side

We can distinguish three types of farmworkers according to immigration costs and local amenities: native workers, authorized immigrants, and undocumented immigrants. In the present paper, immigration costs are expressed in terms of apprehension risk, smuggler fees, and transportation expenses. Local amenities refer to education conditions, medical accessibility, environmental conditions, and social welfare. Immigration costs and local amenities influence workers' decisions on whether to move from Mexico to the U.S. and therefore the labor supply quantity in the host country. Assume that σ is immigration cost, ε is local amenity, h is working hour, w is wage rate, x is agricultural product consumption, p is the vector of prices of agricultural product, z is a numeraire non-agricultural good, and y is non-labor income. Utility functions of the three worker types, $u(h, x; \sigma, \varepsilon)$, are assumed identical with the usual properties. The problem of the representative worker is to choose labor quantities h to satisfy a budget constraint:

(1) $$\max_h u(h, x, z; \sigma, \varepsilon) \text{ subject to } px + z \leq wh + y$$

The budget constraint says expenses for the agricultural and non-agricultural good are less than or equal to the sum of labor and non-labor income. $\frac{\partial u}{\partial \sigma} < 0$ because σ is a proxy for the immigration cost and $\frac{\partial u}{\partial \varepsilon} > 0$ because ε is a proxy for the local amenity.

Forming the Lagrangian gives

$$L(h,x,z,\lambda) = u(h,x,z) - \lambda(px + z - wh - y)$$

Taking first derivatives and solving for first-order conditions in *h* and *x*, I get

$$\frac{\partial L}{\partial h} = \frac{\partial u}{\partial h} + \lambda w$$

$$\frac{\partial L}{\partial x} = \frac{\partial u}{\partial x} - \lambda p$$

Setting them equal to zero, I obtain

$$\frac{\partial u}{\partial h} + \frac{w}{p}\frac{\partial u}{\partial x} = 0 \text{ or } w = -\frac{\partial u / \partial h}{\partial u / \partial x} p_x$$

where $\frac{\partial u}{\partial h} < 0$ and $\frac{\partial u}{\partial x} > 0$ because of utility function convexity. Maximizing *u* with respect to *h* yields the labor supply function

(2) $$h^s = h^{s*}(w, p; \sigma, \varepsilon, y)$$

The labor supply can also be written in its inverse form, reflecting the wage rate that workers demand.

(3) $$w^s = w^s(h, p; \sigma, \varepsilon, y)$$

The labor supply curve can be backward bending. When a worker initially substitutes leisure for work, the curve is positively sloped. But when the worker is willing to substitute work for leisure, the curve is negatively sloped. I assume farmworkers are in the former situation because they engage in the low-skilled and low-paid jobs with low wages. The farmworker market equilibrium condition is given by

(4) $$V(w, p; \sigma, \varepsilon, y) \geq \overline{V}$$

where $\bar{V}$ is a reservation utility determined endogenously in general equilibrium. Wages must adjust so that utility is at least as great as reference point $\bar{V}$ established by farmworkers in other locations. Otherwise some workers would have an incentive to migrate (Roback, 1982).

Price Determination on the Demand Side

Assume a representative grower produces output *q* using labor quantity *h* and material quantity *m*. The grower is indifferent among the types of farmworker it hires. Only two production inputs, labor and materials, are considered. I assume a twice differentiable aggregate production function that describes the nursery industry's production technology in the form

(5) $$q = Q(h,m;t)$$

where t is a time variable which serves as a proxy for technology. The production set is convex, so that $Q'(h) > 0$, $Q'(m) > 0$, $Q''(h) < 0$, and $Q''(m) < 0$. Labor and material inputs drive up output, but their marginal substitution rate decreases following the law of diminishing marginal utility. The problem for the representative grower is, given the wage rate *w*, input price *r*, and output price *p*, to choose input labor quantity *h* and material quantity *m* to maximize profit conditional on technology:

(6) $$\max_{h,m} \pi(w,r,p;t) = pq - wh - rm \text{ subject to } Q(h,m;t) \geq q$$

where *q* is the output determined by the production function $Q(h,m;t)$. By Hotelling's lemma, optimal labor demand is obtained as the wage rate's marginal profit:

(7) $$h^d = -\frac{\partial \pi(w,r,p;t)}{\partial w} = h^{d*}(w,r,p;t)$$

Since the profit function is convex and continuous in *w*, the demand curve is downward sloping: $\frac{\partial h^d}{\partial w} = \frac{\partial(-\partial \pi / \partial w)}{\partial w} = -\frac{\partial^2 \pi}{\partial w^2} \leq 0$. Cross-price effects are symmetric because $\frac{\partial h^d}{\partial r} = -\frac{\partial^2 \pi}{\partial w \partial r} = -\frac{\partial^2 \pi}{\partial r \partial w} = \frac{\partial m^d}{\partial w}$. If $\frac{\partial h^d}{\partial r} > 0$, the labor and material input are substitutable; otherwise, if $\frac{\partial h^d}{\partial r} < 0$, the labor and material input are complementary. The grower's market equilibrium condition is given by

(8) $$\pi(w,r,p;t) \geq \bar{\pi}$$

where $\bar{\pi}$ is a reservation profit determined endogenously in general equilibrium. Wages must adjust so that profit is at least as great as reference point $\bar{\pi}$ determined by competing growers' optimizations. Otherwise, the modeled grower will go bankrupt.

Equilibrium

The interaction of equilibrium conditions (4) and (8) for farmworkers and growers together determine wage rates and working hours. Farm workers enjoy higher wages and better amenities at the price of immigration costs, and growers trade lower labor costs for higher material costs. This framework can be used to reveal the effect of immigration costs and local amenities on wage rates and working hours.

In equilibrium, wage rates are higher in periods with higher immigration costs. For example, when border apprehension risk rises on account of tightened immigration policy, the labor supply function would move to the left, boosting wage rates. On the other hand, wage rates are lower in locations with better amenities. For example, if expectations of a stable earning rate rise, the labor supply function moves to the right, decreasing the equilibrium wage rate. These results can be obtained by differentiating (4) and (8) with respect to immigration cost σ and amenity ε and solving for $\frac{dw}{d\sigma}$ and $\frac{dw}{d\varepsilon}$:

$$\frac{dw}{d\sigma} = -\frac{V_\sigma \pi_p}{V_w \pi_p - V_p \pi_w} > 0$$

$$\frac{dw}{d\varepsilon} = -\frac{V_\varepsilon \pi_p}{V_w \pi_p - V_p \pi_w} < 0$$

where $V_\sigma < 0$, $V_\varepsilon > 0$, $\pi_p > 0$, $V_w \pi_p - V_p \pi_w > 0$, and $V_w \pi_p - V_p \pi_w > 0$. The derivations are presented in Appendix A. On the demand side, because the demand curve is downward sloping, higher wage rates reduce the grower's labor demand, $\frac{dh}{dw} < 0$.

Multiplying $\frac{dw}{d\sigma} > 0$ and $\frac{dw}{d\varepsilon} < 0$ by $\frac{dh}{dw}$ gives the respective effect of immigration costs and local amenities on working hours:

$$\frac{dh}{d\sigma} = \frac{dh}{dw}\frac{dw}{d\sigma} < 0$$

$$\frac{dh}{d\varepsilon} = \frac{dh}{dw}\frac{dw}{d\varepsilon} > 0$$

For example, higher immigration costs reduce the number of immigrants and better amenities attract more workers to cross the border. Although immigration costs and local amenities are assumed not to affect agricultural production directly, both of them influence wage rate and working hours indirectly via the profit function.

However, the effects of minimum wage legislation on the agricultural labor market are mixed. In the short run, minimum wage legislation serves as a price floor on labor. Increasing the minimum wage drives up the wage rates and decreases the employment of minimum-wage workers, but the labor supply and demand curves themselves do not change. In the long run, minimum wage legislation serves as a proxy for the amenity of a stable earnings rate. Thus, the minimum wage shifts the labor supply curve to the right, decreasing the equilibrium wage rate and increasing the number of hours employed. In next section I use Oregon nursery labor data to conduct an empirical analysis of minimum-wage impacts.

Empirical Model

In the model derived above, equations (3) and (7), wage rates and working hours are determined simultaneously. I approach the empirical analysis by employing log-linear functional specifications in both the structural and reduced form. Structural-form equations can be used to determine the relationship between wage rates and working hours on both the supply and demand side, and reduced-form equations to identify how wage rates and working hours are affected by immigration costs, local amenities, input prices, and output prices.

Empirical Specification

Consider first labor supply in the nursery industry. Labor supply can be expressed either by the number of hours workers are willing to provide at a given wage, or by the wage rate they demand for certain working conditions and hours worked. Total labor supply equals total working hours of those willing to take a job in a nursery, whether they are foreign-born or native workers, whether from Mexico or other states or industries. A worker is willing to take a job in the Oregon nursery if and only if $V(h, p; \sigma, \varepsilon, \bar{y}) \geq \bar{V}$, which is the maximum utility he can achieve in Oregon facing immigration costs σ and local amenities ε. Total labor supply in the Oregon nursery can be written as

(9) Supply $$w_i^s = \iint \iint_{V(h,\, p; \sigma, \varepsilon, \bar{y}) \geq \bar{V}} f_i(h, p, \sigma, \varepsilon) w^s(h, p, \sigma, \varepsilon) dh dp d\sigma d\varepsilon$$

where $f_i(h, p, \sigma, \varepsilon)$ is the joint probability density function corresponding to $(h, p, \sigma, \varepsilon)$, for a worker in nursery *I*, and $w^s(h, p, \sigma, \varepsilon)$ is agricultural labor wage demanded in equation (3). Thus $f_i(h, p, \sigma, \varepsilon) w^s(h, p, \sigma, \varepsilon)$ reflects the portion of the mean wage that workers demand in nursery *I* under conditions $(h, p, \sigma, \varepsilon)$. In log-linear form, total labor supply of a worker in nursery *I* is estimated as

(10) Supply $$\ln w^s = a_0 + \alpha_1 \ln h + \alpha_2 \ln \sigma + \alpha_3 \ln \varepsilon + e^s$$

In particular, I suppose in (10) that the lagged number of border apprehensions B is a proxy for immigration cost σ, considering the time an immigrant spends crossing the border to find a job in the United States. In the long term, the minimum wage in Oregon $w_{\min}^{OR}$ and in Mexico $w_{\min}^{MEX}$ can be used respectively as proxies for local amenities ε in those two countries. Construction wage rates w_{con} are proxies for the workers' alternative labor opportunities in Oregon.

Next consider the demand side of the labor market. Generally speaking, nursery production includes costs of labor, land, machinery, and management; expenses for materials such as seeds and plants, fertilizers, chemicals, and fuel; and irrigation and marketing costs[3]. I am interested in the labor and material inputs because they occupy the top two shares of total production expenses. Capital is held fixed because it is not as important as labor and materials in nursery production. Growers choose the combination of labor and materials to maximize profit. A nursery is willing to hire workers if the profit obtained satisfies $\pi(w, r, p; \tau) \geq \bar{\pi}$. Total labor demand in nursery *I* then is

(11) Demand $$h_i^d = \iint_{\pi(w,r,p;t) \geq \bar{\pi}} \iint g_i(w, r, p, t) h^d(w, r, p, t) dwdrdpdt$$

where $g_i(w, r, p, t)$ is the joint distribution function under conditions (w, r, p, t) in nursery *I*, and $h^d(w, r, p, t)$ is the labor demand function in equation (7). Thus $g_i(w, r, p, t)h^d(w, r, p, t)$ measures the portion of the mean working hours a nursery demands under conditions (w, r, p, t). Total labor demand in nursery *I* is estimated by log-linear function

(12) Demand $$\ln h^d = \beta_0 + \beta_1 \ln w + \beta_2 \ln r + \beta_3 \ln p + \beta_4 t + e^d$$

Based on the data available, I use the PPI of nitrogen *r* to proxy for the prices of fertilizer materials, packaging prices, and pottery prices. Housing starts *H* are proxies for nursery product prices because rising housing starts expand nursery product demand, driving up nursery product prices.

The last step is to include dummy variables in the supply and demand models. Our theory indicates local amenities affect migration decisions, and nursery characteristics affect employment decisions. Given that such information is not included in our data, I use a fixed effect model to capture the omitted amenities and nursery characteristics. Here, vector $D_{nursery}$ captures unobserved and time-constant nursery individual effects. Because nursery production shows a strong seasonal pattern and all data are quarterly, I include a dummy variable D_q for each season. Letting *I* index nurseries, I thus finally represent the structural form of my fixed-effect model as

(13) Supply

$$\ln w_i^s = a_0 + \alpha_1 \ln h_i^s + \alpha_2 \ln B + a_3 \ln w_{con} + a_4 \ln w_{\min}^{OR} + \alpha_5 \ln w_{\min}^{MEX} + \sum_{q=1}^{3} \alpha_{6q} D_q + \sum_{n=1}^{92} \alpha_{7n} D_{nursery} + e_i^s$$

(14) Demand

$$\ln h_i^d = \beta_0 + \beta_1 \ln w_i^d + \beta_2 \ln r + \beta_3 \ln H + \beta_4 t + \sum_{q=1}^{3} \beta_{5q} D_q + \sum_{n=1}^{92} \beta_{6n} D_{nursery} + e_i^d$$

Wage rates and working hours in these structural equations are the critical endogenous variables. One might equally have written wage rates on the right side of the supply function or working hours on the right side of the demand function because workers decide upon the working hours they are willing to provide based on the wage rates they are offered, and growers offer wage rates based on the working hours they hire. Different from the case in which either wage or working hours are exogenous, endogeneity induces a correlation between working hours and the error term in (13) as well as between wage rates and error term in (14), leading to a bias in the elasticity estimates from OLS regressions.

For example, assuming X is a vector of all explainable variables including wage rates in supply equation (13), the expectation of the estimated supply flexibility by OLS is expressed as

$$E(\widehat{\alpha_1}) = \alpha_1 + E((X'X)^{-1}X'e_i^s)$$

The expectation of estimated supply flexibility is unbiased if and only if $E((X'X)^{-1}X'e_i^s) = 0$. That is, there is no correlation between working hours and error term. However, $E((X'X)^{-1}X'e_i^s) \neq 0$ for $E(h_i^s e_i^s) \neq 0$. In the presence of an unobserved positive supply shift, moving the supply curve to the right, working hours would tend to rise given all other variables fixed, inducing a positive correlation between unobserved shock and working hours: $E(h_{it}^s e_{it}^s) > 0$ or $E((X'X)^{-1}X'e_i^s) > 0$. Then $E(\widehat{\alpha_1}) = \alpha_1 + E((X'X)^{-1}X'e_i^s) > \alpha_1$. That is, the estimated supply flexibility would be biased positively. Because supply elasticity is approximately equal to the reciprocal of supply flexibility, supply elasticity would be biased negatively.

In a similar way, I prove that without adjusting for the endogeneity of wage rates in equation (14), the demand elasticity would be biased positively. The reason is that, in the presence of an unobserved positive demand shift, moving the demand curve to the right, wage rates would tend to rise if all the other variables are constant, causing a positive correlation between unobserved shock and wage rates: $E(w_{it}^d e_{it}^d) > 0$.

The other variables are regarded here as exogenous. On the supply side, workers' immigration decisions don't affect border enforcement, Oregon minimum wage policy, Mexican minimum wage policy, or construction wage rates. On the demand side, growers' production decisions don't affect material input or production output prices. Another possible argument is that border enforcement may serve as an endogenous variable because the government may strengthen border patrol enforcement when illegal immigration efforts rise dramatically. Such influence may be significant in the southwest states (Arizona, California, and Texas) but could be negligible in Oregon, which is not a major immigration destination in the United States. Thus, equations (13) and (14) comprise the simultaneous equation system estimated in this chapter.

Data

Quarterly data containing 93 nurseries during the 1991-2008 period are used to estimate the simultaneous equation system. Table 2.1 presents the statistics summary for all variables in the empirical study. All data are collected, from a variety of sources, as a quarterly basis.

Data on wage rates and working hours are provided by the Oregon Employment Department (OED). Real wage rates are calculated by dividing a nursery's total wages by total working hours and deflating all nominal wages to 2009 dollars with CPI. The distribution of real wage rates is skewed to the right, showing that wage rates of most farmworkers are under $15 and the range $0-$26 covering almost all worker wage rates (in 2009 dollars). If a worker's reported average wage rate is higher than $26, three times the Oregon minimum wage, the worker most likely is a manager or owner, not of interest to the present analysis. To clean the dataset, I remove the observations with a real wage higher than $26. The final quarterly dataset includes 93 nurseries over 18 years, giving 6388 observations in total because records were missing in some nurseries.

Southwest border apprehensions are available from U.S. Customs and Border Protection (CBP). They indicate the quarterly numbers of individuals the Southwest border patrol apprehends when attempting to cross U.S. borders illegally. I select data on the Southwest border because the majority of the apprehensions of low-skilled workers are from the U.S.-Mexico border. Linewatch hours are used as an alternative proxy for border patrol effort in some literature, but they are available only during the 1991 –2004 period, inconsistent with the 1991 – 2008 period used in the present paper.

Oregon minimum wage rates are obtained from the U.S. Department of Labor. Mexican minimum wage rates, measuring potential immigrants' opportunity costs, are taken from the Bank of Mexico. I use constant-dollar mandated minimum wage rates in Oregon and constant-peso mandated minimum wage rates in Mexico and express both in 2009 dollars. The peso to U.S. dollar exchange rate is taken from the Bank of Mexico. Expressing the Oregon and Mexican real mandated minimum wages in the same currency allows a comparison of the real wage gap between the nations.

The wage rate in the construction industry reflects a nursery worker's opportunity price because the construction industry competes with the nursery industry for low-skilled labor. Data on it are available from the Oregon Employment Department. I calculate real average construction wage rates by dividing the quarterly construction payroll by total number of construction employees and deflating it to 2009 dollars.

On the demand side, the Producer Price Index (PPI) of nitrogen, obtained from the Bureau of Labor Statistics, provides a proxy for nursery material prices. It is also deflated to 2009 from 1984 dollars. Data on housing starts, taken from the U.S. Census Bureau, are defined as the number of new privately owned housing units started in the Western Region of the United States.

Econometric Issues

Before discussing the estimation results, it is necessary to conduct a Hausman specification test of whether simultaneity is present in the system. If the test shows that labor supply and demand are determined by each other simultaneously, instrumental variables are needed; otherwise, OLS is preferred. Consider two estimators, b_{ols} obtained with OLS and b_{iv} obtained with instrumental variables. The null hypothesis in a Hausman test is that both b_{ols} and b_{iv} are consistent. Alternate hypothesis is that only b_{iv} is consistent. First, endogenous variables *h* and *w* are regressed on all exogenous factors respectively, as shown in equation (a) and (b) below, and estimated residuals $\hat{e}_1$ and $\hat{e}_2$ are derived. I take the logarithm of all variables in these equations:

(a) Demand $$h = f_1(B, w_{con}, w_{\min}^{OR}, w_{\min}^{MEX}, r, H, t, \mathbf{D}_q, \mathbf{D}_{nursery}, e_1)$$

(b) Supply $$w = g_1(B, w_{con}, w_{\min}^{OR}, w_{\min}^{MEX}, r, H, t, \mathbf{D}_q, \mathbf{D}_{nursery}, e_2)$$

Then, as shown in equation (c) below, *w* is regressed on residuals $\hat{e}_1$ along with endogenous variable *h* and the exogenous factors in equation (13). Similarly, as shown in equation (d) below, *h* is regressed on residual $\hat{e}_2$ along with endogenous variable *w* and the exogenous factors in equation (14). The estimating equations are

(c) Supply $$w = f_2(h, B, w_{con}, w_{\min}^{OR}, w_{\min}^{MEX}, \mathbf{D}_q, \mathbf{D}_{nursery}, \hat{e}_1)$$

(d) Demand $$h = g_2(w, r, H, t, \mathbf{D}_q, \mathbf{D}_{nursery}, \hat{e}_2)$$

I then perform a *t*-test on residuals $\hat{e}_1$ and $\hat{e}_2$. As shown in table 2.2, $\hat{e}_1$ is significant in equation I but $\hat{e}_2$ is not significant in equation (d). This means *w* in the supply function is correlated with error term $\hat{e}_1$ derived from the demand function. Simultaneity thus exists between labor supply and demand. OLS is not applicable when dependent variable is correlated with the error term. A Hausman test shows instrumental variables are required to validly estimate the structural model.

To attain efficiency, a three-stage least squares estimator (3SLS) is employed to estimate the simultaneous equation system. In 3SLS, all exogenous variables are used as instrumental variables to correct the endogeneity problem. That is, in the first stage, the predicted values of wage rates and working hours are estimated by regressing wage rates and working hours on all exogenous variables. In the second stage, equations (13) and (14) are estimated by substituting the predicted values of wage rates and working hours in place of observed ones. I then use the residuals from the second stage to obtain a variance-covariance matrix and apply generalized least squares (GLS) in the final-stage estimation.

Next step is to perform relevance and exogeneity tests and to determine the validity of instruments. First, instrument relevance is examined by two regressions. In the first-stage regression of wage rates on all exogenous variables, R-square is 0.593. In the first-stage regression of hours-employed on all exogenous variables, R-square is 0.850. As shown by the F-test of joint significance, the exogenous variables are overall statistically significant and most of the variables are individually significant as well. All exogenous variables should be used as instruments when estimating hours-employed and wage rates.

An exogeneity test is necessary to determine whether the instruments are uncorrelated with the structural error and hence truly exogenous. The Basmann test (1960) is one method of conducting an exogeneity test. As reported in tables 2.6 and 2.7, p-values of the Basmann test of the 2SLS model are 0.015 and 0.077 in the supply and demand function, respectively, indicating both are insignificant at the 1% level. The instruments pass the over-identifying test in both equations of this model. The tests confirm that the instruments used in the first stage are valid and I keep all the exogenous variables as instruments.

With pooled cross-nursery time-series data, autocorrelation and heteroscedasticity violate the minimum-variance assumption. While they do not bias the coefficient estimates, standard errors and therefore inferences are suspect. To test for autocorrelation, I first regress equations (13) and (14) by 3SLS to obtain e^s and e^d. I then use 3SLS to regress the current errors against the lagged residuals e^s_{-1} and e^d_{-1} and against the nursery dummy variables. The coefficients of e^s_{-1} and e^d_{-1} are significant at the 1% level in those regressions (table 2.3). The inference is that autocorrelation is present in the structural model.

The Breusch-Pagan test is a common method for examining possible heteroscedasticity. The null hypothesis is that the fixed-effects model without autocorrelated correction is homoscedastic. Equation (e) and (f) below are estimated by 3SLS to verify whether the independent variables are jointly significant in the demand and supply regressions, and whether the hypothesis of no heteroscedasticity is rejected.

(e) Supply $$(e^s)^2 = f_3(h, B, w_{con}, w^{OR}_{\min}, w^{MEX}_{\min}, \mathbf{D}_q, \mathbf{D}_{nursery})$$

(f) Demand $$(e^d)^2 = g_3(w, r, H, t, \mathbf{D}_q, \mathbf{D}_{nursery})$$

P-values of the F test in both equations are <0.0001. The null hypothesis is rejected and the structural model appears to have a heteroscedasticity problem. The supply equation's error variance widens the greater are the working hours, while the demand equation's error variance shrinks the higher are the wage rates.

The last step is to check whether the estimators would be more efficient if autocorrelation and heteroscedasticity were corrected. There are two alternative ways to correct autocorrelation. One way is to assume error terms follow an AR(1) process. With the assumption, the estimated ρ^s is 0.255 on the supply side, and estimated ρ^d is 0.337 on the demand side, as shown in table 2.3. The associated autocorrelation correction in a log-linear model is similar to that in a linear model. That is, suppose the log-linear model is $\ln y_t = \beta \ln x_t + \varepsilon_t$, where $\varepsilon_t = \rho\varepsilon_{t-1} + v_t$. In the previous period, $\ln y_{t-1} = \beta \ln x_{t-1} + \varepsilon_{t-1}$. Solving the equations by eliminating ε, the following equation is

$$\ln y_t - \rho \ln y_{t-1} = \beta \ln x_t - \rho\beta \ln x_{t-1} + \varepsilon_t - \rho\varepsilon_{t-1} = (1-\rho)\beta(\ln x_t - \ln x_{t-1}) + v_t \,.$$

If the serial correlation process just above is indeed AR(1), error v_t in the equation above is non-autocorrelated.

Using this process, equations (13) and (14) can be transformed to equations (15) and (16):

(15) AR Transformed supply model

$$w_{i,t}^s - \rho^s w_{i,t-1}^s = (1-\rho^s)a_0 + \alpha_1(h_{i,t}^s - \rho^s h_{i,t-1}^s) + \alpha_2(B_{t-1} - \rho^s B_{t-2}) + a_3(w_{con,t} - \rho^s w_{con,t-1}) + a_4(w_{\min,t}^{OR} - \rho^s w_{\min,t-1}^{OR}) + \alpha_5(w_{\min,t}^{MEX} - \rho^s w_{\min,t-1}^{MEX}) + \sum_{q=1}^{3}\alpha_{6q}D_q + \sum_{n=1}^{92}\alpha_{7n}D_{nursery} + e_{it}^s$$

(16) AR Transformation demand model

$$h_{i,t}^d - \rho^d h_{i,t-1}^d = (1-\rho^d)\beta_0 + \beta_1(w_{i,t}^d - \rho^d w_{i,t-1}^d) + \beta_2(r_t - \rho^d r_{t-1}) + \beta_3(H_t - \rho^d H_{t-1}) + (1-\rho^d)\beta_4 t + \sum_{q=1}^{3}\beta_{5q}D_q + \sum_{n=1}^{92}\beta_{6n}D_{nursery} + e_{it}^d$$

If the error process is AR(1), assuming the estimated value of ρ is correct, the error terms in equations (15) and (16) are not autocorrelated.

Another way to correct autocorrelation is to add the lagged dependent variable w_{it-1}^s and $h_{i,t-1}^d$ to the right-hand side of equations (13) and (14) to estimate a dynamic model, as in equations (17) and (18).

(17) Dynamic supply model

$$w_{i,t}^{s} = a_0 + a_1 h_{i,t}^{s} + a_2 B_{t-1} + a_3 w_{con,t} + a_4 w_{\min,t}^{OR} + a_5 w_{\min,\ t}^{MEX} + a_6 w_{it-1}^{s} + \sum_{q=1}^{3} a_{7q} D_q + \sum_{n=1}^{92} a_{8n} D_{nursery} + e_{i,t}^{s}$$

(18) Dynamic demand model

$$h_{i,t}^{d} = b_0 + b_1 w_{i,t}^{d} + b_2 r_t + b_3 H_t + b_4 t + b_5 h_{i,t-1}^{d} + \sum_{q=1}^{3} b_{6q} D_q + \sum_{n=1}^{92} b_{7n} D_{nursery} + e_{i,t}^{d}$$

Model (17) and (18) assume $\rho = 1$.

A heteroscedasticity-consistent covariance matrix (HCCM) is then applied to correct the variance-covariance matrix because σ_{it}^2 is unknown (White, 1980). White (1980) computes the weighted least square (WLS) estimator using a HCCM and investigates modified HCCM estimators for OLS, 2SLS, and 3SLS respectively. I used the HCCM estimator designed for 2SLS in order to obtain significant results. Estimation results after correcting for autocorrelation and heteroscedasticity are shown in tables 2.4 and 2.5.

Unfortunately, the above ways of correcting autocorrelation and heteroscedasticity generate other problems. In the AR transform model, the coefficient of working hours is not significant. In the dynamic and HCCME models, the coefficients of wage rates are positive, contrary to theory. As a result, I employ full information maximum likelihood (FIML) estimation to approach the empirical analysis. FIML estimators, as well as 2SLS and 3SLS estimators, of structural model (13) and (14) are reported in tables 2.6 and 2.7. The 3SLS estimators of model (13) and (14) are consistent with the FIML estimators, including sign, magnitude, and statistical significance, indicating that autocorrelation and heteroscedasticity in the structural model are negligible when using 3SLS or FIML.

Empirical Results

The simultaneous equations illustrate the interactions between labor supply and demand as well as the effects of important exogenous supply and demand factors. The FIML estimates of these supplies and demands are reported in the last columns of tables 2.6 and 2.7. Most coefficients are statistically significant at the 5% level and have signs consistent with economic theory.

On the supply side, working hours has a statistically significant, positive effect on wage rates as expected. Supply flexibility is 0.19, as shown in table 2.6. Houck (1965) proves that the reciprocal of a direct price flexibility is the lower absolute limit of a direct price elasticity. Thus, labor supply elasticity is larger than 5.15 which is the reciprocal of the supply flexibility. A small wage-rate increase attracts large numbers of additional foreign workers. This labor supply elasticity is much higher than the estimators in Evers et al. (2005), implying that undocumented labor migration is more sensitive than domestic labor migration is to changes in wage rates. Surprisingly, border apprehensions show a significant negative effect on Oregon nursery wage rates. Ten percent rise in border apprehensions reduces demanded wage rate by statistically significant but modest 0.3%. However, the construction wage, Oregon minimum wage rate, and Mexican minimum wage rate have a significantly positive effect on Oregon nursery wage rates. As an alternative labor opportunity in Oregon, the construction industry is a strong competitor to the nursery industry in this low-skilled labor market. The results show that a one percent boost in the construction wage rate would lift nursery wage rates by 0.22 percent.

The Oregon minimum and Mexican minimum wage rate are each a proxy for social and economic conditions in their respective locations. Oregon minimum wage rates have stronger effects on nursery wage rates than Mexican minimum wage rates do (0.39 vs 0.04 in table 2.6). The fixed-effects model includes 92 nursery dummy variables. To simplify reporting, the dummy coefficients are omitted in table 2.5, although most are significantly different from zero. Nursery dummies reflect the mean worker's preference to a given nursery's location, manager, or other attributes once the remaining supply factors, including working hours demanded, are accounted for.

Wage rates have a significantly negative effect on the working hours that nurseries demand. The demand elasticity is -0.64, as shown in table 2.7. This labor demand elasticity estimate is consistent with Thilmany (2000), where the mean demand elasticity is -0.74. In these proportionate terms, wage-rate rises have a moderate but not small effect on reducing labor demand quantities. Nitrogen prices, used to proxy for fertilizer prices, do not have significant effect on working hours demanded. Housing starts, a proxy for nursery output prices, have a significantly positive effect on working hours. A one percent increase in housing starts drives demanded working hours upward by 0.17 percent, as shown in table 2.7. Again, nursery dummies are omitted but most are significant. These dummies reflect a given nursery owner's own business strategies and technologies, for example the use of container, bar-boot, ball and burlap, or greenhouse technologies, once the remaining demand factors are accounted for.

In summary, the structural model identifies the significant exogenous supply and demand factors and estimates the effects of these factors on supplied and demanded wage rates and labor usage. In the next section, I use reduced-form equations, derived from the structural model, to evaluate the net or equilibrium effects on wage rates and hours employed. By setting labor supply quantities equal to labor demand quantities, $\ln h_{it}^{s} = \ln h_{it}^{d}$, substituting the labor demand function into the supply function, and solving for wage rates, I derive the equilibrium wage rates as a function of border apprehension rates, construction wage rates, the Oregon minimum wage, Mexican minimum wage, nitrogen prices, housing starts, time, seasonal dummies, and nursery dummies as shown in the first column of table 2.8. Using a similar way, by setting labor supply price equal to labor demand price and solving for labor quantities, I derive the equilibrium working hours as a function of border apprehension rates, construction wage rates, the Oregon and Mexican minimum wage rates, nitrogen prices, housing starts, time, seasonal dummies, and nursery dummies as shown in the second column of table 2.8. In contrast to structural model (13) and (14), I have here only exogenous variables on the right side of the reduced-form model.

Impacts of Immigration Policy

Border apprehensions are commonly used in the literature to analyze immigration's effect on the U.S. labor market (Hanson, 1999 and Borjas, 2001). As shown in figure 2.1, there is a strong correlation between border apprehensions and the U.S. real GDP growth rate. The number of border apprehensions increased dramatically during the period 1995-2000, when the U.S. experienced a high GDP growth rate. After reaching a peak in 2000, border apprehensions fell gradually during the period of 2001-2008, when the U.S. GDP growth was smaller. Border apprehensions also show a seasonal pattern similar to GDP growth rate. Usually both of them bottom out in the first quarter, peak out in the second quarter, then decline in the third quarter.

As shown in figure 2.2, seasonally adjusted border apprehension variation closely follows linewatch hour variation. After accounting for seasonal factors, linewatch hours explain 63 percent of variation in border apprehensions. The regression of border apprehensions on linewatch hours and seasonal dummies shows that a ten-percent rise in linewatch hours lifts the border apprehension rate by 0.27 percent. If linewatch hours proxy for border enforcement, this conclusion is in line with Hanson and Spilimbergo (1999), who state that apprehensions are strongly positive correlated with border enforcement.

My results show that previous-period border apprehensions have a significant negative relationship with nursery wage rates (table 2.6). When previous-period border apprehensions rise one percent, nursery labor wage rates fall 0.02 percent, consistent with Borjas (2003). On the other hand, this implies border enforcement does not restrict illegal immigration very effectively. The risk or consequences of apprehension are not high enough to prevent illegal immigrants from entering the U.S. via Mexico. As Hanson

(1999) and Borjas (2001) argue, migration flows from Mexico to the U.S. are more sensitive to economic differences between the two countries than to border enforcement.

Impacts of Minimum Wage Legislation in Oregon and Mexico

At $8.40 in 2010, the Oregon minimum wage is higher than the federal minimum ($7.25 in 2010) and the second-highest in the U.S. It therefore is a positive attractant to farmworkers. Changes in minimum wage affect not only wage level but also wage structure, that is not only the worker who earns minimum wage but the worker who earns a higher wage. If a grower had been paying less than the new minimum, he had to increase the wage and, perhaps, reduce the working hours employed. If a grower had paid higher than the new minimum, he may reduce the wage rate because more farm workers have now become available. Overall, a ten-percent minimum-wage boost lifts the mean wage workers demand by 3.5%. Nursery demand for working hours falls by 2.2% (table 2.8).

The flexibility of labor wage demanded with respect to the Oregon minimum wage is seven times larger than with respect to the Mexican minimum wage. As shown in the last column of table 2.6, a ten-percent rise in the Oregon minimum wage boosts the mean nursery wage by 4.3 percent, while a ten-percent rise in the Mexican minimum wage boosts it by only 0.6 percent. This gap is partly a product of the minimum wage gap between Oregon and Mexico ($8.40 versus $0.57 in 2010). At minimum wage levels in the two countries, Mexican workers earn in one day is what U.S. workers earn in an hour. The large minimum wage disparity between Oregon and Mexico will continue to attract immigration flows from Mexico to the United States.

On January 1, 2004, the Oregon minimum wage underwent a structural change in which the rate would be adjusted for inflation by a formula employing the U.S. city average consumer price index for all urban consumers and items. To examine the effect of this structural change, I used FIML to re-regress equation (13) and (14) with the shorter 1991-2003 data set. As shown in the last column of table 2.6, after Oregon indexed its minimum wage to inflation in 2004, the minimum wage's nursery-wage effect fell by a slight 0.035. The real minimum wage in Oregon has changed very little since the nominal rate began being adjusted for inflation. Furthermore, the real minimum wage in Mexico has not undergone large variations. Hence the wage gap between Oregon and Mexico has not varied much since 2004 (figure 2.3). Thus, the effects of Oregon and Mexican minimum wage legislation on immigration flow fell slightly after 2004.

Impacts of Labor Mobility

The variability of agricultural labor demand stems partly from the seasonal pattern of agricultural production and from the competition with other low-skilled industries. The nursery labor market shows the same seasonal pattern as does the nursery industry, achieving a different equilibrium each season, as shown in figure 2.4. Labor supply is higher by 5% in the spring and summer than in the fall and winter. Labor demand is largest in the fall, followed by the summer and spring, and lowest in the winter. The net effect is that fall exhibits the highest equilibrium wage rate and greatest equilibrium number of working hours, while spring exhibits the lowest wage rates and winter the fewest working hours. Seasonal differences on the demand side are larger than on the supply side, implying labor demand is more sensitive to season than labor supply is.

Workers can turn to other low-skilled jobs – such as in construction, tourism, and catering – during the off-peak nursery season, and then return during the peak. For example, when wage rates in the construction industry rise, some low-skilled workers will be attracted to that industry, leaving their nursery jobs. Hence, nursery managers must boost their wage rates to retain these workers or attract them back to the nursery. Oregon nurseries' strongest labor competitor is the construction industry because it is large and pays higher wages than the nursery sector does. As shown in the reduced-form equations (table 2.8), a ten-percent construction wage rise significantly lifts the nursery wage rate by 1.9% and reduces hours employed in the nursery by 1.2%.

Relative Contributions of Supply and Demand Drivers

Although the results in tables 2.6 and 2.7 identify supply and demand drivers in the nursery labor market and demonstrate their significant influences, they say little about the relative contributions of each driver to variations in wage rates and working hours. The answer to the third question – what are the relative importances of labor market factors – can be illustrated using reduced-form equations. The derivation process is presented in Appendix B.

Table 2.8 shows the relative importances of the exogenous variables, and their contributions to the variation in predicted wage rates and working hours, between 1991 and 2008. The Oregon minimum wage, the construction wage, and border apprehensions account for 15.5%, 14.3%, and 6.6% of the predicted time-wise changes in the average wage. In contrast, the Mexican minimum wage, nitrogen prices, and housing starts make negative contributions to the average wage, accounting for -7.4%, -6.3%, and -2.9%, respectively. The real Mexican minimum wage and housing starts largely fell during the 1991 – 2008 period.

Similarly, decreases in the real Mexican minimum wage account for 1.5% of the predicted working-hours changes. In contrast, nitrogen prices, housing starts, the Oregon minimum wage, the construction wage, and border apprehensions account for -18.1%, -5.9%, -4.0%, -3.7%, and -2.7%, respectively. Nitrogen prices, the Oregon minimum wage, and the construction wage make negative contribution because, as discussed in the previous section they have a negative relationship with working hours. The negative contribution from housing starts and border apprehensions are caused by the secular declines in these two variables.

The construction wage, the Oregon minimum wage, and the Mexican minimum wage make a larger contribution to average wage-rate changes than to working-hours changes. The contribution of housing starts, nitrogen prices, and technology to variations in wage rates and working-hours-employed are similar to one another in direction and magnitude. Border apprehension’s impacts on average wage and working hours are much smaller than are the other exogenous variables’ impacts. Overall, the exogenous variables fit average wage better than working hours because they explain 72.7% of wage variation and 31.8% of working-hours variation.

Table 2.9 reports the factual variation in average wage and working hours. Positive (negative) values indicate that the factor contributes to an increasing (decreasing) average wage or an increasing (decreasing) hours-worked. Table 2.10 reports predicted wage and hours-worked in seven simulation scenarios, including no 1991- 2008 change in: border apprehension rate, the construction wage, the Oregon minimum wage, the Mexican minimum wage, housing starts, nitrogen prices, and technology. Average-wage variation between 1991 and 2008 are small, and in working hours are large. The simulation results reveal that the Oregon minimum wage rate plays an important role in the nursery labor market. Table 2.9 shows that, between 1991 and 2008, the Oregon minimum wage rate contributed $0.24 to the average wage rate and reduced quarterly work time by 137 hours per nursery. Its impact on wage rates and working-hours-employed is much larger than is the impact of border apprehension rate, construction wage rates, or Mexican minimum wage. For example, border apprehension rate contributed only $0.10 to average wage and reduced quarterly work time by 93 hours. Table 2.10 further demonstrates these points.

Conclusions

The purpose of this chapter has been to answer three questions: (1) What are the major factors in agricultural labor supply? (2) What are the major drivers of agricultural labor demand? (3) What are these factors' relative contributions to labor supply and demand? I have developed a framework to identify and estimate labor supply and demand in a simultaneous setting, and have used it to analyze policy and socioeconomic effects on the Oregon nursery labor market. A theoretically consistent empirical model is specified and estimated to answer these questions.

Empirical results show that border control, the construction wage, the Oregon minimum wage, and the Mexican minimum wage affect immigrant location decisions and therefore agricultural labor supply. Total labor supply elasticity is at least 5.15, much higher than the domestic unskilled labor supply elasticities quoted in the literature. The implication is that the illegal labor force is sensitive to wage and can respond promptly to changes in it. I find that border apprehensions, a proxy for border control effort, do not have an influential role in labor supply, while the Oregon and Mexican minimum wage do have significant effects. The explanation for this phenomenon is the substantial gap between the U.S. and Mexican economies, reflected for an example in the minimum wage gap, which attracts a continual flow of immigrants. The risk of border apprehension is not great enough to prevent the flow. Another important driver on the supply side is the wage rate in the construction industry. With higher wage rates and greater overall labor demand, the construction industry serves as a strong competitor to the nursery industry in the low-skilled labor market. A one percent increase in construction wage rates would push nursery wage rates up by 0.22 percent.

The model also suggests that nursery product price and technology change play important roles in growers' labor demand decisions. Consistent with previous estimates, a one percent rise in wage rate would reduce working-hours-employed by 0.64 percent. Nursery labor demand is greatest in the fall, followed by the summer and spring, and lowest in the winter.

Simulation analysis implies the model accounts for 72.7% and 31.8% of the predicted variation between 1991 and 2008 in average wage and working hours. Except for technology change, the Oregon minimum wage serves as the largest contributor to market wage variation, accounting for 15.5% of it, followed by the construction wage (14.3%) and border apprehension rate (6.6%). And except for technology change, nitrogen price is the largest contributor to the variation in working hours, accounting for -18.1% of it, followed by housing starts (-5.9%) and the Oregon minimum wage rate (-4.0%). These results have implications for the design of policies to limit illegal immigration flows. Although much of the secular change in the agricultural labor market can be attributed to technology improvement, growers and farm workers do respond to the Oregon minimum wage and to border control efforts. Overall, the Oregon minimum wage is more effective than are border apprehension policies in boosting the average wage and in reducing the number of hours that illegal immigrants work in the nursery sector.

Endnotes

[1] http://www.doleta.gov/agworker/report9/chapter1.cfm.
[2] "No-match" rule requires employers to penalize or fire workers whose numbers don't match up with the Social Security Administration database.
[3] http://aesop.rutgers.edu/~farmmgmt/ne-budgets/methodology.html.

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Appendices

Appendix A

Recall equations (4) and (8), where utility and profit are equated to reservation utility and profit respectively:

(4) $$V(w, p; \sigma, \varepsilon, y) = \overline{V}$$

(8) $$\pi(w, r, p; t) = \overline{\pi}$$

Differentiate (4) and (8) with respect to σ and *w* respectively to obtain

$$V_\sigma + V_w \frac{dw}{d\sigma} + V_p \frac{dp}{d\sigma} = 0$$

$$\pi_w \frac{dw}{d\sigma} + \pi_p \frac{dp}{d\sigma} = 0$$

Solving for $dw / d\sigma$ and $dp / d\sigma$:

$$\frac{dw}{d\sigma} = -\frac{V_\sigma \pi_p}{V_w \pi_p - V_p \pi_w}$$

$$\frac{dp}{d\sigma} = \frac{V_\sigma \pi_w}{V_w \pi_p - V_p \pi_w}$$

Using a similar method, differentiate (4) and (8) with respect to ε and *w* respectively to obtain

$$V_\varepsilon + V_w \frac{dw}{d\varepsilon} + V_p \frac{dp}{d\varepsilon} = 0$$

$$\pi_w \frac{dw}{d\varepsilon} + \pi_p \frac{dp}{d\varepsilon} = 0$$

Solving for $dw / d\varepsilon$ and $dp / d\varepsilon$:

$$\frac{dw}{d\varepsilon} = -\frac{V_\varepsilon \pi_p}{V_w \pi_p - V_p \pi_w}$$

$$\frac{dp}{d\varepsilon} = \frac{V_{\varepsilon}\pi_{w}}{V_{w}\pi_{p} - V_{p}\pi_{w}}$$

Appendix B

Consider the predicted average wages for all the nurseries in 1991 and 2008, $\overline{ln\widehat{w}_{91}}$ and $\overline{ln\widehat{w}_{08}}$, respectively. The wage rate reduced-form function can be written as

$$\overline{ln\widehat{w}_{91}} = \frac{1}{N}\sum_{l\in G^{\tau}} \ln\widehat{w}_{l} = \frac{1}{N}\sum_{l\in G^{\tau}} (\frac{1}{4}\sum_{j} \ln\widehat{w}_{lj})$$
$$= \frac{1}{N}\sum_{l\in G^{\tau}} (\alpha_0 + \alpha_1\overline{\ln B_{\tau}} + \alpha_2\overline{\ln w_{con,\tau}} + \alpha_3\overline{\ln w_{min,\tau}^{OR}} + \alpha_4\overline{\ln w_{min,\tau}^{MEX}} + \alpha_5\overline{\ln H_{\tau}}$$
$$+ \alpha_6\overline{\ln r_{\tau}} + \alpha_7\bar{t} + \frac{1}{4}\sum_{q=1}^{3} \alpha_{8q} + \alpha_{9n})$$

where τ = 91 or 08 indicates the respective year for which the value is predicted. G^{τ} is the set of nurseries and N is the number of nurseries in year τ. The α's are the coefficients of the reduced-form equation as reported in table 2.6. Wage rate variation is

$$\overline{ln\widehat{w}_{08}} - \overline{ln\widehat{w}_{91}}$$
$$= \alpha_1(\overline{\overline{\ln B_{08}}} - \overline{\overline{\ln B_{91}}}) + \alpha_2(\overline{\overline{\ln w_{con,08}}} - \overline{\overline{\ln w_{con,91}}}) + \alpha_3(\overline{\overline{\ln w_{min,08}^{OR}}}$$
$$- \overline{\overline{\ln w_{min,91}^{OR}}}) + \alpha_4(\overline{\overline{\ln w_{min,08}^{MEX}}} - \overline{\overline{\ln w_{min,91}^{MEX}}}) + \alpha_5(\overline{\overline{\ln H_{08}}} - \overline{\overline{\ln H_{91}}})$$
$$+ \alpha_6(\overline{\overline{\ln r_{08}}} - \overline{\overline{\ln r_{91}}}) + \alpha_7(\overline{\overline{t_{08}}} - \overline{\overline{t_{91}}})$$

where the variables with a double overline are the averages of the corresponding variable in G^{τ}. Quarter and nursery dummy variables are suppressed. Dividing both sides by $(\overline{ln\widehat{w}_{08}} - \overline{ln\widehat{w}_{91}})$ gives

$$1 = \frac{\alpha_1(\overline{\overline{\ln B_{08}}} - \overline{\overline{\ln B_{91}}})}{\overline{ln\widehat{w}_{08}} - \overline{ln\widehat{w}_{91}}} + \frac{\alpha_2(\overline{\overline{\ln w_{con,08}}} - \overline{\overline{\ln w_{con,91}}})}{\overline{ln\widehat{w}_{08}} - \overline{ln\widehat{w}_{91}}} + \frac{\alpha_3(\overline{\overline{\ln w_{min,08}^{OR}}} - \overline{\overline{\ln w_{min,91}^{OR}}})}{\overline{ln\widehat{w}_{08}} - \overline{ln\widehat{w}_{91}}}$$
$$+ \frac{\alpha_4(\overline{\overline{\ln w_{min,08}^{MEX}}} - \overline{\overline{\ln w_{min,91}^{MEX}}})}{\overline{ln\widehat{w}_{08}} - \overline{ln\widehat{w}_{91}}} + \frac{\alpha_5(\overline{\overline{\ln H_{08}}} - \overline{\overline{\ln H_{91}}})}{\overline{ln\widehat{w}_{08}} - \overline{ln\widehat{w}_{91}}} + \frac{\alpha_6(\overline{\overline{\ln r_{08}}} - \overline{\overline{\ln r_{91}}})}{\overline{ln\widehat{w}_{08}} - \overline{ln\widehat{w}_{91}}}$$
$$+ \frac{\alpha_7(\overline{\overline{t_{08}}} - \overline{\overline{t_{91}}})}{\overline{ln\widehat{w}_{08}} - \overline{ln\widehat{w}_{91}}}$$

The right-hand side of the above equation represents the share of the predicted 1991 *vs* 2008 difference in the average wage. Similarly, the shares of the predicted 1991 *vs* 2008 difference in working hours can be expressed as

$$1 = \frac{\beta_1(\overline{\overline{\ln B_{08}}} - \overline{\overline{\ln B_{91}}})}{\overline{\ln\widehat{h}_{08}} - \overline{\ln\widehat{h}_{91}}} + \frac{\beta_2(\overline{\overline{\ln w_{con,08}}} - \overline{\overline{\ln w_{con,91}}})}{\overline{\ln\widehat{h}_{08}} - \overline{\ln\widehat{h}_{91}}} + \frac{\beta_3(\overline{\overline{\ln w^{OR}_{min,08}}} - \overline{\overline{\ln w^{OR}_{min,91}}})}{\overline{\ln\widehat{h}_{08}} - \overline{\ln\widehat{h}_{91}}}$$
$$+ \frac{\beta_4(\overline{\overline{\ln w^{MEX}_{min,08}}} - \overline{\overline{\ln w^{MEX}_{min,91}}})}{\overline{\ln\widehat{h}_{08}} - \overline{\ln\widehat{h}_{91}}} + \frac{\beta_5(\overline{\overline{\ln H_{08}}} - \overline{\overline{\ln H_{91}}})}{\overline{\ln\widehat{h}_{08}} - \overline{\ln\widehat{h}_{91}}} + \frac{\beta_6(\overline{\overline{\ln r_{08}}} - \overline{\overline{\ln r_{91}}})}{\overline{\ln\widehat{h}_{08}} - \overline{\ln\widehat{h}_{91}}}$$
$$+ \frac{\beta_7(\overline{\overline{t_{08}}} - \overline{\overline{t_{91}}})}{\overline{\ln\widehat{h}_{08}} - \overline{\ln\widehat{h}_{91}}}$$

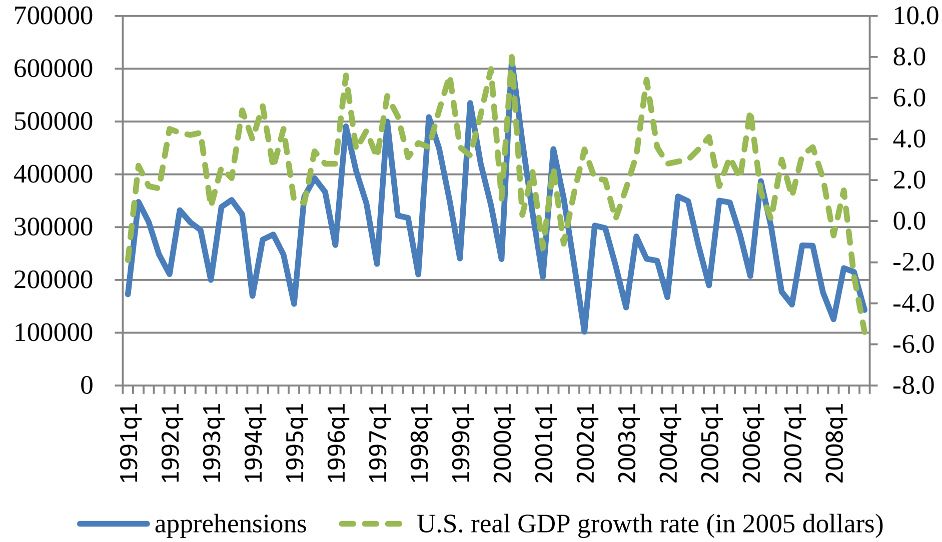

Figure 2.1. Border apprehensions and U.S. GDP growth rate, 1991-2008.

Note: Border apprehensions are shown in the left axis and U.S. GDP growth rates are shown in the right axis.

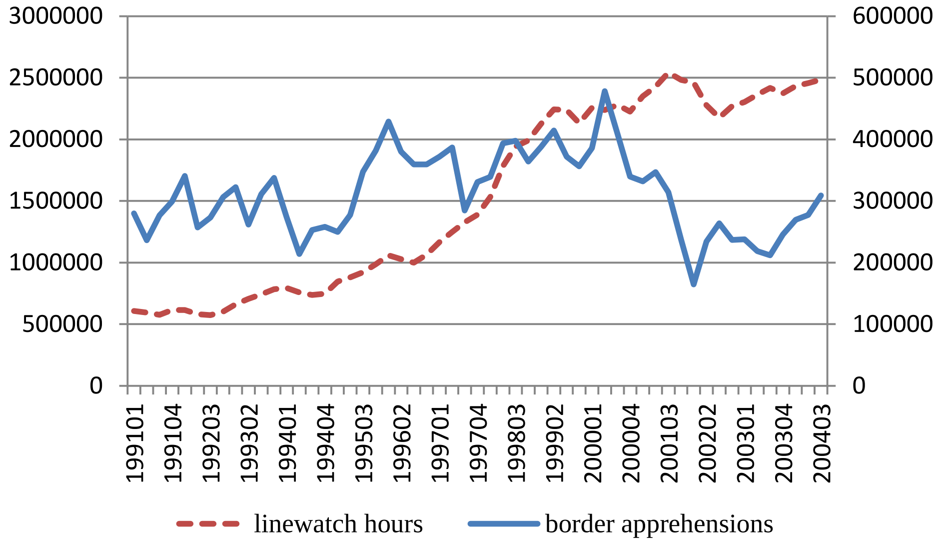

Figure 2.2. Southwest linewatch hours and seasonally adjusted border apprehensions January 1991 to September 2004

Note: Linewatch hours are shown in the left axis and border apprehensions are shown in the right axis.

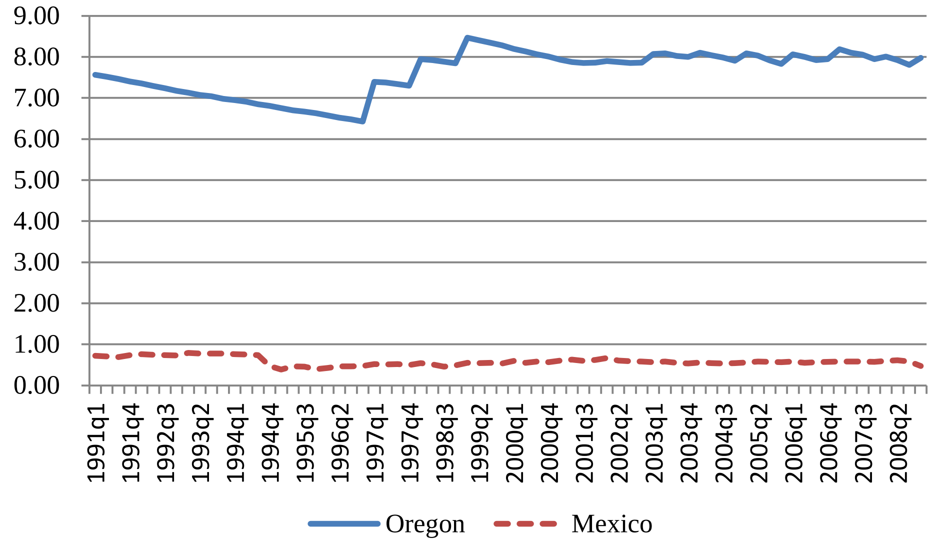

Figure 2.3. Real minimum wage rates in Oregon and Mexico, 1991-2008.

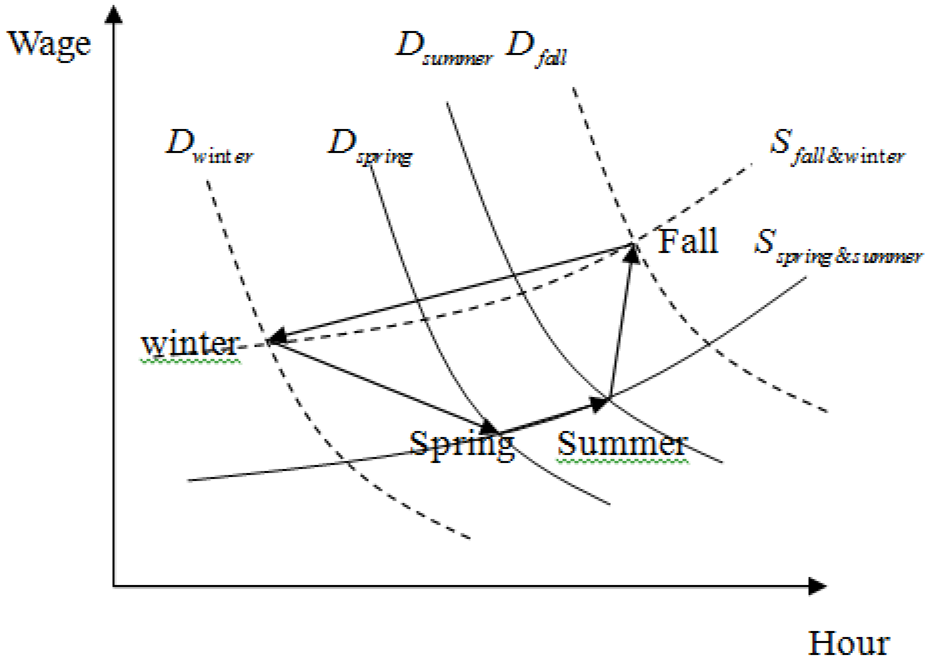

Figure 2.4. Oregon nursery labor mobility over four seasons

Note: In Oregon, quarter 1, 2, 3, and 4 are winter, spring, summer, and fall, respectively.

Table 2.1. Descriptive Statistics of Explanatory Variables

Symbol	Variable	Unit	Mean	Std. Dev.
w	Real nursery wage	US $2009 per hour	12.58	3.47
h	Hours employed	Hours	27073	51203
B	Border apprehensions	People per quarter	294804	103356
w_{con}	Construction wage	US $2009 per hour	21.52	1.54
$w_{\min}^{OR}$	Real min wage, Oregon	US $2009 per hour	7.63	0.53
$w_{\min}^{MEX}$	Real min wage, Mexico	US $2009 per hour	0.58	0.10
r	PPI: nitrogen	Index	180.96	54.33
H	Housing starts	Unit	1518.44	313.12

Table 2.2. Hausman Test Results

Supply (equation c) Dependent Variable: nursery wage rate			
Variable	Coefficient	Std. Error	*t*-value
Constant	-0.410**	0.495	-0.83
Hours employed	0.186***	0.052	3.58
Apprehension	-0.026***	0.009	-2.73
Wage in Construction	0.199***	0.057	3.49
Min wage, Oregon	0.400***	0.044	9.00
Min wage, Mexico	0.056***	0.019	2.86
Quarter 1	0.011	0.016	0.69
Quarter 2	-0.068***	0.010	-7.08
Quarter 3	-0.050***	0.008	-6.46
Wage rate residual from equation (a)	*-0.261****	*0.052*	*-5.00*

Demand (equation d) Dependent Variable: hours of nursery labor employed per quarter			
Variable	Coefficient	Std. Error	*t*-value
Constant	9.765***	1.384	7.05
Wage rate	-0.490	0.392	-1.25
Nitrogen	-0.027	0.068	-0.40
Housing starts	0.182***	0.040	4.57
Time	0.003**	0.001	2.54
Quarter 1	-0.272***	0.024	-11.45
Quarter 2	-0.033	0.029	-1.15
Quarter 3	-0.075**	0.033	-2.28
Working hours residual from equation (b)	*-0.139*	*0.394*	*-0.35*

Asterisks ***, ** and * denote statistical significance at 1%, 5%, 10% level.
Coefficients of nursery dummies are omitted.

Table 2.3. Autocorrelation Test Results, 3SLS

Supply side dependent variable: e^s			
Variable	Coefficient	Std. Error	*t*-value
Constant	0.002	0.025	0.09
e^s_{-1}	*0.255**** (ρ^s)	*0.012*	*20.82*

Demand side dependent variable: e^d			
Variable	Coefficient	Std. Error	*t*-value
Constant	0.022	0.056	0.40
e^d_{-1}	*0.337**** (ρ^d)	*0.012*	*28.05*

Asterisks ***, ** and * denote statistical significance at 1%, 5%, 10% level.
Coefficients of nursery dummies are omitted.

Table 2.4. Parameter Estimates of Structural Model after Correcting Autocorrelation or Heteroscedasticity: Labor Supply

Dependent Variable: *nursery wage rate*			
Variables	Transform model (equation 15)	Dynamic model (equation 17)	HCCME
	3SLS	3SLS	2SLS
Intercept	0.266	0.368*	-0.010
	(0.43)	(1.19)	(-0.04)
Hours employed	0.092	0.077***	0.140***
	(1.01)	(5.64)	(6.59)
Apprehensions	-0.020	-0.030**	-0.026
	(-1.40)	(-3.25)	(-2.52)
Construction wage	0.246***	0.187***	0.200***
	(2.90)	(3.37)	(3.04)
Min wage, OR	0.387***	0.348***	0.423***
	(5.69)	(9.40)	(9.16)
Min wage, MEX	0.042	0.020	0.044**
	(1.48)	(1.36)	(2.23)
Lagged wage		0.198***	
		(18.28)	
Quarter 1	-0.040	-0.033***	-0.000
	(-1.62)	(-3.11)	(-0.01)
Quarter 2	-0.073***	-0.075***	-0.068***
	(-4.91)	(-7.75)	(-6.05)
Quarter 3	-0.077***	-0.058***	-0.051***
	(-7.21)	(-7.42)	(-5.73)
$D_{nursery}$	Y	Y	Y
R^2			0.45

Asterisks ***, ** and * denote statistical significance at 1%, 5%, 10% level.
t-values are in parentheses. Coefficients of nursery dummies are omitted.

Table 2.5. Parameter Estimates of Structural Model after Correcting Autocorrelation or Heteroscedasticity: Labor Demand

Dependent Variable: *hours of nursery labor employed per quarter*			
Variables	Transform model (equation 16)	Dynamic model (equation 18)	HCCME
	3SLS	3SLS	2SLS
Intercept	6.189****	5.556***	-0.297
	(6.16)	(9.32)	(-0.17)
Wage rate	-0.267	0.004	2.613***
	(-0.63)	(0.03)	(5.41)
PPI: nitrogen	-0.035	-0.002	0.413***
	(-0.48)	(-0.04)	(4.87)
Housing starts	0.181***	0.147***	0.288***
	(3.72)	(4.35)	(4.80)
Time	0.002***	0.001*	-0.006***
	(1.98)	(1.77)	(-3.75)
Lagged Hours		0.326***	
		(27.36)	
Quarter 1	-0.267***	-0.259***	-0.142***
	(-6.52)	(-14.41)	(-4.11)
Quarter 2	0.070**	0.070	0.156*
	(2.02)	(3.74)	(3.81)
Quarter 3	-0.068	-0.053**	0.150***
	(-1.44)	(-2.73)	(3.38)
$D_{nursery}$	Y	Y	Y
R^2	0.69	0.84	0.66

Asterisks ***, ** and * denote statistical significance at 1%, 5%, 10% level.
t-values are in parentheses. Coefficients of nursery dummies are omitted.

Table 2.6. Parameter Estimates of the Structural Model: Labor Supply

Dependent Variable: *nursery wage rate* Variables	2SLS (1991-2008)	3SLS (1991-2008)	FIML (1991-2008)	FIML (1991-2003)
Intercept	-0.410	-0.161	-0.518	-1.145
	(-0.66)	(-0.27)	(-0.94)	(-1.36)
Hours employed	0.186***	0.155**	0.194***	0.294***
	(2.83)	(2.43)	(3.48)	(3.09)
Apprehensions	-0.026**	-0.029***	-0.028**	-0.035**
	(-2.16)	(-2.65)	(-2.51)	(-2.05)
Construction wage	0.199***	0.222***	0.219***	0.131
	(2.76)	(3.42)	(3.30)	(1.38)
Min wage, OR	0.400***	0.408***	0.391***	0.426***
	(7.12)	(7.82)	(7.61)	(6.77)
Min wage, MEX	0.056**	0.033	0.043**	0.063**
	(2.26)	(1.50)	(2.24)	(2.47)
Quarter 1	0.011	0.006	0.016	0.028
	(0.55)	(0.36)	(0.87)	(1.12)
Quarter 2	-0.068***	-0.066***	-0.066***	-0.071***
	(-5.61)	(-5.82)	(-5.72)	(-4.38)
Quarter 3	-0.050***	-0.048***	-0.047***	-0.044***
	(-5.11)	(-5.14)	(-4.94)	(-3.41)
$D_{nursery}$	Y	Y	Y	Y
R^2	0.488	0.830		
P-value of over-identification test	0.015	0.009	0.017	0.082

Asterisks ***, ** and * denote statistical significance at 1%, 5%, 10% level.
t-values are in parentheses. Coefficients of nursery dummies are omitted.

Table 2.7. Parameter Estimates of the Structural Model: Labor Demand

Dependent Variable: *hours of nursery labor employed per quarter*				
Variables	2SLS (1991-2008)	3SLS (1991-2008)	FIML (1991-2008)	FIML (1991-2003)
Intercept	9.765***	10.289***	10.507***	10.417***
	(7.05)	(8.16)	(9.26)	(7.23)
Wage rate	-0.490	-0.591	-0.640*	-0.856**
	(-1.25)	(-1.61)	(-1.83)	(-2.47)
PPI: nitrogen	-0.027	-0.077	-0.084	-0.051
	(-0.40)	(-1.27)	(-1.62)	(-0.85)
Housing starts	0.182***	0.178***	0.169***	0.183**
	(4.57)	(4.73)	(4.65)	(1.71)
Time	0.003**	0.003***	0.004***	0.005***
	(2.53)	(3.21)	(3.57)	(2.92)
Quarter 1	-0.272***	-0.275***	-0.277***	-0.300***
	(-11.44)	(-11.86)	(-12.14)	(-11.74)
Quarter 2	-0.033	-0.039	-0.041	-0.062**
	(-1.14)	(-1.38)	(-1.52)	(-2.23)
Quarter 3	-0.075***	-0.082***	-0.086***	-0.102***
	(-2.27)	(-2.64)	(-2.86)	(-3.30)
$D_{nursery}$	Y	Y	Y	Y
R^2	0.855			
P-value of over-identification test	0.077	0.075	0.072	0.151

Asterisks ***, ** and * denote statistical significance at 1%, 5%, 10% level.
t-values are in parentheses. Coefficients of nursery dummies are omitted.

Table 2.8. Parameter Estimates of the Reduced-Form Equations, FIML

Independent Variable	Wage rate	Hours employed
Intercept	1.36	9.64
Apprehensions	-0.02	0.02
Construction wage	0.19	-0.12
Min wage, OR	0.35	-0.22
Min wage, MEX	0.04	-0.02
PPI: nitrogen	-0.01	-0.07
Housing starts	0.03	0.15
Time	0.001	0.003
Quarter 1	-0.03	-0.26
Quarter 2	-0.07	-0.001
Quarter 3	-0.06	-0.05

Table 2.9. Relative Contributions of Labor Supply and Demand Factors

	Supply: wage rates		Demand: working hours	
	%	$	%	Hours/quarter
Explained variation				
Apprehensions	6.6	0.10	-2.7	-93.0
Construction wage	14.3	0.22	-3.7	-127.0
Min wage, OR	15.5	0.24	-4.0	-136.7
Min wage, MEX	-7.4	-0.11	1.5	51.7
PPI: nitrogen	-2.9	-0.10	-18.1	-621.5
Housing starts	-6.3	-0.05	-5.9	-203.8
Time	52.8	0.82	64.7	2222.1
Total variation				
Explained	72.7	1.13	31.8	1091.8
Unexplained	27.3	0.42	68.2	2341.5
Total	100	1.55	100	3433.3

Table 2.10. Simulated Changes in Average Wage Rates and Working Hours, 1991-2008

	Wage ($)	Working hours (hours/quarter)
Factual	12.87	28624
No change in		
Apprehensions	12.73	10423
Construction wage	12.61	10457
Min wage, OR	12.59	10467
Min wage, MEX	12.95	10278
PPI: nitrogen	12.93	10951
Housing starts	12.88	10534

Chapter 3 : Sales and Contract Arrangement in Oregon Nurseries

Cheng Li

Introduction

Vertical contracts between producers and retailers are becoming increasingly popular in agricultural industries. The issue therefore attracts more and more attention from agricultural economists, for example in the broiler (Knoeber and Thurman, 1995), pork (Martin, 1997), winegrape (Goodhue, Heien, Lee, and Summer, 2003), and nursery industries (Batt and Miller, 2004). The nursery industry consists of wholesale nurseries – which I will call the producers – and their customers, namely retail nurseries, landscapers, garden centers, and big-box stores. When purchasing from a producer-nursery, a retailer makes a decision about how far ahead of delivery to place the order (pre-order interval). The producer-nursery then lists the plant price on the basis of the plant type, quality, and any pre-order terms. Compared with a spot market transaction, pre-order contracts reduce the producer's inventory and market risk, while providing retailers with purchase discounts. The most recent U.S. nursery and greenhouse survey was led by Hodges, A., M. Palma, and C. Hall in 2009 in all 50 states, reflecting 2008 data. They find that forward contracting is an important marketing practice that many producers use as a risk management tool. Mortimer (2008) finds that vertical coordination between producers and retailers increases the profits of both the upstream and downstream firm. In the present chapter, I investigate producer and retailer nurseries' choices of contract terms.

In terms of payment types, a pre-order contract can be divided into two groups: pay-by-order and pay-by-scan. Pay-by-order is a contract in which the producer is paid once the retailer receives the shipment. Pay-by-scan is a contract in which the buyer and seller agree that payment will not be made until the good is sold to customer. In terms of order frequency, pre-order contracts can be divided into two types: single-order contracts and annual contracts. Single-order contracts refer to purchase orders in which retailers may negotiate with the producer over the plant prices in a given shipment. They are common in sales to independent nursery retailers. Annual contracts, which refer to purchase orders in which the producer contracts to sell a product to a given retailer at given price during the selling season, are commonly used in sales to big-box stores. In annual contracts, the retailer may reorder at the same price agreed upon in the original contract, and the producer's responsibility is to satisfy the retailer's demand at any time at that price. Because producers ordinarily keep reserve inventories to meet retailers' unexpected demands, the producers' stocking fee in an annual contract is larger than it is in a variable-price contract. Therefore, pre-order contracts in Oregon nurseries can be divided into four types: (I) pay-by-order and single-order contract; (II) pay-by-scan and single-order contract; (III) pay-by-order and annual contract; (IV) and pay-by-scan and annual contract.

The goal is to analyze producers' and retailers' choices of, and reactions to, various contract types in the Oregon nursery industry. To this end, I successively employ two alternative behavioral scenarios. In the first step or scenario, retailers choose whether to sign a pre-order contract given a particular pre-order interval. In the second scenario, producers determine the price discount on the basis of that pre-order interval selected. Nursery producers usually offer two alternative discount methods: (i) a direct plant price discount and (ii) a payment grace period, which is an indirect discount. In my modeling of the two-step contracting process, I predict in the first step, with logistic regression and a Tobit model, the retailer's decision regarding the pre-order interval. For the second step, I estimate with a Tobit model the producer's decision regarding any direct price discount, and with a multinomial logit model the producer's decision regarding any indirect discount via a grace period before payment is demanded. Different from a one-step model, the two-step model in the present paper allows transaction and retailer characteristics to affect decisions about the pre-order interval differently from how they affect decisions about a direct price discount and payment grace period discount. In what is the first systematic empirical analysis of Oregon nursery contracts, I use daily 2005-2010 transaction data from a nationwide-selling nursery company in Oregon. The detailed information on transaction price and quantity in this dataset allows exploration of the producer's marketing strategy, risk attitude, and bargaining power in dealings with various retailers.

Literature Review

Vertical contracts have been widely studied in industrial organization, production economics, and supply chain management. Researchers examine the effects of contract arrangement on pricing, risk allocation, marketing channels, transaction types, and profits allocation between producers and retailers.

The classical "newsvendor" problem, which determines optimal inventory levels given fixed prices and random demand, is one of them. A newsvendor who sells a particular type of newspaper can order as many copies as he likes and sells them at a given price. Because the demand is uncertain, he will waste expenditure when ordering too much, and forego sales when ordering too few. The newsvendor should choose the order amount that will maximize profit. Chen and Chuang (2000) extend the newsvendor model to seasonal agricultural products with the assumptions that: (i) if a retailer orders in advance, the vendor will offer him a discount; and (ii) the later the retailer makes the commitment to purchase, the more information he will have about the market eventual demand. In their model, the retailer decides on the optimal purchase timing and quantity simultaneously. Chen and Chuang provide evidence that optimal purchase timing is earlier and optimal pre-order quantity is larger when market demand is predictable than when market demand is unpredictable.

Some studies focus on contract efficiency. Cachon (2004) investigates the impacts of push contracts, pull contracts, and pre-order discount contracts. In push contracts, all products are ordered before the selling season and the retailer bears all the inventory risk. In pull contracts, the retailer purchases as needed during the season and the producer holds all the inventory risk. In pre-order discount contracts, the retailer bears the inventory risk and the producer is responsible for the production risk, namely the risk that product volume may exceed the ordered amount. Mathematical models and simulations show that pre-order discount contracts Pareto-dominate pull and push contracts. Möller and Watanabe (2010) establish a monopolistic seller model to explore why it is sometimes early buyers, and other times late buyers, who receive price discounts in the airline industry. Their conclusion is that a pre-order discount is more likely to be observed in a market where: (i) temporal capacity limits are easy to implement; (ii) marginal costs of capacity are relatively high; (iii) the producer can adjust price according to demand; and (iv) resale is not feasible.

Other literature explains how to set the wholesale price and pre-order discount so as to allocate profit between producers and retailers. Gale (1993) examines the impacts of transaction timing on price discrimination by comparing monopoly and duopoly models. He takes the U.S. airline industry as an example to show that, considering aggregate demand uncertainty, capacity constraints, and *ex ante* product differentiation, price discrimination is larger under duopoly than under monopoly. Chen (2011) finds that in a buy-back policy, the producer can find a discounted wholesale price in a returns-discount contract which raises the profit of both producer and retailer. The reason is that producer profit is insensitive to wholesale price change when producer price approaches its optimum. When a producer offers a wholesale price discount, the buyer is likely to order more products. As a result, such contracts can significantly lift the profit of both producer and retailer.

Although such theoretical work has been well-established, empirical work on these issues lags behind. Due to the scarcity of the relevant intra-firm data, most theoretical results are supported by simulation rather than real business information. The complicated pricing systems observed in the presence of highly differentiated product lines make such data collection even more difficult. An exception is Goodhue, Heien, Lee, and Sumner (2003), who collect contract data via a survey of California winegrape producers and examine the relationship between product quality and contracting choices. Logistic regression models are used to estimate the effects of producer characteristics, contract provisions, and price incentives. By comparing producers' choices of contract type and provisions, they conclude that producers who grow high-quality grapes are likely to use formal written contracts, including provisions restricting the production process. Similarly, Fraser (2005) collects data via a mail survey of grape producers and, using multinomial logit and ordered logit models, examines Australian winegrape supply contracts. Fraser's empirical analysis reveals that contract clauses such as bonus/penalty payments, contract duration, and risk-shifting, influence grape quality, while bottle price of wine determines the risk distribution between winery and producer.

Katchova and Miranda (2004) are another example of the literature employing business data to examine market contracts. Maximizing a farmer's expected utility yields not only the adoption probability, but the producer's choice of quantity, frequency, and contract type. They prefer a double-hurdle model because farm characteristics affecting decisions to adopt market contracts differ from those affecting decisions on contract terms. First, a Probit model is specified to examine whether a farm will adopt a marketing contract. Second, the farmer's choices about product quantity, contracting frequency, and contract type are investigated with Tobit and truncated regression, Poisson and truncated Poisson, and multinomial and binomial logit models. Mortimer (2008) employs a two-stage model to analyze movie distributors' and video stores' choices of, and reactions to, two contract types in the video rental industry: revenue-sharing contracts and linear pricing contracts. In her paper, a monopolistic upstream firm is assumed to produce one product that is sold in the downstream market. The upstream firm chooses rental quantity and inventory to maximize distributor profit. The downstream firms observe the contracts, and select the optimal contract and inventory to maximize retailer profit. The model shows that both upstream and downstream profits rise by 10% under the revenue-sharing contract for popular titles.

In Mortimer's paper, utility theory is the foundation for establishing discrete choice models in which contract type is a binary or multinomial dependent variable, and personal and product attributes are independent variables. In the present paper, I use a successive model to examine how a retailer selects the transaction timing to minimize retailer transaction cost, and how a producer chooses discount rates to maximize producer profit given the retailer's decision.

Producer and Retailer Price Contract Model

Following Mortimer's (2008) market assumptions, I assume first that there is no coordination across retailers, an assumption supported by the diversity of retailer type and location. Second, the producer can adjust plant price according to market demand. Third, plants can either be grown or purchased at market. The difference between the nursery's and video rental industry's technology is that the nursery industry follows a seasonal pattern on account of a plant's life-cycle. It is critical for nursery producers and retailers to find the optimal transaction timing, order quantity, and order discounts over a selling season.

Retailer Problem

In the nursery industry, the retailer is a bridge between nursery producers and consumers. The retail nursery's problem is to maximize retailer profit by choosing the optimal number of days ahead of delivery on which to order the plant, an interval I will call the *pre-order interval*. Retail nurseries can satisfy consumer demands *via* three alternative channels: (a) purchase from wholesale nurseries in advance; (b) purchase from other retail nurseries at the spot market; or (c) production of the plants oneself. In other words, channel (b) means retailer can sell the plants either purchased from wholesaler or produced by itself to other retailers. Retailers decide, considering these three channels, the optimal length of the pre-order interval.

At market equilibrium, the profits generated from these three channels should be equated to each other. Given the zero-profit condition in a competitive market, the profit from channel (b) – namely revenue at spot market R minus the retailer's production cost C_P – is equal to zero: $R = C_P$. Retailer production cost is influenced by production scale, scope, business experience, market trends, retailer location, and retailer type.

For the same reason, profit from channel (b) above – namely revenue R at spot market minus the present-value of pre-order cost $e^{rt}C_A$ – is equal to zero. This is expressed as $R = e^{rt}C_A$, where C_A is pre-order cost – namely the pre-order price charged by the wholesale nursery – and $e^{rt}C_A$ is pre-order cost's present value at compound interest rate r. Combining the two conditions above, the equilibrium condition is

(1) $$C_P - e^{rt}C_A = 0$$

Solving for t gives the optimal pre-order interval t^* at which the order contract is signed:

(2) $$t^* = \frac{1}{r}(lnC_P - lnC_A)$$

Optimal pre-order interval t^* is determined from the retailer's production cost C_P and the cost C_A of pre-ordering. Equation (2) implies the optimal pre-order interval has a positive relationship with retailer's production cost ($\frac{\partial t^*}{\partial C_P} > 0$), and a negative relationship with pre-order cost ($\frac{\partial t^*}{\partial C_A} < 0$).

Assume retailer production technology follows the Cobb-Douglas production function, $q = AL^{\alpha}K^{\beta}M^{\gamma}$, where *L, K, M,* and q are the quantities of labor, capital, material, and product, and $\alpha + \beta + \gamma$ is a measure of returns of scale. Given the price of labor, capital, and materials, the Cobb-Douglas cost function is $C(q; P_L, P_K, P_M) = q^{\frac{1}{\alpha+\beta+\gamma}}c(P_L, P_K, P_M)$, implying that production cost is related to quantity, returns to scale, and input prices. In my nursery retail model, plant quantity is represented collectively by total plant volume per order (*scale*) and number of plant species per order (*scope*). Under decreasing returns to scale (scale diseconomy), production cost rises as scale does; under increasing returns to scale (scale economy), production cost falls as scale rises. Similarly, under decreasing returns to scope or scope diseconomy, production cost rises as scale does; under increasing returns to scope or scope economy, production cost falls as scale rises.

In the nursery industry, raw materials include pots, soil, water, chemicals, and fertilizers, whose prices are generally indexed in my model by nursery producer price index. Due to the seasonal pattern of a life-cycle of a plant's value in the nursery, I include season dummy $\boldsymbol{D}_{quarter}$ in the model. Geographic dummies $\boldsymbol{D}_{region}$ are used to capture the local market characteristics. The retailer's production cost can thus be written as

(3) $$C_p = C_p(Scale, Scope, PPI, \boldsymbol{D_{region}}, \boldsymbol{D_{quarter}})$$

Like production cost, pre-order price C_A charged by the wholesale nursery in equation (4) is affected by total plant volume per order (*Scale*), number of plant species per order (*Scope*), nursery producer price index (*PPI*), housing starts (Housing), length of the history of the nursery-retailer trading relationship (*Experience*), and retailer type (D_{bb}). The larger are the plant volume and the number of varieties in an order, the larger retailer's total expenditure would be. Housing starts are a proxy for plant demand. The trading relationship between producer and retailer (*Experience*) contributes to the trust between these two parties and thus reduces pre-order cost. Retailer types D_{bb} , such as independent retailer and big-box store, affect the discount rate because – with their substantial negotiating power – big-box stores may demand higher discount rates than do independent retailers. Pre-order cost thus can be specified as

(4) $$C_A = C_A(Scale, Scope, PPI, Housing, Experience, D_{bb})$$

where D_{bb} equals 1 when the retailer is a big-box store; zero otherwise. Combining these factors, equation (2) can be written as

(5) $$t = f(Scale, Scope, PPI, Housing, Experience, D_{bb}, \boldsymbol{D_{region}}, \boldsymbol{D_{quarter}})$$

Taking the derivative of t^* with respect to *Scale* and using equation (2), (3), and (4), we obtain

(6) $$\frac{\partial t^*}{\partial Scale} = \frac{1}{rC_p}\frac{\partial C_P}{\partial Scale} - \frac{1}{rC_A}\frac{\partial C_A}{\partial Scale}$$

The expected sign of this relationship between pre-order interval and scale depends upon whether a scale economy or diseconomy is present in production cost function $\frac{\partial C_P}{\partial Scale}$ and pre-order cost function $\frac{\partial C_A}{\partial Scale}$ in equation (6). Empirical evidence on this topic is provided in the section below. If scale economy rules, the greater a plant order's size, the lower the marginal production cost and the shorter the buyer's optimal pre-order interval. Otherwise, the larger the order, the larger the marginal production cost and the greater the optimal pre-order interval. The same relationship applies to scale's effect on pre-order cost. Therefore, the expected sign of $\frac{\partial C_P}{\partial Scale}$ and $\frac{\partial C_A}{\partial Scale}$ are unknown *a priori*. In addition, scale's effect on pre-order interval depends upon whether the scale's effect $\frac{\partial C_P}{\partial Scale}$ on production cost dominates or is dominated by its effect $\frac{\partial C_A}{\partial Scale}$ on pre-order cost in equation (6).

The same argument applies to the impact of the per-ordered variety of plant species, in a given transaction, on that transaction's optimal pre-order interval. If a scope economy is present, the greater the number of plant species per order, the lower is the marginal cost and thus the shorter the pre-order interval. Otherwise, the greater the number of plant species in an order, the larger marginal cost and the greater the optimal pre-order interval. On the other hand, retailers must consider the balance between a species' effect on production cost and its effect on pre-order cost because the two would offset each other.

Nursery producer price index at nursery, garden, and farm supply stores is a proxy for raw material prices. Taking the derivative of t^* with respect to PPI and using equation (2), (3), and (4), we obtain

(7) $$\frac{\partial t^*}{\partial PPI} = \frac{1}{rC_p}\frac{\partial C_P}{\partial PPI} - \frac{1}{rC_A}\frac{\partial C_A}{\partial PPI}$$

Product cost C_P and pre-order cost C_A rises with the prices of such raw materials as chemicals and fertilizers, we know that $\frac{\partial C_P}{\partial PPI} > 0$ and $\frac{\partial C_A}{\partial PPI} > 0$. That is, nursery producer price index's effect on pre-order interval depends upon whether the nursery PPI's effect

$\frac{\partial C_P}{\partial PPI}$ on production cost dominates or is dominated by its effect $\frac{\partial C_A}{\partial PPI}$ on pre-order cost in equation (7).

Housing starts (*Housing*), defined as the number of privately owned new houses on which construction has been started in a given period, is a proxy for plant demand. Because inventory cost falls with the rises in plant demand due to the large turnover rate, we know that $\frac{\partial t^*}{\partial Housing} = -\frac{1}{rC_A}\frac{\partial C_A}{\partial Housing} > 0$. That is, as housing starts rise, optimal forward-delivery interval t^* should increase as well.

Transaction trust between a producer and retailer is difficult to model. Increasing trust presumably reduces such transaction costs as information search, negotiation, transaction monitoring, and contract implementation. For example, a transaction with an old customer saves a seller's expenditure in searching for and negotiating with a new buyer and in monitoring the buyer's default probability. I use the number of years over which nursery and retailer have conducted business over a given period to proxy for transaction trust. The longer the period over which two parties have conducted trade with one another, the greater the number of transactions that will be recorded and hence the greater amount and accuracy of company information shared between the parties. Because $\frac{\partial C_A}{\partial Experience} < 0$, it follows that $\frac{\partial t^*}{\partial Experience} = -\frac{1}{rC_A}\frac{\partial C_A}{\partial Experience} > 0$. The greater the length of the nursery-retailer trading relationship, the greater would be the trust between them, so the greater the optimal pre-order interval.

Producer Problem

Given the retailer's decision on pre-order interval t^*, the producer's problem is to maximize its profit by determining the rate at which the price to the retailer should be discounted below the spot price as a reward for the pre-order commitment. If the spot market price is P and the pre-order price is P_A, the discount can be expressed as

$$\delta = \frac{P - P_A}{P}$$

In the nursery industry, it is difficult to calculate average invoice price because so many highly differentiated products, whose prices vary by plant species and size, are present in each invoice. But the discount rate is an appropriate measure for comparing average prices across invoices.

Nursery producers deal mainly with two types of retail nurseries: independent retailers and big-box stores such as Walmart, Lowe's, and Home Depot. Two payment types are commonly used in the nursery industry: pay-by-scan and pay-by-order. In pay-by-scan, the producing nursery is paid only for the plants that are purchased and kept by the retailer-customer, while in pay-by-order the producer is paid once the retailer receives the shipment. "Contract frequency" is divided into single-order contracts and annual contracts. In table 3.1, I segment nursery contracts into four groups, based on payment type and contract frequency.

The producer's problem is to maximize profit for each contract type. Assume in figure 3.1 the producer's unit cost is a step function of plant quantity. Let c_j be the unit cost per plant when plant quantity is in the range between q_{j-1} and q_j, given $(c_j, q_j) \in R_+^2$, and j is an index of output range. If $q_i > q_j$, then $c_i > c_j$. Unit cost rises as output does. Each rectangle in figure 3.1 is unit cost in the given output range. Total contract cost is the sum of costs over the output range, $C = \sum_{j=1}^{J}(c_j - c_0)(q_j - q_{j-1})$, where $c_0 = 0, q_0 = 0$. Unit cost is zero if output is zero. Switching price and output domains as in figure 3.2, contract cost can be written as $C = \sum_{j=0}^{J}(c_{j+1} - c_j)(Q - q_j)$, where Q is total plant quantity q_J. Furthermore, c_i is a function of pre-order interval t^* and of contract characteristics $\underline{X}$, where $\frac{\partial c}{\partial t^*} < 0$. That is, unit production costs fall with increases in the committed pre-order interval.

Let P be the spot market price, δ the discount rate, and $\bar{Q}$ the shipment quantity in Contract I. Following Cross, Buccola, and Thomann (2006), the producer's profit function when using Contract Type I in table 3.1 then is

(8) Contract I: pay-by-order and single-order contract

$$\pi_I = e^{-rt^*}(1-\delta)P\bar{Q} - \sum_{j=0}^{J}(c_{j+1} - c_j)(\bar{Q} - q_j)^+$$

where discount rate δ is defined relative to spot market price P, and $(\bar{Q} - q_j)^+ = \max(\bar{Q} - q_j, 0)$. Profit function (8) applies to the contract between a nursery producer and an independent retailer who have decided to adopt a pay-by-order and single-order contract. If the independent retailer has booked pre-order interval t^*, so that it has ordered amount $\bar{Q}$ today and will pay for them t^* days later at discounted price $(1-\delta)P$, then the present value of payment received by the producer is $e^{-rt^*}(1-\delta)P\bar{Q}$.

The difference between Contract I and Contract II is payment method. Contract II with pay-by-scan allows buy-back, while Contract I with pay-by-order does not allow it. For example, with a pay-by-scan contract, if a plant dies before payment has been made, the retailer can return it without paying the producer. If $|Q' - \bar{Q}|$ is the number of plants returned to the producer, the profit function is

(9) Contract II: pay-by-scan and single-order contract

$$\pi_{\text{II}} = e^{-rt^*}(1-\delta)P\bar{Q} - \sum_{j=0}^{J}(c_{j+1} - c_j)(\bar{Q} - q_j)^+ + e^{-rt^*}(1-\delta)P|Q' - \bar{Q}|$$

where $(\bar{Q} - q_j)^+ = \max(\bar{Q} - q_j, 0)$.

The difference between Contract Type I and Contract Type III is contract frequency. Contract III allows shipment quantity to remain unspecified in the contract, so that shipment amount is random at the time of contract-signing. This form is common with big-box stores. If $\tilde{Q}$ is the random shipment quantity in Contract III, shipment quantity expectation $E(\tilde{Q})$ is used instead of fixed $\bar{Q}$ in the profit function:

(10) Contract III: pay-by-order and annual contract

$$\pi_{\text{III}} = e^{-rt^*}(1-\delta)PE(\tilde{Q}) - \sum_{j=0}^{J}(c_{j+1} - c_j)(E(\tilde{Q}) - q_j)^+$$

where $(E(\tilde{Q}) - q_j)^+ = \max(E(\tilde{Q}) - q_j, 0)$.

Contract Type IV, which calls for pay-by-scan and open-ended (unspecified) shipment quantity, is common in sales to big-box stores. If $|Q' - E(\tilde{Q})|$ is the quantity of defective plants returned to the producer, the profit function is

(11) Contract IV: pay-by-scan and annual contract

$$\pi_{\mathrm{IV}} = e^{-rt^*}(1-\delta)PE(\tilde{Q}) - \sum_{j=0}^{J}(c_{j+1} - c_j)\big(E(\tilde{Q}) - q_j\big)^+ + e^{-rt^*}(1-\delta)P|Q' - E(\tilde{Q})|$$

where $(E(\tilde{Q}) - q_j)^+ = \max(E(\tilde{Q}) - q_j, 0)$.

The long-run condition for maximizing profit across contract types is that the contract types be designed such that profit at expected equilibrium satisfies $E(\pi_I) = E(\pi_{II}) = E(\pi_{III}) = E(\pi_{\mathrm{IV}})$. Otherwise, the producer will engage increasingly in the contract type with the largest profit until profit with that contract type becomes the same as with the other contract types. The first-order conditions of this problem with respect to the pre-order discount decision is a function of pre-order interval t^* and of contract characteristics $\underline{\boldsymbol{X}}$. Based on the above first-order conditions, we now may derive hypotheses about contract characteristics' impacts on the pre-order discount. In the Empirical Results section below, I will then test these hypotheses.

Consider contract I in equation (8) for example. Solving for δ gives the optimal pre-order discount δ^*:

$$\frac{\partial \pi_I}{\partial \bar{Q}} = e^{-rt^*}(1-\delta)P - c_J(t^*, \underline{\boldsymbol{X}}) = 0$$

(12)
$$\delta^* = 1 - e^{rt^*}\frac{c_J(t^*, \underline{\boldsymbol{X}})}{P}$$

Holding plant price fixed at spot market P, the pre-order discount rises as contract cost falls: $\frac{\partial \delta}{\partial c(t^*, \underline{\boldsymbol{X}})} < 0$. Because contract cost is a function of contract characteristics, the factors that reduce contract costs raise the optimal pre-order discount. Furthermore,

assuming $\frac{\partial c}{\partial t^*} < 0$, pre-order discount rises as pre-order interval rises: $\frac{\partial \delta}{\partial t^*} =$
$e^{rt^*} r \frac{c_J(t^*, \underline{\boldsymbol{X}})}{P} + \frac{e^{rt^*}}{P} \frac{\partial \delta}{\partial c} \frac{\partial c}{\partial t^*} > 0.$

In order to capture the characteristics of all four contract types, I include two dummies variables, D_{paid} and D_{bb}. D_{paid} denotes payment type, which is unity if the contract requires the retailer to pay-by-order; zero if pay-by-scan. D_{bb} denotes retailer types or contract frequency, represented by unity for annual contracts or big-box stores, and zero for single-order contracts or independent retailers. Contract types thus are defined as:

- Contract I: $D_{paid} = 1$ and $D_{bb} = 0$
- Contract II: $D_{paid} = 0$ and $D_{bb} = 0$
- Contract III: $D_{paid} = 1$ and $D_{bb} = 1$
- Contract IV: $D_{paid} = 1$ and $D_{bb} = 1$

Other important contract characteristics affecting the pre-order discount rate include – along with the symbols I will use for them: plant quantity (*Scale*), plant diversity (*Scope*), length of nursery-retailer trading relationship (*Experience*), percentage of unpaid balance (*Owe*), nursery producer price index (*PPI*), housing starts (*Housing*), and transaction season ($\boldsymbol{D_{quarter}}$). Some of these factors, such as *Scale*, *Scope*, *Experience*, *PPI*, *Housing*, and $\boldsymbol{D_{quarter}}$, are the same as those defined in the optimal pre-order interval function. The other variable, unpaid amount (*Owe*), reflecting financial risk is new to this analysis. *Owe* is the percentage of the retailer's unpaid balance in the previous year. Equation (12) which is applicable to four contract types can be written as

(13) $$\delta = f\left(t^*, \underline{\boldsymbol{X}}\right)$$
$$= f(t^*, Scale, Scope, PPI, Housing, Experience, own, D_{paid}, D_{bb}, \boldsymbol{D_{quarter}})$$

Taking the derivative of discount δ with respect to contract characteristics $\underline{\boldsymbol{X}}$ gives $\frac{\partial \delta}{\partial \underline{\boldsymbol{X}}} = \frac{\partial \delta}{\partial c}\frac{\partial c}{\partial \underline{\boldsymbol{X}}}$. Provided $\frac{\partial \delta}{\partial c} < 0$ and $\frac{\partial c}{\partial \underline{\boldsymbol{X}}} < 0$, we have $\frac{\partial \delta}{\partial \underline{\boldsymbol{X}}} = \frac{\partial \delta}{\partial c}\frac{\partial c}{\partial \underline{\boldsymbol{X}}} > 0$; otherwise, if $\frac{\partial c}{\partial \underline{\boldsymbol{X}}} > 0$, then $\frac{\partial \delta}{\partial \underline{\boldsymbol{X}}} = \frac{\partial \delta}{\partial c}\frac{\partial c}{\partial \underline{\boldsymbol{X}}} < 0$. That is, retailer characteristics such as length of nursery-retailer trading relationship, which reduce the unit cost between buyer and seller, will raise the discount rate. On the other hand, factors that boost unit cost will reduce the discount rate. An example is the retailer's debt-to-credit limit. As a proxy of a retailer's payment history, retailer's debt-to-credit limit reflects the retailer's ability and willingness to pay for its balance. The higher is the percentage of the retailer's unpaid balance, the worse is the retailer's financial situation, so the greater the producer's cost in collecting payment and the lower the optimal discount rate.

Model Specifications

In the two-step model derived above, the factors affecting retailer's and producer's decision include transaction attribute, retailer attribute, region effect, and season effect. In equation (5), the retailer determines the optimal pre-order interval. Then, in equation (13), the producer decides on the pre-order discount rate given the retailer's pre-order interval choice and transaction characteristics. The nursery producer is assumed to provide two alternative discount methods: plant price discount and payment grace period. Payment grace period is a discount method because it allows retailers to pay for the obligations over a longer period without extra penalty. I assume that these two discount methods are influenced by the same set of factors. The present two-step model allows the parties to choose the pre-order interval and discount rate in separate stages. Such a two-step method is in line with the contract processes in many real businesses.

Pre-order Interval Models

Equation (2) shows the linear relationship between the optimal pre-order interval and the difference between logged production cost and logged pre-order cost. Assuming production cost and pre-order cost functions follow a logarithmic functional form, production cost and pre-order cost bear a linear relationship to transaction attribute, retailer attribute, region effect, and season effect. Therefore, equation (5) can be written as

(14) $$t = \begin{cases} t^* \; if \; t^* > 0 \\ 0 \; if \; t^* \leq 0 \end{cases}$$

where

$t^* = \beta_0 + \beta_1 lnR + \beta_2 lnS + \beta_3 Y + \beta_4 lnPPI + \beta_5 lnH + \beta_6 D_{bb} + \boldsymbol{\beta}_7 \boldsymbol{D}_{region} + \boldsymbol{\beta}_8 \boldsymbol{D}_{quarter} + \varepsilon$

and $\varepsilon \sim N(0, \sigma^2)$

Here, *t* is pre-order interval, *R* is sale revenue per invoice, *S* is the number of plant species per invoice, *Y* is the length of the nursery-retailer trading relationship, *PPI* is the nursery producer price index, and *H* is the index of housing starts. D_{bb} equals 1 when the retailer is a big-box store; 0 otherwise. $\boldsymbol{D}_{region}$ is a regional dummy denoting West, Midwest, Northeast, South, or other regions. $\boldsymbol{D}_{quarter}$ is a seasonal dummy for spring, summer, autumn, and winter. Bold font denotes vectors. Because the logged total sales and plant species may each have a non-linear relationship with pre-order interval, an alternative specification is to include square terms for logged sale and scope. Equation (14) then can be written as

(15) $$t = \begin{cases} t^* \; if \; t^* > 0 \\ 0 \; if \; t^* \leq 0 \end{cases}$$

where $t = \beta_0 + \beta_1 lnR + \beta_{11}(lnR)^2 + \beta_2 lnS + \beta_{22}(lnS)^2 + \beta_3 Y + \beta_4 lnPPI + \beta_5 lnH + \beta_6 D_{bb} + \boldsymbol{\beta}_7 \boldsymbol{D}_{region} + \boldsymbol{\beta}_8 \boldsymbol{D}_{quarter} + \varepsilon$

and $\varepsilon \sim N(0, \sigma^2)$

Equation (15) is a corner-solution model because dependent variable *t* is continuous at positive values, but becomes discontinuous at zero points. Green (2002) shows that conventional regression methods fail to account for the qualitative difference between limit (zero) observations and nonlimit (continuous) observations. The dependent variable is a censored variable and the censoring point is zero. OLS regression leads to inconsistent parameter estimates because the sample is not representative of the population. A Tobit model (1958) can in this situation be used instead of OLS, and estimated with maximum likelihood methods (MLE). As proved in Green (2002), MLE has the desirable properties of consistency, asymptotic normality, asymptotic efficiency, and invariance under regularity.

To depict the Tobit approach, denote the exogenous factors **X** as $\boldsymbol{X} = (1, ln\text{R}, (lnR)^2, \text{lnS}, (lnS)^2, \text{Y}, ln\text{PPI}, ln\text{H}, D_{bb}, \boldsymbol{D_{region}}, \boldsymbol{D_{quarter}})$

$$f(t|x) = \{(2\pi)^{-\frac{1}{2}}\sigma^{-1}e^{-\frac{(t-\boldsymbol{X}'\boldsymbol{\beta})^2}{2\sigma^2}}\}^{1(t>0)}\{1 - \Phi\left(\frac{\boldsymbol{X}'\boldsymbol{\beta}}{\sigma}\right)\}^{1(t=0)}$$

where $f(t|x)$ is the function of pre-order interval given the exogenous factors $\boldsymbol{X}$, $\Phi\left(\frac{\boldsymbol{X}'\boldsymbol{\beta}}{\sigma}\right)$ is the standard normal cumulative distribution function, and exponential indicator functions are $1(t > 0)$ and $1(t = 0)$. The log-likelihood of the model is

$$lnL = \sum_{t_i>0} -\frac{1}{2}[\log(2\pi) + ln\sigma^2 + \frac{(t_i - x_i'\boldsymbol{\beta})^2}{\sigma^2}] + \sum_{t_i=0} \ln[1 - \Phi(\frac{x_i'\boldsymbol{\beta}}{\sigma})]$$

The expected value of *t*, namely pre-order interval, is then

$$E(t|\boldsymbol{X}) = P(t = 0|\boldsymbol{X}) \times 0 + P(t > 0|\boldsymbol{X})E(t|\boldsymbol{X}, t > 0)$$
$$= P(t > 0|\boldsymbol{X})E(t|\boldsymbol{X}, t > 0)$$

where $P(t > 0|\boldsymbol{X}) = E[1(t > 0)|\boldsymbol{X}] = P(t^* > 0|\boldsymbol{X}) = P(\varepsilon > -\boldsymbol{X\beta}|\boldsymbol{X}) = \Phi(\frac{\boldsymbol{X\beta}}{\sigma})$.

In addition, $E(t|\boldsymbol{X}, t > 0) = \boldsymbol{X\beta} + E(\varepsilon|\varepsilon > -\boldsymbol{X\beta}) = \boldsymbol{X\beta} + \sigma[\frac{\phi\left(\frac{\boldsymbol{X\beta}}{\sigma}\right)}{\Phi\left(\frac{\boldsymbol{X\beta}}{\sigma}\right)}]$, so that

(16) $$E(t|\boldsymbol{X}) = \left\{\boldsymbol{X\beta} + \sigma\left[\frac{\phi\left(\frac{\boldsymbol{X\beta}}{\sigma}\right)}{\Phi\left(\frac{\boldsymbol{X\beta}}{\sigma}\right)}\right]\right\}\Phi\left(\frac{\boldsymbol{X\beta}}{\sigma}\right) = \boldsymbol{X\beta}\Phi\left(\frac{\boldsymbol{X\beta}}{\sigma}\right) + \sigma\phi\left(\frac{\boldsymbol{X\beta}}{\sigma}\right)$$

Because $P(t > 0|\boldsymbol{X}) = \Phi(\frac{\boldsymbol{X\beta}}{\sigma})$, $\frac{\partial P(t>0|\boldsymbol{X})}{\partial x_i} = \frac{\beta_i}{\sigma}\phi(\frac{\boldsymbol{X\beta}}{\sigma})$, and $\frac{\partial E(t|\boldsymbol{X})}{\partial x_i} = \Phi(\frac{\boldsymbol{X\beta}}{\sigma})\beta_i$, taking the derivative of equation (15) with respect to x_i gives

(17) $$\frac{\partial E(t|\boldsymbol{X})}{\partial x_i} = \frac{\partial P(t>0|\boldsymbol{X})}{\partial x_i}E(t|\boldsymbol{X}, t > 0) + P(t > 0|\boldsymbol{X})\frac{\partial E(t|\boldsymbol{X},t>0)}{\partial x_i}$$

Equation (17) implies that the contract characteristic's effect $\frac{\partial E(t|\boldsymbol{X})}{\partial x_i}$ on the pre-order interval depends upon its effect $\frac{\partial P(t>0|\boldsymbol{X})}{\partial x_i}$ on the probability that the retailer will pre-order and on the pre-order interval ($\frac{\partial E(t|\boldsymbol{X},t>0)}{\partial x_i}$) itself. To estimate the probability that the retailer will pre-order, I define a new binary variable, namely whether a pre-order contract has been signed or not, as the dependent variable in the logistic regression

(18) $\ln(\frac{p_i}{1-p_i}) = \beta_0 + \beta_1 lnR + \beta_2 lnS + \beta_3 Y + \beta_4 lnPPI + \beta_5 lnH + \beta_6 D_{bb} + \boldsymbol{\beta}_7 \boldsymbol{D}_{region} + \boldsymbol{\beta}_8 \boldsymbol{D}_{quarter} + \varepsilon$

where p_i is the probability of pre-order contract. If a pre-order contract has been signed, a pre-order interval is specified in the contract. If a pre-order contract has not been signed, the pre-order interval is set to be zero. Coefficients $\boldsymbol{\beta}$ can be estimated by maximum likelihood methods. To sum up, I use equation (18) to estimate the probability that the retailer pre-orders, then use equation (15) to estimate the pre-order interval given that the retailer has signed a pre-order contract.

Price Discount Model

Knowing the retailer's decision regarding a pre-order interval, the producer will, as discussed at equations (12), (13), and elsewhere, determines the discount rate maximizing the producer's profit. To provide functional form, I rewrite equation (13) by assuming the log linear relationship between discount rate and independent variables:

(19) $ln\delta = \alpha_0 + \alpha_1 \hat{t} + \alpha_2 lnR + \alpha_3 lnS + \alpha_4 Y + \alpha_5 lnPPI + \alpha_6 lnH + \alpha_7 F + \alpha_8 D_{paid} + \alpha_9 D_{bb} + \boldsymbol{\alpha}_{10} \boldsymbol{D}_{quarter} + \epsilon$

where δ is discount rate, $\hat{t}$ is predicted pre-order interval, R is sales revenue per order, S is the number of plant species per order, *Y* is the length of nursery-retailer trading relationship, *PPI* is the nursery producer price index, *H* is the index of housing starts, D_{paid} is payment dummy, D_{bb} is retailer type dummy, and $\boldsymbol{D}_{quarter}$ is season dummy. Bold font denotes vectors. *F* is the retailer debt-to-credit limit in the previous year, used here to reflect the retailer's financial condition. Because, as discussed in equation (15), logged total sales and plant species may have a non-linear relationship with discount rate, an alternative specification is to include the squared forms of logged sales quantity and scope in equation (19). Equation (19) then can be written as

(20) $ln\delta = \alpha_0 + \alpha_1\hat{t} + \alpha_2 lnR + \alpha_{21}(lnR)^2 + \alpha_3 lnS + \alpha_{31}(lnS)^2 + \alpha_4 Y + \alpha_5 lnPPI + \alpha_6 lnH + \alpha_7 F + \alpha_8 D_{paid} + \alpha_9 D_{bb} + \boldsymbol{\alpha}_{10}\boldsymbol{D}_{quarter} + \epsilon$

and estimated with OLS.

Payment Grace Period Model

As discussed above in the Model Specification section, the payment grace period is an alternative, indirect way for the producer to provide a price discount. Because modeling the producer's choice of indirect discount by way of a payment grace period requires specifying multiple categories in the dependent variable, I use a multinomial logistic model to investigate the producer's choice of grace period. The payment grace periods in the model are

1. m = 0: pay within 15 days of delivery
2. m = 1: pay within 30 days of delivery
3. m = 2: pay within 60 days of delivery
4. m = 3: pay within one year of delivery

The probability that the producer will offer the indicated payment grace period is

$$P(Y_i = m) = \frac{\exp(\boldsymbol{\alpha}_k'\boldsymbol{X}_i)}{1 + \sum_{k=1}^{M}\exp(\boldsymbol{\alpha}_k'\boldsymbol{X}_i)} \quad \text{for } m = 1, 2, 3$$

where $\boldsymbol{X} = (\mathbf{1}, \hat{t}, ln\text{R}, ln\text{S}, \text{Y}, ln\text{PPI}, ln\text{H}, \text{F}, D_{paid}, \boldsymbol{D_{quarter}})$, namely the same exogenous variables as in the direct price-discount model. In particular, the probability the producer will demand payment within 15 days is

$$P(Y_i = 0) = \frac{1}{1 + \sum_{k=1}^{M} \exp(\boldsymbol{\alpha}_k' \boldsymbol{X}_i)}$$

Suppose the first category, m = 0, is the reference one. Then for m=1, 2, 3:

$$(21) \qquad ln\frac{P(Y_i=m)}{P(Y_i=0)} = \boldsymbol{\alpha}_k' \boldsymbol{X}_i$$

$$= \alpha_{m,0} + \alpha_{m,1}\hat{t}_i + \alpha_{m,2}lnR_i + \alpha_{m,3}lnS_i + \alpha_{m,4}Y_i + \alpha_{m,5}lnPPI_i + \alpha_{m,6}lnH_i + \alpha_{m,7}F_i + \alpha_{m,8}D_{paid,i} + \boldsymbol{\alpha}_{m,9}\boldsymbol{D}_{quarter,i}$$

Equation (21) is used to predict the probability of a given grace period, along with the effects of exogenous factors $\boldsymbol{X}$ on the producer's choice of that grace period. The dependent variable in equation (21) can be expressed as $ln\frac{P(m=j)}{P(m=0)}$.

Data Description

Data on contract and retailer characteristics were provided by one of the largest nurseries[1] in Oregon. The dataset consisted of 691,192 records, beginning in 2005 and ending in 2010, at the plant level. Each record includes all the plant information available regarding a given retailer's order on a given date, including order number, order date, delivery date, company shipped to, address shipped to, invoice discount, plant name, plant variety, plant size, plant type, unit price, ordered quantity, shipped quantity, freight cost, amount paid, and amount due. If several records share the same order number, they are based on the same order. To clean the dataset, I removed any record corresponding to a gift or to a sample with a 100% discount, or if it reflects a refund or replenishment of a previous transaction. To facilitate the analysis of a market contract, I organized the original dataset at the plant level into a new dataset at the order level by grouping together all records of the same order number. In this way, I obtained 46,000 observations, each of which represent an order, including total revenue, number of plant species, customer's name and address, invoice discount, retailer's requested delivery date, and ultimate delivery date.

Table 3.3 shows the summary statistics of these variables, defined in table 3.2. Some variables are, for proprietary purposes, not reported. According to nursery business practice, an independent retailer's pre-order interval is the difference between order date and delivery date. Because big-box stores usually use annual contracts in which big-box stores negotiate price structure with the producer at the beginning of a year and sign an annual contract at that time, I assume that, for big-box stores, pre-order intervals are the difference between the first day of each year and the delivery date. If the minimum pre-order interval is larger than zero in table 3.3, the retailer has selected a pre-order contract; otherwise, the retailer has chosen the spot market contract. Spot-market contracts constituted 29.5%, and pre-order contracts 70.5%, of the sample transactions. The overall sample mean pre-order interval is 110, implying retailers typically establish a contract about three months ahead of delivery. Independent retailers usually place a contract a week ahead of expected delivery. Big-box stores, on the other hand, usually place a contract five months ahead.

As discussed above, price discount and payment grace period are the producer's two alternative promotion methods. Characterizing the payment grace period is econometrically straightforward; but calculating a price discount differs from the normal method. The normal method of calculating discount rate is

$$\delta = \frac{P_{market} - P_{selling}}{P_{market}}$$

In the present paper, I use maximum price rather than market price to calculate discount rate. Because plant price depends on variety and size, I regarded – in order to capture the main discount drivers – plants in the same variety and size category to be of a single product type. Because most invoices include multiple products, I use the weighted average discount across products as the aggregate discount on that invoice. In particular, if an invoice includes *n* types of plants, the invoice discount rate equals the discount rate on each plant type weighted by its sale revenue.

(22) $$\delta = \sum_{i=1}^{N} \frac{Sale_i}{Sale} \frac{P_{max,i} - P_i}{P_{max,i}}$$

where P_{max} is the highest price charged for a plant in a given variety and size category. Because a given plant type's spot market price is unknown, the maximum observed plant price within a given product type is used as the reference point to calculate that product type's plant discount. In this way, "standardized" discounts can be compared among orders.

In order to study the producer's price-discount decision, I adjust plant prices to the price stated at producer location. Two price categories are provided on the nursery's receipt: (i) price stated at producer location, and (ii) price stated at buyer location. In the nursery examined here, whether (i) the shipping fee is stated or (ii) the shipping fee is missing and the buyer has hired the driver, the buyer is assumed to pay the shipping fee and price on receipt is price at producer location. If, on the other hand, the shipping fee is missing and the producer has hired the driver, the producer is assumed to pay the shipping fee and price on receipt is price at buyer location. In this latter case, I converted price on receipt to price at producer location by removing the estimated shipping fee. Because the nursery providing the data for the present study sells its product throughout the country, shipping costs are non-negligible. Especially among big-box stores, the producer typically offers a free shipping service as an indirect discount. I estimated shipping fee in three steps. The first step is to collect buyers' zip codes. With the SAS software macro, distance between producer and buyer is calculated by city-based zip codes. The second step is to estimate the transportation fee as a function of distance and shipping unit in each transaction. The third step is to use the estimated transportation fee equation to predict shipping fee in each transaction.

Each product's percentage of sales revenue in an invoice is the appropriate weight for computing the invoice discount rate in equation (22). Using equation (22), I obtain the weighted average discount rate in each invoice. Because the highest price charged for a plant in a given variety and size category is given as exogenous, discount rate δ captures the impacts of transaction and retailer characteristics on product price. The histogram of the discount rates in the 46,000 observations, although not provided in the present paper, shows that the weighted discount follows an approximately normal distribution.

I have noted that, considering its time value, payment grace period is equivalent to, or another way to measure, a price discount rate. Payment grace period is defined as the number of days allowed before the buyer is required to pay without incurring penalties. The grace period category the producer optimally offers, such as within 15 days, within 30 days, ..., and within one year, depends on transaction and retailer characteristics. The twelve categories of grace period provided in the data are grouped here into six segments in order to avoid cases of missing observations in a category. Most transactions are stipulated to be closed within two months (60 days). Grace periods differ between big-box stores and independent retailers. Most big-box stores are required to pay within 60 days (46%), while independent retailers are mostly required to pay within 30 days (53%).

The number of invoices in our sample varies by region, year, season, and retailer type. For example, 86% of transactions are with Western retailers, 5.9% with Midwestern, 2.2% with Northeastern, 3.9% with Southern, and 1.9% with Canada and Alaska. The largest number of clients was 380 (in 2010); the lowest number of clients was 321 (in 2006). The percentage of transactions in each year between 2005 to 2010 were respectively 2.6%, 11.0%, 13.6%, 12.7%, 15.5%, and 44.6%, strongly suggesting that increasing proportions of the firm's records became represented in the data as time passed. Percentages of data drawn from the 1st quarter to the 4th quarter were respectively 24.4%, 48.3%, 22.4%, and 5.9%, illustrating the seasonal pattern in nursery sales. In terms of retailer type, 71.1% of transactions were with big-box stores and 28.9% with independent retailers.

Summary statistics in table 3.3 compare transactions with big-box stores and those with independent retailers. Big-box stores recently are the fast-growing phenomenon in the industry. Because these stores are rather new customers for our sample nursery, it is not surprising that the nursery's business experience with them is much shorter than it is with independent retailers. The producer's average per-order sales revenue with big-box stores is smaller than with independent retailers, but big-box stores' transactions tend to be of higher frequency. Seventy-nine percent of contracts with big-box stores are on a pay-by-order basis and 21% on a pay-by-scan basis. Ninety-seven percent of contracts with independent retailers follow pay-by-order and only 3% follow pay-by-scan.

Standard deviation (the 7th column in table 3.3) is a widely used measure of variability or diversity from the average. Coefficient of variation (CV) (last column in table 3.3), or relative standard deviation, is a normalized measure of dispersion, allowing a comparison of two variables' dispersions with their central tendencies or means. Because contract attributes' standard deviations and coefficients of variation among big-box stores are smaller than among independent retailers, big-box stores' contract behaviors are less volatile and more predictable than independent retailers' are. In particular, contract characteristics such as pre-order interval, sales revenue per order (transaction scale), annual sales revenue, plant species per order (transaction scope), and unpaid balance (retailer lagged debt) are less variable among big-box stores than among independent stores. Similarity of contract attributes across big-box stores, and their large transaction scales, are what especially attract producer-nurseries to big-box stores.

Empirical Results

The two-step model employed here predicts pre-order interval, price discount, and grace-period discount on the basis of transaction attributes, retailer attributes, region effects, and season effects. In the present section, I discuss estimation results of the logistic, Tobit, and multinomial logit models described in the Model Specification section. Tables 3.4 – 3.9 present the estimation results for pre-order interval t, price discount rate δ, and payment grace period d.

Factors Affecting Pre-order Interval

Estimation results for the pre-order probability (equation 18) are reported in the second column of table 3.4. Parameter estimates and *t*-statistics are each shown. Pseudo R^2 is 0.76 and coefficients are all statistically significant at the 5% level except for the Western Region dummy. Tobit estimation results for the pre-order interval length (equation 15) are reported, with parameter estimates and t-statistics, in the last three columns of table 3.4. The Tobit is estimated by retailer type because transaction and retailer characteristics vary on that basis. The Pseudo R^2 in the pooled-data, big-box store data, and independent retailer data models are respectively 0.10, 0.07, and 0.01. Most coefficients are statistically significant at the 1% level. To help explain the economic implications of these results, I report in table 3.5 the factor elasticities derived from these Tobit models.

Findings in Tables 3.4's logistic regression are consistent with the Tobits. Table 3.4's logistic results show that for every 1% rise in transaction scale, the relative probability that plants have been pre-ordered instead of spot-purchased rises by 1.27%. Corroboration of this is found in the corresponding Tobit models. Coefficients of transaction scale's linear and squared terms are, in the last three columns of table 3.4, significant, implying a non-linear relationship between logged transaction scale and pre-order interval. Among big-box stores, the negative linear term and positive squared term indicate that transaction scale's impact on pre-order interval follows a "U" curve. As the scale of an order first begins to rise, the demanded pre-order interval falls; but as scale rises further, demanded pre-order interval rises. However, among independent retailers, the positive linear term and negative squared term indicate that transaction scale's impact on pre-order interval follows an inverse "U" curve.

If economies are achieved as transaction scale rises, increases in the size of a sale order would reduce cost per transaction and thus reduce the optimal pre-order interval. If scale economies instead are negative, growth in transaction scale instead would increase the pre-order interval. Thus, the turning point in the impact of transaction scale on pre-order interval is an estimate of the threshold between scale diseconomy and scale economy. One way of determining the sign of the *overall* effect is to compare the turning point with the sample mean and the two-standard-deviation range of the relevant transaction-scale variable. Among big-box stores, for example, the turning point (1.49) is less than the sample mean (7.76), implying scale diseconomies are present overall in contracts with big-box stores. Among independent retailers, the turning point (7.89) is less than the sample mean (8.49), implying instead that scale economies are present overall in contracts with independent retailers.

Transaction scope's impact on pre-order *probability* is weaker than transaction scale's impact. Table 3.4's logistic results indicate that, for every 1% rise in transaction scope, the relative probability that plants have been pre-ordered instead of spot-purchased increases by 0.79%. In the last two columns of table 3.4, the coefficients of scope's squared terms are statistically significant, implying a non-linear relationship between logged transaction scope and pre-order interval. The logic in employing these coefficients to examine scope's per- transaction cost effects is the same as it is in examining scale's effects. In particular, among big-box stores, the positivity of the linear term and negativity of the squared term indicate that transaction scope's impact on pre-order interval follows an inverse "U" curve. As order scope first starts to rise, the demanded pre-order interval also rises; but as scope rises further, demanded pre-order interval falls. Among independent retailers, the negative linear term and positive squared term indicate that transaction scope's impact on pre-order interval follow a "U" curve itself. As order scope first begins to rise, demanded pre-order interval falls; but as scope rises further, the demanded interval rises.

If economies are achieved as transaction scope rises, increases in transaction scope reduce cost per transaction and thus decrease the optimal pre-order interval. If, in contrast, scope economies are negative, transaction scope growth instead boosts the optimal pre-order interval. Thus, the turning point in the impact of transaction scope on pre-order interval is an estimate of the threshold between scope diseconomy and scope economy. Among big-box stores, for example, the turning point (0.23) is less than the sample mean (2.63), implying scope economies largely dominate in contracts with big-box stores. Among independent retailers, the turning point (0.66) is less than the sample mean (2.47), implying scope diseconomy are largely present in contracts with independent retailers. In order to achieve scope economies, independent retailers would reduce the number of plant species per order. The elasticity of transaction scope in table 3.5 shows that independent retailers are more sensitive to transaction scope than are big-box stores. For every 1% rise in transaction scope, big-box stores demand a 0.02% lower pre-order interval, but independent retailers a 0.21% greater one.

Length of the nursery-retailer trading relationship significantly affects the chances that retailer will select a pre-order contract. Table 3.4's logistic regression indicates a one-year rise in the nursery-retailer trading relationship boosts by 1.08 the relative probability that the buyer will want to pre-order. However, the relationship length's impact on the pre-order interval itself is significant only among big-box stores; and even there, the magnitude is small. As shown in table 3.5, a 1% rise among big-box stores in the length of the nursery-retailer trading relationship reduces a big-box store's pre-order interval preference by only 0.01%. Once a buyer chooses to pre-order, buyer-seller familiarity seems to have little material impact on the length of pre-order interval itself.

A higher nursery PPI, a proxy for input price, enhances the relative probability the retailer will select a pre-order contract. As shown in table 3.4, for every 1% increase in nursery PPI, the relative probability that plants have been pre-ordered rises by 11.50%. However, rises in nursery PPI reduce the retailer's motivation to contract for a longer pre-order interval. It has a negative impact on the pre-order interval in the corresponding Tobit model, and does not impact independent retailers' pre-order decisions significantly. Table 3.5 shows, for every 1% increase in nursery PPI, big-box stores demand 1.20% lower pre-order interval. The fact that nursery PPI has a negative impact on pre-order *interval* once the pre-order decision has been made is best explained by supposing that PPI's effect on pre-order interval is dominated by its effect $\frac{\partial C_A}{\partial PPI}$ on pre-order cost in equation (7).

Housing starts, an indicator of market demand, has significant impact on relative pre-order probability in table 3.4. For every 1% increase in housing starts, the relative probability that plants have been pre-ordered instead of spot-purchased decreases by 0.24%. The reason is that rising housing starts not only boost market demand and plant price but also reduce retailers' market risks. Retailers therefore become less likely to choose pre-order contracts as a risk management tool. Housing starts also are significant in the corresponding Tobit model of the pre-order interval magnitude. The elasticities in table 3.5 show that, for every 1% increase in housing starts, big-box stores demand 0.06% longer pre-order interval. The greater the consumer demand (thus the greater the price consumers are willing to pay for plants), the greater is the seller's opportunity loss if it does not have the plants available for sale when the consumer wants them. Thus, the greater is the incentive for the retailer to pre-order and have it available on demand. Independent retailers' behavior is different in this regard from big-box stores. Among independent retailers, for every 1% increase in housing starts, independent retailers demand 0.56% lower pre-order interval. Rises in housing starts reduce instead of enhance the motivation to contract ahead of time with the producer-nursery. Perhaps this is because housing-start growth implies, for both retailer types, an imminent rise in plant price. However, retailers' ability to deal with plant price boost differs. Big-box stores have enough cash flow to cover plant price rises. In contrast, uncertain cash flows among independent stores discourage them from pre-ordering plants.

Evidence of the variety of retailers' pre-ordering preferences is seen in the significant positive effect of the retailer-type dummy variable in table 3.4's logistic model. The relative probability that big-box stores will pre-order plants is a rather large 0.62 less than that independent retailers will do so. However, once a pre-order contract is chosen, big-box store demand 148 day more pre-order interval than independent retailers do, holding constant all the other pre-ordering factors I discuss above, and which table 3.3 shows differ substantially between these two retailer types.

Coefficients of the regional dummy variables in table 3.4's logistic regression reveal that the choice to pre-order is most common among Midwestern retailers and least common among Western retailers, holding the above factors constant. The Tobit model of demanded pre-order *magnitudes* is consistent with this finding. Midwestern and

Northeastern retailers order about one month earlier than others do. Because I already have netted transportation cost from plant price, the regional dummies reflect the impacts on contract preferences of market characteristics specific to the buyer's locale. Ninety percent of the sample nursery's plants are sold to Midwestern and Western retailers. Comparatively early pre-ordering in the Midwest probably is at least partly explained by the amount of time required to ship to the Midwest.

Linear Regression for Discount Model

Contract and retailer characteristics affect not only the retailers' choice of pre-order interval, but the producer's decisions on discount rate as well. Results of our price discounting model (equation 20), estimated separately for the pooled data, big-box and independent retailers, are reported in table 3.6. Because of the material differences between big-box and independent retailer behaviors, I report the discount-rate impacts of contract and retailer characteristics separately by these two retailer types. Parameter estimates and *t* statistics are reported. Adjusted R^2 of the pooled-data, big-box, and independent retailer models are respectively 0.11, 0.12, and 0.17. Because of the large proportion of zeros in them, I avoided logging predicted pre-order interval, length of nursery-retailer trading relationship, or previous-year retailer debt-to-credit limit in the table 3.6 model. Most coefficients are statistically significant at the 1% level. As a way of better explaining the table 3.6 coefficients, elasticities of contract and retailer characteristics are reported in table 3.7.

The first factor shown in table 3.6 to affect the producer's price-discount offer is the predicted (thus censored) pre-order interval *t* from the Tobit model in equation (15), table 3.4. Table 3.7 shows that, in the pooled data, if the pre-order interval increases by 1%, the discount rate rises on average by 0.35%. Discount rates vary by retailer type. If a big-box store's pre-order interval rises by 1%, the producer offers a 0.62% greater discount rate. This is consistent with the significant positive coefficient of nursery type dummy D_{bb} in table 3.6 which, as table 3.7 shows, indicates big-box stores are provided with discounts 19% larger than independent retailers are, holding other factors constant. Likely, chain stores have more price negotiating ability than independents do. Interestingly, a 1% rise in an independent retailer's pre-order interval *reduces* its offered discount by 0.05%. I surmise that when independents place orders in advance, the orders typically involve a large variety of plants, which boosts handling costs and thus reduces the discount rate. This is consistent with the hypothesis I derived from equation (13) in the Producer Problem section. Transactions with independent retailers involving a larger unit cost will be offered at lower discount rate.

The relationship in table 3.6 between transaction scale and price discount is, on account of the statistical significance of the squared scale term, non-linear. The logic in examining the linear and squared terms is the same in the discount model as in the pre-order-interval model. Among big-box stores, the positive linear term and negative squared term indicate that the impact of transaction scale on discount rate follows an inverse "U" curve. That is, as the scale of an order first begins to rise, the discount rate also rises; but as scale rises further, discount rate falls. Under increasing returns to scale (scale economy), cost per transaction falls as scale rises, so that the optimal discount rate rises also. Under decreasing returns to scale (scale diseconomy), cost per transaction instead rises as scale does, so that the optimal discount rate falls. Thus, the turning point in the impact of transaction scale on discount rate is the threshold between scale economy and diseconomy. Among big-box stores, the turning point (9.60) is larger than the sample mean (7.76), implying scale economy is largely present in contracts with big-box stores. Among independent retailers, the turning point (0.50) is less than the sample mean (8.49), implying scale economy is also present – overall – in contracts with independent retailers. The OLS regression in table 3.7 indicates that, for every 1% rise in transaction scale, the discount rate big-box stores are offered rises by 0.04%, and the discount rate independent retailers are offered rises by 0.19%.

Transaction scope's impact on discount rate is different from transaction scale's impact. Table 3.7 shows that, for every 1% rise in transaction scope, the producer offers a 0.11% lower discount rate to big-box stores, and a 0.15% lower one to independent retailers. Among big-box stores, the negative linear term and positive squared term indicates the impact of transaction scope on discount rate follows a "U" curve. If economies are achieved as transaction scope rises, increases in the transaction scope reduce cost per transaction and thus enhance discount rate. If scope economy is negative, the transaction scope growth instead decreases the discount rate. The turning point is the threshold between scope diseconomy and scope economy. Among big-box stores, the turning point (3.28) is larger than the sample mean (2.63), implying scope diseconomy largely dominate in contracts with big-box stores. Among independent retailers, the fact that the coefficient of the linear term is negative and of the squared term is insignificant indicates that discount rates fall as transaction scope rises. Scope diseconomy is therefore overall present in contracts with independent retailers.

Besides contract characteristics, retailer characteristics and histories play an important role in the producer's decisions about discount rates. The length of the nursery-retailer trading relationship has a significantly positive effect on the price discount both to chain stores and independents (table 3.6). As shown in table 3.7, if the length of trading relationship rises by 1%, the discount rate accorded to big-box stores and independent retailers increases by 0.11% and 0.13%. This is consistent with the hypothesis I developed in the Model Specification section. The reason is that the length of nursery-retailer trading relationship reduces contract costs and therefore increases the discount rate.

Nursery PPI's impact on price discount is negative. Table 3.7 shows that if the nursery PPI rises by 1%, the producer accords a 0.48% lower discount rate to big-box stores, and a 0.31% lower one to independent retailers. This is because as nursery PPI rises, raw material prices rises also, pushing production cost upward. Thus, optimal discount rates fall.

Housing starts, the indicator of market demand, has a significantly negative relationship with discount rate in table 3.6. As shown in table 3.7, for a 1% improvement in quarterly housing starts, the producer accords a 0.28% lower discount rate to big-box stores, and a 0.13% lower one to independent retailers. As housing starts are lifted, the demand for nursery products improves, and pushes plant prices upward. Thus, the discount rates fall.

Regression coefficients of the retailer debt-to-credit limit show the impact of the retailer's financial situation on the discount rate accorded to that retailer. All of those coefficients in table 3.6 are significant, although their signs differ. In table 3.7, if the debt-to-credit-limit rises by 1%, the discount rate to big-box stores falls by 0.23%. That presumably is because the higher the retailer's unpaid balance, the greater is the probability the producer presumably assigns to the retailer's default. And the producer would be expected to offer lower discounts to retailers with higher default probabilities. Surprisingly, however, a1% rise in an independent retailer's debt-to-credit-limit boosts rather than reduces the discount rate afforded to it by a moderate 0.01%. In contrast, big-box stores with larger unpaid balances attract *lower* discount rates. This counter-intuitive result implies the producer is risk neutral when facing independent retailers and a risk avoider when facing big-box stores. The counter-intuition might be explained as follows. Because big-box stores usually hold larger credit limits and debt than independent retailers do (table 3.3), severe financial problems arise if big-box stores fail to pay back on schedule. Independent retailers' debts tend to be much smaller than big-box stores'. A reasonable discount may help the retailer's cash flow and motivate independent retailers to maintain a business relationship with the sample nursery.

Multinomial Logit Model of Payment Grace Period

I use a multinomial logistic model in equation (21) to examine the producer's decisions among alternative payment grace periods, such as zero days (cash), within 30 days, within 60 days, …, and within one year. To avoid small grace-period segments, I group them into the following four: within 15 days, within 30 days, within 60 days, and within one year. Estimation results are reported in table 3.8 by retailer type. Because the maximum grace period accorded to big-box stores is 60 days, a within-one-year grace period is not included in the multinomial logit model for big-box stores. The within-15-day grace period is the base group in the table 3.8 results. Most coefficients in table 3.8

are statistically significant at the 1% level and have the expected signs. For explanation convenience, the coefficients in table 3.8 are converted to elasticities and reported in table 3.9.

The first factor in tables 3.8 and 3.9 is the predicted (thus censored) pre-order interval *t* from the Tobit model in equation (15). The multinomial logistic model in table 3.8 shows, for both types of retailers, that the coefficient of predicted pre-order interval is positive. Table 3.9 shows that a 1% rises in a *big-box store's* choice of pre-order interval boosts by 20.79% the probability (relative to a within-15-day) that the producer will offer this store a within-30-day grace period, and by 1.40% a within-60-day grace. A 1% rise in an *independent retailer's* choice of pre-order interval boosts by 2.22% the probability (relative to a within-15-day) that the producer will offer this store a within-30-day grace period, by 3.70% a within-60-day grace, and by 4.41% a within-one-year grace. The producer is more likely to provide a longer grace period to independent retailers who contract longer pre-order intervals.

Transaction scale significantly affects the producer's decision on the payment grace period to allow the retailer. Greater transaction scale is, among big-box stores, associated with a longer grace period but, among independent retailers, with a shorter one. This is because, as transaction scale rises, the cost of transacting with big-box stores falls on account of returns to scale, while the cost of transacting with independent retailers rises because returns to scale are absent. Table 3.9 shows that a 1% rise in a *big-box store's* transaction scale increases by 0.25% the probability (relative to a within-15-day) that the producer will offer this store a within-30-day grace period, and by 1.12% a within-60-day grace. A 1% rise in an *independent retailer's* transaction scale reduces by 0.41% the probability that the producer will offer this store a within-30-day grace period, by 0.04% a within-60-day, and by 0.10% a within-one-year grace.

Transaction scope's impact on the grace period probability is different from scale's impact. As the species scope of a given transaction rises, both retailer types are more likely to be accorded a within-30-day grace period. Table 3.9 shows that a 1% rise in a *big-box store's* transaction scope boosts by 2.59% the probability (relative to a within-15-day) that the producer will offer it a within-30-day grace period, and reduces by 0.02% a within-60-day grace. A 1% rise in an *independent retailer's* transaction scope boosts by 0.15% the probability that the producer will offer it a within-30-day grace period, and reduces by 0.41% a within-60-day grace and by 0.56% a within-one-year grace.

Length of the nursery-retailer trading relationship has positive impact on grace period length. For both types of retailers, longer relationship with producer helps to be provided longer grace period. Table 3.9 shows that a 1% rise in a *big-box store's* length of the nursery-retailer trading relationship boosts by 1.59% the probability that the producer will offer it a within-30-day grace period, and by 9.80% a within-60-day grace. A 1% rise in an *independent retailer's* length of the nursery-retailer trading relationship boosts by 0.07% the probability the producer will offer it a within-30-day grace period, but reduces by 1.05% a within-60-day grace, and by 1.54% a within-one-year grace.

The impact of nursery PPI on grace period probability differs by retailer type. Table 3.9 shows that a 1% rise in nursery Price Produce Index reduces by 99.17% the probability the producer will offer a *big-box store* a within-30-day grace period, and by 29.18% a within-60-day grace. A 1% rise in nursery Price Produce Index boosts by 3.96% the probability an *independent retailer* will be offered a within-30-day grace period, by 7.16% a within-60-day grace, and by 9.14% a within-one-year grace.

The impact of housing starts on grace period probability is similar to nursery PPI's impact. Table 3.9 shows that a 1% rise in housing starts reduces by 11.39% the probability a *big-box store* will be offered a within-30-day grace period, and by 14.23% a within-60-day grace. Because annual contracts – common in sales to big-box stores – that leave shipment date and quantity open lead to higher transaction costs than do single-order contracts with a pre-determined shipment date and amount, the producer must reduce the grace period to offset transaction costs of being unable to forecast shipment date and quantity. A 1% rise in housing starts boosts by 0.26% the probability an *independent retailer* will be offered a within-30-day grace period, by 0.58% a within-60-day grace, and by 1.06% a within-one-year grace. Because the probability an independent retailer will default during a market expansion is low, the producer is likely to offer a longer grace period in an economic expansion than in an economic recession to attract independent retailers.

The retailer's debt-to-credit limit, a proxy of retailer financial situation, has significant effect on grace period probability. The higher the percentage of the retailer's balance remaining unpaid, the worse is the retailer's assumed financial situation, the greater the producer's cost in collecting payment, and the shorter the grace period the producer will offer. Table 3.9 shows that a 1% rise in a *big-box store's* debt-to-credit limit reduces by 23.07% the probability it will be offered a within-30-day grace period, and by 12.27% a within-60-day grace. A 1% rise in an *independent retailer's* debt-to-credit limit reduces by 0.13% the probability it will be offered a within-30-day grace period and by 0.11% a within-60-day grace, and boosts by 0.04% a within-one-year grace.

The impact of payment type on grace period choice differs by retailer type. Table 3.9 shows that, among big-box stores, the maximum possible grace period afforded in a pay-by-order contract is within 30 days. Among independent retailers, the maximum is within 15 days. Because the time required to complete a pay-by-order contract generally is shorter than required to complete a pay-by-scan contract, a retailer with a pay-by-order contract is provided a shorter grace than one with a pay-by-scan contract.

Conclusions

I have established a two-step model to investigate the relationship between contract type and retailer characteristics in the Oregon nursery industry. On the basis of order frequency and payment type, nursery contracts are divided into four groups: single-order contracts using pay-by-order, single-order contracts using pay-by-scan, annual contracts using pay-by-order, and annual contracts using pay-by-scan. Effects of transaction and retailer characteristics on pre-order interval, price discount, and grace period differ by contract type. The analysis suggests big-box stores with annual contracts are less likely than are independent retailers with single-order contracts to make pre-order contracts with the producer. However, once a pre-order contract is chosen, big-box store demand a longer pre-order interval than independent retailers do. Regarding payment type, pay-by-order contracts are more likely to provide a higher discount rate than are pay-by-scan contracts.

As predicted in the conceptual model, transactions with independent retailers exhibit – on average over the sample range – scale economies and scope diseconomies. Yet the degree of scale or scope economy in transactions with big-box stores depends on pre-order interval and discount rate. Boosting per- transaction revenue scale and number of species sold to big-box retailers enhances transaction efficiency. Furthermore, greater trust between producers and retailers, reflected in the length of the nursery-retailer trading relationship, reduces pre-order cost and boosts discount rates in pre-order contracts.

The way in which the producer-nursery reacts to a retailer's financial condition, proxied by the retailer's debt to the producer expressed as a proportion of the retailer's credit limit, suggests the producer's risk attitude varies by retailer type. An increase in a debt-to-credit limit implies the retailer's financial condition has worsened. Because big-box stores usually hold larger credit limits and unpaid balances than do independent retailers, a big-box store's failure to pay the balance would lead the producer to especially severe financial problems. When a big-box retailer's financial condition deteriorates, the producer reacts as a risk avoider by providing a lower discount rate. When, on the other hand, an independent retailer's financial condition deteriorates, the producer exhibits risk-neutral behavior by raising the discount rate only moderately. Because independent retailers' unpaid balances are much smaller than are big-box stores', a moderate discount may help an independent continue its business with the producer and thus eventually pay its unpaid balance.

Endnotes

[1] The name of the nursery is omitted for proprietary purposes.

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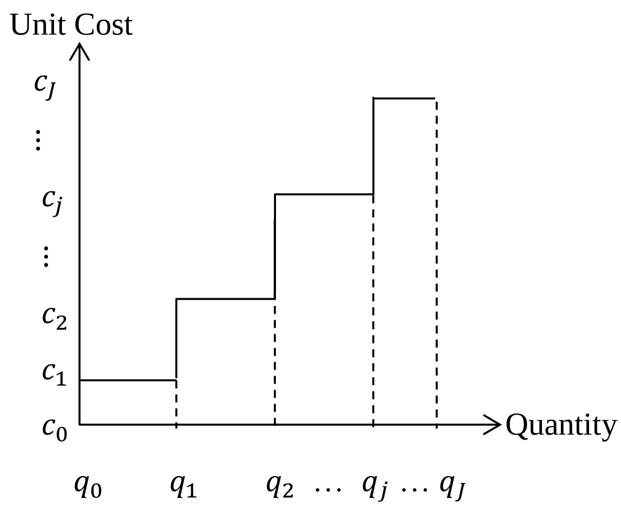

Figure 3.1. Wholesale Nursery Cost Function (1)

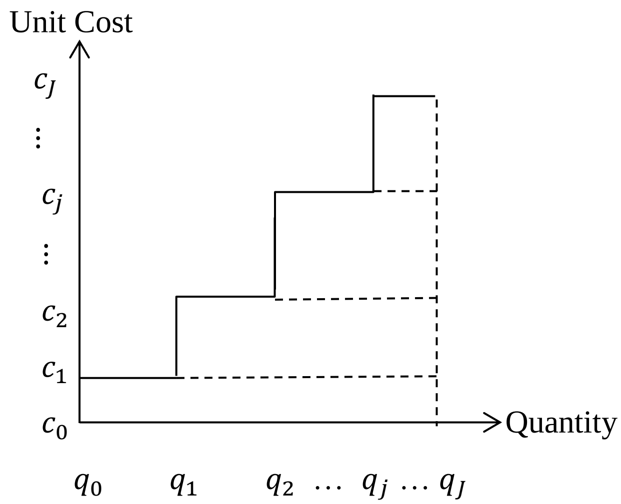

Figure 3.2. Wholesale Nursery Cost Function (2)

Table 3.1. Contract Types in Nursery Industry

	Pay-by-order (D_{paid} =1)	Pay-by-scan (D_{paid} =0)
Single-order (D_{bb}=0)	Contract I e.g. Independent retailers	Contract II e.g. Independent retailers selling to big-box stores
Annual Contract (D_{bb} =1)	Contract III e.g. Lowe's	Contract IV e.g. Home Depot

Table 3.2. Definitions of Variables

Variable	Definition	Unit	Mark
Pre-order Interval	Number of days between order date and delivery date	days	*t*
Weighted Discount Rate	Difference between benchmark and pre-order price, expressed as weighted ratio of benchmark price	%	*D*
Transaction Scale	Sales revenue per order	dollars	*Scale*
Transaction Scope	Number of plant species in given order		*Scope*
Length of Nursery-Retailer Trading Relationship	Number of years over which nursery and retailer have conducted business	years	*Experience*
Nursery PPI	Producer price index in nursery, garden, and farm supply stores	--	*PPI*
Housing Starts	Number of privately owned new houses on which construction began in a given quarter	units	*Housing*
Retailer Lagged Debt	Retailer's unpaid payment in previous year	dollars	*Owe*
Credit Limit	Maximum credit seller will extend to retailer for given credit line	dollars	*Credit*
Payment Grace Period	Number of days allowed before retailer must pay without penalty 1. within 15 days; 2. within 30 days; 3. within 60 days; 4. within one year.	days	m $m = 0$ $m = 1$ $m = 2$ $m = 3$
Nursery Type	Independent retailer Big-box store		$D_{bb}=0$ $D_{bb}=1$
Payment Type	Types of payment in nursery contract 1. Pay-by-scan: nursery producer payable only for the plants customers purchases; 2. Pay-by-order: nursery producer payable when retailer receives shipment.		D_{paid} $D_{paid}=0$ $D_{paid}=1$

Region	Retail nurseries are divided into the following five regions:	D_{region}
	1. West: AZ, CA, CO, ID, MT, NM, NV, OR, UT, WA, and WY	*West*
	2. Midwest: IA, IL, II, IN, KS, MI, MN, MO, ND, NE, OH, SD, and WI	*Midwest*
	3. Northeast: CT, MA, ME, NH, NJ, NY, PA, RI, and VT	*Northeast*
	4. South: AL, AR, DC, DE, FL, GA, KY, MD, MS, NC, OK, SC, TN, VA, and WV	*South*
	5. Others: AK and Canada	*Others*

Table 3.3. Descriptive Statistics

Variable	Group	N	Min	Max	Mean	Std Dev	CV
Pre-order Interval	all	46000	0	494	110.48	92.53	0.84
	big-box	32683	2	494	151.97	76.47	0.50
	independent	13317	0	348	8.67	25.14	2.90
Weighted Discount Rate	all	45997	0	99.82	25.39	13.59	0.54
	big-box	32682	0	95.79	24.78	13.41	0.54
	independent	13315	0	99.82	26.89	13.9	0.52
Transaction Scale	all	46000	0.5	143637	3080	4449	1.44
	big-box	32683	1.44	31114	2343	2343	1.00
	independent	13317	0.5	143637	4889	6721	1.37
Annual Scale	all	45999	16.2	10504364	3984148	3708225	0.93
	big-box	32683	23069	10504364	5554034	3289823	0.59
	independent	13316	16.2	1064410	130993	203517	1.55
Transaction Scope	all	45999	1	224	13.25	13.54	1.02
	big-box	32683	1	92	13.84	12.17	0.88
	independent	13316	1	224	11.81	16.34	1.38
Length of Nursery-Retailer Trading Relationship	all	46000	1	30	8.05	6.75	0.84
	big-box	32683	1	12	6.35	4.71	0.74
	independent	13317	1	30	12.24	8.86	0.72
Nursery PPI	all	46000	114.33	131.22	120.19	5.69	0.05
	big-box	32683	114.33	131.22	119.17	5.41	0.05
	independent	13317	114.33	131.22	122.7	5.59	0.05
Housing Starts	all	46000	525.7	2120.3	924.42	488.17	0.53
	big-box	32683	525.7	2120.3	835.9	431.02	0.52
	independent	13317	525.7	2120.3	1141.67	548.47	0.48
Retailer Lagged Debt	all	46000	-12046	2267590	473035	733283	1.55
	big-box	32683	0	2267590	659722	797017	1.21
	independent	13317	-12046	621228	14861	53717	3.61
Retailer Debt-to-Credit Limit in Previous Year	all	45337	-0.76	5.66	0.14	0.18	1.29
	big-box	32683	0	0.23	0.15	0.09	0.60
	independent	12654	-0.76	5.66	0.14	0.31	2.21

Notes: some variables are not reported for proprietary purposes.

Table 3.4. Factors Affecting Pre-order Interval, by Retailer Type

	Logistic Model	Tobit Model		
	Pooled data	Pooled data	Big-box stores	Independent retailers
Variables	$\ln(\frac{P}{1-P})$	t	t	t
Transaction Scale	1.269***	-5.770***	-0.771	12.616***
	(58.44)	(-7.13)	(-0.70)	(10.58)
Transaction Scale^2		0.546***	0.259**	-0.799***
		(-8.27)	(2.54)	(-9.90)
Transaction Scope	0.793***	3.497***	0.337	-0.664
	(23.82)	(-3.96)	(0.27)	(-1.12)
Transaction Scope^2		-0.749***	-0.731**	0.502***
		(-3.48)	(-2.36)	(3.31)
Length of Nursery-Retailer Trading Relationship	0.074***	-0.152***	-0.274**	0.003
	(16.93)	(-3.13)	(-2.50)	(-0.13)
Nursery PPI	11.500***	-129.475***	-182.333***	-8.359
	(15.12)	(-18.04)	(-21.69)	(-1.44)
Housing Starts	-0.272***	4.700***	8.817***	-4.817***
	(-3.54)	(6.87)	(10.14)	(-9.37)
Nursery Type (Big-box store = 1)	-0.975***	148.274***		
	(-14.16)	(205.54)		
West	-0.173	-2.693	-3.129	-2.727***
	(-1.00)	(-1.55)	(-0.84)	(-2.88)
Midwest	3.503***	36.601***	44.546***	8.911***
	(12.19)	(18.7)	(11.67)	(6.89)
Northeast [d]	1.396***	32.806***		13.339***
	(3.65)	(14.02)		(11.21)
South	0.879***	3.589***	-8.548***	5.878***
	(3.57)	(1.73)	(-2.02)	(5.11)
Spring	-0.697***	-96.570***	-219.242***	0.687
	(-6.61)	(-77.95)	(-116.43)	(0.87)
Summer	-0.429***	-59.987***	-162.051***	0.699
	(-4.42)	(-51.09)	(-89.91)	(0.94)
Autumn	-0.0275	-5.298***	-76.041***	-0.336
	(-0.27)	(-4.35)	(-41.51)	(0.41)
Constant	-60.68***	651.941**	1113.105***	30.722
	(-17.45)	(19.83)	(28.54)	(1.14)
Pseudo R^2	0.76	0.10	0.07	0.01
Log likelihood	-6745	-243163	-174362	-57541
N	45999	45999	32683	13316

a. Logistic regression is from equation (18). Dependent variable is the relative probability $\ln(\frac{P}{1-P})$ that plants have been pre-ordered instead of spot-purchased.
b. Tobit model is from equation (15). Dependent variable is pre-order interval *t*.

c. Italic denotes the logged term;
d. Northeast is not included in big-box stores model because there is no big- box store in the Northeast doing business with the sample nursery;
e. z statistics are in parentheses of logistic regression and *t* statistics are in parentheses of Tobit model.

*** Significant at 1% level, ** Significant at 5% level, * Significant at 10% level

Table 3.5. Elasticities of Factors Affecting Pre-order Interval, by Retailer Type

Variables	Pooled data	Big- box stores	Independent retailers
Transaction Scale	0.03	0.02	-0.11
Transaction Scope	0.00	-0.02	0.21
Length of Nursery-Retailer Trading Relationship	-0.01	-0.01	0.00
Nursery PPI	-1.17	-1.20	-0.96
Housing Starts	0.02	0.06	-0.56

Italic denotes logged term.

Table 3.6. Factors Affecting Price Discount, by Retailer Type

Variables	Pooled data *lnδ*	Big-box stores *lnδ*	Independent retailers *lnδ*
Predicted Pre-order Interval	0.003*** (13.80)	0.004*** (11.67)	-0.004** (-2.33)
Transaction Scale	0.060***	0.211***	-0.012
	(6.95)	(17.71)	(-0.41)
Transaction Scale^2	0.004***	-0.011***	0.012***
	(6.18)	(-9.76)	(6.08)
Transaction Scope	-0.314***	-0.531***	-0.169***
	(-33.34)	(-38.66)	(-12.12)
Transaction Scope^2	0.031***	0.081***	0.003
	(13.43)	(24.09)	(0.92)
Length of Nursery-Retailer Trading Relationship	0.006*** (12.08)	0.018*** (12.69)	0.011*** (17.09)
Nursery PPI	-0.138***	-0.478***	-0.310***
	(-1.67)	(-4.23)	(-2.22)
Housing Starts	-0.130***	-0.278***	-0.125***
	(-17.27)	(-22.26)	(-9.67)
Retailer Debt-to-Credit Limit in Previous Year	-0.036** (-2.20)	-1.557*** (-22.26)	0.079*** (4.42)
Payment Type	0.174***	0.143***	-0.016
(Pay-by-order = 1)	(20.90)	(15.87)	(-0.49)
Nursery Type	-0.233***		
(Big-box store = 1)	(-7.95)		
Spring	0.269***	0.725***	0.101***
	(12.54)	(10.1)	(5.45)
Summer	0.114***	0.425***	0.109***
	(7.16)	(7.89)	(6.28)
Autumn	-0.019	0.205***	0.015
	(1.40)	(6.55)	(0.77)
Constant	-0.661*	1.408**	0.419
	(-1.72)	(2.38)	(0.65)
Adjusted R^2	0.11	0.12	0.17
F value	403	356	194
N	45084	32669	12415

a. Estimates are from equation (20). Dependent variable is logged discount rate;
b. Predicted pre-order interval is predicted censored value derived from Tobit model, equation (15);
c. Italic denotes the logged term; d. *t* statistics are in parentheses.
*** Significant at 1% level, ** Significant at 5% level, * Significant at 10% level

Table 3.7. Elasticities of Factors Affecting Price Discount, by Retailer Type

Variables	Pooled data	Big-box stores	Independent retailers
Predicted Pre-order Interval	0.35	0.62	-0.05
Transaction Scale	0.70	0.04	0.19
Transaction Scope	-0.15	-0.11	-0.15
Length of Nursery-Retailer Trading Relationship	0.05	0.11	0.13
Nursery PPI	-0.14	-0.48	-0.31
Housing Starts	-0.13	-0.28	-0.13
Retailer Debt-to-Credit Limit in Previous Year	-0.01	-0.23	0.01
Payment Type (Pay-by-order = 1; Pay-by-scan=0)	19%	15%	-2%
Nursery Type (Big-box store = 1)	-21%		

a. Predicted pre-order interval is predicted censored value derived from Tobit model, equation (14);
b. Italic denotes logged term.

Table 3.8. Factors Affecting the Relative Probability of the Indicated Grace Period, by Retailer Type

	Annual Contacts among Big-Box Store		Single-order Contracts among Independent Retailer		
Variable	$ln\frac{P(m=1)}{P(m=0)}$	$ln\frac{P(m=2)}{P(m=0)}$	$ln\frac{P(m=1)}{P(m=0)}$	$ln\frac{P(m=2)}{P(m=0)}$	$ln\frac{P(m=3)}{P(m=0)}$
Predicted Pre-order Interval	0.134*** (9.92)	0.009 (0.70)	0.171*** (6.40)	0.285*** (10.62)	0.340*** (12.46)
Transaction Scale	0.249**	1.116***	-0.413***	-0.039	-0.102**
	(2.09)	(20.17)	(-10.45)	(-0.95)	(-2.33)
Transaction Scope	2.594***	-0.021	0.146***	-0.405***	-0.557***
	(15.24)	(-0.24)	(2.75)	(-7.47)	(-9.71)
Length of Nursery-Retailer Trading Relationship	0.251** (2.16)	1.543*** (15.73)	0.006 (0.85)	0.086*** (11.79)	0.126*** (16.57)
Nursery PPI	-99.169***	-29.176***	3.960***	7.159***	9.135***
	(-10.92)	(-3.66)	(2.74)	(4.81)	(5.77)
Housing Starts	-11.390***	-14.231***	0.255*	0.582***	1.064***
	(-6.89)	(-8.75)	(1.67)	(3.73)	(6.50)
Retailer Debt-to-Credit Limit in Previous Year	-153.778*** (-18.29)	-81.826*** (-10.29)	-0.908*** (-7.84)	-0.776*** (-6.26)	0.295*** (2.87)
Payment Type	1.204***	-1.305***	-0.234	-0.851**	-1.929***
(Pay-by-order = 1; Pay-by-scan=0)	(3.08)	(-10.39)	(-0.62)	(-2.21)	(-4.95)
Spring	47.401***	13.093***	0.397**	0.263	0.027
	(11.10)	(4.45)	(2.11)	(1.36)	(0.14)
Summer	30.052***	7.805***	0.047	0.088	-0.412**
	(8.20)	(3.48)	(0.29)	(0.53)	(-2.34)
Autumn	10.033***	1.700	-0.141	-0.203	-0.390**
	(3.30)	(1.35)	(-0.83)	(-1.15)	(-2.11)
Constant	511.385***	226.799***	-17.121***	-39.329***	-52.571***
	(11.62)	(5.74)	(-2.57)	(-5.72)	(-7.20)
N	32673		12654		
Pseudo R^2	0.91		0.15		
Log Likelihood	-3045		-11704		
LR chi2(18)	61510		LR chi2(33)	4006	
Significance level	(0)			(0)	

a. Estimates are from multinomial logit model, equation (21).

b. $ln\frac{P(m=1)}{P(m=0)}$: Log-odds that the producer offer a within-30-day grace period relative to a within-15-day grace period;
$ln\frac{P(m=2)}{P(m=0)}$: Log-odds that the producer offer a within-60-day grace period relative to a within-15-day grace period;
$ln\frac{P(m=3)}{P(m=0)}$: Log-odds that the producer offer a within-one-year grace period relative to a within-15-day grace period.
c. Predicted pre-order interval is predicted censored value derived from Tobit model, equation (14);
d. Italic denotes logged term;
e. *z* statistics in parentheses.

*** Significant at 1% level, ** Significant at 5% level, * Significant at 10% level

Table 3.9. Elasticities of Factors Affecting Grace Period, by Retailer Type

Variable	Big-Box Store $\frac{P(m=1)}{P(m=0)}$	Big-Box Store $\frac{P(m=2)}{P(m=0)}$	Independent Retailer $\frac{P(m=1)}{P(m=0)}$	Independent Retailer $\frac{P(m=2)}{P(m=0)}$	Independent Retailer $\frac{P(m=3)}{P(m=0)}$
Predicted Pre-order Interval	20.79	1.40	2.22	3.70	4.41
Transaction Scale	0.25	1.12	-0.41	-0.04	-0.10
Transaction Scope	2.59	-0.02	0.15	-0.41	-0.56
Length of Nursery-Retailer Trading Relationship	1.59	9.80	0.07	1.05	1.54
Nursery PPI	-99.17	-29.18	3.96	7.16	9.14
Housing Starts	-11.39	-14.23	0.26	0.58	1.06
Retailer Debt-to-Credit Limit in Previous Year	-23.07	-12.27	-0.13	-0.11	0.04
Payment Type (Pay-by-order = 1; Pay-by-scan=0)	233%	-73%	-21%	-57%	-85%

a. $\frac{P(m=1)}{P(m=0)}$: Probability that the producer offer a within-30-day grace period relative to a within-15-day grace period;
$\frac{P(m=2)}{P(m=0)}$: Probability that the producer offer a within-60-day grace period relative to a within-15-day grace period;
$\frac{P(m=3)}{P(m=0)}$: Probability that the producer offer a within-one-year grace period relative to a within-15-day grace period.
b. Predicted pre-order interval is predicted censored value derived from Tobit model, equation (14);
c. Italic denotes logged term.

Chapter 4 : Supply and Demand in Oregon Nursery Industry

Cheng Li

Introduction

The nursery and greenhouse production sector is comprised of growers of nursery stock, shrubbery, bulbs, fruit stock, and sod, under cover or in open fields. Because 77 percent of nursery product sales were through wholesale outlets, [1] vertical relationships between wholesale nurseries – which I will call the producers – and retailers are important in the nursery industry. Another critical characteristic distinguishing nursery products from many other agricultural crops is the high degree of product differentiation. A representative nursery wholesaler produces about 500 varieties of broadleaf evergreens, deciduous flowering shrubs, conifers, Japanese Maples, and ornamental plants. Plant forms include Bare root, Ball & Burlap, and Container, ranging in size from 3.5" bio-degradable to 20 gallon pots. Enormous product diversity arises from combinations of variety, plant material, and plant size. Each nursery producer tries to create a different plant by altering the plant variety, size, and plant form, the services it offers, and other variables such as brand name, advertising, and customer relationship. High product differentiation, along with climate requirements, plant knowledge, and customer and plant supplier relationships, build barriers to entry and move the nursery industry toward monopolistic competition. In such market structures, the wholesaler has a degree of control over prices, presumably setting them to maximize profit in light of production and transaction costs.

The Oregon nursery provides an interesting background from which to study the effects of product differentiation on supply and demand elasticities. The "Oregon Mix" is unique for its plant health, variety mix, early market readiness, and special growing climate. Nursery producers compete on price, service level, product quality, and the breadth and uniqueness of products offered. The Oregon nursery industry presently is recovering after reaching the bottom of a down-cycle in 2011. [2] Supply excesses and demand shortages from 2007 to 2011 have led to a number of perplexities for the Oregon nursery industry, such as inventory buildup, tight cash flow, limited new plantings, and quality concerns. When disaggregated to the product level, the problem can best be analyzed in terms of a range of attribute-specific disequilibria. Price strategy in particular is critical for most profitably meeting market demand.

The present study is the first to systematically examine the interaction between supply and demand in Oregon nursery products. Data were collected from a variety of sources, including the Oregon Association of Nurseries, the invoices of a representative nursery company, and the Oregon Employment Department. Based on a theoretical model, a simultaneous equation system is here estimated to evaluate supply and demand elasticities by variety, size, and presence of intellectual property. Results are employed to make recommendations for improved price strategy and profitability.

Literature Review

Perfect competition and pure monopoly are two commonly used assumptions for studying the market structure. Recently, agricultural economists have begun to focus on the middle ground between these two polar extremes. The homogeneous-commodity assumption is one of the constraints removed in the process. Because a given product is defined by such as quality, size, vintage, services provided, and brand, no single product is completely homogeneous with another. Degree of product differentiation is subjective. Chamberlin (1933) argues it is useful to group similar products and refer to them as a product group. But constructing a category according to how close one pair of goods can substitute for another is arbitrary, especially in an industry without broadly accepted product standards.

Economists have introduced a variety of theories to study the characteristics of differentiated products of a supply-and-demand framework. Berry (1994) conducts a supply-and-demand analysis of a cross section of oligopoloid markets with differentiated products. His primary method was to assume that demand can be described by a discrete-choice model and that prices are endogenously determined by price-setting firms. On the demand side, he employed a discrete-choice model such as the logit or probit to study product characteristics, price, and consumer preferences. On the supply side, firms are assumed to be price setters by maximizing profits. Demand and supply elasticities are determined jointly by way of the demand and supply function.

Deng and Ma (2010) apply Berry's (1994) discrete-choice method to China's automobile market. They conducted a market analysis of the Chinese automobile industry using market-level data. Vehicles were grouped by size in order to deal with product differentiation. On the demand side, they used a nested multinomial logit model to ascertain demand features, including market share by vehicle type and such automobile characteristics as size, horsepower, speed, and model. On the supply side, they assumed Bertrand behavior to reveal the markups set by automobile manufacturers. By jointly estimating a demand and supply function, they found that price elasticities are lower for the luxury segment, and that greater competition within a group leads to more elastic demand.

Davis, Ahmadi-Esfahani, and Iranzo (2008) employ Berry's (1994) theory to the U.S. wine market. Wine is a highly differentiated product on account of the mix of brand, quality, size, vintage, grape type, producer location, and reputation. They grouped wines by brand, quality, and producer to investigate wine characteristics. The Australian wine industry was found to be in oversupply at the aggregate level; but at a disaggregated, attribute-specific level, the nature of the disequilibrium was different. A discrete choice model of product differentiation is used to estimate, at wine brand level, the demand for Australian wine in Australia's second largest export market, the United States. Price is determined endogenously by a quality nesting model at the first stage. They find that price elasticities provide insight into how pricing policies may be used to effectively boost sales and reduce excess supply. In particular, sales of brands with relatively elastic demands may be lifted discounting their prices. However, high inelasticity indicates the price discount may be ineffective and that US consumers dislike the brand.

Other empirical analyses of differentiated agricultural products have employed hedonic models. Its focus on product attributes is suitable for products with some degree of differentiation, and log-linear estimation and semi-parametric methods are used to achieve results more accurate than in linear regression. Price can be expressed as a function of product characteristics. For example, automobile price may depend on brand name, car model, engine capacity, fuel consumption, and horsepower (Baltas and Saridakis, 2010). Wine price may be affected by age, production region, grape variety, vineyard, and vintage (Costanigro, McCluskey, and Mittelhammer, 2007). A wine market may be segmented by price level including commercial, semi-premium, premium, and ultra-premium. From the production perspective, Buccola and Iizuka (1997) use a hedonic econometric framework to study the U.S. dairy industry. A hedonic cost model was estimated in which the output aggregator is a function of total output and the percentage concentrations of its components, including protein, butterfat, and fluid carrier. This method is helpful for studying the contribution of each product characteristic and captures the equilibrium points of demand and supply.

The study of demand or supply elasticity at the product level reveals consumer preferences, which are hidden at the aggregate level. Bresnahan and Reiss (1985) and Tyagi (1999) show that in equilibrium, the market power of an automobile manufacturer and dealer is proportionate to the slopes of the demand curves they face. Buccola and VanderZanden (1997) study own and cross-price demand elasticities in Oregon red and white wines using scanner data. Red wine demands are much less sensitive to price changes than are white wine demands, suggesting Oregon red wine consumers have more discriminating tastes than do white wine consumers. This conclusion has implications for state wine tax rates, price strategy, and consumer utility. Kotakou (2011) studies supply and input demand elasticities, including for fertilizer, energy, and other intermediate inputs, in the Greek cotton industry. A particular interest was the relationship between farm size and cotton supply elasticity. She applied pooled, random-effects, and fixed-effects estimation and found estimation method affected parameter estimates and significance. The best specification appeared, with unbalanced panel data, to be fixed-effects estimation. Cotton supply elasticity generally varies by farm size.

Due to data limitations, empirical study of demand and supply elasticities in the nursery industry is rare. Thanks to the National Nursery Survey, provided at five-year intervals since 1988, an increasing amount of data on nursery production and marketing practices is being collected for empirical analysis. Gineo and Omamo (1990) find that household expenditure on nursery products depends on household income, the number of single-family home construction starts, and the education and age composition of the population. Campbell and Hall (2010) show that a nursery's marketing strategies (for example trade shows, appeals to repeat customers, discounting and other negotiated terms, export volumes, and advertising) play a large role in plant sales. But demand characteristics (population level and growth, household income, and urbanicity) and business characteristics (business age, location, and use of permanent *versus* temporary employees) play a limited role. Velástegui Andrade and Hinson (2009) indicate the factors affecting a grower's market channel choice include location, market strategy diversification, and trade show attendance. These studies provided theoretical support for considering such product, market, and business characteristics in the present study of the Oregon nursery industry.

Oregon Nursery Industry

The nursery or horticulture industry is comprised of a variety of businesses involved in the production, distribution, and services associated with ornamental plants, landscape, and garden supplies and equipment (Hodges, Hall, and Palma, 2011). Industry products include nursery crops and floricultural plants (*Industry Perspective: Nursery/Greenhouse*, 2012). Nursery crops refer to plants grown for environmental as well as ornamental purposes, and generally live many years. Examples are outdoor landscaping plants – including trees, shrubs, and ground covers – and unfinished plant materials, bulbs, and sod. Floriculture plants are grown primary for ornamental and decorative purposes and typically live only one season. The floricultural sector consists primarily of cut flowers, cut cultivated greens, potted flowering plants, potted foliage plants, and bedding and garden plants. The *National Nursery Survey* (2008) shows that the top plant types by sales are deciduous shade and flowering trees, followed by flowering annual bedding plants, flowering potted plants, evergreen trees, and broadleaved evergreen shrubs. These top-five plant types comprise 42 sales percent of total sales.

The Oregon nursery industry began before Oregon was a state (O'Connor, 2008). Because of the unique mix of rich oil, moderate weather, and plentiful rainfall, Oregon is one of the top three nursery stock producing states in the U.S. The majority of nursery sales from the Pacific Northwest come from Oregon. [3] The Oregon nursery industry is concentrated in the northern Willamette Valley. The top five producing counties – Marion, Clackamas, Washington, Yamhill, and Multnomah/Lane – account for 86 percent of the industry's total production. [4] As shown in figure 4.1, these counties are mainly located in the northwest of Oregon.

The *Oregon Nursery and Greenhouse Survey* (2006-2010) shows total sales grew rapidly, from the $315 million in 1990 to the peak $988 million in 2007, with an average annual growth rate of 7% (figure 4.2). Since 2008, sales have fallen on account of economic recession. Between 2007 and 2010, sales dropped to $676 million and the number of nursery operations declined by 14%. In 2010 the Oregon nursery industry consisted of 1800 operations, one-half of them with less than $20,000 in sales. These small nurseries generated only 0.6 percent of industry sales. In contrast, 70 nursery growers, each with sales of more than $2 million, comprised 69% of industry sales. The suggestion is that the Oregon nursery industry might approximate monopolistic competition. The recession appears to have had a most depressing effect on firms with more than $2 million in sales. By 2010 the number of firms with greater than $2 million in sales had fallen by 30%, after four straight years of declining sales. [5] In the Oregon Nursery and Greenhouse Survey 2010, nursery economists predicted that 2011 could be the bottom of the down-cycle and 2012 the year of recovery.

The nursery industry can be segmented into four groups by production method: bare root, container, ball & burlap, and greenhouse. The container method is the largest segment, with 41% of total sales in 2010. Sales in the other three categories are near one another, frequently exchanging rank. With the general sales declines, sales per segment fell by 17%, 14%, 8%, and 2% respectively in bare root, container, ball & burlap, and greenhouse between 2009 and 2010.

The two principal market levels in the nursery industry are wholesale and retail. In Oregon, 98.9 percent of sales were at wholesale and only 1.1 percent at retail. [6] Wholesale market outlets include mass merchandisers, home centers, single location garden centers, multiple location garden centers, landscape, and re-wholesalers. In Oregon, the most popular outlet as a share of total wholesale sales was the single-location garden center, with 46.1 percent of sales in 2008, followed by re-wholesalers (23.6%), multiple-location garden centers (12.5%), landscapers (10.3%), home centers (7.3%), and mass merchandisers (0.2%).

Marketing practices of nursery growers include sales to repeat customers, negotiated sales, brokerage sales, contract sales, and export sales. More than 90 percent of Oregon nursery sales were to repeat customers, which indicates the importance of customer relationship. Forward contracting is another important marketing practice as a risk management tool. With regard to sale destination, out-of-state buyers dominate Oregon nursery sales. *Oregon Nursery and Greenhouse Survey* (2010) found that 74 percent of Oregon's nursery total sales are outside of Oregon. Besides Oregon, the top four areas are upper Midwest, [7] northeast states, [8] Atlantic states, [9] and Washington.

As a labor intensive industry, one of the largest production costs in nursery industry is wage. In Oregon's nursery, greenhouse, and floricultural production, the share of labor expenses of all production expenses was 49.2% in 2007 (Britsch, 2010). Employment shows a seasonal pattern, the lowest in winter and highest in autumn. The 2010 survey found the Oregon nursery industry employed 9,500 full time workers and 11,100 seasonal workers. Average annual worker income was $14,016. A large portion of nursery workers in Oregon are immigrants from Mexico.

The nursery surveys further analyzed the drivers impacting nursery supply and demand. They include GDP growth rate, unemployment, input costs (including diesel and gasoline price), consumer confidence, personal saving rate, local government demand, market outlets, home building, and home improvement. All these factors will be guide the present supply and demand framework.

Theoretical Framework

My framework draws heavily from Bresnahan and Reiss (1985) and Tyagi (1999), who focus on the vertical relationship between wholesalers and retailers and on product differentiation. In my application of their methods, I examine a nursery that produces differentiated products and sells to retail nurseries, landscapers, garden centers, and big-box stores. Plant prices are distinguished by product characteristic, for example by plant genus, plant size, popularity, and patent status.

I model a representative wholesaler operating in a monopolistically competitive environment, in which the wholesaler can set price to maximize profit in a particular product niche. Although this is a strong assumption, wholesalers in the nursery market usually grow differentiated plants to avoid competition from other wholesalers. Because most nursery growers in Oregon produce more than one plant, I consider multi-product firms in the framework. A one-unit rise in plant price may lead to an impact on plant supply and demand that depends on plant genus, size, popularity, and patent status. The assumption of a single product would assume the impacts are the same for all plants. I also assume a special temporal structure, in particular that the wholesaler and retailers act sequentially. The wholesaler set its wholesale prices first, then retailers set retailer prices given the wholesale prices. This leader-follower market relationship can be solved by backward induction, namely by considering the retailer's problem first.

Downstream Market

I begin by assuming consumer demand function $Q(P)$, where P is retailer price set by the retail nursery. For retailers, the demand function is written in its inverse form:

(1) $$P = P(Q) = (P(Q_1), P(Q_2), \dots, P\big(Q_J\big)),$$

where $Q = \big(Q_1, Q_2, \dots, Q_J\big)\ and\ P'(Q) < 0.$

The retailer is assumed to have marginal selling cost v_j for each product j. In the model, the retailer follows wholesale price W_j because it is an important input cost in the retail profit function. The retailer's decision problem is then given by:

(2) $$\max_Q \pi^r = \sum_j Q_j (P_j(Q) - W_j - v_j)$$

The retailer's profit function is nondecreasing in *P*, nonincreasing in *W*, homogenous of degree one in *P* and *w*, and convex in *P* and *W*. The first order condition is:

(3) $$\frac{\partial \pi^r}{\partial Q_i} = P_i(Q) - W_i - v_i + \sum_j Q_j \frac{\partial P_j(Q)}{\partial Q_i} = 0$$

$$\text{i.e. } P_i(Q) + \sum_j Q_j \frac{\partial P_j(Q)}{\partial Q_i} = W_i + v_i$$

Equation (3) provides a solution to the retailer's problem. At downstream market equilibrium, the retailer's marginal revenue ($P_i(Q) + \sum_j Q_j \frac{\partial P_j(Q)}{\partial Q_i}$) is equal to its marginal cost ($W_i + v_i$). Equation (3) also contains the retailer's demand function for the wholesaler product, namely

(4) $$W_i = P_i(Q) + \sum_j Q_j \frac{\partial P_j(Q)}{\partial Q_i} - v_i$$

Equation (4) implies the retailer's plant demand price W_i depends on plant quantity *Q*, on retail price P_i – which in turn depends on consumer market demand and confidence, on marginal selling cost v_i – including labor, gasoline, and other input prices, and on consumer demand elasticity $\frac{\partial P_j(Q)}{\partial Q_i}$ by plant type. According to Hotelling's lemma, optimal plant demand quantity is obtained as the marginal profit with respect to plant input price:

(5) $$Q_i^* = Q_i(P, W) = -\frac{\partial \pi(P,W)}{\partial W_i}$$

Because the retailer profit function is nonincreasing, convex, and continuous in *w*, the demand curve is downward sloping: $\frac{\partial Q_i}{\partial W_i} = \frac{\partial(-\frac{\partial \pi(P,W)}{\partial W_i})}{\partial W_i} = -\frac{\partial^2 \pi}{\partial W_i} \leq 0$ or, written in inverse form, $\frac{\partial W_i}{\partial Q_i} \leq 0$.

Upstream Market

Next, I consider the wholesaler's problem. I assume the wholesaler sets its wholesale output price W_j and has unit costs of production u_j. The wholesaler's profit-maximization problem is written as:

(6) $$\max_Q \pi^m = \sum_j Q_j (W_j(Q) - u_j)$$

The wholesaler's profit function is nondecreasing in *W*, homogenous of degree one in *W*, and convex in *W*. The first-order condition is:

(7) $$\frac{\partial \pi^m}{\partial Q_i} = W_i(Q) - u_i + \sum_j Q_j \frac{\partial W_j(Q)}{\partial Q_i} = 0$$

$$\text{i.e. } W_i(Q) + \sum_j Q_j \frac{\partial W_j(Q)}{\partial Q_i} = u_i$$

Equation (7) provides a solution to the wholesaler's problem. At upstream market equilibrium, the wholesaler's marginal revenue ($W_i(Q) + \sum_j Q_j \frac{\partial W_j(Q)}{\partial Q_i}$) is equal to its marginal cost (u_i). Equation (7) also implies the wholesaler's supply to the retailer is specified as

(8) $$W_i = u_i - \sum_j Q_j \frac{\partial W_j(Q)}{\partial Q_i}$$

Equation (8) implies the wholesaler's plant supply price depends on plant quantity *Q*, on marginal production cost u_i – including labor, material, and other input prices – and on plant supply elasticity $\frac{\partial W_j(Q)}{\partial Q_i}$ by plant type. According to Hotelling's lemma, optimal plant supply is obtained as the marginal profit with respect to plant output price:

(9) $$Q_i^* = Q_i(P, W) = \frac{\partial \pi(P,W)}{\partial W_i}$$

Because the wholesaler profit function is nondecreasing, convex, and continuous in *W*, the supply curve is upward sloping: $\frac{\partial Q_i}{\partial W_i} = \frac{\partial (\frac{\partial \pi(P,W)}{\partial W_i})}{\partial W_i} = \frac{\partial^2 \pi}{\partial W_i} \geq 0$ or, written in inverse form, $\frac{\partial W_i}{\partial Q_i} \geq 0$.

Equilibrium

The wholesale nursery sets wholesale price to maximize its profit considering production cost and plant quantity demand. Retail nursery behavior affects wholesale price by way of the quantity of plants demanded and by selling costs. The equilibrium in both downstream and upstream market can be obtained by combining equations (4) and (8).

(10) $$W_i = P_i(Q) + \sum_j Q_j \frac{\partial P_j(Q)}{\partial Q_i} - v_i = u_i - \sum_j Q_j \frac{\partial W_j(Q)}{\partial Q_i}$$

i.e. $$\frac{P_i(Q)-(W_i+v_i)}{W_i-u_i} = \frac{\sum_j Q_j \frac{\partial P_j(Q)}{\partial Q_i}}{\sum_j Q_j \frac{\partial W_j(Q)}{\partial Q_i}}$$

In a single-product case, equation (10) can be written in a simple form. Equation (11) shows that, in equilibrium, both wholesaler and retailer margins are in proportion to the slopes of the demand curves they face.

(11) $$\frac{P-(W+v)}{W-u} = \frac{Q\left[\frac{dP(Q)}{dQ}\right]}{Q\left[\frac{dW(Q)}{dQ}\right]}$$

$$= \frac{slope\ of\ retailer's\ demand\ function}{slope\ of\ wholesaler's\ demand\ function}$$

Lerner index $L = \frac{P-MC}{P}$ describes a firm's market power. A higher number implies greater market power. For a perfectly competitive firm, $L = 0$ or $P = MC$ implies that the firm has no market power. Equation (11) can be further written in the form of Lerner index:

(12) $$\frac{L^r}{L^w} = \frac{\frac{P-(W+v)}{P}}{\frac{W-u}{W}} = \frac{\frac{Q}{P}\frac{dP(Q)}{dQ}}{\frac{Q}{W}\frac{dW(Q)}{dQ}}$$

$$= \frac{retailer's\ demand\ elasticity}{wholesaler's\ demand\ elasticity}$$

Equation (12) indicates that the ratio of wholesaler to retailer market power is proportional to retailer and wholesaler demand elasticities. According to our model assumption, the wholesaler operates in a monopolistically competitive environment and the retailer in a more competitive environment. Thus the wholesaler has more price negotiation ability than the retailer does, i.e. $\frac{L^r}{L^w} < 1$. Thus, the wholesaler's demand elasticity is much larger than the retailer's.

Data

Equations (4) and (8) simultaneously determine plant wholesale price and plant quantity, and equations (10) – (16) show the interaction between plant supply and demand. In the present paper, I employ these simultaneous equations to study the Oregon nursery industry from 2005 to 2010. Sample data on wholesaler, retailer, and plant characteristics were provided by one of the largest nurseries [10] in Oregon. Records were provided for each invoice. The dataset consisted of 691,192 records, beginning in 2005 and ending in 2010, at the invoice level. Each record includes order number, order date, delivery date, company shipped to, address shipped to, invoice discount, plant name, plant variety, plant size, plant type, unit price, ordered quantity, shipped quantity, freight cost, amount paid, and amount due. If a single order is specified multiple genera or sizes, that order generates ten econometric observations with the same order number. To clean the dataset, I removed any record corresponding to samples with a 100% discount, or if it reflects a refund of a previous transaction.

Because the present study is designed at the firm level, I further converted the data from a transaction basis to a quarterly basis. Aggregating the transaction-level data to the whole-firm level is also consistent with most supply and demand studies, and makes it easier to link order data with quarterly released macroeconomic data. To do so, I calculated the quarterly-average plant sales revenue and quantities for each retail nursery to which it is sold by genus and plant size. Plant variety is the first indicator provided in the wholesale nursery's plant description. With this aggregation, I obtained 71,483 observations, each of which represents total sales revenue and quantity of a given genus sold to a particular retail nursery in a particular quarter. Real average plant price of a given genus is generated by dividing total sales revenue by total quantity and deflating to 2012 dollars.

As mentioned above, nursery plants are highly differentiated. Even after the above aggregation, the representative nursery wholesaler produced 277 plant genera. In order to avoid too many dummies in the model, I concentrated on the top plant genera by sales. Among the 277 genera, the top 50 comprised 90% of total sales, the top 20 comprised 72% of sales, and the top ten comprised 55% of sales. In the present demand and supply analysis, I use only the top ten sale plant genera, comprising 21,873 observations. Ninety-four percent of these observations are non-patented plants and six percent are patented plants. As shown in the description below, the top ten genera include coniferous trees, deciduous trees, and evergreen shrubs. Real plant price varies from below $1 to the hundreds of dollars, depending on plant genus and size. The highest average price is for Acer, followed by Picea. The lowest average price is for Heather, followed by Euonymus. In a given genus, the larger the plant size, the higher the plant price.

Following are the genera in the three major categories examined here:

1. Coniferous plants

- Thuja: a genus of coniferous trees in the family Cupressaceae
- Picea: a genus of coniferous evergreen trees
- Juniper: coniferous plants of the cypress family Cupressaceae
- Pinus: a genus of Pines in the family Pinaceae

2. Deciduous plants and evergreen shrubs

- Acer: maple in the family Sapindaceae, mostly deciduous trees
- Berberis: a genus of deciduous and evergreen shrubs
- Buxus: slow-growing evergreen shrubs and small trees in the family Buxaceae

3. Flowering plants

- Euonymus: a genus of flowering plants in the staff vine family Celastraceae, deciduous and evergreen shrubs and small trees

- Rhododendron: evergreen or deciduous, most with showy flowers
- Heather: a group of flowering plants found most commonly in acid and infertile growing conditions

Supply and Demand Factors

The wholesale nursery provides a longer payment grace period to customers with the better payment reputations, and more generally to those involving lower transaction costs. Payment grace period is defined as the number of days allowed before the buyer is required to pay without incurring penalties. Considering the time value of money, the retailer's payment grace period is indeed equivalent to, or another way to measure, the wholesaler's financial costs themselves. I consider six segments of grace period in order to avoid cases of missing observations in a category. Most transactions are stipulated to be closed within two months. Grace periods differ between big-box stores and independent retailers. Most big-box stores are required to pay within 60 days (46%), while independent retailers are mostly required to pay within 30 days (53%).

The other supply and demand variables are collected from various sources. Table 4.2 shows the summary statistics of these variables, defined in table 4.1. Producer price index measures the purchase prices of materials and supplies typically purchased by the production sector. In the present paper, the PPI is a proxy for the prices of intermediate materials in nursery production, for example pots and fertilizers. The PPI at nursery, garden, and farm supply stores is from the Bureau of Labor Statistics. It is deflated to 2012 dollars.

The U.S. farm wage is from the National Agricultural Statistics Service of USDA. It has been reported quarterly since 1990. Because farm wage rate is missing in the 1st quarter of 2007, I generated it with a regression of the quarterly wage rate growth rate on quarterly dummies from 2000 to 2010. The missing wage rate is then calculated as the predicted growth rate in the 1st quarter of 2007. Nominal U.S. farm wage rates are deflated to 2012 dollars with the CPI. After considering its seasonal adjustment, the real U.S. farm wage has from 2005 to 2010 been held at $11 per hour (in 2012 dollars).

Housing Starts are seasonally adjusted new privately owned housing units started (U.S. Census Bureau). The real estate market experienced a significant housing start decline from a monthly 2,120,000 units in the 1st quarter of 2006 to a monthly 526,000 units in the 1st quarter of 2009. Until the end of 2010, national new privately owned housing units started remained near 539,000 units per month, below historical norms. Market demand in the nursery sector is highly correlated with healthy housing starts.

Standard deviation (6th column of table 4.2) is a commonly used measure of variability or diversity from the average. Coefficient of variation (CV) (last column of table 4.2), or relative standard deviation, is a normalized measure of dispersion, allowing a comparison of two variables' dispersions with their central tendencies or means. These two statistics indicate that transaction quantity has a larger dispersion than transaction price has. Relative volatility in the market factors – nursery PPI, U.S. farm wage, and housing starts – is less than in such transaction variables as transaction quantity, transaction price, and payment grace period.

Empirical Specification

In the model derived above, plant wholesale price and plant quantity are determined simultaneously in equations (4) and (8). I employ log-linear equations in both structural and reduced form. The structural-form equations can be used to determine the relationship between plant wholesale price and plant quantity on both the supply and demand side. The reduced-form equations identify how equilibrium plant wholesale price and plant quantity are affected by payment grace period, input prices, and market demand.

Consider first plant demand facing the wholesale nursery industry. Plant demand can be expressed by the number of plants retailers are willing to purchase. A retailer is willing to purchase plants from the Oregon nursery if and only if $\pi(w, r, g, h) \geq \bar{\pi}$, which is the maximum profit he can achieve in Oregon when facing wholesale price *w*, average U.S. farmer wage rate *r*, gas price g, and housing starts h. Total plant demand in the Oregon nursery can be written as

(17) Demand $$q_i^d = \iiint_{\pi(w,r,g,h)\geq\bar{\pi}} f_i(w,r,g,h)\, q^d(w,r,g,h)drdgdh$$

where $f_i(w,r,g,h)$ is the joint probability density function corresponding to (w,r,g,h) for retail nursery I, and $q^d(w,r,g,h)$ the plant quantity demanded in equation (4). Thus $f_i(w,r,g,h)q^d(w,r,g,h)$ reflects, in the limit, the portion of the mean quantity of plant genus *I* demanded under conditions (w,r,g,h). I use a log-linear form to estimate non-linear function (17). Total plant demand from retailer *I* is estimated as

(18) Demand $$lnq^d = \alpha_0 + \alpha_1 lnw + \alpha_2 lnr + \alpha_3 lng + \alpha_4 lnh + \alpha_5 D_b + \alpha_6 D_p + e^d$$

I suppose in (18) that average U.S. farmer wage rate *r* is a proxy for retailers' labor input costs. Gas PPI g is a proxy for the material input costs, considering that transportation expenses constitute a large portion of material input costs. Housing starts h are a proxy for the nursery market demand because rising housing starts expand the demand of nursery products and therefore drive up nursery product prices. Retailer type dummy D_b allows a distinction between bigbox stores and independent retailers because their marketing costs tend to differ from each other. Patent dummy D_p distinguishes between patent-protected and –unprotected plants. One might equally have written plant price on the right side of the demand function in equation (19); that is

(19) Demand $$lnw^d = \alpha_0 + \alpha_1 lnq + \alpha_2 lnr + \alpha_3 lng + \alpha_4 lnh + \alpha_5 D_b + \alpha_6 D_p + e^d$$

Next consider the supply side of the wholesale nursery market. Plant supply can be expressed either by the number of plants a wholesaler is willing to provide or by the wholesale price he demands under certain cost conditions. Generally speaking, nursery production includes the costs of labor, land, machinery, and management; the expenses of materials such as seeds and plants, fertilizers, chemicals, and fuel; and irrigation and marketing costs. [11] In the present model, I use nursery PPI to proxy for total production expenses. Growers choose the best combination of input costs *p* and payment grace period *t* to maximize profit. A wholesale nursery is willing to sell plants if the profit obtained satisfies $\pi(q,p,t) \geq \bar{\pi}$. Total plant supply for producing plant genus *I* is

(20) Supply $$w_i^s = \iint_{\pi(q,p,t)\geq\bar{\pi}} g_i(q,p,t)\, w^s(q,p,t) dpdt$$

where $g_i(q,p,t)$ is the joint distribution function under conditions (q,p,t) in plant genus *I*, and $w^s(q,p,t)$ is plant supply function in equation (8). Expression $g_i(q,p,t)w^s(q,p,t)$ thus measures the portion of the mean wholesale price under conditions (q,p,t). Total plant supply of plant genus *I* is estimated in log-linear form.

(21) Supply $$lnw^s = \beta_0 + \beta_1 lnq + \beta_2 lnp_{-2} + \beta_3 lnt + e^s$$

Given data availability, I use nursery PPI *p* to proxy for the prices of labor, land, capital, fertilizer materials, packaging prices, and pottery prices. Nursery PPI, denoted *p*, is lagged here because a wholesale producer spends average 2.5 years to grow plants.

The last step is to include dummy variables in the supply and demand models. Our theory indicates plant genus characteristics affect pricing and purchase decisions. Given that characteristics information is not included in our regressions, I use a fixed-effects model and interaction terms to capture the omitted data. Because demand and supply elasticity may vary across plant genus, I introduce the interaction terms between plant quantity and plant genus dummies in both the demand and supply functions. For the same reason, I introduce an interaction term between plant quantity and plant patent dummy in the demand function to allow a test of whether plant patent status affects plant demand. Here, vector D_s and D_p capture plant size and plant genus effects. Because nursery production shows a strong seasonal pattern and all data are quarterly, I include a dummy variable (D_q) for each season. Letting *I* index plant genus, I thus represent my final fixed-effects model in structural form as

(22) Demand

$$lnw^d = \alpha_0 + \alpha_1 lnq + \sum_{i=2}^{10} \alpha_{1i} lnq \times D_{p,i} + \alpha_2 lnr + \alpha_3 lng + \alpha_4 lnh + \alpha_5 D + \alpha_{5i} lnq \times D_i$$
$$+ \alpha_6 D_b + \sum_{q=1}^{3} \alpha_{7q}\, D_q + \sum_{s=2}^{4} \alpha_{8s}\, D_s + \sum_{i=2}^{10} \alpha_{9i}\, D_{p,i} + e^d$$

(23) Supply

$$lnw^s = \beta_0 + \beta_1 lnq + \sum_{i=2}^{10} \beta_{1i} lnq \times D_{p,i} + \beta_2 lnp_{-2} + \beta_3 lnt + \sum_{q=1}^{3} \beta_{4q}\, D_q + \sum_{s=2}^{4} \beta_{5s}\, D_s$$
$$+ \sum_{i=2}^{10} \beta_{6i}\, D_{p,i} + e^s$$

Plant quantity and wholesale price in these structural equations are the critical endogenous variables. As distinct from the case in which either wholesale price or plant quantity is exogenous, endogeneity induces a correlation between plant quantity and error term in (22) as well as between wholesale price and error term in (23), leading to a bias in the elasticity estimates of OLS regressions.

For example, assume *X* is a vector of all explainable variables, including wage rates, in demand equation (22). The expectation of the OLS-estimated supply flexibility is then expressed as

$$E(\widehat{\alpha_1}) = \alpha_1 + E((X'X)^{-1}X'e^d)$$

The expectation of estimated demand elasticity is unbiased if and only if $E((X'X)^{-1}X'e^d) = 0$, that is when there is no correlation between wholesale price and error term. However, $E((X'X)^{-1}X'e^d) \neq 0$ for $E(q^d e^d) \neq 0$. An unobserved positive demand shift, moving the demand curve to the right, would tend to raise plant quantity transacted, given all other variables fixed. Hence it creates a positive correlation between the unobserved shock and plant quantity transacted ($E(q^d e^d) > 0$ or $E((X'X)^{-1}X'e^d) > 0$). Thus $E(\widehat{\alpha_1}) = \alpha_1 + E((X'X)^{-1}X'e^d) > \alpha_1$. The estimated demand elasticity would be biased positively. Because demand elasticity is approximately equal to the reciprocal of demand flexibility, demand elasticity would be biased negatively.

In a similar way, I prove that without the adjustment of endogeneity of wholesale price in equation (23), supply flexibility would be biased positively because unobserved positive supply shifts, moving the supply curve to the right, would tend to reduce plant quantity given all other variables constant. This creates a negative correlation between unobserved shock and plant quantity transacted ($E(q^s e^s) < 0$). Because supply elasticity is approximately equal to the reciprocal of supply flexibility, supply elasticity would be biased positively.

Except for wholesale price and plant quantity, all variables in equations (22) and (23) are used as instrumental variables in the 3SLS estimation. Plant size and plant genus dummies capture the plant characteristics information that is not included in the model. Seasonal dummies capture the nursery industry's seasonal pattern. On the demand side, a retailer's order decisions do not affect nursery production input prices. On the supply side, a wholesaler's pricing decisions do not affect labor wage rate, material input prices, or market demand. Thus, equations (22) and (23) comprise the simultaneous equation system estimated in this chapter.

Econometric Issues

Simultaneous equations (22) and (23) illustrate the interactions between wholesale price *w* and plant quantity *q* as well as the effects of important exogenous supply and demand factors. Three-stage least squares (3SLS) estimation is used to solve the simultaneous system. Because the simultaneous equations include interaction terms between quantity and genus dummy and between quantity and patent dummy, I also endogenize the interaction terms in the estimation of wholesale price *w* and plant quantity *q*.

Before discussing the estimation results, it is necessary to conduct Hausman specification test of whether simultaneity is present in the system. If the test shows that wholesale price and plant quantity are determined by each other simultaneously, instrumental variables are needed; otherwise, OLS is preferred. Consider two estimators, b_{ols} obtained with OLS and b_{iv} obtained with instrumental variables. The null hypothesis in a Hausman test is that both b_{ols} and b_{iv} are consistent. The alternative hypothesis is that only b_{iv} is consistent. First, endogenous variables *w* and *q* are each regressed on all exogenous factors, as shown in equation (24) and (25), and estimated residuals $\hat{e}_1$ and $\hat{e}_2$ derived. I employ the variables' logs in all these equations. Variable *r* denotes average U.S. farmer wage rate, *g* gasoline price, *h* housing starts, *t* payment grace period, D the patent dummy, D_b the retailer-type dummy, D_q the season dummy, D_s the plant size dummy, and D_p the plant genus dummy.

(24) Demand $w = f_1(r, g, h, p_{-2}, t, D, D_b, D_q, D_s, D_{p,i}, e_1)$

(25) Supply $q = f_1(r, g, h, p_{-2}, t, D, D_b, D_q, D_s, D_{p,i}, e_2)$

Then, as shown in equation (26) below, *w* is regressed on residuals $\hat{e}_1$ along with endogenous variable *q* and the exogenous factors in equation (23). Similarly, as shown in equation (27) below, *w* is regressed on residual $\hat{e}_2$ along with endogenous variable *q* and exogenous factors in equation (22). The estimation equations are as

(26) Supply $w = f_2(q, q \times D_{p,i}, p_{-2}, t, D_q, D_s, D_{p,i}, \hat{e}_1)$

(27) Demand $q = g_2(w, w \times D_{p,i}, r, g, h, D, w \times D_i, D_b, D_q, D_s, D_{p,i}, \hat{e}_2)$

I then perform a *t*-test on residuals $\hat{e}_1$ and $\hat{e}_2$. As shown in table 4.3, $\hat{e}_1$ is significant in equation (26) and $\hat{e}_2$ is significant in equation (27). The implication is that *w* in the supply function is correlated with error term $\hat{e}_1$ derived from the demand function, while *q* in the demand function is correlated with error term $\hat{e}_2$ derived from the supply function. Simultaneity thus exists between plant supply and demand. OLS is not applicable when the dependent variable is correlated with the error term. The Hausman test shows instrumental variables are required for estimating our structural model.

In 3SLS, all exogenous variables are used as instrumental variables to correct the endogeneity problem. That is, in the first stage, the predicted values of wholesale price and plant quantity are estimated by regressing wholesale price and plant quantity on all exogenous variables. In the second stage, equations (22) and (23) are estimated by substituting the predicted values of wholesale price and plant quantity in place of observed ones. In the third stage, I use the residuals from the second stage to obtain a variance-covariance matrix and apply generalized least squares (GLS) to obtain the final estimators.

The next step is to perform relevance and exogeneity tests and to determine the validity of instruments. First, instrument relevance is examined by way of two regressions. In the first-stage regression of wholesale price on all exogenous variables, R-square is 0.79. In the first-stage regression of plant quantity on all exogenous variables, R-square is 0.32. As shown by the F-test of joint significance, exogenous variables are overall statistically significant and most are individually significant as well. All exogenous variables thus should be used as instruments for wholesale price and plant quantity.

An exogeneity test is necessary for determining whether the instruments are uncorrelated with the structural error, that is are truly exogenous. The Basmann test (1960) is one of the methods for conducting an exogeneity test. As reported in the first column of tables 4.4 and 4.5, the p-values of the Basmann test on the 3SLS model are 0.003 and 0.001 in the supply and demand functions respectively, indicating both are significant at the 1% level. That is, the instruments pass the Basmann test in both equations of this model. The test shows the instruments used in the first stage are valid and I keep all the exogenous variables as instruments.

Estimation Results

In this section I provide the empirical results beginning with the supply estimations. Following the estimation of supply parameters are the calculations of supply elasticity by genus, using 3SLS regression. I then discuss the demand parameters and demand elasticities.

Although price-dependent demand and supply functions constitute the final model in tables 4.4 – 4.6, I present the system of price-dependent supply function and quantity-dependent demand function as a reference in table 4.7. The latter model is not employed because the R-square of quantity-dependent demand function is only 0.14, much lower than the former one.

Supply Parameters

Table 4.4 gives the supply parameter results of estimating equation (23), using the 2005 – 2010 sample. To calculate the supply parameters in a simultaneous system, I regress the log of wholesale price on the log of plant quantity, interaction terms between logged plant quantity and genus, the log of two-year lagged nursery producer price index, the log of payment grace period, and the season, size, and genus dummies, using both OLS and 3SLS estimation. In the season dummies, the base season is “fall.” In size dummies, the base size is “small.” In genus dummies, the base genus is “Thuja.” All dummy coefficients are interpreted relative to these base attributes.

In most genera, supply elasticities are significantly positive in the 3SLS estimates in columns (1) and (2), but negative in the OLS estimates in columns (3) and (4). Had we not considered the endogeneity between wholesale price and plant quantity, OLS estimation would have led us to negatively sloped supply functions.

On the supply side, the two-year-lagged nursery PPI – used to approximate for time-wise variation in such nursery production costs as labor, materials, and water – shows a significantly positive relationship with wholesale price. For every 1% increase in nursery PPI, the wholesale price rises by 0.35%. Wholesale prices are moderately pushed up by production costs. Because few inputs are expended once the plant is already shipped, current nursery PPI shows a nonsignificant relationship with wholesale price. Overall, the nursery industry appears unable to respond strongly or quickly to cost changes, and therefore vulnerable to unexpected input price changes.

Another supply factor, payment grace period, shows a significantly negative relationship with wholesale price. One percent rise in payment grace period reduces the wholesale price by 0.13%. A long payment grace period is provided to customers with good payment reputation and low default probability. Because transaction costs with qualified customers are relatively low, the price the wholesale nursery provides to its qualified customers is lower than with less qualified customers. The size dummy coefficients show a robust positive correlation between plant size and price. Larger plants require more materials and other inputs and so are charged higher prices.

Supply Elasticities

The magnitude of the supply elasticities varies by genera, and all are larger than unity. Price elasticities of supply in column (1) of table 4.6 are calculated from the supply flexibilities in table 4.4. Except for Picea and Pinus, all genera's supply elasticities are positive. In the top-ten-in-sales genera, average supply elasticity is 10.18. A large supply elasticity implies the marginal cost function is rather flat, that is price does not rise much as production volume rises. Several factors contribute to the large supply elasticity. First, a large elasticity is expected in the nursery industry because production processes tend to employ, except perhaps for suitable land, widely available inputs. Research and development costs are comparatively low. Labor largely are unskilled and material inputs are generally accessible. Second, the supply elasticity of a representative wholesaler is expected to be larger than that of the nursery market as a whole. This is because a single nursery can change factor usage without driving up factor prices. Third, after four straight years of declining sales in the Oregon nursery industry, many wholesale nurseries have accumulated unused capacity or previously produced plants, along with an ageing inventory that needed to be liquidated.

The most supply-elastic genus is Buxus, mainly evergreen shrubs, followed by Thuja, mainly coniferous trees, with average elasticities of 35.53 and 23.94, respectively. Heather (8.29) is the genus least responsive to price change. The low supply elasticities of the flowering plants probably is explained by the scarcity of the wholesale nursery's supply of these items. The next two genera with relatively low supply elasticities are also flowering plants, Rhodo (10.10) and Euonymus (10.71). Supply elasticities of the remaining genera are between 11 and 20. For example Acer, a family of deciduous trees, has a supply elasticity of 11.29. Berberis, a genus of deciduous and evergreen shrubs, has 13.04. Juniper, a genus of coniferous plants, has 15.23. In sum, the supply elasticities of coniferous plants are larger than those of deciduous plants, which in turn are higher than those of flowering plants.

Demand Parameters

Table 4.5 gives the demand parameter results of estimating equation (22) with the 2005 – 2010 sample. To calculate the demand parameters in a simultaneous system, I regress the log of wholesale price on the log of plant quantity, interaction terms between log of plant quantity and genus, the log of real U.S. average farmer wage, the log of real gasoline price, the log of housing starts, interaction term between logged plant quantity and patent dummy, and the season, size, genus, and patent dummies, under both OLS and 3SLS. Base dummies in the demand function are the same as in the supply function.

Demand flexibilities of non-patented Thuja, given by the quantity variable, are about -0.08 and -0.09 in the 3SLS and OLS models, respectively. In other words, Thuja demand elasticities are -11.97 and -11.09 in the 3SLS and OLS models. OLS estimates of the demand elasticities were lower than the 3SLS estimates, both in the patented and non-patented categories and in the other genera as well, further suggesting the endogeneity problem between wholesale price and plant quantity. The OLS estimates likely are biased, as discussed above.

I assume retail nurseries purchase not only plants from the wholesale nursery, but various other retailer inputs such as retailer labor and transportation. Our concern is with the retail buyer's demand for the plant or material input. Because retail nurseries are located all over the country, I use U.S. average farm wage to proxy for the retailer's labor wage. However, U.S. farm wage does not show significant correlation with wholesale plant price.

Transportation is another important expenditure item at retail nurseries. The wholesale nursery may help retail nurseries arrange for trucks and drivers, but the shipping fee is eventually paid by the retailer. Real gasoline price is one direct measure of shipping cost. Table 4.5 shows that, for every 1% rise in real gasoline price, wholesale price falls by 0.04%. Gasoline price increases push the transportation input demand function to the left, reducing the wholesale price that retailers are willing to pay.

A one percent rise in housing starts, proxying for consumer demand for nursery products, would increase the wholesale plant price by 0.05%. Housing starts as well as other construction involving housing beautification, scenic program, and landscaping, significantly lift the demand for nursery stock and hence the wholesale price. However, the effect is rather low, perhaps because I have left out of the model other factors that are correlated with housing starts but with an effect on demand opposite to that of housing starts.

The coefficient of the buyer-type dummy indicates that big-box stores are charged with wholesale prices 43% higher than independent retailers are, holding other selling factors constant. This interesting result is explained by the fact that transactions with big-box stores are usually on a pay-by-scan basis. In pay-by-scan, the wholesale nursery is paid only for the plants that are purchased and kept by the chain store's customer. In other words, the wholesale nursery may have to buy back the unsold plants. Because of the high transaction cost this restriction imposes on the wholesaler, the latter will charge a higher price to the big-box store than it will to the independent retailers. The coefficients of the size dummies are consistent with those in the supply function: buyers are willing to pay more for larger plants than for smaller ones.

Demand Elasticities

Demand elasticities for patented and non-patented plants are summarized in columns (2) and (3) of table 4.6. All price elasticities of demand are negative. Average demand elasticity in the top-ten non-patented plants is -35.72, indicating that the shape of the demand curve is rather flat and that plant demand is very sensitive to price. The reason can be explained in terms of the homogeneity condition of demand: own-price elasticity (which is negative) plus cross-price elasticity (which normally is positive) plus income elasticity (which normally is positive) equals zero. Hence, a good's own-price elasticity is a high negative number if its cross-price elasticity is high (implying the good has strong substitutes) and/or if its income elasticity is high (implying the consumer's marginal utility for the good doesn't decline much as his consumption quantity grows). In the present study, the high demand elasticities suggest either strong substitutability with other goods in the wholesale nursery or high plant-consumer income elasticities, especially among flowering plants.

At the genus level, Heather has the largest demand elasticity (-200.44), followed by Rhodo (-37.41) and Euonymus (-28.58). All of these are flowering plants. Pinus has the lowest demand elasticity (-4.94), followed by Picea (-4.98) and Buxus (-10.25). All of three of these are evergreen coniferous trees. Demand elasticities of the remaining genera are Thuja (-11.97), Juniper (-16.07), Berberis (-18.46), and Acer (-24.13). Thuja and Juniper are genera of coniferous trees, and Berberis and Acer of deciduous trees. In contrast to the supply elasticities, demand elasticities of flowering plants are the highest of all, followed by deciduous plants, and finally by coniferous trees.

Putting the above together with our analysis on the supply side, coniferous trees have the highest supply elasticity but lowest demand elasticity of all plant groups I have examined. One therefore would expect these trees to exhibit relatively high quantity-transacted variation and relatively low price variation. In contrast, flowering plants have the lowest supply elasticity but highest demand elasticity. Flowering plants thus would, in the presence of demand fluctuations, exhibit lower quantity-transacted variation and higher price variation than coniferous trees would. The demand for flowering plants will, more than for coniferous trees, depend on marketing and sales strategy. More generally, price discounts on flowering plants will boost sales more than will discounts on conifers.

As mentioned earlier, in order to study the demand impact of intellectual property, I have included both a patent dummy and patent slope dummy (patent dummy x quantity) in the demand model. Effects of patenting a Picea and Heather genera cannot be estimated because no patents in these genera are present in the dataset. As shown in table 4.6, the coefficient of the patent dummy is negative, implying a patented plant's price tends to be lower than a non-patented plant's. Furthermore, the average demand elasticity among the eight patented genera is -55.44, indicating that the demand for patented plants is more rather than less elastic than it is for non-patented ones. These results suggest the wholesale nursery's plant patenting activity is not directly successful in the sense of reducing demand elasticity and driving price upward. However, customers still may be generally attracted by the plant uniqueness that patenting brings.

Conclusions

The objectives of this chapter are to: (a) study the interaction among the major drivers of nursery supply and demand in an industry of high product differentiation; and (b) draw management implications on the basis of the estimated supply and demand elasticities. To do so, I have developed a framework for identifying and estimating plant supply and demand at a single firm in a simultaneous setting, assuming the firm operates as a monopolistic competitor, and to assess the effects of macroeconomic factors in that setting. A theoretically consistent empirical model is specified and estimated to solve these problems. Because of the high degree of product differentiation in the Oregon nursery industry, I examine only the genera falling into the top-ten-in-sales in the 2005 – 2010 sample.

Empirical results show that nursery production costs two years ago, and transaction costs, affect wholesale nursery decisions regarding the minimum prices it is willing to accept and therefore on the plants it supplies to retailers and other buyers. On the other side, transportation costs and consumer demand for nursery products play important roles in retail nurseries' plant demand decisions.

Overall, average supply elasticity in the top-ten-in-sales genera is relatively high, implying supply quantities are sensitive to nursery per-unit production and transaction cost. Put differently, the supply functions of the nursery's principal inputs – land, labor, and production materials – appear to be rather flat, even with quarterly data, although I have not estimated these supply functions themselves. Average demand elasticity in the top-ten-in-sales genera is also high, with however large variation across genera. The high demand elasticities imply either strong demand substitutability with other goods or high plant-consumer income elasticities. At the genus level, supply and demand elasticities are similar within the coniferous plant, deciduous plant, and flowering plant groups but different across these groups. The supply elasticities of coniferous plants are larger than those of deciduous plants, which in turn are higher than those of flowering plants. The demand elasticities are the lowest in coniferous trees followed by deciduous plants, then flowering plants.

This conclusion has implications for the understanding of nursery production structure, management, and marketing strategy. The rather flat wholesale nursery supply functions I have estimated imply the oversupply during the economic recession. Many wholesale nurseries have accumulated unused capacity or previously produced plants, along with an ageing inventory that needed to be liquidated.

Second, differing demand elasticities among the plant genera imply differing marketing strategies. Generally, price discounts on plants with relatively high demand elasticities would significantly boost sales and enlarge the market, while those on plants with low demand elasticities would have less sales impact. Therefore, the demand for flowering plants will, more than for coniferous trees, depend on marketing and sales strategy. Price discounts on flowering plants will boost sales more than will discounts on conifers.

Third, retailer type influences wholesale nursery decisions on plant prices. Big-box stores are charged wholesale prices higher than independent retailers are, holding other selling factors constant. However, big-box stores' pay-by-scan compensation method imposes relatively high transaction costs on the wholesaler.

A final implication of this study relates to plant patenting. Empirically, patenting seems to bring no direct signs of greater profitability, such as through a lower demand elasticity that would generate higher prices. The wholesale nursery may wish to reconsider the pricing and marketing policies of its patented plants to differentiate them more effectively from its non-patented plants.

Endnotes

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[2] Northwest FCS Nursery/Greenhouse Knowledge Team. 2012. "Industry Perspective Nursery/Greenhouse 2012." Northwest Farm Credit Services, Advancing Rural America's Success.

[3] Northwest FCS Nursery/Greenhouse Knowledge Team. 2012. "Industry Perspective Nursery/Greenhouse 2012." Northwest Farm Credit Services, Advancing Rural America's Success.

[4] USDA-NASS Oregon Field Office. 2011. "Oregon Nursery and Greenhouse Survey 2010". September.

[5] USDA-NASS Oregon Field Office. 2011. "Oregon Nursery and Greenhouse Survey 2010". September.

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[7] Upper Midwest includes: ND, SD, NE, KS, MN, IA, MO, WI, IL, MI, IN, OJ, KY.

[8] Northeast States includes: ME, NH, VT, MA, CT, RI, NY, PA, NJ.

[9] Atlantic States include: MD, DE, WV, VA, NC, SC, GA, FL.

[10] For proprietary purposes, the name of the nursery is omitted.

[11] http://aesop.rutgers.edu/~farmmgmt/ne-budgets/methodology.html.

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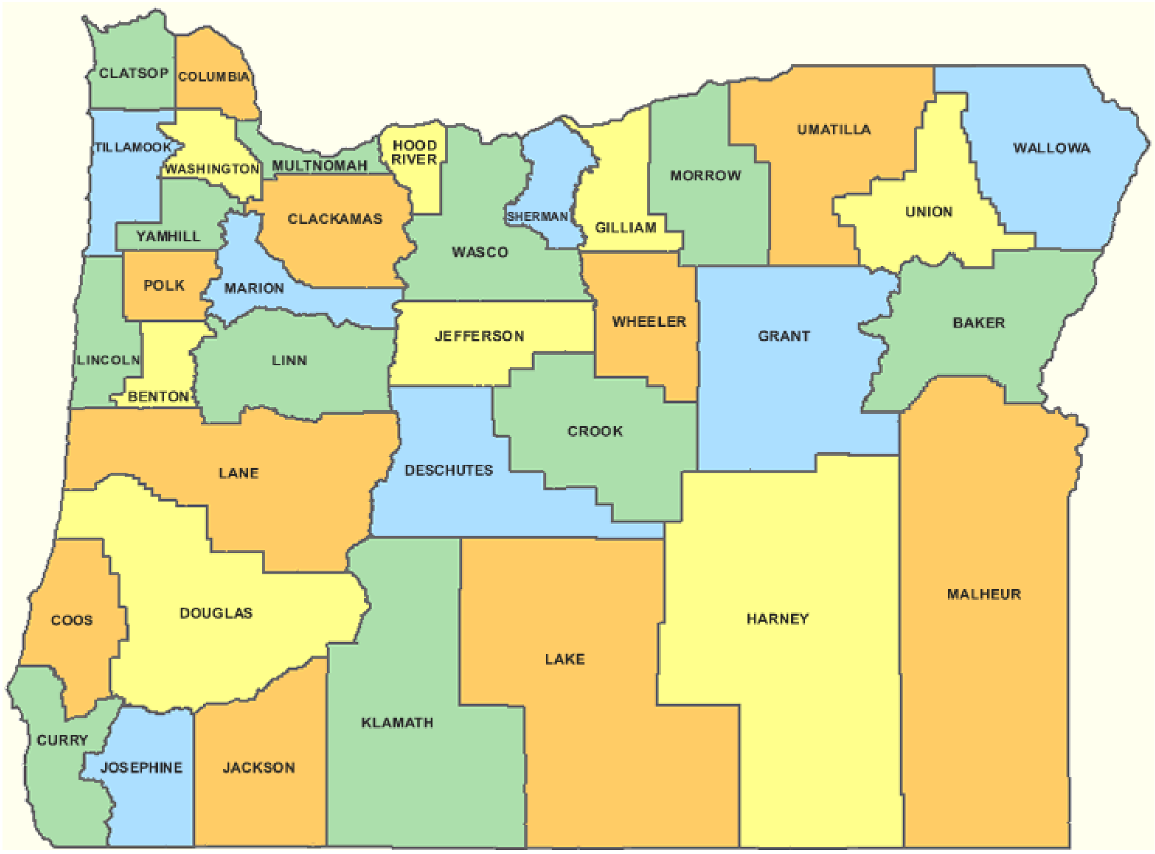

Figure 4.1. Oregon County Map

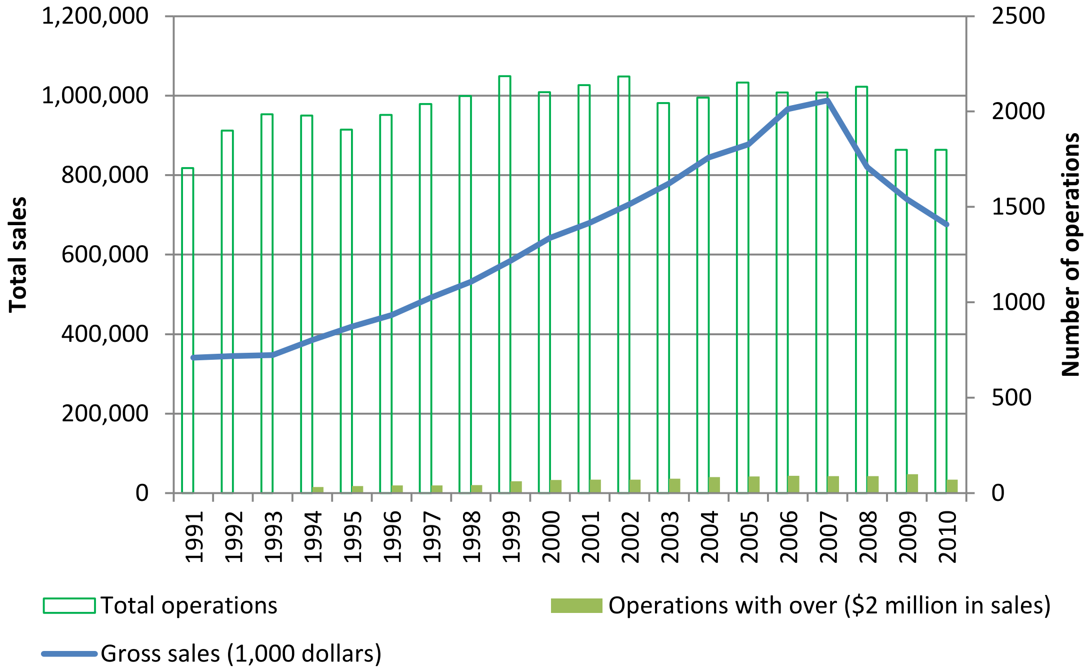

Figure 4.2. Total Sales and number of operations in the Oregon nursery industry

Table 4.1. Definitions of Variables

Variable	Definition	Unit	Mark
Transaction Quantity	Total number of plants for each genus sold to a retailer in a quarter		Q
Transaction Price	Average price for each genus sold to a retailer in a quarter	dollar	P
Payment Grace Period	Number of days allowed before retailer must pay without penalty	days	d
Nursery PPI	Producer price index for nursery, garden, and farm supply stores		PPI
U.S. Average Farmer Wage	U.S. all hired farm wage rate, quarterly data	dollars	$Wage$
Housing Starts	Number of new privately owned housing units started, not seasonally adjusted	thousand	H
Nursery Type	Independent retailer Big-box store		$D_{bb}=0$ $D_{bb}=1$
Patented Plant	A distinct and new variety of plant with a patent		D_{patent}

Table 4.2. Descriptive Statistics

Variable	N	Min	Max	Mean	Std Dev	CV
Nursery PPI	21873	150	186	172	3.9	0.02
U.S. Average Farmer Wage	21873	10.78	11.75	11.33	0.3	0.03
Housing Starts	21873	526	2120	1137	542	0.48

Notes: some variables are not reported for proprietary purposes.

Table 4.3. Hausman Test Results

Plant Supply (equation 26)
Dependent Variable: wholesale price

Variable	Coefficient	Std. Error	*t*-value
Intercept	-4.827***	0.291	-16.57
Quantity	0.049***	0.009	5.77
*Quantity * Picea*	-0.113***	0.010	-10.87
*Quantity * Juniper*	0.002	0.011	0.19
*Quantity * Acer*	0.012	0.012	1.03
*Quantity * Buxus*	-0.010	0.012	-0.81
*Quantity * Euonymus*	0.038***	0.012	3.28
*Quantity * Berberis*	0.004	0.012	0.34
*Quantity * Rhodo*	0.032***	0.012	2.61
*Quantity * Heather*	0.071***	0.015	4.77
*Quantity * Pinus*	-0.119***	0.011	-10.39
Nursery PPI_2-year Lag	1.240***	0.059	20.93
Payment Grace Period	-0.110***	0.008	-14.2
Winter	-0.001	0.010	-0.14
Spring	0.006	0.009	0.65
Summer	-0.038***	0.011	-3.62
Medium Size	0.881***	0.008	104.89
Medium-large Size	1.153***	0.010	111.1
Large Size	1.654***	0.009	177.26
wholesale price residual from equation (24)	-0.137***	0.009	-15.66

Plant Demand (equation 27)
Dependent Variable: plant quantity

Variable	Coefficient	Std. Error	*t*-value
Intercept	23.813***	4.055	5.87
Quantity	-6.581***	0.224	-29.38
*Quantity * Picea*	0.334***	0.071	4.74
*Quantity * Juniper*	0.041	0.072	0.57
*Quantity * Acer*	1.104***	0.108	10.24
*Quantity * Buxus*	-0.240***	0.079	-3.03
*Quantity * Euonymus*	-0.253***	0.085	-2.99
*Quantity * Berberis*	0.035	0.083	0.42
*Quantity * Rhodo*	0.521***	0.082	6.35
*Quantity * Heather*	-0.465***	0.116	-4.01
*Quantity * Pinus*	0.130*	0.076	1.72
U.S. Average Farmer Wage	-7.074***	1.591	-4.45
Gasoline Price	-0.780***	0.115	-6.77
Housing Starts	0.721***	0.039	18.55

*Quantity * Patent*	-0.088*	0.053	-1.65
Patent Dummy	-0.844***	0.120	-7.03
Bigbox Dummy	3.511***	0.047	75.08
Winter	0.784***	0.057	13.82
Spring	0.476***	0.039	12.07
Summer	-0.388***	0.060	-6.50
Medium Size	4.737***	0.188	25.21
Medium-large Size	6.465***	0.249	25.95
Large Size	9.001***	0.356	25.30
Plant quantity residual from equation (25)	5.140***	0.226	22.79

a. The asterisks ***, ** and * denote statistical significance at 1%, 5%, 10% level.
b. The coefficients of genus dummies are omitted.
c. Italic denotes logged term.

Table 4.4. Parameter Estimates of the Structural Model: Plant Supply

Dependent Variable: *Wholesale price*				
	3SLS		OLS	
Variable	Coefficients	*t* value	Coefficients	*t* value
	(1)	(2)	(3)	(4)
Intercept	-0.390**	-1.98	-4.590***	-15.53
Quantity	0.042***	4.32	-0.068***	-15.40
*Quantity * Picea*	-0.117***	-9.92	-0.045***	-8.11
*Quantity * Juniper*	0.024*	1.90	-0.016***	-2.77
*Quantity * Acer*	0.047***	3.48	0.026***	3.69
*Quantity * Buxus*	-0.014	-0.97	-0.007	-1.10
*Quantity * Euonymus*	0.052***	3.90	0.028***	4.42
*Quantity * Berberis*	0.035***	2.62	0.022***	3.30
*Quantity * Rhodo*	0.057***	4.17	0.040***	5.90
*Quantity * Heather*	0.079***	4.72	0.041***	5.63
*Quantity * Pinus*	-0.119***	-9.18	-0.056***	-9.02
Nursery PPI_2-year Lag	0.348***	8.71	1.215***	20.14
Payment Grace Period	-0.125***	-14.32	0.013**	2.03
Winter	0.006	0.59	0.035***	3.62
Spring	-0.002	-0.20	0.033***	3.55
Summer	-0.061***	-5.18	-0.025**	-2.30
Medium Size	0.887***	93.56	0.786***	99.98
Medium-large Size	1.154***	98.43	1.060***	105.35
Large Size	1.663***	158.15	1.500***	186.94
Picea	0.903***	18.41	0.567***	22.19
Juniper	-0.017	-0.30	0.106***	3.89
Acer	0.881***	17.22	0.850***	30.08
Buxus	0.264***	4.15	0.222***	7.20
Euonymus	-0.106*	-1.85	-0.084***	-2.85
Berberis	0.020	0.34	0.036	1.17
Rhodo	-0.125**	-2.20	-0.103***	-3.36
Heather	-0.272***	-3.55	-0.142***	-3.98
Pinus	0.760***	14.73	0.446***	16.39
R^2	0.7916		0.812	
P-value of over-identification test	0.0001			

a. The asterisks ***, ** and * denote statistical significance at 1%, 5%, 10% level.
b. Italic denotes logged term.

Table 4.5. Parameter Estimates of the Structural Model: Plant Demand

Dependent Variable: *Wholesale price*				
	3SLS		OLS	
Variable	Coefficients	*t* value	Coefficients	*t* value
	(1)	(2)	(3)	(4)
Intercept	1.723***	3.79	3.179***	3.18
Quantity	-0.084***	-8.22	-0.090***	-20.53
*Quantity * Picea*	-0.117***	-11.20	-0.042***	-7.73
*Quantity * Juniper*	0.021*	1.90	-0.005	-0.89
*Quantity * Acer*	0.042***	3.51	0.025***	3.54
*Quantity * Buxus*	-0.014	-1.13	0.001	0.08
*Quantity * Euonymus*	0.049***	4.12	0.030***	4.86
*Quantity * Berberis*	0.029*	2.47	0.027***	4.02
*Quantity * Rhodo*	0.057***	4.66	0.041***	6.14
*Quantity * Heather*	0.079***	5.30	0.050***	7.01
*Quantity * Pinus*	-0.119***	-10.36	-0.052***	-8.55
U.S. Average Farmer Wage	-0.277	-1.55	-0.981**	-2.49
Gasoline Price	-0.040***	-2.98	-0.085***	-2.96
Housing Starts	0.054***	11.57	0.097***	10.88
*Quantity * Patent*	0.022***	4.73	0.002	0.25
Patent Dummy	-0.161***	-8.90	-0.110***	-3.94
Bigbox Dummy	0.358***	15.96	0.336***	27.22
Winter	0.078***	7.32	0.094***	6.79
Spring	0.049***	5.16	0.055***	5.64
Summer	-0.053***	-4.63	-0.062***	-4.38
Medium Size	0.776***	81.46	0.770***	99.15
Medium-large Size	1.047***	91.95	1.041***	104.91
Large Size	1.477***	121.19	1.470***	184.32
Picea	0.828***	18.93	0.557***	22.15
Juniper	-0.022	-0.44	0.087***	3.20
Acer	0.818***	17.88	0.863***	30.81
Buxus	0.277***	4.91	0.209***	6.90
Euonymus	-0.148***	-2.90	-0.077***	-2.62
Berberis	0.027	0.52	0.042	1.35
Rhodo	-0.155***	-3.05	-0.099***	-3.29
Heather	-0.291***	-4.27	-0.165***	-4.71
Pinus	0.655***	14.23	0.427***	15.91
R^2			0.817	
P-value of over-identification test	0.0001			

a. The asterisks ***, ** and * denote statistical significance at 1%, 5%, 10% level.
b. Italic denotes logged term.

Table 4.6. Supply and Demand Elasticities at a Production Nursery

	Supply Elasticity	Demand Elasticity	
		Non-Patented	Patented
	(1)	(2)	(3)
Coniferous Plants			
Pinus	-13.02	-4.94	-5.55
Picea	-13.29	-4.98	N.A.
Thuja	23.94	-11.97	-16.32
Juniper	15.23	-16.07	-24.99
Deciduous Plants and Evergreen Shrubs			
Buxus	35.53	-10.25	-13.27
Berberis	13.04	-18.46	-31.31
Acer	11.29	-24.13	-52.02
Flowering Plants			
Euonymus	10.71	-28.58	-78.30
Rhodo	10.10	-37.41	-221.73
Heather	8.29	-200.44	N.A.

a. Patent flag means a particular genus contains one or more patented varieties.

Table 4.7. Parameter Estimates of the Structural Model

Plant Supply			Plant Supply		
Dependent variable: *Wholesale Price*			Dependent variable: *Plant Quantity*		
Variable	Coefficients	*t* value	Variable	Coefficients	*t* value
	(1)	(2)		(3)	(4)
Intercept	-2.501***	-8.27	Intercept	12.368**	2.51
Quantity	0.027***	3.47	*Price*	-5.206***	-14.64
*Quantity * Picea*	-0.068***	-7.78	*Price * Picea*	-1.334***	-14.67
*Quantity * Juniper*	0.066***	7.01	*Price * Juniper*	-0.306***	-3.25
*Quantity * Acer*	0.090***	9.16	*Price * Acer*	-0.681***	-5.02
*Quantity * Buxus*	-0.011	-1.08	*Price * Buxus*	-0.043	-0.41
*Quantity * Euonymus*	0.038***	3.92	*Price * Euonymus*	1.024***	9.43
*Quantity * Berberis*	0.016	1.62	*Price * Berberis*	1.134***	10.45
*Quantity * Rhodo*	0.027**	2.57	*Price * Rhodo*	1.593***	14.77
*Quantity * Heather*	0.043***	3.48	*Price * Heather*	1.754***	11.85
*Quantity * Pinus*	-0.055***	-5.63	*Price * Pinus*	-1.541***	-15.62
Nursery PPI_2-year Lag	0.842***	13.41	*U.S. Average Farmer Wage*	-2.519	-1.30
Payment Grace Period	-0.188***	-24.69	*Gasoline Price*	-0.463***	-3.28
Winter	-0.007	-0.67	*Housing Starts*	0.550***	11.30
Spring	-0.008	-0.78	*Price* Patent*	1.724***	27.15
Summer	-0.053***	-4.46	Patent Dummy	-4.292***	-29.46
Medium Size	0.880***	93.36	Bigbox Dummy	3.430***	42.47
Medium-large Size	1.156***	99.03	Winter	0.614***	7.32
Large Size	1.663***	158.58	Spring	0.400***	6.01
Picea	0.719***	19.02	Summer	-0.264***	-2.92
Juniper	-0.196***	-4.62	Medium Size	3.274***	10.85
Acer	0.732***	18.73	Medium-large Size	4.939***	12.36
Buxus	0.258***	5.30	Large Size	7.053***	12.36
Euonymus	-0.057	-1.30	Picea	5.239***	19.26
Berberis	0.100**	2.22	Juniper	0.944***	4.64
Rhodo	-0.016	-0.35	Acer	6.501***	11.79
Heather	-0.104*	-1.82	Buxus	1.370***	5.89
Pinus	0.532***	13.29	Euonymus	-1.421***	-6.37
			Berberis	-1.165***	-4.92
			Rhodo	-3.151***	-12.80
			Heather	-2.047***	-8.10
			Pinus	4.560***	17.42

a. The asterisks ***, ** and * denote statistical significance at 1%, 5%, 10% level.
b. Italic denotes logged term.

Chapter 5 : Conclusions

Cheng Li

This present dissertation systematically analyze the nursery production and marketing structure, including the nursery labor supply and demand, the nursery products supply and demand, and the sales contract between wholesaler and retailers. The results have implications for the understanding of nursery production structure, management, and marketing strategy.

In chapter 2, I have developed a framework to identify and estimate labor supply and demand in a simultaneous setting, and have used it to analyze policy and socioeconomic effects on the Oregon nursery labor market. The results show that border control, the construction wage, the Oregon minimum wage, and the Mexican minimum wage affect immigrant location decisions and therefore agricultural labor supply. Except for technology change, the Oregon minimum wage serves as the largest contributor to market wage variation, followed by the construction wage and border apprehension rate. On the other side, nitrogen prices, nursery product price, and technology change play important roles in growers' labor demand decisions. Except for technology change, nitrogen price is the largest contributor to the variation in working hours, followed by housing starts and the Oregon minimum wage rate. Although much of the secular change in the agricultural labor market can be attributed to technology improvement, growers and farm workers do respond to the Oregon minimum wage and to border control efforts. Overall, the Oregon minimum wage is more effective than are border apprehension policies in boosting the average wage and in reducing the number of hours that illegal immigrants work in the nursery sector.

In chapter 3, I have established a two-step model to investigate the relationship between contract type and retailer characteristics in the Oregon nursery industry. The analysis suggests that big-box stores with annual contracts are less likely than are independent retailers with single-order contracts to make pre-order contracts with the producer. However, once a pre-order contract is chosen, big-box stores demand a longer pre-order interval than independent retailers do. Regarding payment type, pay-by-order contracts are more likely to provide a higher discount rate than are pay-by-scan contracts. Second, greater trust between producers and retailers reduces pre-order cost and boosts discount rates in pre-order contracts. Third, the way in which the producer-nursery reacts to a retailer's financial condition, proxied by the retailer's debt-to-credit limit ratio, suggests the producer's risk attitude varies by retailer type. When a big-box retailer's financial condition deteriorates, the producer-nursery reacts as a risk avoider toward a big-box stores. Because independent retailers' unpaid balances are much smaller than big-box stores', a moderate discount may motivate independents to continue their business with the producer and hence eventually pay their unpaid balances. The producer exhibits risk-neutral behavior toward an independent retailer.

In chapter 4, I have developed a framework for identifying and estimating plant supply and demand at a single firm in a simultaneous setting, assuming the firm operates as a monopolistic competitor, and to assess the effects of macroeconomic factors in that setting. Overall, average supply elasticity in the top-ten-in-sales genera is relatively high. The rather flat supply function reflects accumulated unused capacity and previously produced plants in many wholesale nurseries during the economic recession. Average demand elasticity in the top-ten-in-sales genera is also high, implying either strong demand substitutability with other goods or high plant-consumer income elasticities. At the genus level, supply and demand elasticities are similar within the coniferous plant, deciduous plant, and flowering plant groups but different across these groups. Another interesting finding is that empirically, patenting seems to bring no direct signs of greater profitability. The wholesale nursery may wish to reconsider the pricing and marketing policies of its patented plants to differentiate them more effectively from its non-patented plants.

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