INVESTING IN FARM WORKER HOUSING: A MULTI-SEASON PEAK-LOAD ANALYSIS OF WASHINGTON STATE DATA

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Abstract: This paper develops cost effective investment rules for farm worker housing and applies the model to farm worker housing in the state of Washington. The state must meet varying seasonal farm worker housing needs at minimum expense. In this study we examine investment rules to choose among different housing technologies in order to minimize the total costs of housing consistent with achieving welfare goals. The research extends existing peak-load models to the multi-season planning cycle case and applies the approach empirically to a new subject area.

Introduction

Agriculture is one of the most significant industries in Washington State's economy. Each year tens of thousands of migrant and seasonal workers tend the orchards and harvest a 1.7 billion tree-fruit crop. Work on each crop is characterized by a base level of cultivation (off-season) together with peak seasons for time critical activities like pruning and harvesting. However, the diversity of agriculture production in the state means that the major work season is extended as workers move from crop to crop. The primary farm work season encompassing the various crop-specific peak seasons begins in March and ends in October. The number of workers varies widely-- both within the primary and the off-seasons and from year to year. In 1999, demand for seasonal farm workers statewide ranged from a high of almost 60,000 in July to a low of almost 12,000 in December. The demand for seasonal farm worker is currently met by a continuing flow of migrant workers. Lately, there has been a growing concern for action to improve the farm workers' living circumstances - whether motivated by growers need to attract sufficient worker supply for their harvests or by social concerns about the welfare of the workers. Housing constitutes an important element of this concern. Both growers and farm workers agree that housing is a necessary condition to attract and support an adequate labor force. Anecdotal evidence indicates that growers who provide housing not only are more successful in meeting their time-critical needs, but also have access to a higher quality, more dependable farm labor pool – a core group that returns year after year and recruits better quality workers from their family and acquaintance groups (personal communications with different growers)[1]. More generally, good housing can give specific agricultural enterprises and the tree fruit industry as a whole a competitive advantage in attracting labor during tight labor markets.

Farm Worker Housing in Washington

Housing for farm workers has always been an issue, but the expansion of the fruit industry worsened a chronic shortage of farm worker housing. The Department of Health in Washington State estimated an annual total of 62,300 farm workers in 1996. More than 37,000 workers, amounting to about 60 percent of the total workforce, lack housing during the growing season (these workers sleep in cars, parks, etc.). Another 120,000 members of worker households (seasonal workers and their dependents) live in inadequate housing (WSOCD).

Despite its potential advantage in attracting workers, investing in housing has been an unattractive option for growers because provision of housing is both costly and troublesome. Most growers are not, and do not want to be, in the housing business. Competitive conditions imply that growers cannot afford to pay higher wages or invest in housing that is often used only for a short time. (There is a public goods-free rider problem here, see later discussion.) Furthermore, the state neither requires housing nor provides economic incentives to encourage investment in farm worker housing. However, if growers do provide housing for farm workers, it must meet strict rules and regulations. Under these circumstances, growers have been reluctant to invest in expensive year-round housing. On the other hand the income of farm workers is too low to pay for

[1] This phenomenon might be predicted from a "social capital" view of the seasonal labor market.

market rate housing. Housing costs are a high portion of their income and so many private market alternatives are not realistic. As a result of this situation, many workers live in their cars or in campgrounds in remote areas. Inadequate and incomplete data on the numbers of farm workers and their families lead to diverse opinions and different proposed solutions to farm worker housing problems. Moreover, since work-seasons vary in length and farm workers have a variety of family circumstance, housing needs are diverse and multifaceted. Of immediate interest for this paper are the year to year variation in the number of housing units needed and the variation in the length of time of occupancy. To satisfy these needs, the solution to the housing problem must include a variety of housing services ranging from short-term, seasonally occupied housing to year-round housing.

By the late nineties the lack of investment from the industry and the continuing inability of farm workers to pay market rate rents, created a demand for state action in housing in farm worker housing. The state of Washington began sponsoring different housing projects. The housing to be built differs in terms of the technology used and capital intensity, ranging from capital intensive, year-round structures, to seasonal housing, to emergency tents with high operating costs but low capital costs. This raises the question of determining the optimal (cost effective) level of investment in each category of housing. This is basically a *cost-effectiveness* analysis, because the housing needs are taken as given.

Objectives

The objective of this paper is to present an analysis of investment decisions for the provision of farm worker housing given a set of different technology options. Conceptually, we take the aggregate social view of investment goals and costs. Empirically, we adopt the perspective of the state of Washington. The analysis uses an optimizing model to determine least cost methods of meeting the desired target levels of housing. The transient nature of migrant population -- generated in part by the stochastic fluctuations of agricultural production and the short harvest season -- entails a peak demand on the housing facilities.

In this study a peak load model is applied to data from three different projects funded by the state to provide year-round, seasonal and emergency housing for farm workers for a two season planning cycle situation. Least-cost combinations of technology and levels of investment are derived.

Literature Review on Peak Loading and Investment

The peak-load problem refers to the issue of determining efficient investment and pricing in markets characterized by economically non-storable commodities whose demand varies periodically. The essence of the peak load problem is that the installation of extra capacity to meet peak demand would result in costly underutilization during the off-peak time. (Crew et al., 1995).

Peak load theory was developed to optimize the pricing system and investment schemes in public utilities by applying marginal cost principles. The early literature examined welfare-maximizing prices for a simple, deterministic peak load model

(Boiteaux 1949, Steiner, Williamson, etc). The optimal price in the deterministic model is the sum of two parts: the operational costs plus an additional amount to ration demand. Subsequent work (Boiteaux (1951), Brown and Johnson (B&J)) extended the traditional model into a risky environment, allowing for the more realistic assumption of stochastic demand. B&J found results comparable to the riskless model. However, the inclusion of uncertainty in the model resulted in lower optimal prices at all times and, in generally, higher optimal capacity compared to deterministic models. B&J examined both the peak price and the capacity investment level problems. They recommended that the optimal investment level be selected in such a way that the truncated expectation of the willingness to pay the marginal disappointed user should be equal to the marginal capacity cost. So, willingness to pay would ration demand in a perfect and costless way.

Crew and Kleindorfer (1971, 1976, 1978) expanded the analysis by examining simultaneously the effects of a stochastic demand, multiple planning periods and diverse technology (multiple plant types of differing cost characteristics), on the welfare maximizing policy of public enterprises. They argued that, for the firm peak case, the addition of diverse technology to marginal cost pricing improved the efficiency of peak load pricing under stochastic conditions. Further contributions to the literature encompass the cases of storable products, supply-side uncertainties, outage costs etc. For an extended literature review see Crew et al. (1995).

The relevance of the peak load analysis to problems other than the public utilities problems, for which it was initially created, is indicated by many applications in different fields of the economy. Increasingly, general models of peak load pricing and investment have been applied to a broad set of issues in fields such as telecommunications, transportation, advertising, concerts and games, storage facilities, and the like.

Basic Theoretical Model of Peak-Load Pricing

It is assumed that the goal of the state of Washington is the maximization of the expected value of welfare. A standard measure of welfare as used in Steiner, Brown and Johnson, Crew and Kleindorfer, and others, considers the net social benefits as obtained by the sum of total revenue (TR) and consumer surplus (S) minus production cost (PC) and rationing costs (RC):

(1) $$W = TR + S - PC$$

Each of the components of the social welfare function is examined and the simplifying assumptions are stated as follows.

Demand

For a commodity that faces a stochastic demand, the gross surplus (i.e., $TR + S$) is given by the integral under the inverse demand curve up to the actual amount supplied. Let $x = (x_1,..., x_n)$ be the vector of quantities demanded in period $i = 1,...,n$, and let $p = (p_1,..., p_n)$ denote the corresponding vector of prices. Demand in each period i is assumed to be independent of other period demands and in the additive form can be represented as:

(2) $$D_i(p_i, u_i) = X_i(p_i) + u_i ,$$

where $X_i(p_i)$ is the mean demand in period i, continuously differentiable and has an inverse function P_i, u_i is the disturbance term with expected value $E(u_i) = 0$ and also u_i is a continuous random variable $\forall i$. It is assumed that the relevant planning cycle is divided into n periods of equal length.

Production Costs

Technology is specified as consisting of m types of plants indexed $l = 1,2,\ldots,m$ and having constant marginal operating costs b_l and marginal capacity costs b_l. Further, it is assumed that marginal operating costs b_l and capacity costs b_l are inversely related and can be strictly ranked so that the technologies with the highest capacity costs have the lowest operating costs and so forth:

(3) $$b_1 > b_2 > \ldots > b_m ; \quad 0 < b_1 < b_2 < \ldots < b_m$$

The optimal output $q_{l,i}$ produced by plant l to meet demand level x_i in any period i given the preceding cost structure is:

(4) $$q_{li}(x_i, q) = \min_{q_{1,i},\ldots,q_{l-1,i}} \left\{ x_i - \sum_{k=1}^{l-1} q_{k,i}(x_i, q, q_l) \right\}$$

where $q = (q_1,\ldots,q_m)$ represents the vector of installed capacities of plant types 1 through m. By using an additive demand function, the total production costs can be expressed as follows:

(5) $$PC = \sum_{l=1}^{m} \sum_{i=1}^{n} b_l q_{l,i}\left(D_i(p_i, u_i), q\right) + \sum_{l=1}^{m} \beta_l q_l$$

Let S_i denote the total output from all plants in period i. Then, for any given value of the vectors u, p or q, the actual output in any period i is given by the minimum of real demand or total installed capacity:

(6) $$S_i\left(p_i, u_i\right) = \min\left\{D_i\left(p_i, u_i\right)\right\}$$

Rationing Costs.

For a stochastic demand, whenever demand exceeds capacity, rationing costs that involve the ranking of the customers according to their willingness to pay, generally occur. These costs can be represented as:

(7) $$RC = \sum_{i=1}^{n} r_i\left(D_i\left(p_i, u_i\right) - z\right)$$

where $z = q_1 + ... + q_m$ represents total capacity, r_i is a nonnegative, convex and continuously differentiable function and $R_i = r_i\left(D_i\left(p_i, u_i\right) - z\right)$ denotes the rationing costs in period i.

Incorporating expressions (2), (5) and (6) into (1) the following welfare function is obtained:

(8) $$W\left(u, p, q\right) = \sum_{i=1}^{n} \int_0^{S_i(n_i, \mu_i)} P_i\left(x_i - u_i\right) dx_i - \sum_{i=1}^{n} \sum_{l=1}^{m} b_l q_{li}\left(D_i\left(p_i, u_i\right), q\right) - \sum_{l=1}^{m} \beta_l q_l$$

Taking the expected value of the welfare function results in:

(9) Max $W'\left(p, q\right) = \mathrm{E}_u\left\{W\left(u, p, q\right)\right\}$

and the goal is to maximize W' over the set of non-negative price and capacity vectors assuming that the random variable u is such that $W'\left(p, q\right)$ exists for all feasible price and capacity vectors.

Alternatively, welfare maximization can be achieved by minimizing the expected value of the total production costs expressed in (5) contingent on all the above assumptions.

Application of the Peak-Load Model to Housing Investment

We follow the approach to peak capacity investment decisions developed in Brennan and Lindner. Brennan and Lindner examined investment decisions for storage capacity but considered only one planning period/season (yearly demand for grain storage was examined, i.e., $n = 1$). The model presented here will extend the standard model by dividing the planning cycle (usually one year) into a multi-season planning cycle with n seasons. In principle, n could be any number of equal sized seasons, and the model could also be extended to unequal sized seasons.

The demand for housing in a particular area is derived from the total number of farm workers in need of housing for the area. The number of farm workers (tree fruit industry) in Washington State has fluctuated from 14 thousand workers in January to 65 thousand in July during 1998. In this application we divide the demand for housing into two equal seasons, the off-season and the primary season (i.e., $n = 2$). A low or off-season runs from November through April. Housing demand increases substantially during the May -October primary season as the result of pruning, harvesting and related activities. The consideration of two separate demands for housing is important to adequately account for the substantial differences that are exhibited in the mean and the variance of the number of workers during each period (Table 1).

Let b_{y-r} and b_s indicate the capital construction costs for year-round and seasonal structures, b_{y-r}, b_s, b_e represent the operating costs for year-round structures, seasonal structures and emergency tents and finally let $C_{(y-r)}$, $C_{(s)}$ indicate capacities for year-round structures and seasonal structures. It is assumed that condition (3) holds and that the total unit costs are greater for seasonal housing than for year-round structures as follows:

$$b_s + b_s > b_{y-r} + b_{y-r} \tag{10}$$

Crew and Kleindorfer (1976) point out that, in the case of a stochastic demand, the optimal short-run allocation of demand to capacity is achieved by first using the structures with lowest operating costs. In this study, this implies that year-round housing that has the lowest operating costs should be operated first, followed by an optimal combination of other structures.

The total expected cost function to be minimized for the case of a multi-season ($n-$season) demand and $m=3$ technologies can be expressed as follows:

$$\begin{aligned} TEC = {} & nb_{y-r}C_{(y-r)} + \sum_{i=1}^{n} E\left[b_{y-r}\left(x_i I_{[0,C_{(y-r1)}]}(x_i) + C_{(y-r)} I_{[C_{(y-r)},\infty]}(x_i)\right)\right] + nb_s C_{(s)} + \\ & \sum_{i=1}^{n} E\left\{ b_s \begin{bmatrix} \left(x_i - C_{(y-r)}\right) I_{[0,C_{(y-r)}]}\left(x_i - C_{(y-r)}\right) \\ + C_{(s)} I_{[C_{(s)},\infty]}\left(x_i - C_{(y-r)}\right) \end{bmatrix} \right\} + \sum_{i=1}^{n} E\left[b_e\left(x_i - C_{(y-r)} - C_{(s)}\right)\right] \end{aligned} \tag{11}$$

where $I_A(z)$ is an indicator function that takes the value 1 when its argument is contained in the set A, and equals 0 otherwise.

Taking the derivative of the total cost function with respect to capacities $C_{(y-r)}$, $C_{(s)}$, and solving the first order conditions, the efficient rules of investment are generated[2].

(12) $$1-\sum_{i=1}^{n}\Phi_i\left(C_{(y-r)}\right)=\left(b_{y-r}-b_s\right)/\left(b_s-b_{y-r}\right)$$

(13) $$1-\sum_{i=1}^{n}\Phi_i\left(C_{(y-r)}+C_{(s)}\right)=b_s/\left(b_e-b_s\right)$$

where $\Phi_i\left(C_{(.)}\right)$ is the cumulative distribution function (CDF) of the number of farm workers during period i. The sum of the CDF's over the n periods denotes the probability that a marginal unit of housing is going to be used during that particular time of year. The implications for investment choice based on conditions (12) and (13) are clear. The state should investment in year-round housing as long as the expected cost of using year-round housing equals the expected cost of using seasonal housing (the marginal expected cost of investment in year-round housing does not exceed the marginal expected benefit derived from this investment). This is satisfied for the level of investment in housing capacity of type one, $C_{(y-r)}$, that completes condition (12). Beyond level $C_{(y-r)}$, investment should proceed in seasonal housing up to the point where the expected cost of investment is just equal to the expected cost of supply failure (housing

[2] The normal distribution is implicitly assumed for this analysis.

type three -- emergency housing). This is achieved by investing in housing capacity of type two (seasonal housing) at level $C_{(s)}$, which satisfies condition (13).

Data

Data for this study was collected from three state funded projects in the state of Washington. San Isidoro Project represents a year-round housing complex located in Granger, Washington. Twenty-six housing units make up the project with a total occupancy up to 180 persons. The Diocese of Yakima Housing Services provided the data. The Diocese developed and manages the complex.

The Esperanza project, located in the area of Mattawa, Washington, represents a community-based, seasonally occupied housing project that is available to farm workers for six months out of the year. Migrant workers who are employed by local growers use this complex. Esperanza has 40 units that total 240 beds, and is open to both families and singles. Each unit consists of a 40-foot cargo container transformed into a 320 square foot home. Grant County Housing Authority provided capital construction costs and operating costs for the Esperanza project.

The Pangborn tent-camp located in Wenatchee provides temporary shelter to migrant farm workers during the cherry harvest. The basic concept was developed to house large numbers of farm workers engaged in short-term harvest activities. The practice of the camp is to operate for 21 days on a site. It is then torn down and moved to another site to make the best use of camp resources. The camp has 50 tents and its total occupancy is 300 people per site. North Columbia Community Action Council and the Office of Community Development in Washington provided the data.

Capital costs for the projects analyzed here are considered as annually recurring, non-use related (fixed) costs. They include construction and land costs. Operating costs are defined as use-related (variable) costs and are borne only if the housing unit is being used. Labor costs (management, maintenance and administration wages and benefits) are the bulk expense of the operating costs. Other items include water, electricity, sewer and garbage, maintenance costs etc. Capital and operating costs for the three projects are given in Table 2.

Results and Discussion

Marginal costs of the two first projects are inversely related as described in (7), with year-round housing as capital-intensive structures and seasonally occupied units as more operational cost-intensive. Capital costs for San Isidoro and Esperanza were amortized to obtain a constant annual cost that is equivalent to a present value cost. (The amortization factor is the reciprocal of the present value of an annuity of 1). The interest rate used in this case is 5 percent and the amortization factor (AF) is calculated as follows:

$$AF = \left(1-(1+r)^{-n}\right)/r \qquad (14)$$

where r denotes the relevant interest rate and n indicates the lifespan of the structures.

The operating costs for the Esperanza project were calculated on a 6 months per year period of operation. It is assumed that operating costs would be constant and thus would double if the facility were operated for a year instead of for 6 months. This allows the comparison of marginal operating costs between projects on an annual basis.

The tent camp is considered to be the emergency solution for demand in a peak year. Thus the tent camp represents the default or residual solution – meeting all demand not met by the two main alternatives. All costs are assumed to be borne in the peak-year and hence are treated as variable costs. The tent camp is used as a proxy for all other comparable emergency solutions such as trailers, cheap hotels, etc, and is meant to include all monetary and non-monetary social costs. The fact that social agencies will house people in inexpensive hotels suggests that the social cost of ad hoc solutions like sleeping in cars or parks is equal to the price of these hotels at the margin and the tent camps were found to have comparable costs. The cost per person for the tent camp was calculated by subtracting the cost of the reusable items from the total costs and assuming full occupancy of the camp. Estimates of the marginal costs of the three types of housing are given in Table 3.

The marginal efficiency conditions (12) and (13) allow for the construction of a cost-based efficiency frontier that demonstrates the combination of minimum marginal costs of housing at each level of marginal utilization in the state of Washington as shown in Figure 1. The efficiency frontier is represented by the red line in the diagram. The horizontal axis of the diagram indicates the expected marginal utilization of the total housing capacity as the amount of capacity built increases. At the points farthest left along the horizontal axis capacity is very low and so we are in the neighborhood of a certain event that the marginal unit of housing is going to be used in full. That is, the expected marginal utilization rate is 100 percent. Moving across from the left to the right, as the total level of investment increases and the capacity built increases, the expected marginal utilization of a given unit decreases, becoming zero at very high levels of investment. The vertical axis represents the expected total marginal costs of investing in farm workers housing:

$$(15) \qquad \left(n * b_j + b_j * \sum_{i=1}^{n} \Phi_i \left(C_{(,)} \right) \right)$$

where n denotes the number of periods that demand is divided into, and b_j and b_j indicate the capital and operating costs for each period for the j type of housing.

At the left of the diagram, where capacity is low and the utilization rate is high the expected costs are essentially 100% of the fixed and operating costs. At the far right of the diagram, where capacity is high and utilization rates approach zero, expected costs approximate the fixed costs only. Thus the slope of the line depends on the unit operating costs.

Specifically, when $n = 2$, as is the case for the base and peak seasonal demand in the labor market, the expected marginal costs will take the value of $(2 * b + 2 * b)$ on the left-hand side of the diagram, and decrease to $2 * b$ as the marginal utilization reduces to zero. The diagram indicates that where demand is certain and the level of investment is low, year-round structures are an efficient option since their expected costs are lower compare to those of the alternatives. However, as demand becomes increasingly uncertain, investment in seasonal structures becomes cheaper so that their slope decreases faster than the slope of the year-round structures ($b_s > b_{y-r}$). As the extreme right is approached, the marginal utilization becomes extremely low, suggesting that the use of the tent camps to satisfy emergency situation is the best alternative in these situations.

The graph shows that the projects considered in this study lie on the efficiency frontier. As might be expected, results suggest that year-round housing is the most efficient option and should be used to meet demand 84 percent of the time. Beyond that, investment in seasonal housing should follow about 16 percent of the time.

Consistent with the practice to date, tent camps emerge as an expensive alternative and must be used to satisfy only extra peak demand. Tent camps (emergency housing) should not be used more than 0.01 percent of the time according to the investment model. The kinks in the efficiency frontier correspond to the marginal utilization conditions described in equations (12) and (13).

Optimal Levels of Investment

Optimal (least-cost) levels of investment were calculated based on the historical distributions of the number of farm workers. Marginal efficiency conditions were solved for optimal investment capacity by using nonlinear equation solving software in the GAUSS Mathematical and Statistical System. Results for the state of Washington and five agricultural regions are reported in Table 4. The impact of increased variance is demonstrated in Table 5. In this table optimal levels of investment in year-round structures for the state are derived assuming different levels of variability. An increase in the coefficient of variation (from 0.3 to 0.6) induces an increase in the optimal level of investment in year-round housing of about 30 %.

Sensitivity Analysis With Respect to Expected Costs

The actual projects used as data in this analysis have been implemented for only a short time. Hence we cannot be certain of how representative these projects are. This suggests consideration of wider confidence intervals of the costs of the structures through sensitivity analysis. Changes in the actual costs can have a number of valid hypothesized sources, including changes in technology, minimum wage requirements, and market prices. Data from Table 6 demonstrate that the optimal mix is sensitive to cost assumptions and different optimal levels of investment are obtained as cost assumptions change. For instance, a decrease of capital costs up to 25 % (for example, changes in technology) or an increase of 25 % in operating costs would favor an increase in the ratio of the year-round structures up to 87-88 percent of the time. This change would be accompanied by an increase of 3-3.6 percent in the optimal level of total investment. The opposite outcome would occur with an increase in the capital costs or a decrease in the operating cost. In these cases a shift of the expected marginal utilization towards the left of CDF causes a decrease in the optimal levels of investment.

For a specific application, consider the case when farm workers have families. In our analysis to this point, we have assumed that all housing occupants are workers. The implicit assumption might be that all migrant workers are single males. If contrary to this assumption some workers have dependents, then the number of spaces required per worker would increase. In effect, this means that the cost of housing each worker goes up in proportion to the ratio of total occupants to workers. A change of this sort would affect the investment ratio in favor of seasonal structures and increase the optimal level of the latter up to 5 %. Essentially the opposite results would occur if workers occupied fewer spaces than one each. In some migrant worker situations, workers may share beds where differences in "shifts" mean that workers sleep at different times. Thus, six workers might be housed in space for four. This situation would lower investment costs along the lines discussed above. This later case is more likely for processing sector workers then for field workers. Changes in the cost of the tents, more specifically a decrease of 50 percent in the costs will cause a substitution away of the seasonal structures in favor of the tents in about 9.4% of the optimal investment.

Sensitivity Analysis With Respect to Discount Rates

Effects of different discount rates on the capital costs for year-round housing are given in Table 7. Reducing the discount rate to 3 percent (from 5 percent) has an effect similar to that of an increase in the operating costs as illustrated by the data in Table 7. Reducing the interest rate also lowers the capital costs of the structures and moves the expected marginal utilization to the right of the CDF. The result is an increase in the level of optimal investment in year-round structures of about 5 percent. The opposite impacts occur for a higher discount rate of 8 percent. The increase in interest rate raises the capital costs and leads to a replacement away from the year-round structures in favor of seasonal structures, lowering the optimal levels of investment.

Summary and Conclusions

Agriculture in Washington State and elsewhere is dependent on farm workers who work the field and harvest the crop. Lately, there has been a growing concern for adequate housing for these workers. Both growers and farm workers agree that housing is necessary to attract and support a sufficient labor force. Thus, housing could be a short-to-medium run stabilization policy instrument in potential cases of labor shortages. However, building housing implies potentially non-competitive levels of expenditures for growers. For farm workers, housing in the private market would be a high portion of their income. In the light of the lack of investment from the private sector as well as the difficulty for farm workers to pay market rate rents, Washington State began undertaking different housing projects – ranging from permanent, capital-intensive structures to seasonal housing, to emergency tents. This means that the question of the right combination of types of housing and the optimal levels of investment in each category becomes an important public policy investment question.

This study presents an investment model that determines the optimal mix of technology and capacity choices by applying a peak-load model to data from three state funded projects. In order to perform this analysis, we had to extend existing models of the peak load investment problem to the case of multiple seasons within a planning cycle. The general peak load literature assumes one peak over the planning cycle – often one year. In the case of housing we faced a multi-dimensional peak load problem. First, there were changes in demand over the course of the planning cycle, and second there were changes in demand from year to year (planning cycle to planning cycle). To address this problem we divide the planning cycle into seasons and solved for an investment solution that would meet the peak demands in each season, given that the two seasons interact. This approach enhances the applicability of the model to many other circumstances.

The empirical results of this study indicate that least cost investment would be mainly in two types of projects. Investment in year-round housing should be made to meet most of the demand for housing – covering all employment about 84 percent of the time. Seasonally occupied housing is also an efficient and important option in addressing the needs for housing of migrant workers especially in areas where employment lasts several months out of the year. Investment in this type of housing should be made to cover about 16 percent of the time.

In our results, the emergency housing represented by the tent camp is a cost-effective way of providing housing only for the short, labor-intensive crops. cherry harvest might be such a case. However, it would not be a least cost option to meet demand for housing for crops like apples that would require longer use of the camp. Specifically, the results suggest investment in emergency housing for a very small amount (about 0.01 percent) of the time to meet extreme cases of peak demand. Interestingly, these results agree with practice – a very small number of emergency housing units are currently provided. However, the fact that some farm workers end up "housed" in parks and cars should be noted. The car and park solution is a rational outcome from the point of view of the private costs to growers and to workers, but it does not take into account external, social costs. If we assume that the monetary costs of tent housing is a reasonable proxy for the total social costs of housing farm workers, then the rate at which workers are currently "housed" in parks and cars is socially inefficient. This situation suggests an interesting and important collateral research project to analyze the social costs of housing migrant workers in non-standard places. It is also interesting to note that the cost of temporarily housing workers in tents is approximately the same as housing them in low cost private units such as motels. This suggests that the tent cost may, in fact, approximate the social cost of housing if the social allocation system for housing is taken to be in equilibrium between housing migrant workers in low cost hotels versus non-standard units such as cars and parks.

Given that our analysis is based on costs taken from three case studies, it is important to look at the effects of changes in cost assumptions. Our cases may not represent true expected capital and operating costs. Moreover, there are a number of unknown elements in how housing is used where we had to adopt reasonable, but specific assumptions (example: the occupancy or turnover rate). Therefore, sensitivity analysis was pursued. Sensitivity analysis on the capital and operational costs showed that uncertainty as expressed by variability of demand affects not only the ratio or mix of technology, but also the optimal levels of capacity. An increase in the variance will cause an increase in the level of optimal investment. The optimality of this investment strategy is fairly robust as demonstrated by its stability across the variety of different cost assumptions that were investigated.

This appears to be the first study to examine investment decisions for farm worker housing. Models that provide policy makers with empirical estimates on optimal investment concerning farm workers' housing are not available, probably partly because of data limitations, but also because of a lack of appropriate analytical models. We introduced the peak-load model as an appropriate means to work around these data deficiencies and we applied the available data to derive optimum investment in the presence of diverse housing technology. We should note that the present study clearly simplifies the housing problem. For instance, the issues of size and location of structures are not considered. Still results from this study should prove helpful to the efforts of the state to resolve housing shortages for farm workers in Washington. In particular, the results provide useful insight into the short run optimal levels and mix of investment. Region specific details and priorities should be considered when applying these results in practice.

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TABLE 1. Summary Statistics of the Number of Farm Workers in Washington State for Off and Primary Season Demand, 1994-98.

Region	Off-Season Demand (November-April) Mean	Off-Season Demand (November-April) Standard Deviation	Primary Season Demand (May-October) Mean	Primary Season Demand (May-October) Standard Deviation
Western	2294.5	812.6	5504.8	2330.8
South Central	5864.4	1634.2	17981.8	6068.6
North Central	4230.4	1322.4	14603.5	5932.2
Columbia Basin	2623.9	825.9	7242.6	2225.8
South Eastern	3556.63	1941.4	10029.7	3394.7
State	18707.1	5728.9	54990.7	13577.6

TABLE 2. Construction and Operating Costs for San Isidoro, Esperanza and Pangborn Camp Projects

Project	Capital Construction Cost/Unit ($)	Annual Operating Cost/Unit ($)	Occupancy (Persons)	Life (Years)
San Isidoro	89,715.00	1640.00	180	50
Esperanza	27,279.00	2014.00	240	25
Pangborn Camp	-	12,408.00	3600	-

TABLE 3. Marginal Costs of Investment in Year-Round Housing, Seasonal Housing and Tent Camp in Washington State

Project	Marginal Capital Costs ($/person/year)	Marginal Operating Costs ($/person/year)	Total Marginal Cost ($/person/year)
San–Isidoro (Year-Round)	27.29	234.28	261.57
Esperanza (Seasonal)	8.07	352.33	360.40
Pangborn Camp (Emergency)	0	12,408.00	12,408.00

TABLE 4. Optimal Levels of Investment in Farm Worker Housing for Five Agricultural Regions and the State of Washington

Regions	C.V.* Off and Primary Season Demand	Level of Investment Year-Round Structures (persons)	Level of Investment Seasonal Structures (persons)
Western	0.35; 0.42	7,796	5,182
South Central	0.35; 0.34	23,947	13,497
North Central	0.31; 0.41	20,434	13,183
Columbia Basin	0.31; 0.30	9,430	4,950
South Eastern	0.55; 0.34	13,366	7,548
State	0.29; 0.25	68,337	30,129

*Coefficient of Variation

TABLE 5. The Effect of Uncertainty on the Level of Optimal Investment for Year-Round and Seasonal Housing for the State of Washington

Coefficient of Variation* During Off and Primary Season Demand**	Optimal Investment (Y-R) (persons)	Optimal Investment (S) (persons)
0.6	87,422	73,174
0.5	82,016	61.028
0.4	76,611	48,872
0.3	68,337	30,129

*Coefficient of Variation (C.V.) is assumed equal for both the base and the season demand.
**Mean level for the base demand is 18,707.00 and mean level for season is 54,991.00

TABLE 6. The Effect of Alternative Cost Assumptions on the Optimal Level and Mix of Housing*

Cost Assumptions	Optimal Investment In Year-round Housing (persons)	Optimal Mix of Investment (%)	Change in Optimal Level (%)
Base Case Level	68,337 30,129	(84):(15.99):(0.01)	0 0
Operating Costs Increase 25 %	70,268 29,136	(87):(12.99):(0.01)	3 -3.3
Operating Costs Decrease 25 %	65,609 31,768	(78):(21.99):(0.01)	-4 5
Capital Costs Increase 25 %	66,248 31,379	(80):(19.99):(0.01)	-3 4
Capital Costs Decrease 25 %	70,802 28,849	(88):(11.99):(0.01)	3.6 -4
Only Tent Costs Decrease 25 %	68,337 29,002	(84):(15.99):(0.01)	0 -3.7
Only Tent Costs Decrease 50 %	68,337 27,295	(84):(15.98):(0.02)	0 -9.4

*Mean and C.V. are the historical levels for the state.

Notes: 1. Number of year-round and seasonal units respectively
2. Ratio of units of year-round to seasonal to emergency units

TABLE 7. Sensitivity of Optimal Investment in Year-Round Housing to Changes in the Discount Rate*

Year-Round Housing	Discount Rate (%)	Change in Capital Costs/Person (%)	Optimal Investment (persons)	Change in Optimal Level of Investment (%)
Base Case	3	-29	71,733	5
	5	0	68,338	0
	8	49	63,941	-6
	10	84	61350	-10

* Mean and C.V. are the historical levels for the state

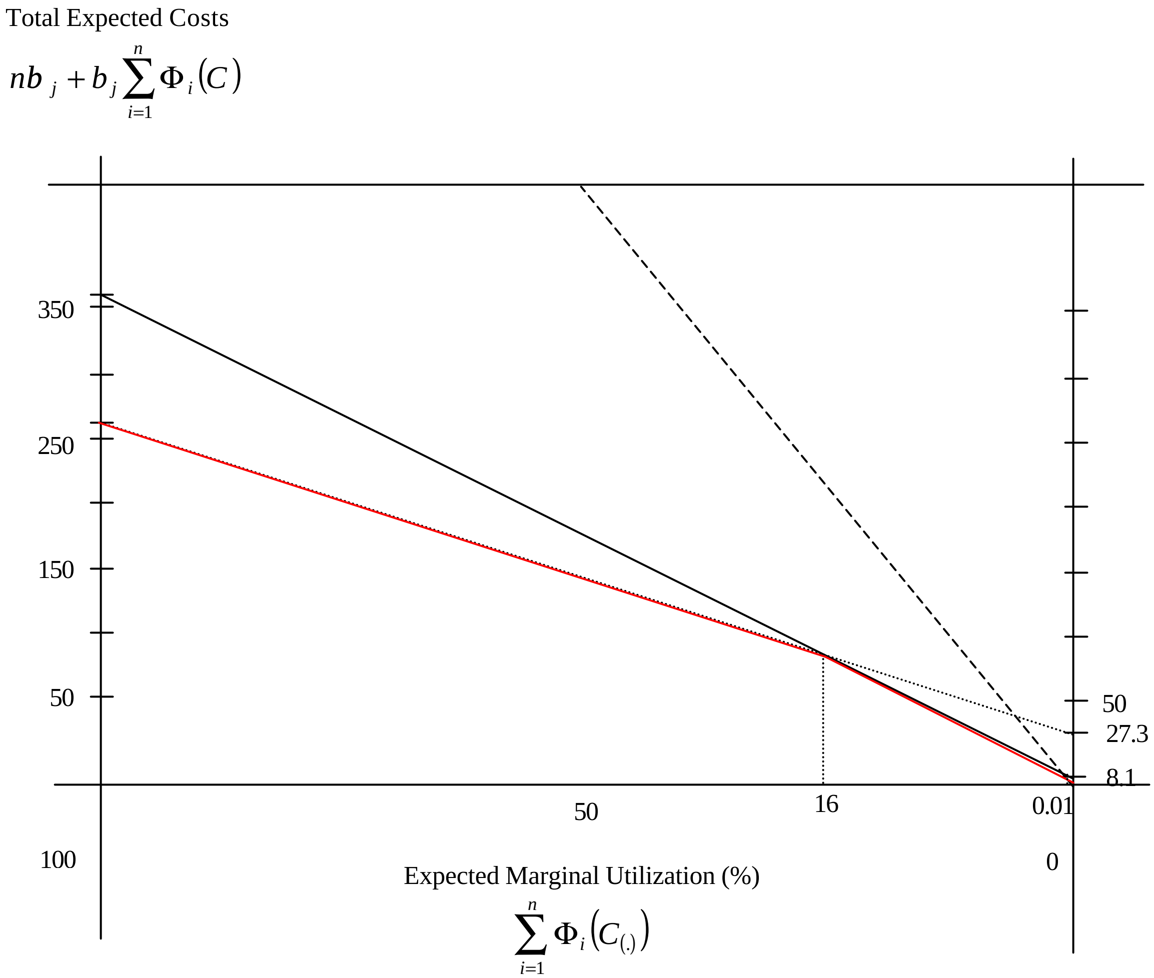

FIGURE 1. Efficiency frontier of the optimal combinations of technology in farm worker housing.