Calculating shadow wages for family labour in agriculture: An analysis for Spanish citrus fruit farms

Andrés J. PICAZO-TADEO
Ernest REIG-MARTÍNEZ

Cahiers d'économie et sociologie rurales, n° 75, 2005

Andrés J. PICAZO-TADEO*, Ernest REIG-MARTÍNEZ**

Calcul des prix virtuels du travail familial en agriculture : une application aux producteurs d'agrumes en Espagne

Résumé – Cet article s'intéresse au calcul des prix virtuels du travail familial en agriculture. En utilisant l'existence d'une dualité entre la fonction de distance d'inputs et la fonction de coût, nous employons la première pour dériver les prix virtuels individuels du travail pour un échantillon des producteurs espagnols d'agrumes. Nos résultats prouvent que le prix virtuel moyen, c'est-à-dire le coût d'opportunité du travail familial employé dans la ferme, est inférieur au salaire horaire moyen du marché payé pour le travail loué. Nous rapportons ce résultat à une stratégie de l'externalisation de beaucoup de tâches de culture actuellement poursuivie par les fermiers pour surmonter le problème posé par une taille moins qu'optimale de ferme.

Mots-clés : prix virtuels, dualité, fonction de distance, coût d'opportunité de travail dans la ferme, externalisation

Calculating shadow wages for family labour in agriculture : An analysis for Spanish citrus fruit farms

Summary – *This paper deals with the calculation of shadow wages for family labour in agriculture. Using the existence of a duality between input distance and cost functions, we use the former to derive individual labour shadow prices for a sample of Spanish citrus fruit producers. Our results show that the average shadow price representing the opportunity cost of family labour employed on-farm, is lower than the average market wage rate paid for hired labour. We relate this finding to a strategy of outsourcing of many growing tasks that is currently pursued by farmers to overcome the problems posed by a suboptimal farm size.*

Key-words : *shadow prices, duality, distance functions, on-farm labour opportunity cost, outsourcing*

* *Universitat de València, Dpto. Economía Aplicada II, Avda dels Tarongers s/n., 46022 Valencia (Spain)*
e-mail : Andres.j.picazo@uv.es
** *Universitat de València and Instituto Valenciano de Investigaciones Económicas, Guardia Civil, 22, 46020 Valencia (Spain)*
e-mail : Ernest.reig@wo.es

The statistical information has been made available to the authors by the Regional Agricultural Board of the Valencian Government. We thank the agronomic experts of the Board for their help in the preparation of the data, and the Spanish Ministry of Science and Technology for the financial aid received (project AGL2003-07446-C03-03). We also gratefully acknowledge the suggestions and comments offered by two anonymous referees. The usual disclaimer applies.

THE small size of farms is a persistent phenomenon in the organisation of agriculture in developed countries. Prevailing farm size has most often been contemplated as **suboptimal** and in connection with inefficient use of resources in agriculture. In fact, many farms are too small even to fully employ the available family labour, forcing a part-time strategy to achieve sustainable income levels. But the **efficiency** issue has to be contemplated in a wider setting, taking into account that farm demands on farm households' resources are frequently competing with demands from off-farm activities (Schmitt, 1991).

Family labour is usually the most important cost item for small farms. Without taking transaction costs into account, the farmer will allocate optimally his own and his family's labour when marginal labour product equals the wage rate that represents opportunity costs of farm labour. But it is not clear which wage rate should be considered representative of labour opportunity costs. Agricultural household literature provides an analytical framework to treat family's labour shadow price (see Singh *et al.* (1986) for a good formal introduction). This literature has pointed out that the household's utility could depend not merely on the household's total labour supply but on its allocation between on-farm and off-farm employment. This would be the case if farmers have a clear preference for self-employment as opposed to a wage-earning activity. Also, transactions costs and the need to supervise hired labourers can prevent household labour and hired labour being perfect substitutes in production. The shadow price of on-farm household work could therefore be exogenously determined only under unrealistic assumptions, as equal either to the off-farm rate or to the hired labour wage rate (López, 1986). Consequently, in many cases an endogenous **shadow** wage rate must be computed, according to farm production technology, output and input prices.

Understanding the existence of an endogenous wage for the household's labour permits a better assessment of the consequences of policy interventions aimed at increasing farm output prices, particularly in the case of developing countries. If output prices increase, for example, the shadow price of on-farm labour will also increase, altering the farm household's decisions on consumption and labour supply allocations (López, 1984). The **neo-classical** farm-household model has also been used to assess the impact of farm policy reform – *e.g.*, the 1992 Common Agricultural Policy reform – on farmers' behaviour in industrialized countries, through the changes induced in its reservation wage by the use of the new policy instruments (Benjamin, 1996).

The **endogenous shadow wage** represents the opportunity cost of time for self-employed farmers and is determined from within the household. The household's capital assets – particularly size and quality of farmland and endowment of skilled and unskilled labour – can be used as predictors of this shadow wage. Farm households will develop different labour market participation strategies, according to their asset position and to the relationship between hired wage rate, off-farm market wage rate and shadow wage, which in turn is largely influenced by transactions costs in labour markets. Some households will be selling labour services, others hiring salaried workers, others being self-sufficient with labour resources of their own, and finally some will be operating with a combination of hired labour and family on-farm labour (Sadoulet *et al.*, 1998). Proportional transaction costs – such as costs of accessing markets owing to transportation and imperfect information – and fixed ones – such as costs of screening and supervision of hired labour – can both heavily influence the household's decision to enter or leave factor and product markets and – as has been empirically demonstrated – aggregate supply elasticities (Key *et al.*, 2000).

Consequently, computation of the farm-level labour shadow price acquires great importance for understanding the determinants of household labour supply, and also to analyse the rationality of different market participation strategies within a given farming system. Computed household shadow wage rates have also been compared with off-farm wage rates and hired farm labour wages, to test the interdependence between the household's utility and profit-maximizing decisions, under the assumption that rejecting the equality of virtual, or implicit, wages and exogenous market wages would amount to a rejection of separability between farmers' consumption and production decisions (Sadoulet, 2001). Pricing the time employed by household members in running the farm is also of interest in order to ascertain the profitability of farm's fixed assets and the way it changes with farm size or other relevant variables.

Most of the attempts to estimate farmers' own labour shadow wages have used a production function approach to obtain the marginal product of labour. Jacoby (1993) calculated the marginal productivity of adult male and female farm labour for each household, using a sample of households in the Peruvian highlands. Then, household labour supply parameters were recovered from variation in these shadow prices. Skoufias (1994) estimated shadow wages and shadow income using panel data on household inputs and outputs from six villages in India. The estimated shadow wages and income were then matched with individual time allocation data and household-specific characteristics. His results rejected the equality of marginal products and the observed wages, lending support to the hypothesis of non-separability between production and consumption decisions of farm households. Some potential explanations were advanced: employment constraints in the rural labour market and/or commuting costs associated with wage work.

Elhorst (1994) modeled the production side of an agricultural household model by using a quadratic functional form for the profit function and making use of **Hotelling's lemma** to study output supply and variable input demand. The empirical analysis was based on cross-section data for Dutch dairy farms, with observations belonging both to the milk pre-quota and post-quota period. The marginal product of on-farm labour was defined as the amount of money by which farm profit would rise if on-farm labour input rose by an hour. It was concluded that this on-farm labour shadow wage was substantially smaller than the market wage rate. But it was also ascertained that farm profit elasticities calculated from a single production model and a relatively complex agricultural household model were similar, so the results were inconclusive concerning the usefulness of coupling or not coupling the consumption and production parts of the model.

The discrepancy between shadow and market wages has been used to give empirical content to farmers' specific preferences for working on-farm. Using data from two French surveys, it has been found that implicit on-farm wages are below off-farm wages for both males and females in farm households (Fall and Magnac, 2004). These authors also estimate medians of lower bounds for preference parameters, providing evidence of a significant taste for working on-farm. They suggest that observed specific tastes can be explained in a dynamic setting if both wages were closer at the beginning of farmers' professional careers and sunk-cost investments in human capital at this time became irreversible afterwards, as wages drifted away.

Within this theoretical framework, in this paper we compute shadow prices for family labour in Spanish citrus fruit farms. The goal of the paper is twofold. First, we wish to compare shadow prices for family labour with the market wages that are paid to contracted labour teams. Additionally, we show the usefulness of a method of computing individual farms' **shadow wages**, based on duality microeconomics and mathematical programming, which can be employed when sample size precludes the use of econometric techniques. Our hypothesis is that market wages should display a positive differential, arising from higher efficiency in labour use and also reflecting superior skills in performing specialized tasks on the part of external workers. The empirical results we obtain seem to confirm this view, as they show that farm market wages are higher than computed shadow wages. If that is the case, some relevant questions can be asked of policy-makers. Instead of wasting time in vain attempts to make citrus production structures conform to the family farm model, by pursuing an increase in the average size of farms, more attention should be paid to the efficiency of those service firms that are effectively in charge of performing basic cultivation tasks.

The paper is organized as follows. In the following section, we briefly explain basic aspects of the methodology. The data are then described, and the results discussed. Finally, we conclude.

Methodology: Input distance functions and shadow prices

In order to briefly describe the main insights of the methodology, let us consider a productive process that uses a vector of inputs x to produce a vector of outputs y. The technology of reference is given by the **input requirement set** $L(y)$ that represents all input vectors that produce at least an output vector y. It is assumed that the technology satisfies the standard axioms initially proposed by Shephard (1970) (see also Grosskopf, 1986). These properties include the possibility of inaction, no free lunch, free disposability of inputs and strong disposability of outputs.

The **input distance function** measures the maximum attainable radial contraction of a given vector of inputs such that the resulting input vector remains within the input requirement set L(y). This function is equivalent to the reciprocal of the input-oriented efficiency measure of Farrell (Farrell, 1957; Färe and Lovell, 1978) and is formally defined by Shephard (1970) as:

$$D_I(y,x) = \text{Sup}\,[\mu : (x/\mu) \in L(y)], \tag{1}$$

where $\mu \geq 1$, given that $x \in L(y)$ if and only if $D_I(y,x) \geq 1$.

Making use of the duality theory, under certain assumptions the input distance function can be used to derive input shadow prices. There exists a duality between the cost function and the input distance function, such that the former can be expressed as:

$$C(y,p) = \text{Min}_x\,[px : D_I(y,x) \geq 1], \tag{2}$$

px being the inner product of input prices and quantities vectors.

The **dual input distance function** is given by:

$$D_I(y,x) = \text{Min}_\rho\,[\rho x : C(y,\rho) \geq 1], \tag{3}$$

where ρ are **cost-normalized** prices (see Färe and Grosskopf, 1990).

Assuming that the cost and input distance functions are both differentiable and making use of **Shephard's dual lemma** (see Jacobsen, 1972), the ratio between the shadow prices of inputs i and j can be computed as the quotient between the partial derivatives of the input distance function with respect to those inputs (for details see Färe and Primont, 1995, pp. 54-59):

$$\frac{p_i}{p_j} = \frac{\partial D_I(y,x)/\partial x_i}{\partial D_I(y,x)/\partial x_j} \tag{4}$$

Under the assumption that there is at least one input optimally allocated, *i.e.*, the observed price of market input j equals its shadow price p_j, the shadow price of input i can be computed from expression (4) as follows:

$$p_i = p_j\,\frac{\partial D_I(y,x)/\partial x_i}{\partial D_I(y,x)/\partial x_j} \tag{5}$$

Finally, in order to obtain shadow prices the input distance function needs to be parameterized and estimated by econometric methods or computed using goal programming techniques.

Other studies have computed shadow prices making use of similar methodologies. Färe *et al.* (1993) pioneered this line of research using an output distance function approach to calculate shadow prices for undesirable outputs generated by thirty paper and pulp mills operating in Michigan and Wisconsin. Coggins and Swinton (1996) computed shadow prices for sulfur dioxide emissions of coal-burning electric plants in Wisconsin. Piot-Lepetit and Vermersch (1998) use the duality between the cost and distance functions to derive a shadow price for inorganic nitrogen produced as a by-product of animal breeding for a sample of French pig farms. Hailu and Veeman (2000) have also performed this type of analysis, dealing with the calculation of shadow prices of **undesirable** outputs for the Canadian pulp and paper industry. Reig-Martínez *et al.* (2001) also estimated an output distance function to calculate the shadow price of **bads** generated in the Spanish ceramic tile industry. These shadow prices were used to construct an environmentally adjusted index of productivity, which was then compared with conventional productivity indices. Finally, in a recent paper, Lee *et al.* (2002) estimate the shadow prices of pollutants through a nonparametric directional distance function approach, including in their analysis the inefficiency involved in the production processes.

The data

The dataset used in this paper has been built from the comprehensive *Survey on Input Use by Farms*[1] gathered in 1997 by the Spanish Ministry of Agriculture, Fishery and Food. The data are restricted to citrus fruit farms operating in the Region of Valencia, which is the main producing and exporting area of the Mediterranean Basin, accounting for over 70 per cent of Spanish citrus fruit production. The Regional Government Board of Agriculture has made the original individual poll forms available to the authors. After eliminating multi-crop farms, observations with missing data and, finally, citrus farms that were not in full production, *e.g.* new-tree plantations, our set of data reached a size of twenty one single crop full production citrus farms.

Output is measured in kilograms of citrus fruit production. The only fixed input is cultivated land (hectares). Variable inputs are: own and hired labour (both measured in annual worker units or AWU), capital (annual hours of use of agricultural machinery), consumption of nitrogen (in kilograms) and, finally pesticides expenditure (in euros). Own labour input sums up the farmer's and his family's on-farm labour, while capital includes hours of use of own and hired machinery and equipment. In relation to the use of chemical products, different commercial fertilizers are in use, with chemical formulae that mix nutrients in different proportions. Agronomic experts from the Valencian Regional Agricultural Board assisted us in translating commercial fertiliser weights into basic nitrogen units. Finally, lack of information on physical quantities led us to measure pesticide input in monetary units. Table 1 reports some descriptive statistics of the data.

Table 1. **Sample description**

Variable	Description	Units	Mean	Standard deviation
y	Citrus fruit production	Kg	92,594	98,787
x_1	Land	Ha	6.54	11.25
x_2	Own-family labour	AWU	0.77	0.49
x_3	Wage-earning labour	AWU	0.53	0.62
x_4	Capital	Hours of use of machinery	634	1,015
x_5	Nitrogen	Kg	2,419	4,949
x_6	Pesticides	Euro	4,417	9,986

---

[1] *Encuesta sobre Utilización de Medios de Producción en la Explotación Agraria*

Empirical specification and results

In our empirical specification, we have parameterized the **input distance function** as a **translog** function. This functional form was initially proposed by Christensen *et al.* (1973) and has the desirable property of being a flexible function that can be easily computed, allowing the imposition of theoretical restrictions. Formally, the **translog** input distance function is defined as:

$$\ln D_I(y, x) = \phi + \sum_{n=1}^{6} \beta_n \ln x_n + \alpha_1 \ln y + \frac{1}{2} \sum_{n=1}^{6} \sum_{n'=1}^{6} \beta_{nn'} (\ln x_n)(\ln x_{n'}) + \alpha_{11} (\ln y)^2 + \gamma_{n1} \sum_{n=1}^{6} (\ln x_n)(\ln y) \quad (6)$$

This input distance function can either be econometrically estimated if sufficient data are available, or **calculated** making use of mathematical programming methods when the sample size is small. The mathematical programming approach to computation of distance functions constitutes a flexible method that allows restrictions of equality and also of inequality to be imposed very easily (see Aigner and Chu, 1968). However, the main shortcoming of this technique is that it does not provide measures of goodness of fit, preventing the testing of hypotheses. Unfortunately, our sample size renders the econometric approach infeasible and, therefore, the distance function has been calculated by goal programming techniques[2]. The main implication of this restriction is that the statistical robustness of the difference between computed shadow family labour wages and observed market wages cannot be tested[3].

---

[2] From a theoretical point of view, there are several potential solutions to this problem. Probably the most obvious would be to estimate by econometric methods a function with fewer parameters, *e.g.* a Cobb-Douglas production function (see Jacoby, 1993), instead of maintaining an input distance approach based on a **parameter-rich** translog functional form. Secondly, maintaining the input distance approach as well as the translog functional form, bootstrapping procedures could be performed to compute confidence intervals for calculated shadow wages (Efron, 1979; also see Ziari and Azzam, 1999). In our empirical application all of these solutions failed to obtain meaningful results due to the characteristics of our sample. Particularly, a sample size of only 21 observations, in addition to the low observed variability of some of our exogenous variables, precludes accurately estimating, *i.e.*, with smaller variance, the parameters of a Cobb-Douglas production function.

[3] This is a very common problem in the literature which, however, does not in general invalidate the results of studies that have calculated shadow prices with small samples using a distance function approach and goal programming methods. This is the case of the pioneering paper by Färe *et al.* (1993), which analysed a sample of 30 paper and pulp mills. Other references are: Coggins and Swinton (1996) – 14 coal-burning electric plants with panel data for 1990-92; Hailu and Veeman (2000) – 36 industry aggregate time series data for the period 1959-94; and also Reig *et al.* (2001) – 18 Spanish ceramic firms.

In essence, the aim of our mathematical programming is to minimize the sum of the deviations from zero of the log of the distance function. Particularly, the parameters on which expression (6) depends have been computed as the solution of the following optimization program[4]:

$$\mathrm{Min}_{(\phi,\beta,\alpha,\gamma)} \sum_{k=1}^{21} \ln \mathrm{D}_I\,(y^k,x^k) \qquad (7)$$

subject to:

$$\ln \mathrm{D}_I\,(y^k,x^k) \geq 0 \qquad k = 1,\dots,21 \qquad \text{(i)}$$

$$\frac{\partial \ln \mathrm{D}_I\,(y^k,x^k)}{\partial \ln x_n^k} \geq 0 \qquad n = 1, \dots,6; \qquad k = 1, \dots, 21 \qquad \text{(ii)}$$

$$\frac{\partial \ln \mathrm{D}_I\,(y^k,x^k)}{\partial \ln y_m^k} \leq 0 \qquad m = 1; \qquad k = 1, \dots, 21 \qquad \text{(iii)}$$

$$\left\{ \begin{array}{l} \sum_{n=1}^{N} \beta_n = 1 \\ \\ \sum_{n'=1}^{N} \beta_{nn'} = 0 \\ \\ \sum_{n=1}^{N} \gamma_{nm} = 0 \end{array} \right\} \qquad n = 1,\dots, 6; \quad n' = 1, \dots, 6; \quad m = 1 \qquad \text{(iv)}$$

$$\beta_{nn'} = \beta_{n'n} \qquad n = 1,\dots, 6; \quad n' = 1,\dots, 6 \qquad \text{(v)}$$

where k denotes farms, n denotes inputs and m output.

The set of restrictions in (i) guarantees that the estimated distance function identifies input-output observations as feasible, *i.e.*, each observation is located within the technology of reference. The restrictions contained in (ii) ensure the input distance function to be non-decreasing in inputs, while constraints in (iii) are needed for the distance to be a non-increasing function of output. Finally, restrictions in (iv) ensure the linear homogeneity in inputs of the distance function, and constraint (v) imposes symmetry.

---

[4] The program has been written and solved using GAMS software.

Our sample size and the characterization of the input-output relationship of citrus fruit farms determined a minimization problem subject to 191 restrictions. In particular, there are 21 restrictions relative to the feasibility constraint, 147 monotonicity restrictions (126 related to inputs and the remaining 21 associated with output), 8 conditions of linear homogeneity and, finally, 15 symmetry constraints, all of them related to inputs. Table 2 shows the calculated parameters of the **translog** input distance function.

Table 2. **Translog input distance function parameter estimates**

Parameters		Parameters	
ϕ	-12.814	β_{26}	0.000
β_1	-0.466	β_{33}	-0.049
β_2	-0.286	β_{34}	0.000
β_3	-0.800	β_{35}	0.096
β_4	0.000	β_{36}	0.000
β_5	2.552	β_{44}	0.000
β_6	0.000	β_{45}	0.000
α_1	1.225	β_{46}	0.000
β_{11}	0.026	β_{55}	-0.022
β_{12}	0.060	β_{56}	0.000
β_{13}	-0.059	β_{66}	0.000
β_{14}	0.000	α_{11}	-0.036
β_{15}	-0.027	γ_{11}	0.095
β_{16}	0.000	γ_{21}	0.055
β_{22}	-0.024	γ_{31}	0.025
β_{23}	0.012	γ_{41}	0.000
β_{24}	0.000	γ_{51}	-0.176
β_{25}	-0.047	γ_{61}	0.000

Individual farms' input distances have been computed using these parameters. On average, input distance takes a value equal to 1.631. It is well known that the input distance function is the inverse of Farrell's inputs technical efficiency index, whose average value is 0.613. In other words, this means that – given the restrictions imposed by technology – by making an efficient use of their resources the farms in the sample would be able to maintain their production using only 61 per cent of the inputs they actually use.

There are six fully efficient farms, *i.e.*, those with an input distance equal to one. The high levels of inefficiency computed should not come as a surprise, since they agree with the results obtained by other studies of Spanish citrus fruit agriculture (Picazo-Tadeo and Reig-Martínez, 2002; also see Reig-Martínez and Picazo-Tadeo, 2004).

In order to calculate the shadow wage of family labour, we have used expression (5) on the assumption that the observed market price of hired labour equals its absolute shadow price[5]. The market price of hired – or wage-earning – labour has been computed dividing monetary expenditure by salaried AWU. Table 3 shows the computations for shadow prices as well as wage-earning labour observed prices. Sample means, medians and standard deviations are also reported. On average, the computed shadow price for family labour equals 5,212 euros per AWU. Likewise, we find that own labour shadow wages estimates differ significantly among farms, as the high standard deviation reveals. This result has also been observed in other studies, which have found important differences among individual firms' shadow prices for inputs or undesirable outputs (see Färe *et al.*, 1993). Here, shadow wages are positive for seventeen farms, while for the remaining four they take a value equal to zero[6]. The presence of zero shadow prices makes medians preferable to averages for comparing market wages to shadow wages. In this case, the median of the distribution of shadow wages of own-family labour is equal to 1,844 euros per AWU, a figure considerably lower than the median of the market wages distribution (7,572 euros).

Table 3. **Own labour shadow prices (euros per AWU)**

	Market observed price of wage-earning labour p_{x3}	Shadow price of own-family labour p^*_{x2}
Mean	7,603	5,212
Median	7,572	1,844
Standard deviation	1,970	6,694
Maximum	12,186	22,886
Minimum	3,720	0

Concerning the economic interpretation of these results, differences between family labour shadow wages and the market wage can arise from a wide range of circumstances, as has been indicated in the introduction. Farmers may have a preference for working on their own farm rather than in off-farm jobs, or they may simply implicitly calculate transport costs and other expenditures associated with off-farm jobs. Institutional restrictions – like minimum working hours – may also limit the range of choice of working time off-farm. Another possible explanation would be an imperfect substitutability between hired labour and family labour.

---

[5] The formula used to obtain shadow prices should be evaluated at the technically efficient frontier of the technology of reference, since cost minimisation requires the firm to be technically and allocatively efficient. Nevertheless, in practice there are no differences between the shadow prices computed at the actual observation and the shadow prices calculated at its technically efficient radial projection. The reason for this is that, due to the linear homogeneity in inputs of the input distance function, the ratio of input derivatives in expressions (4) and (5) is homogeneous of degree zero in inputs.

[6] Drawing the inputs requirement set so that own family labour is on the vertical axis, a zero shadow price points to a farm operating on the horizontal segment of the isoquant, where the marginal rate of substitution between wage-earning labour and own labour equals zero. In these circumstances, the right hand side of expression (5) equals zero and so does the shadow price of own-family labour.

We believe that, besides farmers' preferences for working on their own farm, some special features of the regional citrus fruit labour market lend support to the hypothesis of imperfect labour substitutability. Spanish citrus farms are very representative of the type of small sized productive units operating in a regional economic environment where there are plenty of opportunities for part-time farmers using their labour in off-farm activities – whether as wage-earners in the farming sector or in services or industrial activities. The prevailing source of off-farm income varies according to the economic status of the farmer. Relatively well-off farmers get income from industry or services employment. With a farm size of less than four hectares, farmers usually get wages from the agricultural labour market, while with less than one hectare farmers obtain most of their income as salary (Arnalte *et al.*, 1990). This agricultural labour market does not apparently present any rigidities – minimum quantities or fixed time schedules – that could hinder off-farm labour supply.

Part-time farming can be accommodated with the employment of wage labourers on the farm when there is a gap between agricultural and non-agricultural wages. This is a clear theoretical possibility (Gorgoni, 1980; Sadoulet *et al.*, 1998) and also an empirical observation in Spanish citrus farming (Arnalte, 1980; Arnalte and Estruch, 2000). A strategy of **externalisation** – or **outsourcing** – of many growing tasks (phytosanitary treatments, pruning or fertilisation, among others) has been adopted by citrus farmers in Spain as a way of overcoming the negative effect on costs of the small size of most farms and, at the same time, freeing them to secure a more profitable use of their labour time. Specialized tasks are contracted with services firms or local labour teams, equipped with their own implements or machinery. Harvesting operations are also executed by trading firms or by cooperatives that contract and manage the required labour force. As a consequence, the scale of productive processes is no longer constrained by the dimension of individual farms, and the fragmented structure of agricultural holdings ceases to be an insurmountable barrier to economic rationalization. The farmer's economic profile also changes accordingly and he becomes a manager, mainly involved with key decisions on choosing product varieties and buyers, and progressively less acquainted with farming techniques. As an illustrative figure, less than 7 per cent of citrus farmers devote more than 50 per cent of their working day to their own farm (Arnalte and Estruch, 2001) and most of the small citrus landowners earn wage income from employment in the regional agricultural labour market or, increasingly, in services or industry. All these characteristics make it difficult to classify Spanish citrus farming within the **family farm** class.

In the fifties and sixties, **outsourcing** was first used as a way of farm management by urban middle class professionals, who had invested their savings in citrus orchards and had neither the time nor the expertise to become directly involved in farming, but it expanded later to become a widely dominant system nowadays. Even very small farms are fully **externalized** – wage labour is widely used by farms that hardly exceed 1 hectare. Our hypothesis is that **outsourcing** may be one of the reasons for the difference between market wages and shadow wages. We guess that service firms enjoy some kind of competitive advantage because labour is more efficiently managed and specialization skills can be more easily acquired and profitably used. Very plausibly, these workers are more skilled and efficient than family workers in performing some specific tasks and this would give support to the positive differential displayed by market wages in relation to computed family labour shadow prices. In fact, the market wages of such labour teams are close to those of skilled workers in other activities and are clearly higher than earnings of unskilled workers[7].

In our view, this finding could have important economic policy implications, as we outlined in the introduction. Instead of trying to make Spanish citrus production structures conform to a family farm model, policy-makers should focus their efforts on improving the efficiency of service firms that are effectively performing basic cultivation tasks. Policy measures should be taken to improve their labour force's technical skills, and to make the latest technological innovations more easily accessible to them, having always in mind that it is mainly these firms, not the farmers directly, that really adopt new technologies.

Finally, we would like to highlight that in our results we also find a high shadow wage rate associated to a low use of family labour input. This circumstance may be consistent with off-farm labour opportunities outside farming, whether in the liberal professions, in services, or in manufacturing industries. It could be clearly the case for farmers – or their relatives – who have achieved high educational levels. Unfortunately, lack of additional information on the educational and professional training achievements of both family and external workers, as well as other characteristics, prevents us performing more complete analyses. Likewise, the small size of our sample precludes further analyses to test the statistical significance of our findings. Nevertheless, we really believe that our shadow wages computation contributes to a better understanding of Spanish citrus farms' labour allocation decisions between on-farm and off-farm employment. Obviously, further research prolonging our results is needed as larger samples and more detailed data may become available.

Concluding remarks

Farm-household models have emphasized the interdependence between household's utility and profit-maximizing decisions, and have stressed the assumption of endogenous determination of the household's labour shadow wage as a key

---

[7] In our sample, the average market wage paid per hour of hired labour amounted to 10.74 euros. According to the figures of the Spanish National Statistical Institute (INE), this salary is very close to the earnings reached in 1997 – when the *Survey on Input Use by Farms* that we use was carried out – by skilled workers in other economic activities, *i.e.*, 9.56 euros per hour in the building industry, 11.69 euros per hour in manufacturing activities and 9.83 euros per hour in the service sector. In all these economic activities salaries of unskilled workers were significantly lower, *i.e.*, 6.75, 6.35 and 6.10 euros per hour in construction, manufactures and services, respectively.

issue for an understanding of his different labour strategies. In this paper we have estimated shadow wages for family labour in Spanish citrus farms making use of an input distance function approach and goal programming methods. Accordingly, central importance has been given to the duality between input distance and cost functions, using the former to derive input shadow prices.

The results we obtain show that own labour shadow prices for individual farms are, in general, smaller than the observed citrus labour market wage rate. Other coincidental results, concerning the relationship between opportunity cost of family labour on the farm and the off-farm market wage rate, have been reported in the literature, with a wide range of possible explanations, among them transaction costs, non-substitutability between family labour and hired labour and a preference for labour on-farm.

Our hypothesis is that the strategy of **externalization** of many growing tasks, which has been pursued for a long time by Spanish citrus fruit producers, gives some support to the idea of non-substitutability between family labour and hired labour. We hypothesize that hired labour is more skilled than most of the family labour that the farmer can command, and this would explain the positive differential displayed by market wages in relation to computed family labour shadow prices. In our view, this would lead to some relevant economic policy questions. Long-range regional agricultural policies that try to increase the average size of citrus farms to make them conform to an abstract **family farm model** may be not only unfruitful but also misguided. More attention should be directed to improving the efficiency and technical skills of the service firms, cooperatives and small-specialized labour teams, as potential adopters of technical innovations with a likely impact on labour productivity and competitiveness.

References

Aigner D., Chu S. (1968). On estimating the industry production function, *American Economic Review*, 58, pp. 826-839.

Arnalte E. (1980). *Agricultura a tiempo parcial en el País Valenciano. Naturaleza y efectos del fenómeno en el regadío litoral*, Secretaría General Técnica, Ministerio de Agricultura.

Arnalte E., Estruch V. (2001). Les agrumes dans la région de Valence : facteurs de stabilité et voies d'adaptation du système de production, *in : Milieu rural, agriculture familiale. Itinéraires méditerranéens,* Montpellier, CIHEAM-IAM, RAFAC.

Arnalte E., Estruch V. (2000). Farming systems in Eastern Spain, *in : The CAP reform and the development of Mediterranean agriculture*, Final Report, FAIR 3, CT96-1579, pp. 317-354.

Arnalte E., Estruch V. y Muñoz C. (1990). El mercado de trabajo asalariado en la agricultura del litoral valenciano, *Agricultura y Sociedad*, 54, pp. 135-161.

Benjamin C. (1996). L'affectation du travail dans les exploitations agricoles : une application du modèle du ménage producteur et consommateur, *Cahiers d'économie et sociologie rurales*, 38, pp. 37-60.

Christensen L.R., Jorgenson D.W. and Lau L.J. (1973). Transcendental logarithmic production frontiers, *Review of Economics and Statistics*, 55, pp. 28-45.

Coggins J.S., Swinton J.R. (1996). The price of pollution : A dual approach to valuing SO_2 allowances, *Journal of Environmental Economics and Management*, 30, pp. 58-72.

Efron B. (1979). Bootstrap methods ; another look at the Jackknife, *Annals of Statistics*, 7, pp. 1-16.

Elhorst J.P. (1994). Firm-household interrelationships on Dutch dairy farms, *European Review of Agricultural Economics*, 21, pp. 259-276.

Fall M., Magnac T. (2004). How valuable is on-farm work to farmers ? *American Journal of Agricultural Economics*, 86 (1), pp. 267-281.

Färe R., Grosskopf S. (1990). A distance function approach to price efficiency, *Journal of Public Economics*, 43, pp. 123-126.

Färe R., Grosskopf S., Lovell C. and Yaisawarng S. (1993). Derivation of shadow prices for undesirable outputs : A distance function approach, *The Review of Economics and Statistics*, 75, pp. 374-380.

Färe R., Lovell C.A.K. (1978). Measuring the technical efficiency of production, *Journal of Economic Theory*, 19 (1), pp. 150-162.

Färe R., Primont D. (1995). *Multi-output Production and Duality : Theory and Applications*, Norwell, MA, Kluwer Academic Publishers.

Farrell M. (1957). The measurement of productive efficiency, *Journal of the Royal Statistics Society, Serie A*, 120 (3), pp. 253-282.

Gorgoni M. (1980). Il contadino tra azienda e mercato del lavoro: un modello teorico, *Rivista di Economia Agraria*, 35 (4), pp. 683-718.

Grosskopf S. (1986). The role of the reference technology in measuring production efficiency, *Economic Journal*, 96 (382), pp. 449-513.

Hailu A., Veeman T. (2000). Environmentally sensitive productivity analysis of the Canadian pulp and paper industry, 1959-1994: An input distance function approach, *Journal of Environmental Economics and Management*, 40, pp. 251-274.

Jacobsen S.E. (1972). On Shephard's duality theorem, *Journal of Economic Theory*, 4, pp. 458-464.

Jacoby H.G. (1993). Shadow wages and peasant family labour supply: An econometric application to the Peruvian Sierra, *Review of Economic Studies*, 60, pp. 903-921.

Key N., Sadoulet E. and De Janvry A. (2000). Transactions costs and agricultural household supply response, *American Journal of Agricultural Economics*, 82, pp. 245-259.

Lee J.D., Park J.B. and Kim T.H. (2002) - Estimation of the shadow prices of pollutants with production/environment inefficiency taken into account: A nonparametric directional distance function approach, *Journal of Environmental Management*, 64, pp. 365-375.

López R.E. (1986). Structural models of the farm household that allow for interdependent utility and profit-maximization decisions, *in: Agricultural Household Models. Extensions, Applications, and Policy*, Singh I., Squire L. and Strauss J. (eds), Baltimore, The Johns Hopkins University Press.

López R.E. (1984). Estimating labor supply and production decisions of self-employed farm producers, *European Economic Review*, 24, pp. 61-82.

Picazo-Tadeo A.J., Reig-Martínez E. (2002). Agriculture's externalities and environmental regulation. Evaluating good practices in citrus fruit production, Working Paper, 06/02, Dpt. Economia Aplicada II, Universitat de València, Spain.

Piot-Lepetit I., Vermersch D. (1998). Pricing organic nitrogen under the weak disposability assumption: An application to the French pig sector, *Journal of Agricultural Economics*, 49 (1), pp. 85-99.

Reig-Martínez E., Picazo-Tadeo A.J. (2004). Analysing farming systems with Data Envelopment Analysis: citrus farming in Spain, *Agricultural Systems*, 82, pp. 17-30.

Reig-Martínez E., Picazo-Tadeo A.J. and Hernández-Sancho F. (2001). Shadow prices and distance functions: An analysis for firms of the Spanish ceramic pavements industry, *International Journal of Production Economics*, 69, pp. 277-285.

Sadoulet E. (2001). Mercati imperfetti e modelli di comportamento delle famiglie contadine, *La Questione Agraria*, 3, pp. 39-73.

Sadoulet E., de Janvry A. and Benjamin C. (1998). Household behavior with imperfect labor markets, *Industrial Relations*, 37 (1), pp. 85-108.

Schmitt G. (1991). Why is the agriculture of advanced Western economies still organized by family farms? Will this continue to be so in the future? *European Review of Agricultural Economics*, 18, pp. 443-458.

Shephard R.W. (1970). *The Theory of Cost and Production Functions*, Princeton, NJ, Princeton University.

Singh I., Squire L. and Strauss J. (1986). An overview of agricultural households models, *in: Agricultural household models. Extensions, applications, and policy*, Singh I., Squire L. and Strauss J. (eds), Part I, Baltimore, The Johns Hopkins University Press, pp. 17-91.

Skoufias E. (1994) – Using shadow wages to estimate labor supply of agricultural households, *American Journal of Agricultural Economics*, 76, pp. 215-227.

Ziari H., Azzam A. (1999). Parametrizing non parametric translog models: A goal programming constrained regression study of US manufacturing, *Empirical Economics*, 24, pp. 331-339.