8

Modelling opportunity cost: agricultural output values

Introduction

Having concluded our assessment of the monetary value of land under forestry we now turn to consider the prime opportunity cost of such a decision, namely the value of the major land use in Wales: agriculture. This chapter presents models of net agricultural income[1] received by farmers (referred to as the 'farm-gate' value) and its social or 'shadow price' equivalent which adjusts for the various subsidies and other transfer payments which characterise UK agriculture.[2] As before, a GIS-based approach is used to generate maps of such values for the entire study area. This permits subsequent comparison of total woodland values with those for agriculture (see Chapter 9).

The following section presents the necessary policy background. This establishes the broad and progressively strengthening economic case for the transfer of at least some land out of conventional agriculture and into alternative land uses and overviews the theoretical and methodological basis of our analysis. An overview of developments since our 1990 study period is also presented, showing that there has been a clear worsening of the economic situation for farmers in our study area, which means that our analysis will provide a conservative estimate of the potential for land use change from farming to forestry.

The following two sections outline the GIS-based methodology employed and discuss the data. For modelling purposes, farms in the sample were clustered into distinct groups as explained in the next section, which also reviews definitions of farm-gate and shadow value of production. Thereafter, the results of the modelling

This chapter is an extension of the analysis presented in Bateman *et al*. (1999d)

[1] An alternative approach to valuation might be to examine land prices. However, these have been distorted through subsidised over-use of agricultural land (North, 1990). Furthermore, in debating land purchase as a route towards reducing agricultural output, Colman (1991) argues that, at best, such land purchase schemes will be on a minor scale.

[2] Note that, just as for the case of woodland, certain agricultural externalities are not assessed, for example landscape amenity (see Fleischer and Tsur, 2000).

exercise for both sheep and dairy farming are discussed and the consequent GIS maps are presented. The final section provides a summary and conclusions.

Policy background in the UK

Government intervention within the British agricultural sector can be traced back to at least the Middle Ages (Ernle, 1919) and so it would be wrong to characterise farms as being purely subject to market forces prior to the UK's entry into the EEC in 1973.[3] Nevertheless, the simultaneous entry into the Common Agricultural Policy (CAP) heralded one of the most fundamental changes in the organisation of agriculture in Britain's peacetime history.

The initial CAP support system

The policy principles of the CAP were laid down in 1957 as Article 39 of the foundation document of the EEC, the Treaty of Rome (European Economic Community, 1962). This advocated a basically expansionist ideology enshrined in various potentially conflicting intentions to ensure (i) producer efficiency (ii) market stability (iii) consumer equity, and (iv) a 'fair' standard of living for farmers.[4] In considering the subsequent interpretation and implementation of these aims, commentators have highlighted both the post-war demand for greater food security and the fact that the CAP is a product of the Treaty of Rome and was therefore seen as a cornerstone of the underlying desire, particularly by the Commission of the European Community (CEC), for greater political union among member states (Bowler, 1985; McInerney, 1986; Fennell, 1987; Gilg, 1996).

In practice, a special section of the Community budget, the European Agricultural Guidance and Guarantee Fund (usually known by its French acronym FEOGA), was created to finance the expansion of EEC agriculture. Rather than assistance being paid directly to farmers it was decided that each year the Council of Ministers would set a 'target price' for each commodity, usually significantly above the prevalent world price. This internal EEC target price was principally maintained by imposing an import levy upon non-EEC produce. However, while this was adequate for most goods where the EEC was a net importer, if domestic supply exceeded demand, then the possibility of surpluses depressing internal prices arose. To combat this a system of export subsidies was introduced, payable where internal EEC prices fell below an 'intervention price' level set somewhere below the target price but above world price. Figure 8.1 illustrates the essentials of the support system.

[3] Market restrictions and intervention prior to 1973 are discussed in Bowers and Cheshire (1983), Blunden and Curry (1985), Robinson (1990), Smith (1990), Ritson (1991a) and Cobb (1993).

[4] Discussion of these aims is presented in Blunden and Curry (1985), Franklin (1988), Fearne (1991), Ritson (1991b) and Gilg (1996).

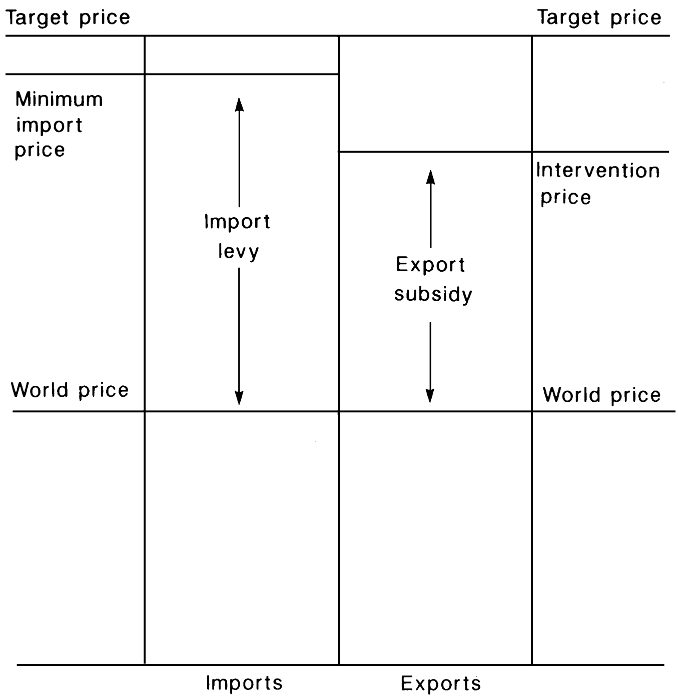

Figure 8.1. Model of a typical CAP price support system. (*Source:* Adapted from Ritson, 1991a.)

A further complexity arose from the internal operation of the CAP prior to monetary union. Support prices were fixed in European Currency Units (ECU) and so had to be translated into actual payments via national currencies. However, fluctuations in exchange rates could lead to substantial and quickly transmitted instability in producer prices. Therefore, for agricultural goods alone, EEC member states were allowed to maintain prior exchange rates (known as 'green' currency) for converting CAP support prices into domestic prices. This system caused differences in realised support prices for the same commodity across countries and if left unchecked would have led to goods moving from low-price to high-price countries prior to their sale into intervention. Consequently, an interim system of border taxes and subsidies (known as Monetary Compensation Amounts, MCA) on intra-EEC trade was also introduced (Fennell, 1987; Ritson, 1991a). The advent of the European Union (EU) Single Market on 1 January 1993 swept away internal borders, making MCAs unworkable. While a strong exchange rate mechanism (ERM) would have reduced many problems, the exit of the UK from the ERM on 16 September 1992 precluded this option and necessitated a compromise solution wherein green currencies effectively 'float', with devaluation in the 'green pound' occurring regularly (Neville and Mordaunt, 1993). This complication persists for the UK following its decision in 1999 not to join the first wave of EU monetary union and fluctuations in the green pound remain a source of problems for UK farmers.

Operation of the CAP in the UK: 1973 to the early 1990s

The UK's entry into the EEC and the CAP in 1973 coincided with the world commodity price boom which was primarily responsible for a substantial increase in agricultural prices, but for which the CAP got much of the blame (Britton, 1990; Hodge, 1990a; Robinson, 1990; Ritson, 1991b). UK food prices rose by 18 per cent in 1974 and 24 per cent the following year (Capstick, 1991). Indeed the retail food price index kept above that of other items for the remainder of the 1970s and the first half of the 1980s (*ibid*.), a trend echoed in the growth of land prices during the period (Harvey, 1991a). During the mid 1970s the price guarantee system and world-wide price buoyancy resulted in increased agricultural stability and incomes (Blunden and Curry, 1985; Hill, 1990; Moyer and Josling, 1990) although this was bought at the cost of welfare losses to consumers and taxpayers (Morris, 1980; Australian Bureau of Agricultural Economics, 1985). However, the natural consequence of increased price subsidies was over-use of land for agricultural purposes (North, 1990), increased food production, and with it higher support costs, which with sluggish growth in domestic demand (Harrison and Tranter, 1989) could only result in higher export subsidies and intervention storage costs (Blunden and Curry, 1985; Buckwell, 1989; Smith, 1990; Cobb, 1993). During the late 1970s and early 1980s the total budget costs of the CAP rose by around 25 per cent per annum (Cobb, 1993) with FEOGA guarantee expenditure increasing from about ECU 2.5 billion in 1970 to nearly ECU 30 billion in 1988 (Moyer and Josling, 1990).

The price pressure of this level of support led to an increased misallocation of resources (Marsh and Swanney, 1980; Tarrant, 1980; Body, 1982; Buckwell *et al*., 1982; Hill, 1984)[5] and resultant inefficiencies, which meant that as producer subsidy equivalents rose from about 30 per cent to peak at over 60 per cent in 1987, so the net economic loss (sum of producer and consumer welfare effects) of the CAP rose to exceed ECU 9 billion in 1986 (Josling, 1993). Despite widespread criticism, little was done in practical terms to alleviate a rapidly worsening situation. Many commentators both then and since have identified the decision-making framework as the principal cause of this policy response lag, with particular criticism being aimed at the willingness of the Council of Ministers to avoid difficult decisions and put the short-term concerns of their national agricultural constituencies before the long-term need for budgetary prudence (Marsh and Swanney, 1980; Hill, 1984;

[5] EEC subsidies and consequent increase in exports and depression of world prices also had major impacts upon non-EEC countries and in particular the less-developed world (Anderson and Tyers, 1991). The economic consequences of this effect are considered subsequently in this chapter.

Bowler, 1985; Fennel, 1987; Hodge, 1990b; Smith, 1990; Fearn, 1991; Josling, 1993; Winters, 1993; Gilg,1996; Billing, 1998). The UK was by no means innocent of such prevarication; for example, the green pound was frequently devalued during this period, thus raising MCA payments to UK farmers (Harris *et al*., 1983). In essence, then, the CAP exhibited all the signs of a classic intervention failure (Burrell, 1987; Tyers and Anderson, 1987; Rosenblatt *et al*., 1988; Anderson and Tyers, 1991).

Eventually the EEC was forced to acknowledge that something had to be done about the spiralling CAP budget (CEC, 1985a). While thresholds upon guarantees had been introduced in 1982 (Cobb, 1993), the first substantial response came with the introduction of milk quotas (CEC, 1985b). While the Council of Ministers still provided a brake upon reform (CEC, 1989, 1990), nevertheless gradual reductions in support for milk (European Economic Community, 1987) and cereals were introduced (CEC, 1987) and in real terms prices began to fall throughout the late 1980s (Moyer and Josling, 1990; Hubbard and Ritson, 1991). This coincided with a reduction in non-price support; for example, UK grants dropped from almost £200 million in 1983/84 to about £23 million in 1988/89 with capital allowances being cut in 1986 (Cobb, 1993).

The severity of these real-price decreases meant that by 1990 the food price index had fallen below that of general prices (Capstick, 1991) and agricultural incomes were in decline (Howarth, 1985; Organisation for Economic Cooperation and Development (OECD), 1987; Hill, 1990; Moyer and Josling, 1990). However, continued increases in productivity and falls in demand (Capstick, 1991; CEC, 1992a) meant that the budgetary costs of the CAP were persistently high and the system remained one of intervention failure (Anderson and Tyers, 1991; Josling, 1993). One of the consequences of this situation was that more land was being used for agriculture than was economically efficient, with estimates of surplus agricultural land in the UK ranging from 0.7 million to 5 million hectares (North, 1990; Harvey, 1991b; Potter *et al*., 1991).

Our study period of 1990 was therefore set within a period when market intervention was unable to reverse long-term agricultural decline, characterised by falling real prices and incomes and over-use of land for farming. We now turn to consider the extent to which these trends have altered or intensified up to the present day.

Operation of the CAP in the UK: the early 1990s to 2001

The early 1990s saw a fusion of concerns regarding the financing of the CAP with long-standing but ongoing concerns regarding the negative environmental impacts of present land use (Nature Conservancy Council, 1977; Shoard, 1980; Body, 1982; Hodge, 1990a,c; MacKenzie, 1990; Whitby, 1991a,b; Turner *et al*., 1994). These dual pressures of increasing subsidy cost and environmental degradation led many commentators to consider the possibility of reorienting support away from conventional production measures and towards a more holistic agri-environmental system where both food and amenity become recognised and remunerative farm outputs (Baldock and Conder, 1987; Bowers, 1987; Blunden and Curry, 1988; Department of the Environment, 1988; Potter, 1988, 1990; Royal Society for the Protection of Birds, 1988; Hodge, 1990d; Neville-Rolfe, 1990; Cobb, 1993; Colman, 1993).

At the national level a number of UK national policies attempted to address these joint aims including the Alternative Land Use and Rural Economy (ALURE) package (Ministry of Agriculture, Fisheries and Food (MAFF), 1987b) which introduced Environmentally Sensitive Area (ESA) payments, the Premium Scheme (MAFF, 1990), and the Countryside Stewardship Scheme (MAFF, 1992d) which arose from the Government White Paper *Our Common Inheritance* (H.M. Government, 1990). However, while some saw these as a significant reorientation of UK agricultural policy and recognition of the symbiosis of land use and the environment (Blunden and Curry, 1988; Department of the Environment, 1988; Neville-Rolfe, 1990; Colman, 1991, 1993) others criticised the limited funding for such schemes (Robinson, 1990; House of Lords, 1992; National Farmers Union (NFU), 1992). A more fundamental response, at the EU level, to pressures for agri-environmental reform was embodied in the Fifth Action Programme on the Environment (CEC, 1992b), commonly known as the MacSharry Reforms after the then European Commissioner for Agriculture, Ray MacSharry. These proposed a substantial reduction in price support compensated by direct payments to farmers which would be conditional upon placing land into non-productive ‘set-aside’ with further requirements to reduce negative environmental impacts. Although subsequently watered down, the principle of such reforms was accepted (CEC, 1992c,d; Neville and Mordaunt, 1993).

The MacSharry Reforms have been complemented by a variety of agri-environmental policies (AEPs) including further ESA schemes, Countryside Stewardship, Nitrate Sensitive Areas, Countryside Access, etc. (Evans and Morris, 1997; Hanley *et al*., 1999; MacFarlane, 2000). However, funding for AEPs has always been relatively modest, with annual spending amounting to about 2.5 per cent of the total of £2,857 million of CAP funds spent in the UK in 1996/97 (Hanley *et al*., 1999).[6]

The small-scale increases of AEP payments during the 1990s pale in comparison to the substantial falls in real agricultural prices which occurred over the decade. With the exception of a brief period of substantial growth between about 1993 and 1995, the decade was a period of unprecedented decline in farm incomes.

[6] Norman *et al*. (1994) provide an early treatise on the application of GIS techniques to target AEPs.

By 1998, total income from farming (TIFF)[7] in the UK fell to £2.51 billion, its lowest level for twenty-five years. After a small rise in 1999, estimates for 2000 showed a further fall to £1.88 billion (DEFRA, 2002). At the farm level, incomes fell across all sectors to levels which were lower than those of our study period at the start of the decade (Countryside Agency, 2001). As the Rural White Paper concluded, 'Farming is going through its most difficult period since before the Second World War. Farm incomes have fallen by around 60% over the past five years. No sector of farming has been unaffected' (Department for the Environment, Transport and the Regions, 2000: p. 89). Similarly a Cabinet Office report to the Prime Minister stated that 'Any assessment of rural areas must begin with the acknowledgement that agriculture, the countryside's most visible and most typical activity, is facing major problems, and that many sectors and people within it are facing real crisis' (Cabinet Office, 2000: p. 4). This was particularly true in Wales where the 1990s proved a desperate time for agriculture, as quantified in Table 8.1.

Table 8.1 shows that all sectors of Welsh farming have experienced sharp declines in agricultural prices and incomes. These have triggered a fall in the number of farms as both farms and herds/flocks increase in size. Declining prices mean that Welsh farmers are now heavily reliant upon subsidies, as recognised in the recent National Assembly for Wales draft policy for the future of agriculture:

> Farmers are overwhelmingly reliant on subsidy for this income. Direct CAP subsidies now account for 420% of the net farm income of the average farmer in Wales: this figure would be far higher if indirect support was taken into account. (*National Assembly for Wales, 2001b: section 1.1*)

Welsh farmers have attempted to bolster falling incomes through increasing the number of beef cattle and sheep. In part this has been facilitated by the increase in permanent grassland and reduction in rough grazing noted in Table 8.1. However, this has also been attempted through increases in stocking density, extending a trend which dates from at least the UK's entry into the CAP. Figure 8.2 illustrates this trend, showing the relationship between altitude and stocking intensity for four periods ranging from the early 1970s to the late 1990s. This shows that in each period stocking densities increase with height above sea level, but that densities have consistently increased at all altitudes over the past thirty years.

Wales now has one of the highest sheep stocking densities in the EU (Fuller, 1996) leading to considerable problems of overgrazing and consequent adverse impacts upon biodiversity (Fuller *et al.*, 1995; Dobson, 1997; Woodhouse *et al.*, 2000). In particular, large increases in the number of sheep over successive decades have been blamed for a significant fall in the density and variety of wildlife observed in

[7] The preferred and internationally agreed measure of aggregate agricultural income.

Table 8.1. *Change in Welsh agriculture 1990 to 2000*

Measure	1990	2000	Change (%)
Dairy			
Number of dairy cows ('000)	326.8	268.6	−17.8
Number of farms	6,374	4,307	−32.4
Average herd size	51	62	+21.6
Beef			
Number of beef cows ('000)	202.4	223.3	+10.3
Number of farms	11,332	9,326	−17.7
Average herd size	18	24	+33.3
Average market price (per kilo)[1]	£1.04	£0.84	−19.2
Sheep			
Number of sheep & lambs ('000)	10,866.6	11,148.0	+2.6
Number of farms	17,587	15,088	−14.2
Average flock size	618	739	+19.6
Average market price (per kilo)[1]	£1.56	£0.84	−53.8
Incomes			
Dairy index[2]	100	36	−64.0
Cattle and sheep (Less Favoured Areas) index[2]	100	24	−76.0
Cattle and sheep (non Less Favoured Areas) index[2]	100	−6	−106.0
Land use			
Permanent grass ('000 ha)	904	933	+3.2
Rough grazing ('000 ha)	516	442	−14.3
Woodland etc. ('000 ha)[3]	50	58	+16.0

Notes: [1] Pounds (sterling) per kilo liveweight.
[2] Incomes index includes subsidies and holds 1989/90 to 1991/92 = 100.
[3] Includes set-aside land; excludes arable land.
Sources: National Assembly for Wales (2000, 2001c).

Wales (National Assembly for Wales, 2001b). For example, the number of breeding pairs of lapwings in Wales has fallen from about 14,000 in 1970, to 7,500 in 1987 and to just 1,700 in 1998 (*ibid*.).

Examination of Welsh agricultural statistics (National Assembly for Wales, 2000, 2001b,c) shows that our 1990 study period was firmly on a declining trend line extending from the late 1970s to the present. Although the present state of farming is indeed parlous, inspection of trends in farm income shows that, if anything, the increase in real agricultural incomes seen in the period from about 1993 to 1995 was against the general decline seen over the past two decades. Looking into the future we see no signs of any impending change in these trends either in Wales or across the UK in general. The most recent CAP reform proposals, known as Agenda 2000,

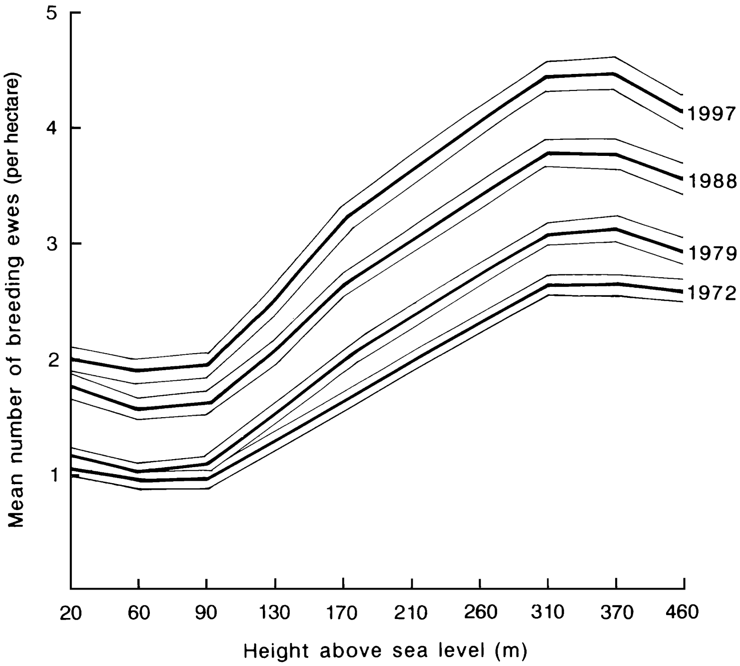

Figure 8.2. Sheep stocking intensity in Wales, 1972 to 1997. (*Source:* Woodhouse, 2002.) The figure shows the mean number (thicker lines; 95% C.I.s shown either side of each line) of breeding ewes per hectare of farmland for 2 km cells in Wales relative to height above sea level.

extend recent policy trends through a continuation of reductions in output-related price support and increased reliance upon area-based measures (Billing, 1998; Hanley *et al.*, 1999; Brouwer and Lowe, 2000a,b; Lowe and Baldock, 2000). Increased measures for agri-environmental support are complemented by further movement away from paying subsidies on a per animal (headage) basis, moves which are specifically designed to discourage excessive stocking in ecologically fragile environments such as the Less Favoured Area designation which embraces most of Wales. Such policies are backed at the UK national level in strategy documents such as the Rural White Paper (Department for the Environment, Transport and the Regions, 2000).

This policy and economic environment means that if Welsh farmers try to compete on price alone they will continue to perform badly. This situation is explicitly recognised by the National Assembly for Wales (2001b), whose agricultural policy recognises farming as a sector in rapid decline which needs to rapidly diversify out of sole reliance upon food production into other activities including, among others, farm woodlands. Although farmers have long been recognised as being resistant to diversification there is recent evidence to suggest that the persistent nature of agricultural decline, compounded by unforeseen and highly damaging shocks such as the BSE crisis and the more recent foot and mouth epidemic, has made farmers more receptive to ideas of diversifying their activities out of traditional food production and into other enterprises. A survey of farmers in England and Wales conducted in 2000 found that 59% of farmers said they would either definitely (26%) or possibly (33%) seek new income from outside their farming businesses (Countryside Agency, 2001). Similarly 48% of farmers said they would either definitely (19%) or possibly (29%) seek to diversify into non-farming use of land, resources or buildings (*ibid*.). This suggests a confluence of economic, policy and psychological factors which together make more viable the type of land use change considered in this study.

Conclusions: the potential for change

This policy review clearly shows the potential for economic gains (both in the sphere of market efficiency and the provision of environmental benefits) from the reform of agricultural policy. In particular there is the possibility of welfare improvements by inducing conversions out of conventional agriculture and into alternative land use such as the woodland option considered in this study. Furthermore, our review of events since our study period shows that declining agricultural values mean that our findings are likely to underestimate the true potential for efficiency gains from such land use change. However, while the possibility of creating positive social net benefits clearly exists, such transfers are unlikely to occur unless we also consider the consequent market value to producers. In subsequent sections we discuss approaches to the modelling of both the shadow and market values of agriculture so that such a comparative analysis can be undertaken.

Developing a GIS-based modelling methodology

Despite the considerable potential of utilising the spatial analytic capabilities of a GIS for modelling in agricultural economics, until recently such systems have only been used to a limited extent (Moxey, 1996). However, whenever there are economic issues with a spatial dimension (e.g. changing patterns of land use, policy measures which are area-sensitive), then the ability to overlay and integrate spatial data (relating, say, to land characteristics) with economic data (which might relate to the farm business), means that a GIS provides the opportunity for much greater realism, comprehensiveness and relevance in modelling. The present analysis adopts such an approach in order to generate estimates of farm-gate and shadow values of agricultural output which could then be used, *inter alia*, to model changing patterns of land use.

Following a review of the literature (Bateman, 1996), it was decided to make an analysis of farm profitability the basis of our modelling methodology. This is a common approach (e.g. Chambers and Pope, 1994) and accords with that adopted by the UK study which most closely resembles the present research, namely the NERC/ESRC Land Use Modelling Programme (NELUP) at the University of Newcastle upon Tyne (O'Callaghan, 1995, 1996).[8] Both the present and NELUP studies use a GIS to integrate the physical environment into an analysis of farm profitability (Moxey and Allanson, 1994; Watson and Wadsworth, 1996; Moxey and White, 1998). However, unlike our own study, the NELUP model did not have access to individual farm-level data (discussed below) but instead depended upon aggregated, parish-level, agricultural census information collected by the Farm Business Survey (Allanson *et al.*, 1992).[9] This is a substantial drawback as it limits the scope for using the capabilities of a GIS to relate the input-output situation of a particular farm to the characteristics of its biophysical environment.

The analytical framework which we present in this chapter was developed iteratively as a result of empirical investigation. An initial single model attempting to relate farm income measures to a variety of input intensity measures (e.g. livestock per hectare), environmental factors (e.g. soil type) and what we refer to as modification variables (e.g. fertiliser per hectare), proved to be overly simplistic for two reasons.[10] First, farm output decisions, and hence incomes, are subject to institutional rules (most noticeably, in the study area, whether or not a given farm holds a milk quota) to the extent that farms cannot be considered a homogeneous group. Second, investigations indicated that, even within a homogeneous subgroup of farms, a single model did not adequately describe a farmer's decision process with regard to how the farm environment influences input and output decision-making and hence income (Bateman and Lovett, 1992).

In order to address the first of these issues, farms were classified into broadly homogeneous groups or sectors (using a cluster analysis described subsequently) within which policy constraints were similar. The second issue was tackled through a two-stage modelling procedure: in stage 1, income values were determined by the array and intensity of inputs utilised; while in stage 2, the inputs employed were dependent on the prevailing biophysical characteristics and possible modifications of those characteristics. Cross-section regression analysis was then used to estimate the parameters of the stage 1 and stage two relationships within each sector. The stage 1 profit–input relationship within each sector was

[8] An alternative, linear programming approach is the Land Use Allocation Model described by Jones *et al.* (1995).

[9] Note, however, that a small farm-level study of ten farms has been conducted under the NELUP programme (Oglethorpe and O'Callaghan, 1995).

[10] The single equation approach was also hampered by multicollinearity between input and biophysical variables (Bateman and Lovett, 1992). Our multistage approach to addressing multicollinearity owes much to Smith and Desvousges (1986).

specified as:

$$\pi_{ij} = f_j(I_{1ij}, I_{2ij}, \ldots, I_{pij}, \ldots, I_{kij}) \tag{8.1}$$

where:

π_{ij} is the profit level of the ith farm ($i = 1, \ldots, n$) in the jth sector ($j = 1, \ldots, m$)
I_{pij} is the intensity of use of the pth input ($p = 1, \ldots, k$) on the ith farm in the jth sector

The stage 2 input–biophysical environment relationship for each input in each sector was specified as:

$$I_{pij} = g_{pj}(B_{1ij}, B_{2ij}, \ldots, B_{hij}, \ldots, B_{zij}, M_{1ij}, M_{2ij}, \ldots, M_{rij}, \ldots, M_{vij}) \tag{8.2}$$

where:

B_{hij} is the level of the hth biophysical variable ($h = 1, \ldots, z$) on the ith farm in the jth sector
M_{hij} is the level of the rth biophysical modification variable ($r = 1, \ldots, v$) on the ith farm in the jth sector

The biophysical variables were stored on a grid cell (raster) basis within the GIS for the entire extent of the study area (see the discussion of data below). Therefore, by holding the modification variables at appropriate levels for the farm sector under consideration, we could use the regression parameters of Equation (8.2) to produce maps of predicted levels for all inputs for that sector. Subsequently a map of predicted income for the study area could be derived by applying the regression parameters of Equation (8.1) to the maps of predicted input levels.

The approach taken characterises farm decision-making as a process in which the farmer first considers the institutional rules and constraints within which the farm must operate,[11] then assesses the physical environment of the farm and the extent to which it may be modified (as described in Equation (8.2)), and finally, decides the type and level of inputs to use which in turn determine outputs and farm profitability (as per Equation (8.1)). We recognise and fully acknowledge the fact that, from a sociological perspective, such a model remains naïve. In particular, the writings of the Wageningen school (Röling, 1993, 1994; van der Ploeg, 1993) show that many economic models of farm decision-making omit consideration of factors such as a farmer's mind-set, intrinsic knowledge base, personal and social experience, risk aversion (and its interaction with the former factors), access to and quality of the local community knowledge base, etc. These are important influences which we do not deny and recognise as a limitation of our model.

[11] One further fundamental constraint is the difficulty for the farmer of moving from one farm to another. Often the farmer may face insurmountable problems in undertaking such a change.

The data

The models outlined above require individual farm-level data on both biophysical characteristics and the variety of input, output and related variables which define a farm. The Farm Business Survey of Wales (FBSW) provided the necessary farm-level cost and revenue data, while biophysical characteristics were taken from the LandIS database compiled by the Soil Survey and Land Research Centre (SSLRC, Cranfield) and other sources. These data are briefly reviewed below.

During the 1989/90 study period the FBSW interviewed and obtained full accounts data for a representative sample of 571 farms across Wales.[12] Farms were geographically referenced according to the location of the farmhouse and for the purposes of this analysis these points were used to assign each farm to a 1 km grid square. Access to the full FBSW dataset was permitted, although interviews with surveyors, who had visited each of the farms concerned, showed that many of the farms in the dataset were unsuitable for inclusion in the present study because either the farmhouse was not located on the land managed or the farm itself covered a diversity of environments, e.g. both lowland and upland areas affording winter shelter and summer grazing. Retention of such farms within the sample risked confounding the relation between farm performance and biophysical characteristics, which would have negated the fundamental research objective of producing models of the output value of a given area of land under a specified usage.[13] Such mixed environment farms were therefore excluded along with those with large non-agricultural incomes, leaving a final sample of 240 farms. The FBSW dataset is based upon full details of the annual accounts of the sample (which by law have to be surrendered, on demand, to the FBSW). It is consequently a highly detailed and rich dataset. Table 8.2 illustrates this by reproducing the annual record sheet for one particular farm, in this case a typical dairy enterprise (to preserve anonymity the grid reference has been changed, as have farm size details, and all financial particulars have been erased). Individual farm details for each of the items listed in Table 8.2 were made available. As can be seen, the level of information afforded by the data is very considerable.

As discussed in Chapter 6, the SSLRC Land Information System (LandIS) was compiled for the Ministry of Agriculture, Fisheries and Food to facilitate 'land use planning and national resource use' (Rudeforth *et al.*, 1984). It represents the most comprehensive and detailed source of information on the biophysical characteristics of land across England and Wales. LandIS includes long-term averages for a variety of agroclimatic variables at a 5 km grid cell resolution. A summary of the variables

[12] This is a routine, annual survey which typically interviews samples of this size. Farms are legally obliged to join the sample when selected.

[13] Note that the exclusion of such farms means that our models are not designed for predicting the incomes of farms which straddle differing environments. However, as made clear here, our objective is to value differing land uses in differing locations, rather than farms *per se*.

Table 8.2. *FBSW annual farm account data: example of a typical farm record*

Farm type: Specialist Dairy   Business size group: 24–39.9 BSU   Farm number: 12345
Location (OS grid ref.): Easting 2170; Northing 3010
Farm area (excluding common grazing):
actual hectares 69.78   Size of business (BSU) : 36.98
effective hectares 65.56   Year ending: 31 March 1990

OUTPUTS BY VALUE[1]		INPUTS BY VALUE[2]	
Dairy	• milk	Feed	• purchased concentrates
	• cattle		• home-grown concentrates
	• net milk quota[3]		• purchase bulk feed
	• valuation change	Tack and stock keep	
Other cattle	• cattle	Veterinary & medicines	
	• valuation change	Other livestock costs[4]	
Sheep	• wool	Seeds	• purchased
	• sheep		• home-grown
	• valuation change	Fertilisers	
Pigs	• pigs	Other crop costs[5]	
	• valuation change	Paid labour[6]	• regular
Poultry	• eggs		• casual
	• poultry	Machinery	• contract work
	• valuation change		• repairs
Other livestock	• livestock		• fuels
	• valuation change	General farm costs[7]	
Crops	• main crops	Land expenses	
	• by-products, forage & cults		
Miscellaneous[8]			
FARM OUTPUT		FARM INPUT	

FARM SURPLUS = FARM OUTPUT − FARM INPUT

Subsidies & grants	• cattle	Rent & rates
	• sheep	
	• miscellaneous	
FARM REVENUE = FARM OUTPUT + Subsidies & grants		FARM EXPENSES = FARM INPUT + Rent & rates

EXCESS OF REVENUE OVER EXPENSES = FARM REVENUE − FARM EXPENSES

Notional outputs	• benefit value	Notional inputs
	• of farm houses	
		Machinery depreciation
TOTAL OUTPUT = FARM REVENUE + Notional outputs		TOTAL INPUT = FARM EXPENSES + Notional inputs + Machinery depreciation

NET FARM INCOME[9] = TOTAL OUTPUT − TOTAL INPUT

INCOME MEASURES	EFFICIENCY MEASURES
Net farm income *less* value of manual labour of farmer & spouse	Milk yield per cow (litres)
	Milk sales per cow (by value)
	Lambs reared per ewe (no.)

Table 8.2. (*cont.*)

Investment income		Fat lamb sales per ewe (no.)[10]	
plus value of managerial input of paid managers		Return on tenant's capital (%)	
		Standard man-day availability[11]	
Management & investment income		Standard man-day requirement[11]	
TENANT'S CAPITAL		LAND UTILISATION (Hectares)	
Livestock		Tillage	• cereals
Machinery			• roots & fodder
Crops		Grassland	• hay
Stores			• silage
Total tenant's capital			• pasture
		Fallow & land let	
		Rough grazing	• sole
		Woods, roads & buildings	
		Total area	
		Rough grazing	• common
		Bare land and forage hired	
LIVESTOCK	Opening number	Closing value	Average number
Dairy cattle			
Other cattle			
Sheep			
Pigs			
Poultry			
Other livestock			
Total livestock			

Notes:

[1] Outputs include any produce given to workers and consumed or used on the farm. Outputs of livestock are given net of any purchases made. Output includes valuation changes which are detailed in the section headed 'Livestock'. Milk output includes quota transactions and any superlevies paid have been deducted.

[2] Inputs include stock changes as well as purchases made during the year.

[3] Net milk quota comprises quota compensation payments, payments for quota 'leased in' and 'leased out', and superlevy payments where applicable.

[4] Other livestock costs include purchased bedding materials and other costs incurred specifically for livestock enterprises.

[5] Other crop costs include crop protection chemicals and other costs incurred specifically for crop enterprises and forage.

[6] Labour costs include cash wages and salaries, other employer's expenses and the value of perquisites.

[7] General farm costs include electricity, water and telephone charges, licences, insurances, subscriptions, etc.

[8] Miscellaneous output includes contract work, farm cottage rents and profit on resale of purchased agricultural produce.

[9] Amount of which is BLSA also specified in FBSW records (BLSA = breeding livestock stock appreciation, i.e. that part of livestock valuation changes relating to the breeding 'stock on the farm'; details are given in the section headed 'Livestock').

[10] On some farms, fat lamb sales per ewe will include fat lambs from the previous year's lamb crop.

[11] Standard man-day availability is the number of eight-hour 'man-days' used on the farm during the year. Standard man-day requirement is the number of eight-hour 'man-days' conventionally regarded as necessary to maintain the farm's enterprises during the year.

Source: FBSW (1990).

Table 8.3. *Agroclimatic variables obtained from LandIS*

Variable name	Label	Definition
Accumulated temperature	Acctemp	Average annual accumulated temperature above 0°C (in °C)
Accumulated rainfall	Rainfall	Average annual accumulated rainfall (in mm)
Field capacity	Fcapdays	Average annual number of days where the soil experiences a zero moisture deficit (in days)
Return to field capacity	Retmed	Median measure from a distribution of the number of days between the date on which a soil returns to field capacity and 31 Dec. of that year (in days)
	Retwet	The upper quartile of the above distribution; a measure of return to field capacity in wet years (in days)
	Retdry	The lower quartile of the above distribution; a measure of return to field capacity in dry years (in days)
End of field capacity	Endmed	Median measure from a distribution of the number of days between 31 Dec. and the subsequent date on which field capacity ends (in days)
	Endwet	The upper quartile of the above distribution; a measure of the end of field capacity in wet years (in days)
	Enddry	The lower quartile of the above distribution; a measure of the end of field capacity in dry years (in days)
Available water	Avwatgra	Soil water available for a grass crop after allowing for gravity-induced drainage; the difference between water content at field capacity and at permanent wilting point adjusted for grass rooting model (in mm)
	Avwatcer	As Avwatgra but adjusted for a cereal crop (in mm)
	Avwatpot	As Avwatgra but adjusted for potatoes (in mm)
	Avwatsb	As Avwatgra but adjusted for sugarbeet (in mm)
Moisture deficit	Mdefgra	Difference between rainfall and the potential evapotranspiration of a grass crop (in mm)
	Mdefcer	As Mdefgra but adjusted for a cereal crop (in mm)
	Mdefsbpt	As Mdefgra but adjusted for a sugarbeet/potatoes crop (in mm)
Workability	Workabil	A seven-point ordinal scale indicating the suitability of the land for heavy machinery work in spring and autumn (ordinal scale)
Spring machinery working days	SprMWD	Average number of days between 1 Jan. and 30 Apr. when land can be worked by machinery without soil damage (in days)

Table 8.3. (*cont.*)

Variable name	Label	Definition
Autumn machinery working days	AutMWD	The average number of days between 1 Sept. and 31 Dec. when land can be worked by machinery without soil damage (in days)
Lowland relief region[1]	Lowrelif	Lowland topographic relief denoted as regions 4, 5 and 6 in Rudeforth *et al.* (1984) (dummy variable)
Soil type[2]	SoilX	SSLRC soil type classification code (various dummy variables for differing soils – specified in notes to regression models)

Note: All the variables listed are continuous unless specified otherwise. For further information on definitions and measurement, see Jones and Thomasson (1985) or Bateman (1996), except for: [1] from Rudeforth *et al.* (1984: p.19); and [2] from Soil Survey of England and Wales (1983) as recategorised by Bateman (1996) and Bateman and Lovett (1998). Some variables were transformed (e.g. by taking natural logarithms) prior to regression analysis; all such transformations are detailed in notes to regression models.

selected for use in this study is given in Table 8.3 (some of which were also discussed in Chapter 6). Further details regarding the compilation of the agroclimatic database and the geostatistical procedures used to interpolate measurements onto a 5 km resolution grid are given by Jones and Thomasson (1985), Ragg *et al.* (1988), Hallett *et al.* (1996) and at the SSLRC website.[14]

To supplement the characteristics extracted from LandIS, measures of elevation and associated variables were generated from the Bartholomew 1:250,000 digital map database for the UK. Contours and spot heights were processed within the GIS to produce a digital elevation model (DEM) of Wales and estimates of elevation, slope angle and aspect were then calculated at a 500 m resolution and subsequently averaged to provide values for 1 km grid cells across the study area.

Integrating the farm and biophysical variables involved linking databases of varying resolutions. The approach taken was akin to a point-in-polygon method (Burrough and McDonnell, 1998) with the grid reference of each farmhouse being used to select values from the 1 km resolution grids of topographic variables and the 5 km cells of the LandIS agroclimatic measures. Characterisation of the biophysical environment facing each farm business was therefore a little generalised, but thought to be appropriate given the nature of the data sources available and the size of the study area. It also should be emphasised that the geographical matching of farm and environmental variables in this study is considerably more meaningful than in previous research reliant on agricultural census data aggregated to parishes.

[14] See www.silsoe.cranfield.ac.uk/sslrc/services/dataproducts/landis.htm. Harrison *et al.* (1991) provide an early examination of the use of GIS in the analysis of countryside data.

Table 8.4. *Farm cluster characteristics: average income and mean percentage of total revenue from specified activities in each cluster of farms*

			Mean percentage of total annual revenue from each activity					
Cluster	No. of farms	Average income (£/ha p.a.)	Milk	Cattle	Sheep	Other livestock	Crops	Misc.
1	86	83	0.4	29.7	64.4	0.1	3.4	0.5
2	107	509	77.8	11.1	7.1	0.5	2.4	0.3
3	29	47	1.8	63.9	28.3	0.5	1.9	0.6
4	10	223	17.2	27.7	39.5	0.4	0.8	13.5
5	2	1,145	0.0	18.2	7.8	74.6	1.1	0.1
6	6	58	5.1	20.1	14.3	0.9	56.6	1.2
All	240	283	35.9	25.1	31.7	1.0	4.1	0.9

Farm sectors and farm income

Initial investigations revealed some substantial contrasts between different groups of farms, most noticeably in terms of principal activity and resultant income levels (Bateman and Lovett, 1992). Ignoring this issue could have led to the underestimation of standard errors and exaggeration of the degree of explanation of any single model applied across all farms. Rather than adopt *ad hoc* rules for sectoral definition, a two-stage classification process was implemented. Firstly, a principal components analysis (Norusis, 1985) was undertaken using farm-level data concerning the proportion of total revenue derived from each of six groups of output activities. Farms were subsequently grouped on the basis of their scores on the six components using a hierarchical agglomerative technique based on the Ward error sum of squares (ESS) statistic (Ward, 1963). Scrutiny of the output of this analysis (particularly the ESS increments in the agglomeration schedule) suggested that a six-cluster solution was the most appropriate.[15] Table 8.4 lists activity and income-level statistics for each cluster.

It was decided that sample sizes were insufficient to justify further analysis of clusters 3 to 6. This left the two principal agricultural sectors for Wales: farms in cluster 1 specialised in sheep production with substantial production of beef cattle (hereafter referred to as ‘sheep farms’); while farms in cluster 2 specialised in dairying (hereafter referred to as ‘milk farms’). As a final test of sectoral homogeneity, standard diagnostic tests for outliers were employed (Minitab, 1992). This identified one outlier in cluster 1 and three in cluster 2 and these farms were

[15] Note that these are reasonably similar to those defined by the FBSW. However, unlike the latter, they do not further subdivide farms according to their size as this may be (and subsequently proved to be) a significant determinant of per hectare farm income.

omitted to leave a final sample of 85 sheep farms and 104 milk farms. The most striking difference between these two clusters was a wide disparity in income levels with mean net income per hectare on milk farms being nearly six times that on sheep farms.

An issue which proved more complex than expected was the definition of appropriate measures of what the farmer perceives as his/her annual net income (which we term farm-gate income, FGI) and of the shadow value equivalent of this (note that to permit comparability between farms of differing size all values referred to subsequently are adjusted to a per effective hectare basis[16]). An immediately appealing measure in the FBSW dataset is the 'net farm income' (NFI) variable.[17] However, following initial investigation (Bateman and Lovett, 1992) this variable was found to be unsuitable for general modelling requirements because, while its output value minus input value part (denoted 'farm surplus' in FBSW publications) is, as expected, positively correlated with the quality of the biophysical farm environment (the variables $B_{1ij}, B_{2ij}, \ldots, B_{hij}, \ldots, B_{zij}$ in Equation (8.2)), for sheep farms the opposite relationship occurs with respect to the 'subsidies and grants' constituent of NFI.[18] This tends to suppress the link between environmental adversity and overall income level which is a substantial focus of interest in this study.

The definition of the correct measure of farm income is inherently problematic and is itself the subject of research (Sturgess, 1996). Following conversations with Tim Jenkins (FBSW Director, Aberystwyth) it was decided to base statistical investigations of agricultural value upon the farm surplus variable with subsequent adjustments of predicted values to estimate FGI. An appropriate definition was agreed with FBSW:

$$\text{FGI} = \text{farm surplus} + (\text{subsidies and grants} - \text{rent and rates} - \text{depreciation}) \tag{8.3}$$

To obtain FGI requires an estimate of (.) in Equation (8.3). Actual observations on (.) can be used to define an adjustment variable, ADJFGI, which is the absolute difference (in £/ha) between FGI and farm surplus. This variable was defined for both the sheep and milk sectors (producing variables ADJFGIS and ADJFGIM respectively). ADJFGIS was generally positive and found to vary according to the

16 This adjustment was at the individual farm level using FBSW data on effective farm area (the latter omits land under roads, buildings, etc.). This applies to all regression models and results reported subsequently.
17 For precise definition of this and subsequent FBSW terms, see FBSW (1990).
18 This is in itself interesting as it shows that, at least on sheep farms, subsidies and grants do compensate for environmental adversity. Further complexity arises because the unpaid labour element of NFI is positively correlated with such adversity, i.e. farmers attempt to combat poor physical environments by devoting relatively more labour to the farm.

biophysical environment (increasing with environmental adversity); accordingly a simple regression model was used to predict its value.[19] In contrast, a simple flat rate of £95 was found to be adequate for ADJFGIM.

The farm-gate price received by farmers for their produce tells us the financial value (to farmers) of that output but it does not necessarily correspond to the wider social value of that output. In order to move closer to the latter we adjust for the following five factors.

(i) *Market price support*. The Organisation for Economic Co-operation and Development produces annual estimates both of the value of output and the value of market price support disaggregated for all major farm products in each member-nation (OECD, 1992). Using this information, a rate of market price support can be calculated and subtracted from the market price of the goods concerned.

(ii) *Direct subsidies and grants*. OECD (1992) also gives values for the amount of direct subsidies and grants paid to farmers. However, unlike our market price support calculation, such a rate of support cannot be said to be a reasonable approximation of the direct payments received by each farm. Fortunately, the FBSW data supplied for this research details individual farm direct subsidies and grants disaggregated under three headings: cattle, sheep, and miscellaneous. Consequently, individual payments can be directly subtracted from the total output value of each farm.

(iii) *Input subsidies*. Rates of input subsidy for each output heading were calculated from data given in OECD (1992). Ideally we would wish to allocate costs to individual outputs and remove input subsidies from these different cost portions. However, given that the same inputs are used on a variety of outputs, such an allocation of costs was not possible. An alternative approach is to calculate input subsidy values for each output by applying relevant input subsidy rates to the value of each output. These can then be added to total input costs.

(iv) *Levies*. These are in effect negative market price supports and can be treated in the same manner. Whereas adjusting for market price support will lower shadow value (with respect to market price), adjusting for levies (where applicable) will reverse the direction of movement (although the value of levies is invariably far below that of market price support).

(v) *Impacts of the above upon world price levels*. The policy instruments above have had a considerable and depressing impact upon world market prices for agricultural produce which needs to be considered in our shadow pricing exercise (Rosenblatt *et al*., 1988). Roningen and Dixit (1989) provide estimates of the rates of world price increase of various farm products resulting from a general liberalisation of agricultural policy as implied by adjusting for the above instruments.[20]

[19] See Bateman (1996) and subsequent discussion of Table 8.4.

[20] Taken from Roningen and Dixit (1989: p. 16, table 5). The trade liberalisation adjustment attempts to remove the distortions inherent in actual world prices stemming from policy intervention in the agricultural sectors of the main developed countries in the late 1980s.

The resulting shadow value (SV) is not the full social value of agricultural output as we ignore non-market externalities. However, such a value is more compatible with cost-benefit analysis than are the farm-gate-based FGI values discussed previously. The SV corresponding to farm surplus was calculated by adjusting the recorded financial values of outputs and inputs to estimated world price equivalents for the sample year. Two steps were involved in this calculation. First, output values were adjusted for market price support and co-responsibility levies and input values were adjusted for input subsidies.[21] Second, the adjusted output value for each farm product was multiplied by a trade liberalisation coefficient which attempted to capture the effect of multilateral agricultural trade liberalisation on the world price of that product. For ease of computation a combined shadow value adjustment factor for sheep and milk farms (SVadjs and SVadjm) allowing for all of these elements was calculated. Results from this analysis indicate that the SV of output was around 55 per cent of farm surplus for the milk farms, a figure that rose to about 60 per cent for the sheep farms in our sample.

We have now established definitions whereby we can identify both FGI and SV. Both of these are derived from farm surplus which we now define as π_{ij} in Equation (8.1). One set of Equations (8.1) and (8.2) is estimated for each of the two farm sectors under consideration.

Modelling farm surplus

Regression analysis proceeded in line with the principles described by Lewis-Beck (1980), particular attention being paid to problems of multicollinearity. Referring back to the modelling terminology defined earlier, we first estimated the stage 1 value function (Equation (8.1)) which defines the input–profit relationship. This identified the explanatory input variables which were best able to predict farm surplus and which subsequently formed the dependent variables in the stage 2 equation set (Equation (8.2)) which defined the input–biophysical environment relationship.

The dataset was extensively investigated with a variety of specifications and functional forms being tested. Table 8.5 reports the best-fitting stage 1 model of farm surplus per effective hectare for the sample of sheep farms and milk farms.

Given their cross-sectional nature, both models have a relatively high degree of explanatory power.[22] Examining the model for sheep farms we can see that farm surplus increases with livestock intensity ($live/eh), with the efficiency of that

[21] All adjustments made were based on data from OECD (1992); further details are given in Bateman (1996).

[22] There is debate as to what is an acceptable value for adj. R^2 in cross-sectional studies. Hanley (1990) recommends a value of 0.2 while Mitchell and Carson (1989) suggest 0.15. The current study relies primarily on the former, more demanding, rule. Note also that the F ratio is significant in all cases and the null hypothesis of zero coefficient of determination is rejected at 1 per cent significance for all our results.

Table 8.5. *Best-fitting stage 1 models of farm surplus/ha on sheep (cluster 1) and milk (cluster 2) farms*

Farm surplus/ha for sheep farms		Farm surplus/ha for milk farms	
constant	−207.77 (−3.35)	constant	4.80 (0.05)
lambs/ewe	180.87 (4.97)	\$live/eh	0.467 (7.38)
\$live/eh	0.151 (3.95)	gShep%TO	−3, 543.2 (−5.13)
\$f&sLab/h	0.010 (2.91)	genC/h	1.680 (2.75)
grants%	−210.43 (−2.15)	\$mlk/cow	0.241 (2.67)
		pLab/h	−0.510 (−2.63)
		catt%FR	−460.6 (−2.43)
R^2 (adj.)	0.62		0.67
n	85		104

where:
lambs/ewe = no. of lambs reared per ewe per annum (efficiency measure)
\$live/eh = value of livestock per effective hectare (input intensity)
\$f&sLab/h = notional value of farmer and spouse labour input per hectare (input measure)
grants% = total subsidies and grants (direct payments) expressed as a proportion of total farm revenue (grant dependency measure)
gShep%TO = sheep grants expressed as a proportion of farm total output value (grant dependency measure)
genC/h = general farm costs (electricity, water and telephone charges, licences, insurances, subscriptions, etc.) per hectare (input intensity)
\$mlk/cow = the value of milk produced per cow (efficiency measure)
pLab/h = value of paid labour per hectare (efficiency measure)
catt%FR = value of cattle output expressed as a proportion of total farm revenue (enforced diversity measure)
Figures in brackets are *t*-statistics.

livestock (lamb/ewe) and with the amount of labour a farmer and/or spouse devotes to the farm (\$f&sLab/h). However, increased revenue dependency upon direct payments (grants%) is synonymous with relatively lower levels of farm surplus.

The stage 1 model for milk farms performs even better than that for sheep farms, achieving a very satisfactory degree of explanation given that this is a cross-sectional analysis. As before we find positive relationships between farm surplus and input intensity (\$live/eh, genC/h). Similarly, farm efficiency is a clear determinant of farm surplus, which increases with the value of milk produced per cow ($mlk/cow)[23] and falls as more paid labour is required per hectare (pLab/h). Finally, we have two variables showing that where milk farms have to rely increasingly upon lower margin, non-core activities such as sheep and cattle (gShep%TO, catt%FR) so farm surplus values tend to decline.

The second stage of the modelling process entails the estimation of predictive models for each of the stage 1 explanatory variables for both types of farm. Thus, stage 2 models are concerned with predicting the relationship between biophysical characteristics and agricultural inputs. Table 8.6 presents the results of the stage 2 models for sheep farms.

Given their cross-sectional nature, the models have reasonable explanatory power, with the possible exception of the model for labour inputs. Inspection of the lamb/ewe model shows that the value of this input efficiency measure is lower for soils prone to waterlogging (lnFCdays), but improves where modification leads to better forage availability (Silag%, $crop/h). Consideration of these variables raises a problem regarding how they should be treated when using the model to predict lamb/ewe for the entire study area. We have full coverage for all of the biophysical variables (i.e. a raster layer for lnFCdays can readily be created within the GIS) but the same is not true of the modification variables. A typical approach to such problems is to hold such variables at defensible constant values.[24] An analysis of the distribution of both modification variables showed them to be somewhat skewed and so, for the purposes of prediction, both were held at their median values ($crop/h = 19.50; Silag% = 0.145).

Livestock intensity ($live/eh) is well predicted by the next model, being negatively related to increased susceptibility to waterlogging (lnFCdays) and positively related to improved access to the land (SprMWDSq) and forage availability (Silag%), the latter being treated as before in generating predictions of $live/eh. The third model shows farmer and spouse labour input rising in more waterlogged areas (Endwet) and following a negative quadratic with respect to accessibility (SprMWD, SprMWDSq), suggesting that as accessibility declines so does labour input but at a declining rate indicative of some minimum level below which labour input will not fall. However, the strongest relationship is with farm size, with small farms exhibiting significantly higher levels of farmer and spouse labour input. Again for predictive purposes this variable was held at its median value (<140eh = 1).

The final stage 2 equation for sheep farms predicts the proportion of total farm revenue derived from subsidies and grants (grants%). Here the dependent variable is purely predicted by biophysical variables which provide a good degree of explanation. As discussed previously, sheep farm grants are a function of environmental adversity, in this case modelled by increased waterlogging and slope.

23 This is analogous to the lamb/ewe variable in the stage 1 model for sheep farms.
24 See, for example, Garrod and Willis (1992a).

Table 8.6. *Best-fitting stage 2 models for sheep farms*

	Dependent variable			
Predictor	lambs/ewe	\$live/eh	\$f&sLab/h	grants%
Constant	3.510	2, 711.9	−791.0	−1.292
	(5.99)	(4.38)	(−0.29)	(−4.94)
lnFCdays	−0.452	−410.0	—	0.272
	(−4.30)	(−3.70)		(5.70)
SprMWD	—	—	−710.0	—
			(−2.41)	
SprMWDSq	—	1.421	78.59	—
		(2.44)	(3.27)	
Endwet	—	—	37.86	—
			(2.60)	
lnSlope	—	—	—	0.032
				(2.93)
Silag%	0.59	1, 035.8	—	—
	(3.16)	(6.14)		
\$crop/h	0.001	—	—	—
	(2.57)			
<140eh	—	—	2, 191.4	—
			(3.56)	
R^2 (adj.)	0.37	0.45	0.25	0.39
n	85	85	85	85

where:
Biophysical variables:
lnFCdays = natural log of the number of days per annum for which soil is at field capacity
SprMWD = number of spring machinery working days
SprMWDSq = square of number of spring machinery working days
Endwet = the end of field capacity period as measured in ‘wet’ years
lnSlope = natural log of mean farm slope angle
Modification variables:
Silag% = proportion of farm area put to silage
\$crop/h = value of crops per hectare
<140eh = dummy for smaller farms (less than 140 effective hectares)
Figures in brackets are t-statistics.

Table 8.7 presents the stage 2 models for milk farms. The model for predicting livestock intensity (\$live/eh) on milk farms fits the cross-sectional data well. Livestock intensity declines in areas of higher waterlogging risk (lnEwet) and rises in areas considered suitable for delicate crops (lnAWpot). There is also a positive general association with lowland relief areas (Lowrelif). Farmers can also improve the ability of the farm environment to support livestock both directly through the fertilisers (Fert/h) and indirectly through inputs of concentrates (pConc/h). As with our sheep models, for predictive purposes data on the biophysical variables (here lnEwet, lnAWpot and Lowrelif) are available for the entire study area. However, as before, we hold the modification variables (here Fert/h and pConc/h) at representative constant values. In the livestock intensity model both modification variables exhibit a slightly skewed distribution and so are held at their median values (pConc/h = 241.2; Fert/h = 88.36).

In the model predicting the proportion of farm total output value derived from direct payments for sheep (gShep%TO), the dependent variable exhibits a quadratic relationship with the waterlogging measure (Enddry), falling at a declining rate as the end of field capacity period increases. This model is relatively weak compared to previous stage 2 models. Nevertheless it does satisfy our theoretical validity criteria (R^2(adj.) > 0.2). However, this is not true of the next model which predicts the general farm costs per hectare input intensity measure (genC/h) and accordingly we have grounds for doubting the validity of using such a model to predict the value of this input in the stage 1 model for milk farms. However, inspection of genC/h showed it to be reasonably normally distributed across farms and so it was decided to hold it at its mean value (85.23) in the stage 1 equation.[25] This is clearly not ideal but it is a recognised and unbiased way of addressing such a problem.

The explanatory power of the best-fitting model for the input efficiency measure $mlk/cow (the value of milk produced per cow) for our milk farm sample is rather better, although a collinearity problem between the two variables AWcerSq and SprMWD (both of which are related to soil moisture) makes their interpretation problematic. Nevertheless, these variables were retained on the grounds that they substantially improved prediction of the dependent variable, which is the prime purpose of the stage 2 models. Other variables are more straightforward to interpret. Soil classes 2 and 3 refer to some of the best (brown earth) soils found in the study area[26] while the variable Lowrelif indicates lowland areas. As expected both are positively related to milk yields as is a higher level of concentrate usage (pConc/h).[27] Interestingly, and in contrast to sheep farms, higher levels of labour input on milk farms seem to be an indicator of inefficiency and consequent lower yields. This seems reasonable and is backed up by the negative sign on paid labour input in the stage 1 milk farm model. It seems that whereas low income levels mean that sheep farmers have no option but to devote additional unpaid labour to their farms, milk farms are generally operating at a much higher level of efficiency where profit maximisation can often be enhanced through cost reductions.

As before, the modification variables are held as constants when the stage 2 models are used for predictive purposes. Here both f&sLab/h and pConc/h were

[25] So in the stage 1 model we multiply the coefficient on genC/h by the mean value of the variable, i.e. 1.680 * 85.23 = 144.7.

[26] See Bateman (1996) for further details.

[27] Tests revealed no significant multicollinearity problem.

Table 8.7. *Best-fitting stage 2 models for milk farms*

	Dependent variable					
Predictor	\$live/eh	gShep%TO	genC/h	\$mlk/cow	pLab/h	catt%FR
Constant	468.0 (0.28)	0.1279 (1.93)	44.19 (3.47)	481.0 (4.49)	227.30 (2.65)	0.092 (7.31)
lnEwet	−736.8 (−2.72)	—	—	—	—	—
lnAWpot	804.6 (2.88)	—	—	—	—	—
Lowrelif	140.24 (2.05)	—	—	84.10 (2.29)	—	—
Enddry	—	−0.002 (−2.34)	—	—	—	—
EnddrySq	—	0.00001 (3.06)	—	—	0.032 (3.03)	—
AWgrSq	—	—	0.002 (2.15)	—	—	—
AWcerSq	—	—	—	0.016 (3.27)	—	—
SprMWD	—	—	—	−11.141 (−2.64)	—	—
soil2&3	—	—	—	152.25 (3.86)	—	—
RainSq	—	—	—	—	−0.0003 (−4.10)	—
MdefCerl	—	—	—	—	−4.802 (−4.58)	—
Grazseas	—	—	—	—	1.0426 (3.17)	—
ElevSq	—	—	—	—	−0.0006 (−2.54)	—
lnSlope	—	—	—	—	—	−0.022 (−2.49)
sinAsp	—	—	—	—	—	−0.026 (−2.16)
pConc/h	0.743 (4.79)	—	—	0.336 (4.03)	—	—
Fert/h	2.296 (3.69)	—	—	—	—	—
f&sLab/h	—	—	0.081 (4.39)	−0.376 (−4.43)	−0.147 (−2.96)	—

Table 8.7. *(cont.)*

	Dependent variable					
Predictor	$live/eh	gShep%TO	genC/h	$mlk/cow	pLab/h	catt%FR
ehaHay	—	—	—	—	—	0.008 (3.38)
R^2(adj.)	0.44	0.24	0.20	0.29	0.27	0.16
n	104	104	104	104	104	104

where:
Biophysical variables:
lnEwet = natural log of the end of field capacity period as measured in 'wet' years
lnAWpot = natural log of available water, measured for potato crop
Lowrelif = farm in SSLRC relief regions 4, 5 or 6 (lowland)
Enddry = end of field capacity period as measured in 'dry' years
EnddrySq = Enddry * Enddry
AWgrSq = square of water availability for grass crop
AWcerSq = square of water availability for cereals
SprMWD = spring machinery working days
soil2&3 = farm located on soil types 2 (brown earths) and/or 3 (podzols)
RainSq = square of the average rainfall (mm per annum) on farm
MdefCerl = soil moisture deficit for cereals
Grazseas = length of grazing season (days per annum)
ElevSq = square of farm elevation (m) above sea level
lnSlope = natural logarithm of average slope on farm
sinAsp = sine of aspect
Modification variables:
pConc/h = value of purchased concentrates per hectare.
Fert/h = value of fertiliser per hectare
f&sLab/h = notional value of farmer and spouse labour input per hectare
ehaHay = effective hectares of farm put to hay
Figures in brackets are *t*-statistics.

found to have somewhat skewed distributions and so were held at median values of 135.6 and 241.2 respectively.

The next model considers another input efficiency measure, namely the value of paid labour per hectare on milk farms (pLab/h). Analysis of this model shows that the level of paid labour employed on farms is lower in areas of relative environmental adversity (indicated by high values of the RainSq, MdefCerl and ElevSq variables) and higher in areas were the environment is more benign (high values for Grazseas and EnddrySq). It is perhaps not surprising to find that the amount of paid labour on farms is inversely related to the farmer and spouse labour input, suggesting that as a farmer's income increases so he/she substitutes paid labour for personal effort. For predictive purposes f&sLab/h is again held at its median value.

Finally the last stage 2 model is concerned with predicting catt%FR, an indicator of a particular, lower margin, non-core activity on our milk farms. This model fails our criterion of theoretical validity. However, catt%FR was approximately normally distributed and was consequently set to its mean value (0.1107) for predictive purposes within the stage 1 equation for milk farms.[28]

The various stage 1 and stage 2 models provide empirical estimates of the relationship between the biophysical environment, levels of inputs and resultant output values on our sheep and milk farms. These estimates can now be applied to the prediction of FGI and SV for both sectors across the entirety of the study area, thereby yielding vital information concerning the potential for land use change and policy impact within the area.

Mapping market and shadow values for farms

An initial attempt to implement our GIS-based methodology revealed that the range of certain biophysical variables across the whole study area was somewhat greater than that of the sample farms. This was most noticeable for the milk farm sample, which lacked substantial upland observations. In general there was not a problem across the vast majority of the study area, but it was at the extremes, particularly in very mountainous areas, that models were effectively being used to predict outside the range of available data.

In practice, there are two possible solutions to such a problem (Altman and Gardner, 1989): either we can refrain from prediction in such areas or we can truncate each biophysical variable to some level represented in our farm sample data. The latter course of action was preferred as it was felt that having holes in the final map of predicted values would be confusing. Affected cells were set to the upper or lower limit of the farm sample data as appropriate. For our sheep farm models, over 90 per cent of the 20,563 1 km land cells constituting the entire surface of Wales suffered no truncation of any variable, 8 per cent of cells had one variable truncated and less than 2 per cent of cells suffered further truncation. However, for our milk sample these proportions were 74, 10 and just over 15 per cent respectively. The reason for this difference is simple, namely that there are relatively few milk farms in extreme upland areas. Consequently we have to be circumspect about predictions of milk farm values in such locations.

Farm surplus values were now estimated by running the various stage 2 models (using truncated biophysical variable surfaces as appropriate) to predict the input variables for the stage 1 models; from these, farm surplus values were then estimated. Table 8.8 details these values for both sectors, emphasising the highly

[28] So in the stage 1 model we multiply the coefficient on catt%FR by the mean value of the variable, i.e. $-460.6 * 0.1107 = -50.99$.

Table 8.8. *Predicted farm surplus values for sheep and milk farms*

	Sheep farms		Milk farms	
Farm surplus (£/ha)[1]	No. of cells	% of all cells[2]	No. of cells	% of all cells[2]
0.00–49.99	2,483	12.1	7	0.1
50.00–99.99	6,346	30.9	37	0.2
100.00–149.99	9,492	46.2	248	1.2
150.00–199.99	1,728	8.4	463	2.3
200.00–249.99	323	1.6	825	4.0
250.00–299.99	191	0.9	261	1.3
300.00–349.99	—	—	274	1.3
350.00–399.99	—	—	317	1.5
400.00–449.99	—	—	307	1.5
450.00–499.99	—	—	500	2.4
500.00–549.99	—	—	1,295	6.3
550.00–599.99	—	—	2,342	11.4
600.00–649.99	—	—	4,845	23.6
650.00–699.99	—	—	5,067	24.6
700.00–749.99	—	—	3,171	15.4
750.00–799.99	—	—	543	2.6
800.00–849.99	—	—	61	0.3

Notes: [1] Categories chosen to facilitate easy comparison with values reported in other chapters.
[2] There are 20,563 1 km land cells in the study area.

significant difference in profitability between the sectors. This difference becomes more extreme if we recall that there are relatively few milk farms in areas of environmental adversity, i.e. those cells at the lower end of the distribution of predicted farm surplus probably refer to very few (if any) real-world milk farms.

By applying the adjustment factors (ADJFGIS and SVadjs for sheep farms and ADJFGIM and SVadjm for milk farms) to the estimates of farm surplus the predicted market and shadow values of output for each sector can be obtained. Considering the sheep farm sector first, Plate 2a shows the resulting GIS-generated map for predicted farm-gate income (FGIs) while Plate 2b illustrates predicted shadow value (SVs). The distribution of predicted values is similar across these maps and conforms strongly to prior expectations. Values are lowest in the Snowdonia, Cambrian and Brecon mountains and increase with movement into lowland areas. Localised variation due to soil quality and related impacts can also be detected. The somewhat blocky nature of parts of these maps is primarily due to these latter effects, as the LandIS variables are at a 5 km resolution whilst the other biophysical measures are recorded on 1 km grid cells. Given this, the overall picture provided by these results seems highly plausible.

Table 8.9. *Predicted farm-gate income and shadow values for sheep and milk farms*

	Sheep farms				Milk farms			
	FGIs		SVs		FGIm		SVm	
Value (£/ha)[1]	No. of cells	% of all cells[2]	No. of cells	% of all cells[2]	No. of cells	% of all cells[2]	No. of cells	% of all cells[2]
−100.00–−50.01	—	—	—	—	3	0.1	—	—
−50.00–−0.01	—	—	—	—	37	0.2	—	—
0.00–49.99	—	—	7,414	36.1	219	1.1	32	0.2
50.00–99.99	—	—	12,389	60.3	418	2.0	364	1.8
100.00–149.99	8,296	40.4	728	3.5	887	4.3	1,184	5.8
150.00–199.99	11,506	56.0	32	0.2	264	1.3	452	2.2
200.00–249.99	527	2.6	—	—	251	1.2	468	2.3
250.00–299.99	234	1.1	—	—	336	1.6	734	3.6
300.00–349.99	—	—	—	—	284	1.4	2,640	12.8
350.00–399.99	—	—	—	—	479	2.3	7,510	36.5
400.00–449.99	—	—	—	—	1,186	5.8	6,566	31.9
450.00–499.99	—	—	—	—	2,231	10.9	613	3.0
500.00–549.99	—	—	—	—	4,582	22.3	—	—
550.00–599.99	—	—	—	—	5,228	25.4	—	—
600.00–649.99	—	—	—	—	3,467	16.9	—	—
650.00–699.99	—	—	—	—	608	3.0	—	—
700.00–749.99	—	—	—	—	83	0.4	—	—

Notes: [1] Categories chosen to facilitate easy comparison with values reported in other chapters.
[2] There are 20,563 1 km land cells.

This analysis was repeated for milk farms and Plate 2c shows the map for predicted farm-gate income (FGIm) while Plate 2d details predicted shadow value (SVm). As both the adjustment factors, ADJFGIM and SVadjm, are constants applied to predicted farm surplus values, these only differ in terms of absolute values. For both we can see strong topographic and soil effects (see, for example, the band of poorer soils extending down the centre of the Pembroke peninsula). As before, the predicted values conform strongly to prior expectations.

Comparing Plates 2a–2d, it is clear that, for each sector, shadow values lie substantially below farm-gate income levels. However, the strongest contrast is between sectors, with milk values very much higher than their sheep equivalents. Table 8.9 illustrates this contrast by summarising frequency distributions for all four variables. This table quantifies the very wide disparities in both farm-gate income and shadow value levels between the sheep and milk sectors. As noted with respect to farm surplus, this disparity becomes even sharper when we recognise that milk farms tend to be concentrated upon better land, i.e. the lower, say, 10 per cent of milk values will, in reality, contain very few actual milk farms.

Summary and conclusions

Any attempt to influence patterns of land use requires an evaluation of the existing usage of that land. This chapter has developed a GIS-based methodology for the estimation of both the market and shadow values of agricultural output for our study area. This methodology permits explicit incorporation of biophysical data within the economic modelling of output values. The capacity to combine diverse spatially referenced data afforded by the use of a GIS allows such modelling to be undertaken at a highly disaggregated level, and yields readily interpretable maps of predicted values as well as more conventional quantitative analyses. These valuation maps are highly compatible not only with those estimated elsewhere in this study but also with the decision-making approaches being developed and employed by agencies such as the Countryside Commission, Forestry Commission and National Assembly for Wales in their land use and planning roles (Countryside Commission and Forestry Commission, 1996; Forestry Commission, 1998).

The application presented in this chapter provides models and mapped estimates of both the market and shadow values of output of the two major farming sectors in the study area: mainly sheep and mainly dairying farms. Results show that, for both sectors, shadow values were considerably below corresponding market values. Furthermore, sheep farm values were substantially lower than those enjoyed by the dairy sector. Both sectors have suffered further losses in real incomes since our study period, implying that our estimated rates of land use conversion are likely to provide lower bounds on the actual potential for efficiency gains from such changes.

The spatial detail of information provided by the resultant GIS-generated maps permits analysts and policy-makers to assess issues such as the likely extent and location of land use response to changes in policy parameters. They also permit ready integration with the maps of woodland recreation, timber and carbon sequestration value estimated in previous chapters to allow us to evaluate the net benefits of transfers out of agriculture and into woodland, a task to which we now turn.