Modelling Policies for Multifunctional Agriculture and Rural Development in a Remote EU Region (Caithness & Sutherland, Scotland, UK)

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Abstract

A modified version of a system dynamics model constructed for an EU-wide case-study project (TOP-MARD) using STELLA software was used to simulate the effects of a number of development scenarios for a remote rural area in Northern Scotland, i.e. Caithness & Sutherland, which is characterised by multifunctional agriculture. In this paper, the context of the modelling work in policy and socio-economic terms is first described. This is followed by the specification of the model and of the modelling scenarios, one of which relates to the "decommissioning" (run-down) of a major industrial site (Dounreay) within the area. The modelling results are discussed, in terms of regional population, land use, economic and other terms, from 2001 to 2015/2031. Finally, some conclusions are drawn, both about the implications of the results for such remote rural regions, and the usefulness of this type of modelling exercise for policy analysis of multifunctionality and rural development.

Keywords: modelling, multifunctionality, input-output, systems dynamics, rural policy

1. Introduction

The multifunctionality of agriculture and the socio-economic development of rural areas are both concepts of rising policy significance in the European Union. Remote areas in the EU are often characterised by falling and aging populations, fragile economies, and ecological systems under threat from declining agricultural practices. Thus, the role of policy is particularly important, since farm incomes are heavily supported by CAP payments, the public sector is a large part of the economy, and nature conservation measures such as Natura sites are often already widespread.

Clearly, the range of policies impacting on such areas is wide, and includes:

- Pillar 1 of the CAP, i.e. single farm payments, payments still "coupled" to agricultural areas or livestock, and market support via border tariffs etc., especially on milk and red meats
- Pillar 2 of the CAP, now being reformulated in terms of three "Axes", for farm/forestry competitiveness, environmental friendly land management, and rural diversification and improved "quality of life" (QoL), respectively
- Structural and cohesion funding for infrastructure and the promotion of general economic development
- Environmental regulation under EU and national/regional legislation, to protect certain areas (e.g. national parks) or wildlife species; such regulation often impacts on agricultural practices and incomes, both positively (e.g. tourism) and negatively (certain operations being banned)
- National/regional policy expenditure and regulations, e.g. for transport, education, health services and housing, as well as social security payments for the unemployed, ill or aged.

Modelling such a wide range of concerns, activities and policies is a formidable task, beyond the capacity of standard economic tools such as input-output or social accounting matrices, time-series econometric regression, or mathematical optimisation. Difficulties include:

- combinations of biophysical, demographic and economic behaviour
- lack of data, within some of the above areas and/or across time
- competing or uncertain policy objectives, e.g. economic, environmental and socio-cultural "sustainability", and local-national/EU differences in political attitudes.

Thus far, modelling efforts – e.g. within the CAPRI, ESPON, SENSOR and MEA-SCOPE projects (see reference list) – have seldom attempted to encompass the full range of issues and activities mentioned above. Some have interpreted "rural" as "agricultural", perhaps with a few environmental

components, e.g. fertiliser use or methane emissions, within the latter, while others have modelled regional economies, usually in a comparative static way but with few social or environmental aspects. Attempts have been made to model water catchment or landscape areas, but these have proved expensive in construction time and data requirements. Others focus on individual farm areas or businesses, which may be useful in terms of differential impacts but do not allow appraisal at an aggregate level. The recent emphasis (CEC, 2007) on QoL has introduced another socio-economic dimension to analytic demands.

This paper reports an effort to utilise the "dynamic systems" approach adopted within the FP6 research project TOP-MARD (Towards a Policy Model of Multifunctional Agriculture and Rural Development), which has focussed on case studies of rural regions (generally NUTS3) within ten EU member states and Norway (UHI, 2007). The core model (POMMARD) has been developed by software specialists in a U.S. university, and has become available for specific adaptation and application within any of these case study areas via the input of area-specific data and the modification of model elements, e.g. representation of the regional economy, or local land-use systems.

The paper first outlines the case study area in Scotland UK, and then the structure of the core POMMARD model. Then it describes how the model was applied to the case study area, including a small number of scenarios used for simulation work. The results of these simulation exercises are reported, before concluding with some more general conclusions about this type of "derived modelling" and its use in policy guidance.

2. Caithness and Sutherland

The (former) counties of Caithness and Sutherland comprise the extreme north of the mainland of Scotland in the United Kingdom, and are characterised by remoteness, very low population density (especially in the interior), upland agriculture and "wilderness", and heavy policy intervention. Following the suppression of the highlands rebellion of 1745-46, the area was "cleared" of much of its indigenous population (and thus their agricultural and other activities) in the late eighteenth and early nineteenth centuries. This exodus of the native population was reinforced by later developments in industrialisation, imperial colonisation, and two world wars. Most of the land outside the few towns became the property of large "estates", often owned by outsiders normally resident in England or even abroad, with land use dominated by sports shooting for deer and grouse, and sport fishing. Agriculture was mainly confined to sheep breeding (with lambs being "finished" elsewhere), often combined with other occupations (small-scale coastal fishing, service jobs), in the "crofting" system. Table 1 presents some basic statistics for the area.

Efforts to support the regional economy and society of the Scottish highlands have been underway since the late nineteenth century, most notably with the establishment of the Highlands and Islands Development Board in the 1960s. In the 1980s, the HIDB was converted into Highlands and Islands Enterprise (HIE), which administers and coordinates development initiatives via Local Enterprise Companies (LECs) such as that for Caithness and Sutherland.

A major feature of the Caithness and Sutherland economy is the Dounreay nuclear site, which was established in the 1960s as an experimental "fast breeder" reactor for the development of technology for the generation of cheaper electricity. At its peak, the site, which is located about 15km west of the town of Thurso (population 9,000), directly employed about 1,000 personnel, some highly skilled and paid. This employment dominated the local economy, which has few other major employers except the public sector (schools and colleges, health, etc.) and a small number of manufacturers and construction or transport contractors. However, the technical and economic results from Dounreay were disappointing, and in 2000 it was decided to "decommission" (i.e. run down and clean up, especially radioactive spills) the site over a 30-year time period. At time of writing, the site employs about 2,400 personnel, both directly and via contractors (Bergmann, 2007).

Table 1 Key Data for Caithness and Sutherland, Scotland, 2001

Population	*Total (head)*	*Change 1991 to 2001*
Aged 0 to 19	9,177	-1,275
Aged 20 to 64	22,584	-601
Aged 65 and over	7,212	923
Total	38,973	-953
Land Use	*Area (ha)*	*Change 1995 to 2001*
Tillage	13,597	4,634
Grass, rough and common grazings	543,442	-46,496
Agricultural woodland	11,771	2,947
Other area	1,747	-1,992
Total	570,556	-40,907
ich Sites of Special Scientific Interest (SSSIs)	214,741	+43,390
Livestock	*Numbers*	*Change 1995 to 2001*
Total sheep	467,525	-17,486
Total cattle	59,944	-1,506
Total pigs	4,131	4,002
Agricultural Labour	*Head*	*Change 1995 to 2001*
Total (includes part-time and casual)	3,896	239
Economy	*Employment (FTEs)*	*Total Demand for Products (£ million)*
Primary sector	2,818	38.4
of which agriculture:	2,231	13.8
Secondary sector	3,897	417.6
of which nuclear fuels (Dounreay):	993	63.8
Private services	6,407	349.5
Public services	4,197	98.0
Total	17,319	903.5

Sources: population and agricultural censuses, and official Annual Business Inquiry.
Note: FTE = full-time equivalent (job).

Agricultural policy in the area is naturally dominated by the Common Agricultural Policy (CAP), primarily in terms of support for sheep and beef farming (now converted into the Single Farm and Less Favoured Area payments) and agri-environmental payments, now via Land Management Contracts (about to become Rural Development Contracts within the new Scottish Rural Development Programme, SRDP). Table 2 gives some detail on this support for the agricultural sector in Caithness and Sutherland, along with available information on other policy support[1]. It is notable that Pillar 2 spending now exceeds Pillar 1 spending (or will do so, when the SRDP begins operations after Commission approval), to a ratio of over 2:1.

[1] For easier comparison, 2000-2006 measures have wherever possible been categorised under those for the period 2007 to 2013. Of possible Pillar 2 measures, Scotland in general has only adopted three: afforestation, Less Favoured Area, and agri-environmental schemes. Structural Fund measures were financed within the framework of the Highland and Islands Special Transition Programme, and included former EAGGF measures e.g. farm investment, and the adaptation & development of rural areas. During the period 2007-2013, the Highland and Island Convergence Programme will apply.

Table 2: EU Spending in Caithness and Sutherland (£'000, annualised)

	Until 2006	From 2007
Common Agricultural Policy, of which:	17,074	26,196
- Pillar 1	9,865	10,013
- Pillar 2, of which:	5,149	16,183
- Axis 1	1,034	4,174
- Axis 2	3,990	9,477
- Axis3 (incl. LEADER £0.4K and £90K resp.)	123	2,440
Structural Funds, of which:	8,937	4,469
- ERDF	4,526	2,263
- ESF	1,771	886
- FIFG	2,640	1,320

Notes: "Until 2006" data based on post-MTR CAP reform spending (SG, 2007a); "From 2007" data based on Scottish Rural Development Plan (SG, 2007b).

3. The POMMARD Model

The POMMARD model is built with the Stella© software (ISEE, 2007), representing stocks and flows using user-defined variables, parameters, equations and time periods. According to the supplier, "intuitive icon-based graphical interface simplifies model building" and understanding, and also data input and output, via spreadsheets and "convertors". The use of this software within TOP-MARD was intended to both cover the wide range of project interest, and to enable modelling to done by some national teams who were not familiar with analysis across the range, e.g. input-modelling, agri-environmental features, or QoL measurement.

POMMARD is used to simulate the behaviour of a rural region as a whole (i.e. not individual farms or other businesses) in terms of its demography, economy, environment and QoL over a number of years (at least 15, in the case of TOP-MARD). It contains 11 modules: Land Use (see below), Agriculture, Non-Commodity Outputs or NCOs (environmental), Economy, Investment, Human Resources (demography), Quality of Life, and Tourism, together with Initial Conditions, Scenario Controls and Indicators (i.e. major model results). Figure 1 describes the overall structure of the model.

The primary engines of the model are final demand by economic sector (23 in the core model), and land use by up to 8 agricultural (and other, e.g. forestry) production systems. Such use, specified by shares of total regional area, determines the amounts of labour employed in these systems, and the output of farm commodities and environmental non-commodities. The regional economy is modelled via an input-output table to which a "households" row and column are added, while the Investment module modifies the capacity of each sector. However, unlike many models of economic relationships, the model is partially supply-oriented, insofar as agricultural activity supplements other demand drivers.

The regional population is modelled in some detail, e.g. four age groups and six educational levels (in and after primary (age 16), secondary (age 19), and tertiary education, respectively). These age-education cohorts are represented in the employment and migration vectors.

The core version of POMMARD was under development throughout 2006 and 2007, and a preliminary version was delivered to the 11 case study area teams in November 2007, along with a 90-page manual or guide. This version required "beta testing", i.e. checking for evaluation and correctness by potential users such as the authors of this paper. At time of writing, these POMMARD items are still under development.

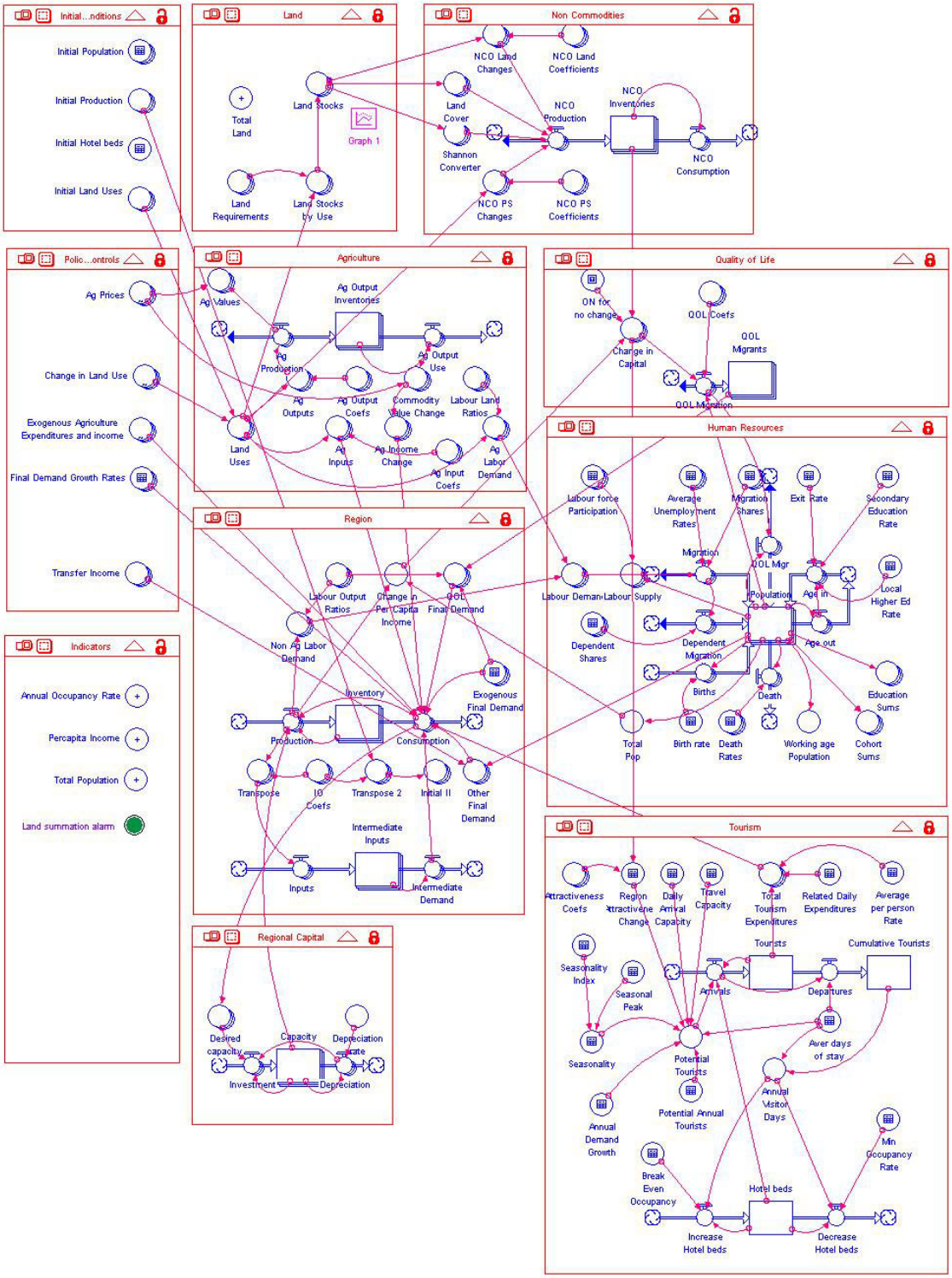

Figure 1: The Structure of the POMMARD Model

4. Modelling Structure and Scenario Specifications

In order to apply POMMARD to Caithness and Sutherland, the core version was modified in a number of ways, as follows:

- The number of sectors was altered to 18 (plus Households), in order to fit the UK SIC structure. These included separate sectors for Agriculture, Forestry, Food Manufacturing and Nuclear Fuels.

Tourism was not separately represented as an economic sector, being proxied mainly by Hotels and Catering.
- With the inclusion of Agriculture and Forestry in the regional economy, redundant links between the Land Use and the Economy modules were cut.

Initial data was then supplied to the model, primarily for the following variables and parameters for the year 2001 and subsequent change:
- Input-output (I-O) coefficients
- Final demand values, by sector
- Population levels and birth and death rates, by age-education cohort
- Coefficients for: land-labour and -NCO ratios, and migration shares (by age-education cohort)
- Rates of changes in total final demand and in labour productivity (both 1.5% p.a.)
- EU policy expenditures (see Table 2) and other expenditures, e.g. Dounreay
- Afforestation (of arable land) falling from 1,000 ha per year in 2001 to around 200 ha per year by 2030.

In most cases, such data was derived from official sources, e.g. the population and agricultural censuses, business and visitor surveys, and agency publications. The I-O coefficients were calculated using an adapted GRIT procedure (Jensen *et* al., 1979) based on the official national (Scottish) I-O table including the household sector. Some data was derived from fieldwork (interviews with farm households and other local residents) carried out within the TOP-MARD study.

The "Initial Base" scenario involved using the above data to run POMMARD from year 2001 to year 2030 without further modification. In general terms, this simulation produced a stable economy providing employment of almost 16,000 full-time equivalents (FTEs) but with a slowly decreasing population due to out-migration of younger persons (often with higher education) and with slowly increasing shares of older people.

In order to provide a more satisfactory basis for current analysis, a "Main Base" scenario was implemented by inserting changes in EU policy expenditures for the year 2007 onwards (see Table 2)[2], with an additional £11 million per year being spent on CAP Pillar 2 measures in the area, and £3.5 million less being spent on ERDF and ESF expenditures, as the Highlands and Islands Special Transition Programme runs out (HIPP 2007). The additional £11 million per year increases total final household expenditures, as it is assumed that in such an extensively farmed area no production changes or adaptations need be made.

Four "alternative" scenarios were then specified in order to explore the implications of various policy options into the future. Two of these scenarios are "EU" in nature, and represent extreme versions of the Commission's new Axis structure within Pillar 2 of the CAP. The other two are more local in nature. In more detail, these scenarios were:

1. CAP Pillar 2 *Axis 1*: all current (planned) Pillar 2 expenditure in Caithness and Sutherland switched into Axis 1, i.e. farm modernisation and investments in direct marketing. This corresponds to an EU strategy of reacting to high world levels of demand for food and fuel by once again increasing support for initiatives designed to improve the output and competitiveness of EU agriculture. More specifically, this scenario assumes an annual increase in both agricultural productivity and

[2] UK adoption of the Mid-Term Review CAP reforms began in 2005, but, as expected, response has not been immediate although sheep numbers have fallen significantly in 2006 and 2007, partly as a result of livestock disease measures. At time of writing, the Scottish Rural Development Programme for 2007-2013 has not yet been approved by the European Commission; however, its main outline is already known. Compulsory and voluntary modulation up to a combined rate of 13.5% by 2009, as announced by Scottish Ministers, has been assumed. No further assumptions about policy change have been made, e.g. to the LFA scheme after 2009, or beyond 2013.

output by 2%. The increased Axis 1 spending is allocated to two sectors: 80% to Construction and 20% to Real Estate and Consultancy.

2. CAP Pillar 2 *Axis 2*: All current (planned) Pillar 2 expenditure in Caithness and Sutherland switched into Axis 2, i.e. for payments to farmers for environmental improvements and land management. This corresponds to continued strengthening of the EU (and especially UK) strategy of increasing support for nature conservation. More specifically, this scenario involves only additional household income, due to the fact that there is not much to do in the area to produce environmental goods and services other than what farmers do already.

3. *Dounreay Decommissioning*: scheduled expenditure by the UK Atomic Energy Authority to clean up and close the nuclear site over about 30 years. The decommissioning expenditures over that period are specified as in official publications, i.e. to peak in 2009 and then fall, to about 65% of current levels by 2015, and to near-zero by 2031. Apart from the Nuclear Fuel sector, four other sectors (Manufacturing, Construction, Real Estate and Consultancy, Public Administration) were specified similarly, according to UKAEA data (NDA/UKAEA, 2006).

4. *Tourism Increase*: in addition to the baseline assumption of growth in tourist demand (2.3 million visits in 2001) of 1.5% per year, an additional growth component of 4% per year was assumed over the period 2007 and 2015 (but not thereafter). This corresponds to the national strategy of increasing tourism spend in (all) Scotland by 50% by the year 2015 (SE, 2006).

5. Model Results

Figure 2 shows in graphical form the evolution over time until the year 2031 of a few key model output ("indicator") results for this Main Base scenario, covering the economic, social and ecological effects of the 2007 changes in Common Agricultural and Regional Policy. Table 3 shows more detailed numerical results for selected years out to 2015. This scenario results in a slight decrease (and ageing) of the population, and a fairly stable economy as well as provision of ecological goods and services. As overall final demand is assumed to increase at 1.5% annually, per capita income increases by about £1,000 (about €1500, or 30%) over the period to 2015.

Table 3: Main Baseline Results for Caithness and Sutherland, 2001 to 2015

	Units	2001	2007	2010	2015
Total Population	head	38,972	39,155	39,086	38,734
Agricultural Labour	FTEs	2,231	2,339	2,355	2,398
Tourism Labour	FTEs	1,124	1,168	1,167	1,164
Total Final Demand	£'000	1,009,201	1,135,425	1,186,269	1,276,835
Per capita Income	£'000	2.84	3.30	3.44	3.73
Biodiversity (index)	n.a.	650,505	650,305	650,205	650,039

Source: model run, 4 January 2008.

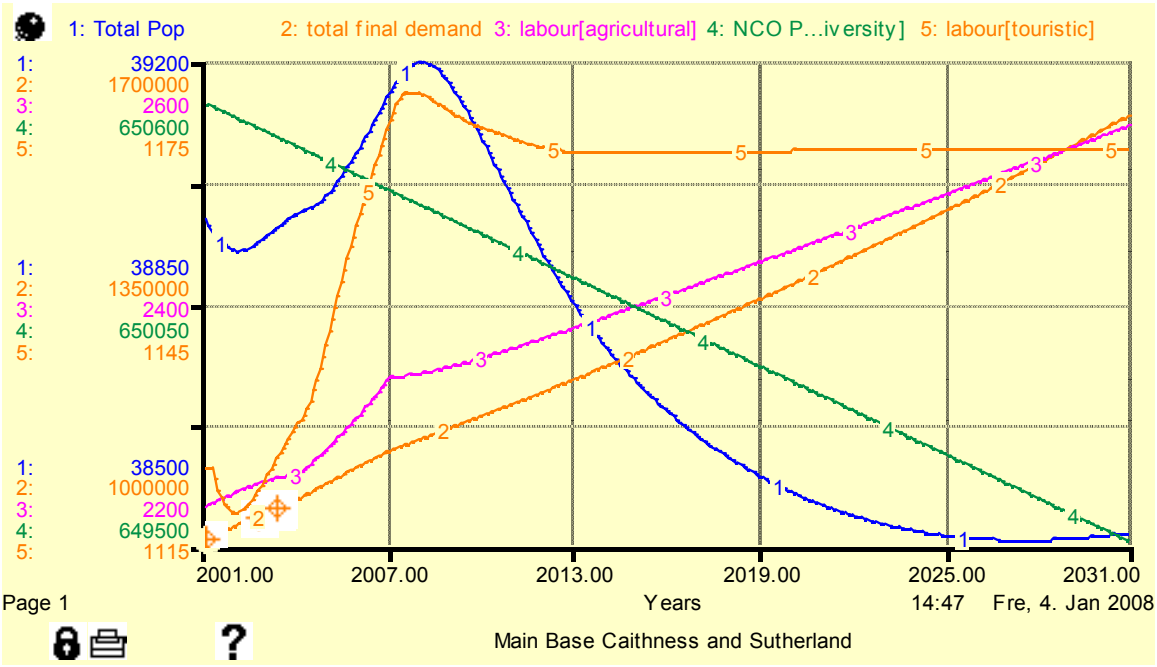

Figure 2: Main Base Scenario Evolution: Population, Total Final Demand for Products (in £), Agricultural Employment (in FTEs), Biodiversity (indexed), and Tourism (Hotels and Restaurants) Employment (in FTEs)

Source: model simulation run, 4 January 2008.

Table 4 shows the model-projected results of the four different "alternative scenario" policy changes in the area, for six key indicators, compared to the main base scenario levels of these indicators.

All scenarios, apart from the Dounreay one, only slightly affect the level of population in 2015 compared to the Main Base. Only the Tourism scenario results in an absolute increase (see data in Table 3) in population, i.e. reverses previous history (see Table 1). However, like agriculture, tourism demands mainly low-skilled labour, and so this higher population would mainly consist of in-migrants, while the out-migration of "home-grown" qualified labour would continue. The Dounreay decommissioning project results in a 4% relative fall in population (rising to 10-15% as decommissioning is completed towards 2031).

Amongst the alternative scenarios, only focussing Pillar 2 spending on Axis 1 significantly (and negatively) affects demand for agricultural labour, which falls slowly in the Main Base scenario. However, it is notable that focussing Pillar 2 spending on Axis 2 has a slight positive effect on this indicator. Tourism employment (i.e. occupation, i.e. including self-employment) behaves in the same directions, but with different magnitudes, especially the Tourism scenario which shows a (relative) increase of nearly 12% by 2015. When further analysed, the detailed results (not presented) show that spending of regional earnings by labour in agriculture and other sectors causes final demand increases for food and food-related services, i.e. the existence of a "virtuous circle" in the local food system.

Total final demand reflects the population results, with only (partial) Dounreay decommissioning having a marked effect by the year 2015. However, given the differential movements and wage-earning capacities of labour (which is simulated by age and qualification) in the various sectors, per capita income levels show rather different patterns, with all scenarios depressing this indicator relative to the Main Base level, except the Axis 2 scenario.

Table 4: Scenario Impacts: Output Indicators for Four Alternative Scenarios compared to Main Base Scenario (%s)

Alternative Scenarios (1-4)	2007	2010	2015
Population (head)			
1. Axis 1	-0.12	-0.53	-0.76
2. Axis 2	-0.04	0.09	0.04
3. Dounreay	0.03	-2.22	-3.84
4. Tourism	0.73	1.14	1.90
Agricultural Labour (FTEs)			
1. Axis 1	-3.16	-4.59	-6.88
2. Axis 2	0.21	0.21	0.21
3. Dounreay	0.00	-0.30	-0.38
4. Tourism	0.21	0.30	0.50
Hospitality (FTEs)			
1. Axis 1	-2.70	-2.65	-2.44
2. Axis 2	2.36	2.26	2.11
3. Dounreay	0.23	-2.40	-2.78
4. Tourism	5.13	7.53	11.78
Total Final Demand (£'000)			
1. Axis 1	-0.35	-0.40	-0.35
2. Axis 2	0.48	0.49	0.45
3. Dounreay	0.10	-4.32	-4.28
4. Tourism	0.79	1.16	1.81
Total Final Agricultural Demand (£'000)			
1. Axis 1	-0.25	-0.27	-0.23
2. Axis 2	0.24	0.25	0.22
3. Dounreay	0.03	-0.30	-0.36
4. Tourism	0.22	0.33	0.51
Per Capita Income (£'000)			
1. Axis 1	-5.76	-4.94	-4.29
2. Axis 2	5.15	4.36	4.29
3. Dounreay	0.61	-3.49	-1.88
4. Tourism	0.00	-0.29	-0.54

Source: model run, 4 January 2008.

6. Conclusions

Various conclusions can be drawn from the modelling exercises reported above, although further work and experience are needed to consolidate and extend these.

1) Perhaps exceptionally for European regions, Caithness and Sutherland can expect more EAFRD money being spent in the period 2007 to 2013 compared to the preceding period 2000 to 2006. For this reason, the CAP reforms imply more people will stay in agriculture than would otherwise have been the case, and that the increased Axis 2 spending will have mostly positive effects on the local economy. Overall, however, the biggest impact on the local society and economy is not related to European Union funding but to a national policy measure, the decommissioning of a nuclear site. However, in an era of globalisation, even the effect of such national measures may be more and more negligible.

2) The main effect of the Main Base scenario (changes in CAP modulation and a change in the regional Structural Funds programmes) is that such measures indeed support the viability of rural

communities. However, ESF and ERDF spending on support for education and training appears to increase the propensity to migrate, and the lower level of such spending after 2007 will reduce the leakage of highly educated people from rural areas, and thus affect population levels.

3) Concentrating Pillar 2 spending on farm investment via Axis 1 does not prevent further depopulation, nor does it increase per capita income as do the other scenarios, due to the fact that such investment is inevitably linked to the introduction of labour-saving technologies into farming. Focussing CAP Pillar 2 spending on Axis 2, i.e. farm household income payments, in such a remote rural and extensively farmed area can marginally help to maintain the total population, but the effect is smaller than for the national policy measures (i.e. Dounreay or Tourism).

4) The best way to avoid further depopulation and to protect rural communities appears to be investment in tourism activities, or indeed a broader development approach which supports manufacturing in the area, rather than only the service sector.

Due to the fact that modelling in the TOP-MARD project is still on-going, only preliminary conclusions can be drawn as regards the modelling approach, i.e. the use of a core systems dynamics model to be adapted to specific rural regions. Applying the core POMMARD model to the Scottish case study area took over 300 man-hours, to carry out beta-testing and to implement region-specific equation changes. Different working practices present unavoidable problems in transnational modelling exercises, and increase the transaction costs of the research. In further modelling projects, special attention should be given to the coordination and distribution of tasks, perhaps linked to official (Commission) provision of incentives and/or mild penalties.

The advantages of a system-dynamic modelling approach based on limited data is valuable in modelling the multifunctionality of agriculture and that of other sectors of the economy, since a wide range of economic, ecological and social effects of policy changes may be modelled, at least crudely. The POMMARD model was also flexible, in that additional variables, modules and linkages could be added relatively easily. Moreover, the time-series nature of such models contrasts favourably with the comparative-static nature of much econometric modelling. However, a rather high degree of arbitrariness was required for initial conditions and behavioural coefficients, and the complexity of the POMMARD structure made beta testing quite difficult at times. Future research should seek to improve the data bases and to calibrate the existing model so that it can be used not only in the 11 case study areas of the TOP-MARD project but anywhere in rural Europe.

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