Title: “Walking in other’s shoes” – experiences of using the DECOIN tools to characterise sustainability trade-offs in Scotland and the Cairngorms National Park

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The paper presents the experiences of using two of the DECOIN tools, SUMMA (Sustainability Multi-criteria Multi-scale Assessment) and MuSIASEM (Multi-Scale Integrated Analysis Societal Ecosystem Metabolism), to characterise sustainability trade-offs in Scotland and the Cairngorms National Park (CNP). The paper reflects on the theoretical basis of the two tools that provide for complex eco-social systems a coherent conceptual and methodological framework within which to understand better sustainability trade-offs. Translating theory into practice, particularly using tools and methods developed by others, however, remains a challenge. The paper reports the progress of the analysis of changes in the sustainability of the agriculture sector (1991 to 2007 using SUMMA) and for the wider economy (2005-2009 using MuSIASEM) for Scotland and the CNP. Approaches to the communication of SUMMA and MuSIASEM outputs for stakeholder audiences are also presented. The paper concludes that the DECOIN tools have significant utility in conducting theoretically coherent, practical for implementation and policy relevant assessments of sustainability trade-offs but that “walking in others shoes” is not always comfortable.

1 Introduction

The Synergies in Multi-Level Inter-Linkages in Eco-social Systems (SMILE)[1] project seeks to further develop and apply the DECOIN[2] tool kit. This toolkit consists of three models: SUMMA (Sustainability Multi-criteria Multi-scale Assessment); MuSIASEM (Multi-Scale Integrated Analysis Societal Ecosystem Metabolism) and ASA (Advanced Sustainability Analysis). The ambition of the SMILE project is to combine these tools into a system of sustainability accounting that provides useful insights into the dynamics of the sustainability of complex coupled eco-social systems (Giampietro et al. 2009).

The authors applied both the SUMMA and MuSIASEM tools in a case study focused on the Cairngorms National Park (CNP). The objectives of the research were to test the utility for end-users and transferability of the DECOIN tools beyond their development teams and applications. This is reported in Blackstock et al. (in this proceeding). The case-study also tried to assess the role of economic growth in achieving sustainability objectives and the trade-offs between sustainability objectives. This paper reports progress made towards these objectives and highlights the strengths and weaknesses of the DECOIN tools.

The SUMMA and MuSIASEM tools take complementary but distinct approaches to the characterisation of the sustainability of eco-social systems. SUMMA is a life-cycle oriented assessment of the economic-environmental performance of a system. SUMMA uses multiple metrics to characterise system performance. SUMMA considers both the upstream draw on resources and the downstream consequences of waste. MuSIASEM is a conceptual approach to assessing overall performance and performance of components of a system. MuSIASEM incorporates human activity, value added, energy use and land, without resorting to a weightings based normalisation to a single unit of measure. Combined together as defined by

[1] http://www.smile-fp7.eu/
[2] http://www.decoin.eu

the MuSIASEM “grammar” these dimensions provide a coherent and systemic characterisation using indicators of stocks and flows of resources.

A key feature of SUMMA and MuSIASEM is the multi-scale nature of the analysis. This allows the explicit comparison of overall performance and of components, be they sectors or geographically defined regions. This can be highly informative as the “averages” of higher level performance may be made up of very distinctive elements, such that policy or other interventions based on the averages may be entirely inappropriate. In both SUMMA and MuSIASEM the extent and intensity of resource use is simultaneously considered. This is essential to ensure that improvements in efficiency are not eliminated by a rebound in consumption (Jevon’s paradox).

2 Materials and Methods

2.1 Case-studies

The Cairngorms National Park was created as a result of the National Park (Scotland) Act in 2003. It is home to approximately 16,000 human residents as well as significant protected habitats and species. National Parks in Scotland are explicitly required to achieve ‘sustainable development’. Therefore, they are not ‘wilderness reserves’ but fit the IUCN category V (protected landscape). With partners at Parthenope University it was decided that the SUMMA based analysis would focus on the production-oriented land-based industries (PoLbI) (agriculture, forestry and sporting estates). The importance of the sector has been variously argued from minimal (gross value added), to marginal (employment), to important (downstream environmental impacts) and finally as crucial (landscape/character of the region). The focus on PoLbI played to the strengths of the authors and built on a tested SUMMA model for the agricultural sector in Campania (Ulgiati et al. 2008). For the MuSIASEM analysis the case study undertook analyses at Scotland wide level, local authority level and for the CNP as a whole. The analyses considered societal averages, the paid work and industry based sub-sectors. The MuSIASEM case-study followed existing published approaches (Giampietro 2004;Giampietro and Mayumi 2000).

2.2 Methods

Figure 1 illustrates the key stages in the case study analysis. For more in-depth description of the materials and methods see the relevant SMILE deliverables[3]. The key challenges in undertaking the analyses were familiarisation with the DECOIN methods (WP2), agreeing a scope with the CNPA through the systems diagramming activity (WP2) and sourcing and integrating the required datasets (WP3). SUMMA is demanding in terms of its data requirements (>250 input values for each of the three time periods). While with MuSIASEM it is possible to progressively step into the degree of detailed required, there were many challenges of incompatible sectoral classifications and units of spatial collection. Several of these could be overcome by accessing more detailed datasets, but energy throughput datasets were limiting both in terms of spatial resolution and length of time series available, (only from 2005). For land use there are multiple sources but their integration (beyond the agricultural sector) is limited. Indeed it was not possible to complete the within-CNP land use analysis within the scope of SMILE.

[3] www.macaulay.ac.uk/SMILE

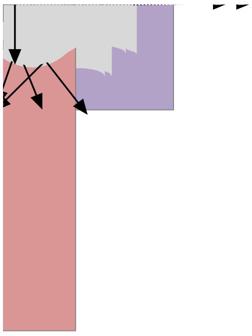

Figure 1: Scotland case study activities and deliverables

3 Results

Within this paper it is only possible to present examples of the key types of outputs used in communications with stakeholders at CNPA, not to summarise all the outputs generated[4].

3.1 SUMMA examples

Emissions are a key issue for land use in Scotland. The extent of emissions tonnages for $Scot_{AG}$ and CNP_{AG} relative to the baseline year (1991) is presented in Figure 2. Note that to assess the GHG potential for each of the tonnages presented they need to be converted to tonnes of CO_2 equivalent. In terms of CO_2 it can be seen that for both the CNP and Scotland there is an increase in the emissions from 1991 to 2001 followed by a decrease to below 1991 values by 2007. This reflects a process of intensification based on the structure of agricultural subsidies that was reversed after 2003. For methane and nitrous oxide the pattern is of a reduction from 1991 but with less reduction after 2001.

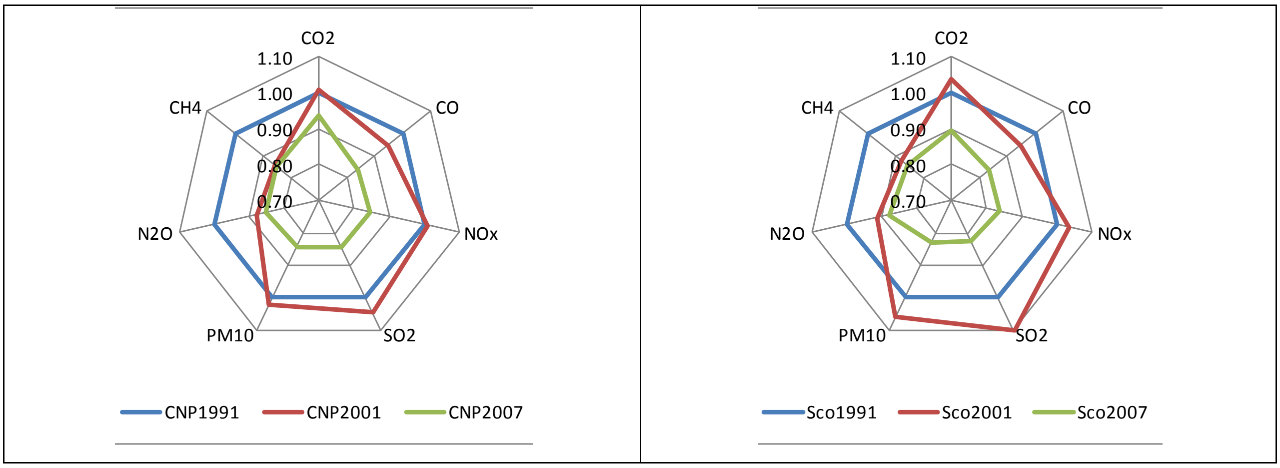

Figure 2 Total Emissions from $Scot_{AG}$ and CNP_{AG} 1991-2007

The relative pattern of emissions for CNP_{AG} and $Scot_{AG}$ have strong similarities in terms of the overall shape of the spider plots. Scotland has a stronger increase by 2001 in CO_2, NO_x, SO_2 and PM10's associated with more mechanised sectors of agriculture, but also a greater reduction

[4] See www.macaulay.ac.uk/SMILE for more comprehensive examples.

(by 2007), perhaps reflecting a greater reduction in intensity in more remote rural areas pulling down the overall Scotland totals.

Comparing CNP_{AG} and $Scot_{AG}$ also provides useful information about the different nature of their production systems. Figure 3 presents the relative emissions intensities for CNP_{AG} and $Scot_{AG}$ for each of the indicators for 2007 (earlier patterns are consistent but with minor variations). The emissions per ha shows the CNP_{AG} as a very low intensity system (less so in terms of CO_2 but still low) compared with an overall $Scot_{AG}$ average. In terms of emissions per kg of dry matter and per Mj of embodied energy the CNP_{AG} system can be seen to be relatively inefficient since it requires up to six times emissions to generate a comparable output. This reflects the marginal nature of the bio-physical resource available to land managers within the park (in terms of production). This lack of efficiency, is though, offset by the higher value per unit of production so that emission per € are three rather than six times the $Scot_{AG}$ average.

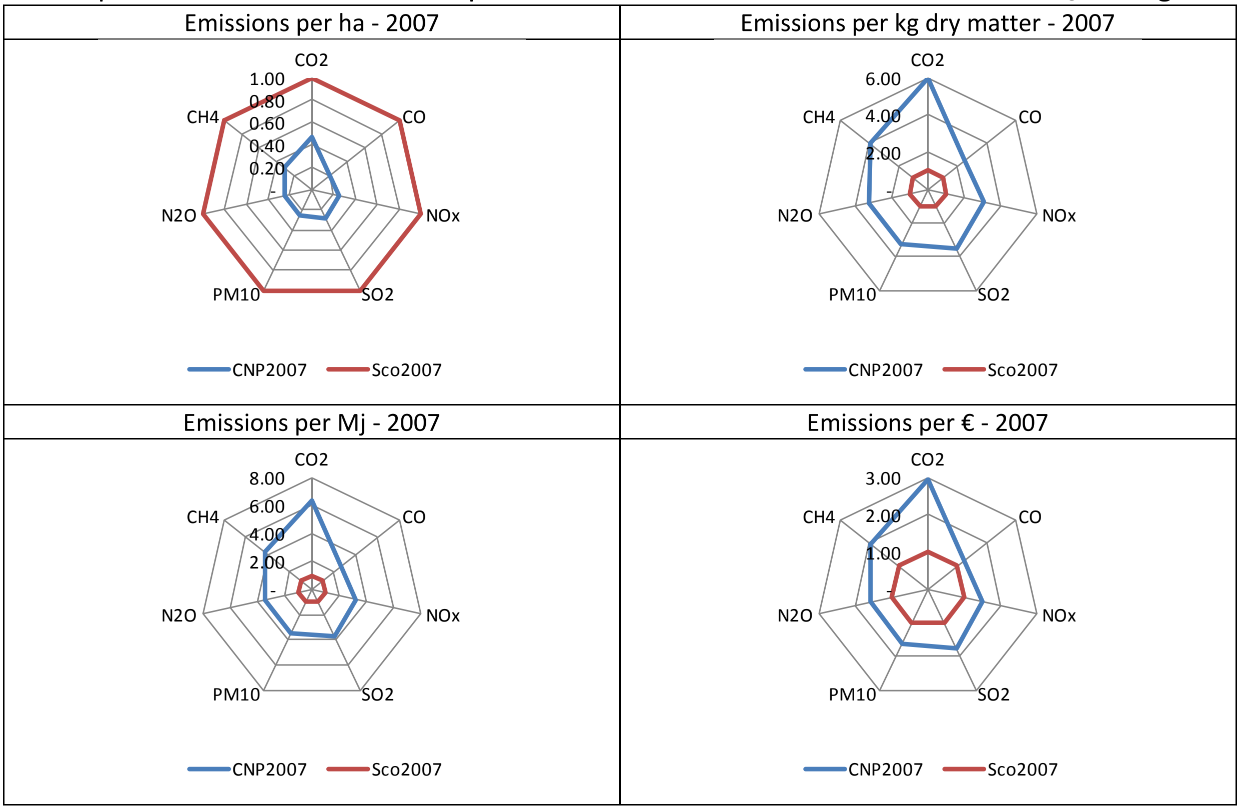

Figure 3: Emissions intensities for CNP_{AG} relative to $Scot_{AG}$ in 2007

3.2 MuSIASEM examples

The combination of Exosomatic Metabolic Rate (mj/hr of activity, EMR) and Economic Labour Productivity (£/hr of activity, ELP) is a particularly useful compound indicator of the sustainability trajectory. This combined analysis reveals complex systems behaviour in terms of trajectories and groups of the regions that can be considered together. Two versions are presented: the societal average and paid work.

Figure 4 presents the societal average EMR/ELP trajectories. Overall there is a pattern of increasing ELP_{SA} with (in nearly all cases) no increase in EMR_{SA}. There is a distinctive pattern to the trajectories, with increases in ELP_{SA} between 2005 and 2007 followed by stagnation (or even decline). For EMR_{SA} the pattern is of either consistent reduction or fairly constant values (2005 to 2007) followed by reductions (2007 to 2009). For regions with lower values for ELP_{SA} the increases in ELP are smaller and in some cases the reductions in EMR are significant (e.g. Clackmannanshire and Fife perhaps reflecting further deindustrialisation). Contrast this with the main population centres (Edinburgh, Glasgow and Aberdeen with its hinterland) where there is significant increase in ELP_{SA} combined with reductions in EMR_{SA}. An overall interpretation from Figure 4 could be that at a societal average level there is a trend to more sustainable growth (albeit to a limited extent). Societal average indicators, however, contain both paid work and household sectors that are behaving quite differently.

For the paid work sector the analysis of EMR/ELP has distinct features. It is clear that for some regions the improved performance for EMR at societal average level is an improvement in the household sector not in the paid work sector as the EMR_{PW} value is near constant (e.g. Edinburgh and Glasgow). Note that for both these cities despite near static EMR values there has continued to be apparent growth in ELP_{PW}. Figure 5 also shows the value of combining EMR_{PW} and ELP_{PW} in terms of distinguishing distinctive clusters of regions with common sustainability characteristics. These clusters include the main cities as noted above, the Scottish Islands (Orkney, Shetland and Western Isles), city regions (Aberdeen and Dundee but also the Greater Glasgow area) and regions that retain industry or intensive agriculture (East and Mid Lothian, Clackmannanshire and Fife, Perth, Kinross and Stirling and Dumfries and Galloway).

The MuSIASEM fund-flow (FF) diagram is a means of simultaneously presenting the relationship between a fund (e.g. human activity) and a flow (e.g. energy throughput) and at two scales (e.g. societal average and paid work, or paid work and sectors of the economy). The FF diagram is helpful in presenting both the extent (on the axes) and the intensity (on the diagonals) of resource use. Figure 6 compares the CNP and Scotland for each sector using THA, GVA and ELP. Within each FF figure it is possible to assess the relative importance of each sector (by size) and the relative efficiency as defined by the ELP. Comparing FF diagrams the balance of sectors within both regions is apparent. Note that all the FF diagrams are scaled in both THA and GVA relative to the largest sectors present. This allows structural comparisons. Note that the shape of the quadrants provides a visual representation of the balance between THA and GVA. Where the proportions are equivalent the quadrant is a square (e.g. construction), where longer in the x-axis the sector generates more GVA than its proportion of THA would predict (e.g. Business, Services and Finance), where longer in the y-axis the sector generates less GVA than the THA would predict (e.g. Pubic Administration and Services and Retail, Recreation and Transport).

4 Discussion and Conclusions

The SUMMA analysis found that there have been significant changes in the extent and intensity of agricultural production and its environmental impacts. Our conclusion is that for the agricultural sector as a whole there are unavoidable trade-offs between production and environmental impacts and little or no evidence of synergies, win-wins, dematerialisation or sustainable growth. There is a pattern of increasing resource use and impact from 1991 to 2001 and a subsequent reduction back to 1991 levels by 2007. This fits well with agricultural policy over the period 1991 to 2007. The high water mark of intensification was pre the 2003 CAP reforms with subsequent reduction in production on the least intensive areas. There is little to suggest fundamental changes in the relationships between resource inputs, the outputs from the system and the environmental load.

The MuSIASEM analysis has shown that there is a complex relationship between economic growth and the other indicators of sustainability. This complexity is in terms of the distribution (spatial, sectoral and between social groups) but also in terms of the nature of the growth. In some cases growth simply means increasing extent with more people supported at the same standard of living. In other cases there are changes in the intensity (productivity of labour and energy). From within this complexity it has been possible to begin to identify groupings of regions, their trajectories in terms of growth and the other indicators and to use these to better understand the overall Scotland level assessment and to contextualise the CNP.

The MuSIASEM results for the CNP are significantly different from the *a priori* expectations of the research team. That the CNP has features in common with the cities of Scotland was unexpected. The importance within the area of tourism and recreation means that the CNP has a significant retail and recreation sector. The attractiveness of the area (physical environment) also means that there is a larger than expected business sector with businesses located in the CNP but providing services beyond the park boundary. That the CNP has a more city-like population distribution, retaining young adults, could indicate a successful and sustainable rural economy. It could also mean that the CNP supports a minimum-wage based service economy based on migrant labour. The CNP GVA figure are noted by the CNPA as being inflated by the distilling industry with the income “leaking” from the Park.

From the MuSIASEM analysis there is little or no evidence of ongoing dematerialisation, that is a break in the fundamental relationship between energy use and wealth (or at least GVA) generation. Lower values of EMR simply reflect a post-industrial sectoral mix that has the net effect of exporting the energy and environmental footprint elsewhere. Given Scotland’s commitment to an 80% cut in greenhouse gas emissions by 2050 it is difficult to see how this can be achieved with the current population and/or standard of living, without fundamentally rethinking and reorganising patterns of production and expectations of consumption.

4.1 Strengths and weaknesses of the tools

SUMMA looks both upstream at the effect of inputs drawn into the system and downstream to the outputs and wastes. It is thus possible to make explicit judgements on the costs and benefits of a system. Emergy analysis, particularly the intensity ratios, is effective in providing a high level summary of the nature of resource use. Time series of SUMMA outputs identify trends and the impacts of key drivers. Comparison between systems or scales provides an external referent against which to objectively judge system performance. Where there is an existing SUMMA application the process of use is simpler than for MuSIASEM. If, however, modifications need to be made, these cannot be easily undertaken by non-experts. This implies a dependence on the SUMMA developers that can be difficult for them to service. Consideration should be given to investing in the development of a more modular and reusable SUMMA tool that is suited to supporting the development of new applications by third parties.

MuSIASEM provides a systematic evaluation of sustainability, linking evaluations of economic growth to population, energy and land use. The use of a decomposition approach is effective in ensuring that “average” values are fully understood as being the outcomes of mixes at regional or sectoral level. The approach is also effective in demonstrating the dependencies between productive and consumptive sectors. The strongly empirical nature of the MuSIASEM analysis means it is grounded in reality as perceived by stakeholders. This is effective in making it accessible to stakeholders but MuSIASEM’s more challenging conceptual basis can be a barrier to credibility. There were significant challenges in sourcing adequate data to support some of the MuSIASEM analysis despite experience and expertise in data integration and manipulation. This can lead to undesirable compromise the indicators used (data shaping the modelling).

Both SUMMA and MuSIASEM are strongest in analysing the links between environment and economics. They make these analyses in a scientifically coherent fashion, rather than through the use of *ad hoc* indicators. Where they perform less well is in including the social and cultural dimension of sustainability. While non-use and existence values have been debated within the SMILE consortium there still remains a significant intellectual challenge in defining analyses that are salient, credible and legitimate. Indeed it may be that such social aspects are inherently unsuitable for computer-based modelling and quantification and need to use mixed methods (incorporating qualitative analysis and participatory research processes).

4.2 **Implications for mainstreaming the use of SUMMA and MuSIASEM**

Both SUMMA and MuSIASEM face an implementation gap in terms of being used for policy-making or management. There are challenges in how to communicate the outputs of the research in a form that is succinct and accessible but does not lose rigour or oversimplify. Issues raised by stakeholders include making transparent the assumptions within the input data, demonstrating how the calculations of the indicators are made and the unfamiliarity of concepts such as emergy. These challenges are doubly difficult when they question established orthodoxy, both in what is important in policy terms (growth) and how it is measured and interpreted. There are significant and powerful vested interests that would be undermined by a more holistic view of sustainability and a more nuanced view of the benefits and detriments of growth. Mainstreaming will require the undertaking of transdisciplinary research, including both academics and stakeholders, with the stakeholders having a more formal role in shaping of research. Such projects ensure the salience of the research and build credibility for the methods and data through processes of stakeholder peer-review. The authors conclude that SUMMA and MuSIASEM have significant utility in conducting theoretically coherent, practical for implementation and policy relevant assessments of sustainability trade-offs but that "walking in others shoes" is not always comfortable.

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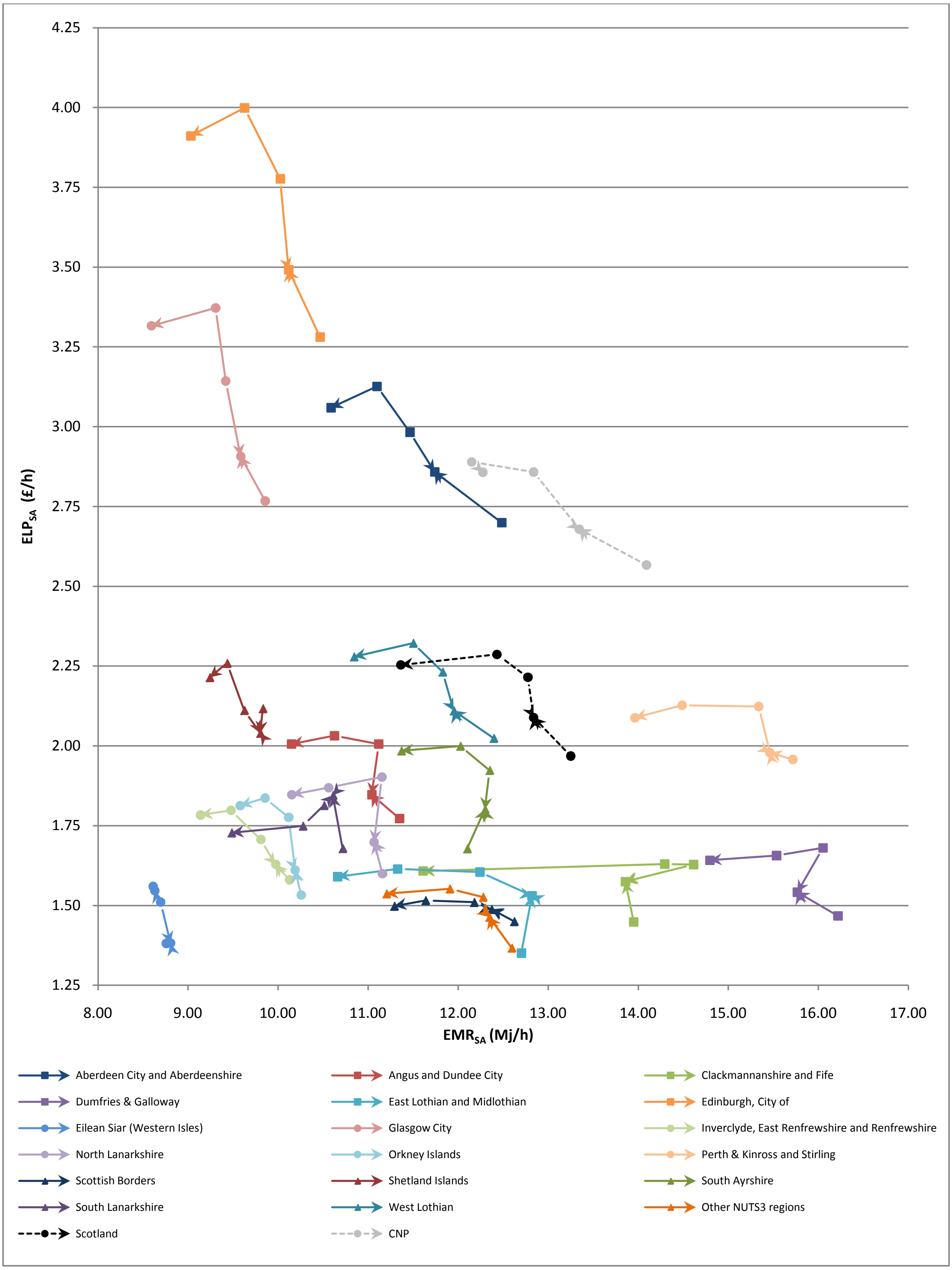

Figure 4: ELP_{SA} vs. EMR_{SA} for Scotland, CNP & NUTS3 (omitting Falkirk)

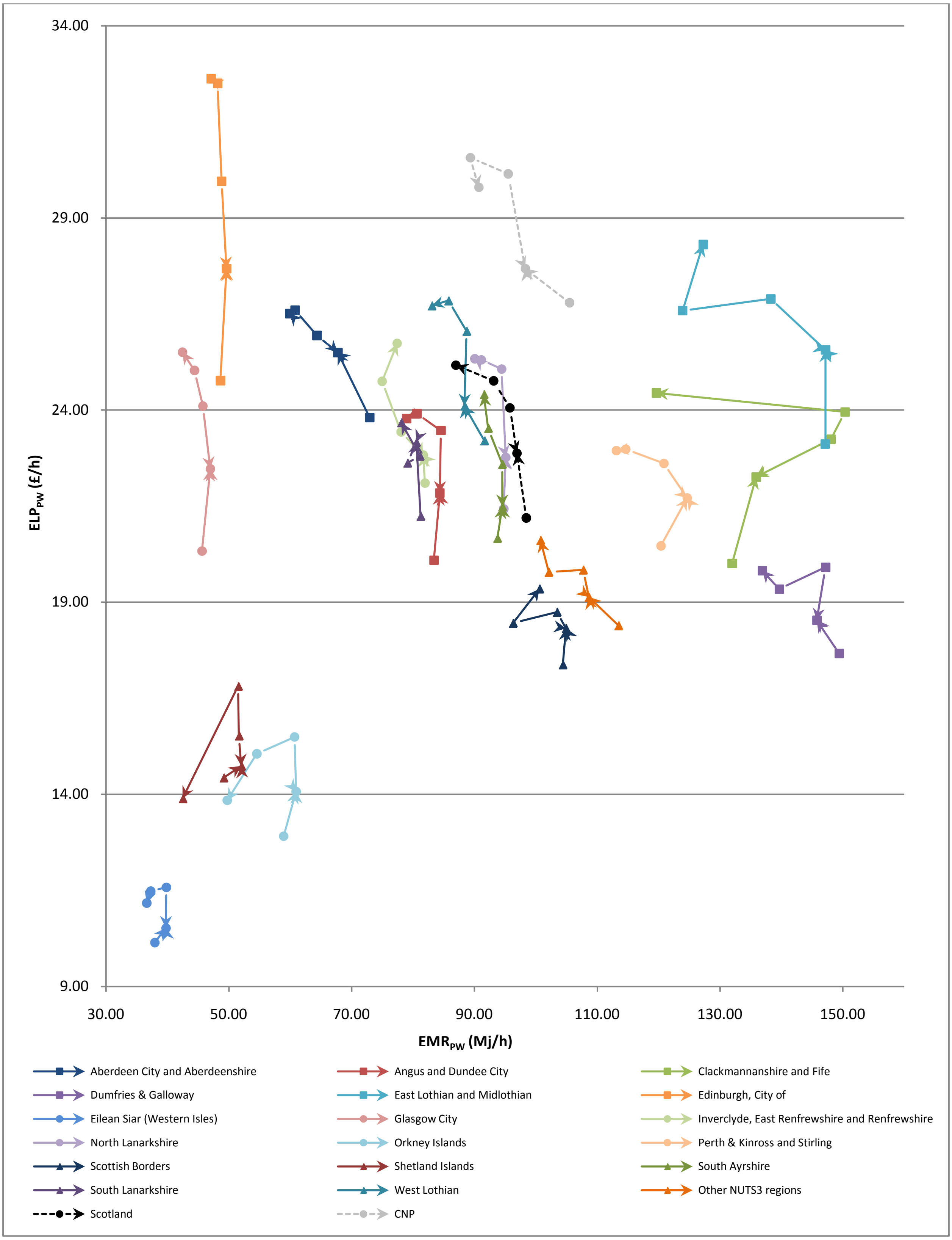

Figure 5: ELP_{PW} vs. EMR_{PW} for Scotland, CNP & NUTS3 - Paid Work (omitting Falkirk)

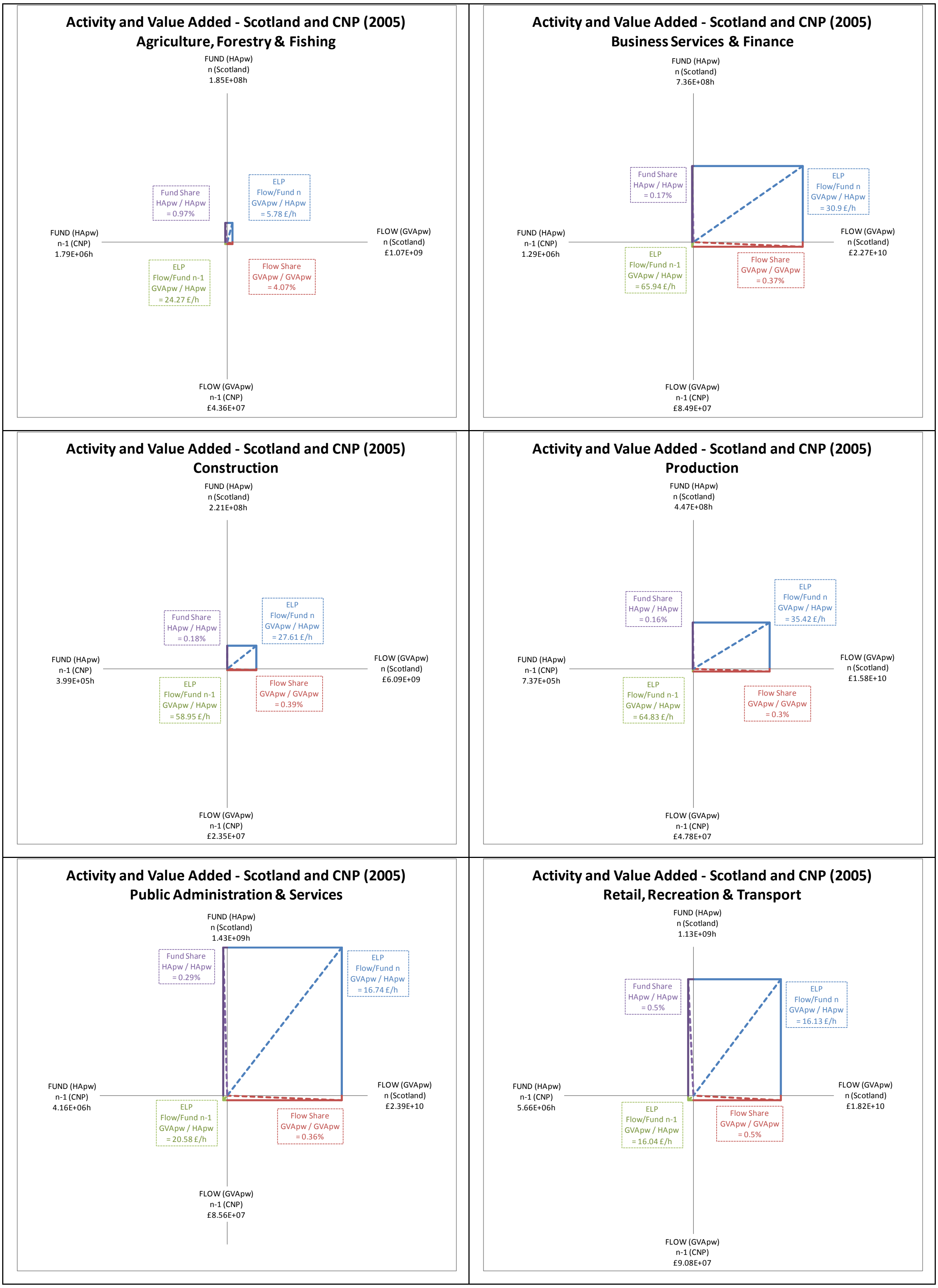

Figure 6: Fund-Flow analysis of Scotland and CNP by sector using GVA and THA