

Chapter 2

Assessment of Multifunctionality and Jointness of Production

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Introduction

The concept of multifunctional agriculture (MFA) arose after implementation of commitments under the Uruguay Round trade negotiations that started in 1995. Countries that advocated the concept of multifunctional agriculture were Switzerland, Norway, Japan, Korea as well as the European Union (EU). Dissenters included a coalition of countries known as the Cairns Group (a 17 strong alliance composed of Australia, New Zealand, Canada and 14 less developed countries).

Usually a distinction is made between the multifunctionality of agriculture (MFA), which has been extensively propounded in Europe (both on political and scientific grounds), and multifunctionality of the rural space. This chapter focuses on the former and addresses multifunctionality of agriculture both at the farm and regional levels.

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Considering multifunctionality as a paradigm for rural development, which emphasises the increasing importance of multifunctional enterprises that link the rural with the urban (OECD 2006), goes beyond the objective of the SEAMLESS project.

There are many definitions of MFA in circulation. The original definition, which was espoused by the advocate countries mentioned above, refers to the joint production of commodity and non-commodity outputs (Sakuyama 2005): agriculture, beyond the production of food and fibre (i.e. commodities), provides important social, environmental and economic functions to society. But these functions manifest themselves in products and services that are usually not marketable (i.e. non-commodities) because most often, they exhibit public good or quasi-public good characteristics whereby no individual or organisation can easily control the use of or access to these products and services (Stapleton et al. 2004). However, as pointed out by Vatn (2002), it does not mean that the notion of multifunctionality only includes a mix of private goods and various public *goods*. Strictly speaking, it also comprises public *bads*: effects that may have negative consequences for welfare. Furthermore, and most importantly, the production of commodity and non-commodity outputs are mutually dependent to some degree so that the provision of the latter cannot be decoupled or considered in isolation from the former without risking sub-optimal provision.

Most of the multifunctionality literature is theoretical rather than empirical; refer for example to the articles provided in Brouwer (2004) as well as Van Huylenbroeck and Durand (2003). The lack of empirical evidence that supports the theoretical ideas and insights has already been clearly stated by the OECD (2001a, 2003). Nevertheless, there are, of course, exceptions. Quantitative work on multifunctionality which has focused on the issue of joint production of commodity and non-commodity outputs can be found in Belletti et al. (2003), Bontems et al. (2005a, b), OECD (2001b) and Wiggering et al. (2006). Quantitative work on multifunctionality has also focused, for example, on how tourists value the contribution to landscape made by farmers (Vanslebrouck and van Huylenbroeck 2003) and analysis of Dutch farmers' motivation for multifunctionality (Jongeneel and Slangen 2004). Moreover, Van der Heide et al. (2007) use a land use change model – with field survey data as an input – to simulate multifunctional land use by applying it to a case-study area in the Netherlands. But most of the time, the quantitative work focuses on the assessment of several “functions” from farming activities (see Waarts 2005 for recent examples).

In this chapter, we propose an alternative approach: instead of assessing environmental or social “functions” from the farming activities, we assume that agriculture provides non-commodity outputs and we aim at designing indicators that measure the degree of multifunctionality involved in the co-production of commodity and non-commodity outputs by farms. It is important that decision makers can measure the sustainable development implications of a given policy intervention in terms of how this affects the multifunctional attributes of a given area. Policy formulation that aims at supplying commodity and non-commodity outputs separately will lead to higher implementation costs than when the policy considers multifunctionality and encourages farmers to supply these outputs jointly (Brunstad et al. 2005; OECD 2001a). More specifically, measuring the degree of jointness will provide insights

into the possible ramifications of any potential decrease in the use of public funds to support agriculture and its associated amenities in the context of the Common Agricultural Policy (CAP). By placing multifunctionality in this prescriptive or normative context – because it prescribes multifunctionality as an alternative strategy to land use segregation – the focus is on the demand for and supply of the multiple functions of agriculture at both the individual farm and regional level.

Multifunctionality has strong links to the concept of sustainability. For example, different functions of the rural landscape – in the sense of different types of land use and related land covers – can be of mutual benefit, for example agro-biodiversity, and generate economic sustainability among rural entrepreneurs and promote and support ecological sustainability in the local area. Multifunctionality is then an important element in the paradigm of sustainability. On the other hand, the various functions can also be conflicting, such as in the case of intensive agriculture versus water storage. We return to this point.

The relationship between multifunctionality and sustainability is not always clear-cut or without conflict. However, SEAMLESS attempts to assess contributions of agriculture to sustainable development of the rural area and therefore is inherently driven by concerns of multifunctionality.

Therein lies the rationale and motivation for the work presented below whereby we present a theoretical framework for joint supply based on the assumption that the degree of jointness has consequences both in terms of commodity production costs and non-commodity production. Based on this framework, we next derive a design for indicators of multifunctionality based on three sequential stages with assessment of this approach undertaken on data from Auvergne, France: a Nomenclature of Territorial Units for Statistics (NUTS) two region according to Eurostat before, finally, drawing some conclusions from this analysis.

Joint Supply, Theoretical Framework

As noted above, we are focusing our analysis of multifunctionality in terms of the joint supply of commodity and non-commodity outputs. Methodologically this is perhaps the most challenging definition to analyse and operationalise in terms of the formalised economics it requires. However couching multifunctionality in different terms such as the independent coexistence of commodity and non-commodity outputs would be largely self-evident and as such not require the level of analysis presented here.

Etymologically, the word ‘joint’ was originally used to describe where two bones meet and move in contact with each other (from Old French *joint* and Latin *junctus*). This is a reasonable metaphor for describing how this word is now being used to emphasise the relationship between commodity and non-commodity outputs in agriculture in the sense that their production is interdependent. Indeed, the notion of jointness is not unique to agriculture and prior to its emergence in this field it had already been used to explain the existence of firms selling multiple products (Baumol et al. 1981).

The nature of commodity outputs is unambiguous in the sense that they are economic in nature with values determined by the market. Key agricultural commodities include crops, livestock, flowers and raw materials for secondary production. Non-commodities refer to environmental and social characteristics which are usually public goods; society deems non-commodity outputs as desirable but markets do not exist to ensure a convergence between supply and demand.¹ Here De Groot's (2006) classification is of interest because when there is a market, this one is related with the services and goods provided, not to the specific functions involved in the supply of these goods and services.

A recurrent problem associated with multifunctional attributes is that providing non-commodities (or, non-food services) is complicated by the fact that multiple and non-unilateral links exist between the different functions fulfilled by agriculture, the ecosystem processes and components involved in fulfilling these functions and the sets of goods and services provided. To the best of our knowledge, only a very recent addition to the literature makes a clear distinction between these very different things: functions, processes and components involved one the one side can be distinguished from the goods and services provided, on the other side (see De Groot 2006). This distinction is important: usually a given component of the landscape (a vegetation root matrix for example) can provide several functions (in our case: soil retention; water regulation and filtering; nutrient regulation) and it can be involved in the supply of several non-commodity outputs and so even the simple description of the relationships between components, functions and services provided is often confused. But the classification proposed by De Groot enables simplifying such a description because each function provides only one type of good and service. Of course, De Groot's classification was elaborated first for natural and semi-natural landscapes and requires some modification for the man-made components of landscapes.

If we take the example of rural landscapes, such landscapes have an important role to play in the maintenance of regulation functions² from De Groot (2006). One of these concerns is climate regulation; fulfilling this function involves biologically mediated processes that influence climate. Furthermore, fulfilling this function provides services, such as the maintenance of a favourable climate for human habitation, health and cultivation. The most important thing to recognise from De

¹This definition of jointness is not universal: other definitions of jointness couch non-commodity outputs solely in terms of environmental characteristics, excluding the social dimension (e.g. Nowicki 2004) which could in part reflect the fact that assessment of social non-commodity outputs is hampered by a lack of available data.

²Regulation functions: 'this group of functions relates to the capacity of natural and semi-natural ecosystems to regulate essential ecological processes and life support systems through bio-geochemical cycles and other biospheric processes. Regulation functions maintain a "healthy" ecosystem at different scale levels and, at the biosphere level, provide and maintain the conditions for life on Earth' (De Groot 2006).

Groot's classification, from our perspective at least, is that the analysis of jointness should be performed only at coherent levels: jointness between functions fulfilled, or between processes involved, or between goods and services provided. Trying to identify relationships between the supply of a commodity and the provision of several non-market functions will lead to conceptual difficulties that will hamper analysis and risk producing results that are spurious.

One important point of the analysis of multifunctionality is the connection of the various activities that take place in a landscape. In the context of this chapter, we consider that multifunctional landscapes support different activities in the same plot of land (e.g. both agriculture and tourism). This position is different from the literature of rural sociologists (Van der Ploeg and Roep 2003, e.g.) who consider that several activities can take place at landscape scales but are distinct on each plot of land (for us, this would be pluri-activity).

To elaborate, a given area can be devoted to diverse but single-function land use types, like croplands, woodlands, recreational areas; in this area, several activities are possible, like farming, wood production or tourism (in the recreation areas). But the large paths that cross the productive woods are built for trucks where tourism would prefer networks of small lanes. In the farmland area, the fields are fenced, the old lanes have been ploughed and the hedges are not part of the productive system and thus poorly kept. The recreational areas look like tourists would derive amenity value from them but are not related to the cultural heritage of the area and their access is controlled. The different activities are not connected to each other: this is pluri-activity. By contrast, a multifunctional landscape may supply farm outputs along with tourism services on multifunctional farms. Of course, tourism services can also be supplied by activities other than farming, wood and genetic biodiversity in multifunctional forests and have a cultural value because of the scenery that includes fields amidst diverse forests, along with the existence of animal species that need forests margins close to open fields.

Thus, we focused our analysis on multifunctionality (and not on pluri-activity) and we argue that the analysis of jointness has to be performed either between functions, or processes or goods and services produced but without crossing these different levels. As a consequence, the analysis of jointness at the farm level will consider jointness between the supply of commodity and non-commodity outputs.

Towards Indicators of Multifunctionality

Determining indicators of multifunctionality (based on the jointness definition) includes three important and sequential steps:

- Step 1: identification of jointness
- Step 2: qualitative assessment of jointness
- Step 3: quantitative assessment of jointness

We need to identify the *existence* of jointness to assess whether the observed levels of commodity outputs are produced along with joint non-commodity outputs or according to a more classical profit function (with separable commodity and non-commodity outputs). This identification can be performed in two stages:

- Identification of multifunctionality at the appropriate scale: does the farm, or the area, fulfil several functions in the three pillars of sustainable development? The presence of multifunctionality can be identified through existing indicators along the economic, environmental and social dimensions of sustainable development.
- In the case where multifunctionality is identified, there is a need to assess whether there is a joint supply of commodity and non-commodity outputs, or whether jointness occurs between processes (e.g., the agricultural activity can mobilise biota for storage and recycling of nutrients, along with the conversion of solar energy to edible plants and provide a large variety in landscapes with potential recreational and cultural value).

The *qualitative* assessment of jointness is necessary to determine if the degree of jointness is strong or weak and to determine whether the provision of non-commodity output increases with the commodity output. Finally, the quantitative assessment should provide the functions describing the relationship between commodity and non-commodity outputs at the farm level. This understanding leads to three main areas of investigation:

- Does the evaluated policy improve sustainability through a development of multifunctional features of agriculture in the targeted areas? In other words is the *ex-ante* impact of policies positive along the three dimensions of sustainable development (economy, environment, social)?
- Does the degree of multifunctionality increase? A regulator may wish to sustain the development of the area she manages through the increase of multifunctional agriculture. Thus we have to estimate the extent to which this multifunctionality increases, or to provide measurements: in places where the multifunctionality increases (or simply develops) is it possible to determine the extent of this increase (i.e. can we at least rank different policies according to their multifunctionality credentials?).
- Does the nature of multifunctionality evolve because of the evaluated policy? The non-commodity outputs of agriculture are non conventional products, but intuitively according to the concept of joint production, most of them result from specific aspects of the agricultural production process. Some of these outputs are closely tied to agricultural production and others³ compete with agricultural production for land or other resources. In this sense, any policy dealing with agricultural production is likely to modify the nature of the multifunctional features in a region.

³Like the establishment or restoration of wetlands, or the creation of wildlife habitat on farmland.

Step 1: Identification of Jointness

De Groot's (2006) classification of functions from natural and semi-natural landscapes distinguishes five categories of functions: regulation, habitat, production, information and carrier functions.⁴ What is particularly appealing in this approach is that:

- The function categories are independent from each other. The functions provided by the farms can be depicted in a coordinate system with categories of function as axes; because these categories of functions are independent, the axes are orthogonal, and thus distances can be measured between farms in this coordinate system.
- There is a clear distinction between the functions, the ecosystems and components involved in these functions, and the goods and services provided by these functions (such a clear distinction is often ignored in the literature).

Jointness at the Farm Gate

At the farm level, starting from De Groot's work to identify the existence of multifunctionality, the identification of jointness focuses on the supply of goods and services at the farm level. We relied on studies that aim at assessing functions from Farm Accountancy Data Network (FADN) data and expertise (Perret 2006). Using this expertise, identification of multifunctionality between an array of different economic, environmental and social outputs can be systematically undertaken (Table 2.1).

The identification of jointness between various economic, environmental and social characteristics associated with agriculture enables a basic comparison between farms in terms of whether or not they exhibit multifunctionality characteristics. Comparison and ranking of farms based on these attributes can therefore serve as an indicator of multifunctionality. However, this binary approach does not provide information as to whether particular characteristics are simply not exhibited or are negatively affected by a particular production activity. Additionally, this system cannot be used to identify whether characteristics are met and not met at different levels of commodity production. This system of identification could be extended to acknowledge these possibilities (Table 2.2).

To elaborate, a production activity yielding high quality agricultural products (commodity outputs) could be associated with positive externalities like landscape quality and negative externalities like the emission of air pollutants which reduces environmental quality and the magnitude of these externalities could differ depending on the magnitude of the commodity output. Although the essence of the multifunctionality concept concerns joint production of goods and not bads, it is worthwhile

⁴De Groot (2006) proposes to 'translate the ecological complexity into a more limited number of ecosystem functions. These functions, in turn, provide the goods and services that are valued by humans. (...) ecosystem functions are defined as "the capacity of natural processes and components to provide goods and services that satisfy human needs, directly or indirectly"'.

Table 2.1 Hypothetical example of the identification of jointness at the farm scale using a binary system to denote the presence (1) or absence (0) of desirable economic, environmental and social characteristics

	Jointness at farm level	Farm 1	Farm 2
Economy	Quality of products	1	0
	Diversity of products	1	0
	Non-agricultural activities ^a	0	0
	Services	1	0
Environment	Water conservation	1	0
	Soil conservation	1	0
	Agricultural landscape	1	1
	Contribution to air quality	0	1
	Use of renewable energy	0	0
	Supply of renewable energy	0	1
	Biodiversity	0	1
Social	Contribution to employment	1	0
	Contribution to rural viability	0	1
	Animal welfare	0	1
	Cultural heritage	0	1
	Provision of recreational areas	0	1

^a“Non-agricultural activities:” are activities that take place on the farm area but are not direct farming activities. Examples of such activities are hosting tourists in on-farm bed-and-breakfast, on-farm restaurants, pedagogic activities (hosting pupils), animals (horses, dogs) hosting, etc.

Table 2.2 Hypothetical example of the identification of jointness at the farm scale denoting the presence (1), absence (0), decline (−1), presence and decline (1/−1) of desirable economic, environmental and social characteristics

	Jointness at farm level	Farm 1	Farm 2
Economy	Quality of products	1	0
	Diversity of products	1	0
	Non-agricultural activities	0	1/−1
	Services	1	0
Environment	Water conservation	1	−1
	Soil conservation	1	1/−1
	Agricultural landscape	1	1
	Contribution to air quality	−1	1
	Use of renewable energy	0	0
	Supply of renewable energy	0	1
	Biodiversity	0	1
Social	Contribution to employment	1	−1
	Contribution to rural viability	0	1
	Animal welfare	1/−1	1
	Cultural heritage	0	1
	Provision of recreational areas	0	1

to emphasise that the latter is also possible because, as already mentioned in the introduction of the chapter, multifunctionality comprises not only public goods, but also public bads. Such a system could be used in either an ex-post or ex-ante context i.e. based on available data or forecasting potential implications of a given policy intervention (such as liberalization of European agricultural markets). Of course, assessment here relies still only on expertise.

Jointness at the Regional Level

Preliminary experiments in five zones of the Rhône-Alpes region (France) emphasized that aggregating individual data concerning multifunctionality from the farm level to a larger area is far from being evident (Gillette et al. 2005a). Aggregating individual information about jointness enabled the authors to design a representation of the multifunctionality of agriculture in a larger zone (groups of municipalities or a small region). This representation was consistent with the common knowledge of the history of the different areas but when compared with local surveys of the relevant areas, it was incomplete because synergies between various farms enhanced the regional multifunctionality (Gillette et al. 2005b).

At the regional level, multifunctionality of agriculture relies on two different concepts: the variety of combinations of commodity and non-commodity outputs in the farms and the synergies and antagonisms between these combinations. As such, the farms can combine the provision of commodity and non-commodity outputs in very different ways. For example, some farms can breed sheep and maintain pastures that contribute to the local cultural heritage but other farms in the same area can choose to restore traditional buildings for hosting tourists and contribute in a different manner to this local cultural heritage. Other examples involve the provision of specific landscape patterns that favour the persistence of particular animals or plants; these specific patterns may be the consequence of maintenance of some hedges by small cattle farms that need trees for their animals, along with mosaics of pastures and cereals fields by mixed farms and specific phytosanitary protection practices in large intensive farms. Moreover, identifying the various ways of combining commodity and non-commodity outputs in a population of farms is of importance when the ecological or social processes exhibit threshold effects,⁵ because there is a need to determine whether the farms that produce them jointly are numerous enough for the global provision of the ecological (or social service) or whether their efforts are lost because they are too few to do so.

The second concept is related to the fact that the various ways of combining commodity and non-commodity outputs in a given region can exhibit synergies or be competitors. Intensive farms selling high quality products at the farm-gate along with improvement of the surrounding scenery may benefit from the preservation of hedges by neighbouring low-intensity dairy farms and at the same time compete

⁵Threshold effects on ecological discontinuities have been defined by Muradian (2001) as sudden modifications of a given system property, resulting from the soft and continuous variation of an independent variable.

with them for land because the latter need large areas to be profitable. Moreover, the average water quality in the area may be good only because the two types of farms are present and the intensive farms may need that the less-intensive ones keep their activity despite competition (otherwise they would be forced to lower their own pressure on water quality).

Step 2: Qualitative Assessment of Jointness

Identification of jointness, discussed above, is an important first step but as an indicator of multifunctionality it is limited in terms of the information it presents to stakeholders. Qualitative assessment of jointness can extend such an analysis by providing answers to two different questions which are not addressed above:

- Is the degree of jointness strong or weak?
- What is the origin of jointness? Jointness can be due to: technical interdependencies in the production process; the existence of a non-allocable production factor i.e. when different products are obtained from a single input such as the case of wheat and straw production or of ovine meat and wool from sheep; outputs competing for an allocable and fixed input so that any increase in the production of one output reduces the quantity of the fixed input available for the production of the other product (OECD 2001a).

Furthermore, a contribution to qualitative assessment of jointness may result from surveys aiming at measuring the public demand for different functions. In an interesting work on public demand for rural landscapes, Hall et al. (2004) have tried to capture information about public preferences for goods and services that are provided by agriculture and the countryside. Rather than looking at the production side, at the services and goods that a system offers, the authors decided to look at the consumption side, at the goods and services that are demanded and valued by consumers. The methods they distinguish as being mostly used to measure consumer preferences consist basically of three types of survey instruments:

- Pools and surveys conducted by conservation organisations, government departments and the EU
- More rigorous surveys trying to quantify public preferences through structured trade-off methods using willingness-to-pay approaches; and
- Deliberative survey methods as a compromise between polls and valuation methods

All three methods have their drawbacks which they suggest can possibly be (partially) overcome by a combination of multicriteria analysis and choice experiments. Interviews with specific key stakeholders could also be applied as a complement to the other methods.

Another approach would be based on spatial analysis of the land use pattern. The basic idea is to visualize the land cover and use of a certain territory and to associate

each class or combination of classes with functions provided, or the related goods and services. Spatial analysis can help to create the maps of land cover and use. Expert knowledge (participative), surveys or interviews and field visits can then help to ‘fill in’ these maps with the functions that can be found. It is possible to combine or overlap several maps at different levels covering, for example: land cover, land use and landscape as well as maps revealing more socio-economic data such as population density, activities in certain sectors and fluxes of people and goods and services (networks). This approach is suggested but not tested by Brandt and Vejre (2004) and Vejre et al. (2006). Knickel et al. (2004) refer to multifunctionality schemes as a way to directly ‘map’ the interrelated functions associated with a certain territory or activity. A promising method is interactive mapping that can be useful as a complementary method to (open) interviews and field visits, or other participatory research methods – questions as to the goods and services provided are directly related to the maps with the representation of the land cover mosaic.

Qualitative assessment of jointness could be particularly important to *ex-ante* analyses: for example, if a particular commodity and non-commodity output are competing for an allocable fixed input then as one output increases, the other necessarily declines and it is unlikely that any change in policy would alter this underlying property.

Step 3: Quantitative Assessment of Jointness

The final, and most difficult, stage is quantitative assessment of jointness which involves specifying the magnitude of the coefficient(s) in each particular jointness function. Graphical examples of these different types of jointness including their most basic underlying equations (functional forms) are provided; the magnitudes of these coefficients are illustrative to reflect the fact that jointness can be strong or weak (Fig. 2.1). This is an extension of work currently available in the literature on jointness which has tended not to explore these underlying equations or a range of potential functional forms. The case of positive jointness (Fig. 2.1a) could be associated with rural development policies in the EU, specifically the introduction of the second pillar to the CAP; this theoretical relationship has been articulated by Belletti et al. (2003) for example. Where increases in commodity outputs are associated with increases in non-commodity outputs (Fig. 2.1a) this could be denoted as true multifunctionality. The policy implication of such positive jointness, *ceteris paribus*, is, simply, dual maximisation of both commodity and non-commodity outputs. As an alternative, Van Huylenbroeck (2003) suggests that agriculture is in most cases a necessary condition to obtain the non-commodity output, but the yield in itself is not as important. This could be termed as static jointness or static multifunctionality and it is possible to express Van Huylenbroeck’s idea graphically (Fig. 2.1b). Although increases in the commodity output do not increase levels of the non-commodity output, neither do they decrease this output. Therefore, the policy implication of such static jointness, *ceteris paribus*, is maximisation of the commodity output.

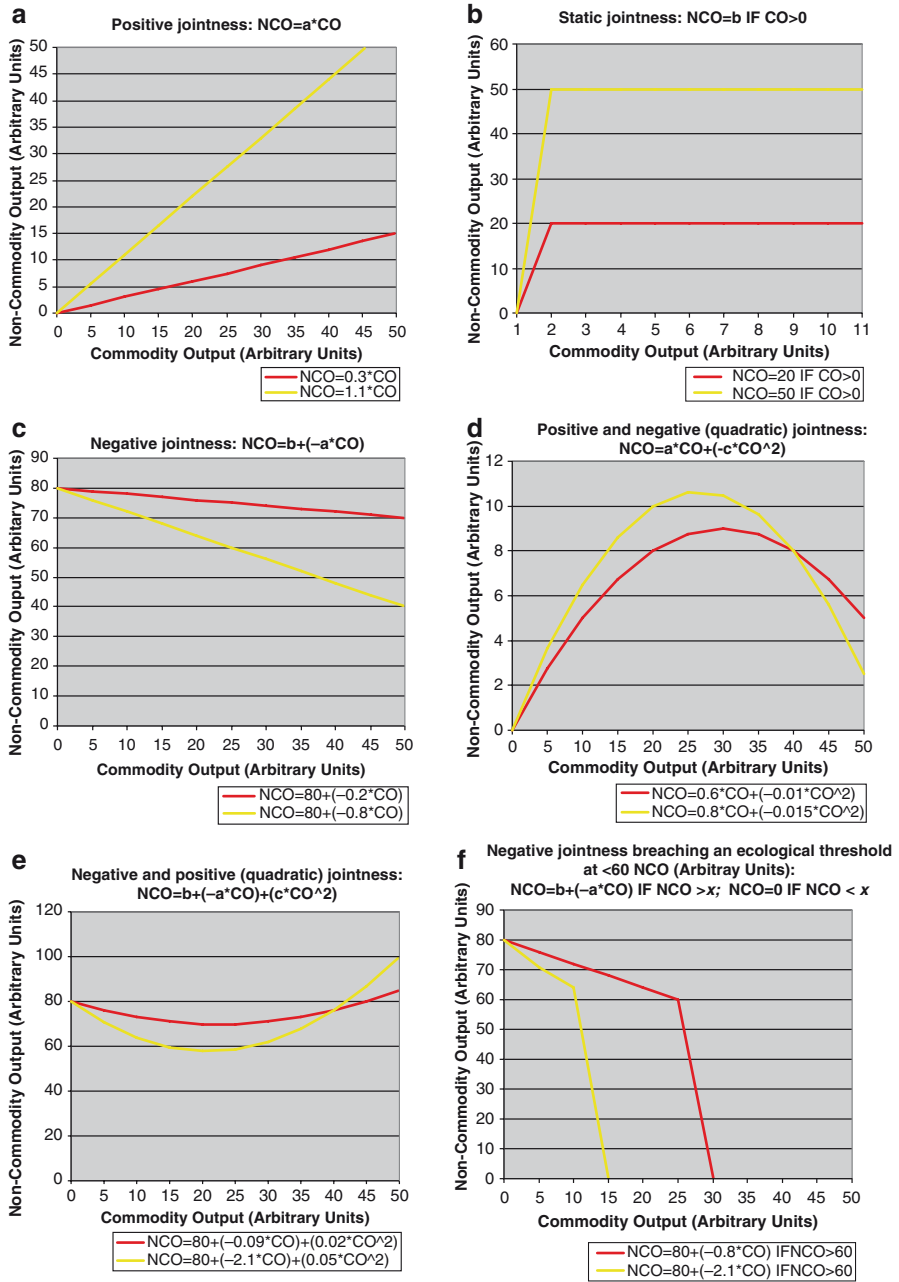


Fig. 2.1 Hypothetical strong and weak jointness between commodity and non-commodity outputs: (a) positive; (b) static; (c) negative; (d) positive and negative; (e) negative and positive; (f) negative breaching an ecological threshold

Negative jointness (Fig. 2.1c) is associated with an agricultural modernisation agenda where non-commodity outputs are secondary considerations compared to agricultural production (Belletti et al. 2003); in the context of EU agriculture this could tally with the historical emphasis on supporting agricultural production through price support measures. However, in the case of negative jointness the production of a commodity output, forsaking a given amount of the non-commodity output could illustrate (a) the existence of a negative externality i.e. the non-commodity output is a non-market good which is not internalised in production decisions, (b) the non-commodity output is wholly or partially internalised by the market but its marginal value is lower than the commodity output resulting in a rational trade-off. Determining the optimal production of the commodity output versus the non-commodity output where the latter is an externality requires some assessment of the value of the non-commodity output, perhaps using a 'stated preference' valuation technique like surveying individuals to determine their willingness to pay for the non-commodity output. The case of positive and negative jointness (Fig. 2.1d) has been articulated graphically in OECD (2001b). Going further, we can note that if the marginal value of the commodity and non commodity output are equal then the optimal solution is the turning point of the function. Mathematically:

$$\begin{aligned}\frac{dNCO}{dCO} &= a + (-2c*CO) = 0 \\ CO &= \frac{-a}{-2c} \\ \frac{d^2NCO}{dCO^2} &= -2c\end{aligned}\tag{2.1}$$

In the case of negative to positive jointness (Fig. 2.1e) dual maximisation of commodity and non-commodity outputs is only a viable option if the reductions in non-commodity output at low levels of commodity output, before the turning point is reached and both outputs start to rise together, is not associated with the breaching of any ecological thresholds i.e. we need a priori knowledge that environmental degradation and pollution are occurring in a linear fashion. In reality, many important environmental non-commodity outputs have critical ranges and thresholds which, if breached, could result in drastic and uncontrollable loss of that non-commodity output and thus, potentially, the commodity depending on the interaction between the two outputs (Fig. 2.1f).

An *ex-post* empirical investigation of the magnitudes of non-commodity outputs at different levels of commodity output could elucidate a number of relationships; from an *ex-ante* perspective it is important to understand whether a particular policy will:

- Shift the commodity/non-commodity relationship from one trajectory to another (alter the underlying functional form of the relationship) e.g. from negative jointness (Fig. 2.1c) to positive jointness (Fig. 2.1a)

- Shift the commodity/non-commodity relationship off one trajectory into a mutual decline because of the breaching of an ecological threshold (relevant to Fig. 2.1c and e)
- Make no alteration to the commodity/non-commodity trajectory but alter the position on that trajectory e.g. concomitant increases in commodity and non-commodity output in Fig. 2.1a
- Alter the strength of the association between commodity and non-commodity outputs e.g. from weak positive jointness to strong positive jointness

An *ex-ante* analysis such as this obviously depends critically on a case-by-case ex-post empirical investigation of an array of different commodity and non-commodity output relationships i.e. it's important to understand past relationships between commodity and non-commodity outputs in order to predict future relationships in response to policy changes. Furthermore, the origin of jointness as discussed above is particularly important to aiding an ex-ante analysis. For example, if particular commodity and non-commodity outputs compete for an allocable fixed input, an increase in one output could only be achieved by a decline of the other. In the short run, farms will adapt to policy changes by altering their position on a trajectory. In the long run, they can alter that linkage, for example by achieving a more rational use of labour through the adoption of labour saving technologies but this would require time and investment.

Testing Against Data in Europe

Identification of Jointness

Jointness at the Farm Gate

Some drivers of farm income are drawn from the FADN database and the variables selected include outputs supplied, inputs used, as well as compensatory payments for participation in agri-environment programmes and other farm-support programmes. These data concern only values for commodity outputs and their drivers, because no data is available from FADN for the provision of non-commodity outputs. Nevertheless, these data enable a rough comparison of the evolution of the production structure of the farms and provide insights into how they combine their different activities.

We analyse the drivers for farm income on a per hectare basis to enable consistent comparison between farms with quite different sizes. Table 2.3 depicts the regression coefficients for Eq. (2.2):

$$\begin{aligned} \text{farm income} = & \beta_0 + \beta_1 O + \beta_2 I + \beta_3 IC + \beta_4 S + \beta_5 ES + \beta_6 ES.O + \beta_7 ES.I \\ & + \beta_8 ES.IC + \beta_9 ES.S + \varepsilon \end{aligned} \quad (2.2)$$

Table 2.3 Regression results for the farms' income.... for several years from the European FADN (all the coefficients are significant at 1% level, except ES.output for the year 2002). Note ES.output is the crossed-effect of environmental subsidies on the marginal effect of outputs on farm income

Driver	Unit	Estimated coefficient	1990	1995	2000	2001	2002	2003	2004
Constant	–	β_0	-21.02	-62.68	-60.13	-31.51	-22.67	-14.93	11.72
Output (O)	Euros/ha	β_1	1.02	1.00	0.99	0.99	0.99	1.04	0.99
Input (I)	Euros/ha	β_2	-0.01	0.06	0.03	0.02	0.07	0.13	0.01
Intermediate consumption (IC)	Euros/ha	β_3	-1.02	-1.07	-1.03	-1.01	-1.10	-1.26	-0.99
Non-environmental subsidies (S)	Euros/ha	β_4	0.99	1.00	1.08	0.97	1.03	1.07	0.99
Environmental subsidies (ES)	Euros/ha	β_5	0	2.20	1.76	1.50	1.45	1.38	1.13
ES.output/1000		β_6	0	0.45	-0.03	-0.05	(ns)	0.19	0.20
ES.input/1000		β_7	0	-0.58	-0.54	-0.10	-0.40	-2.86	-0.43
ES.intcons/1000		β_8	0	0.00	0.91	0.19	0.61	4.20	0.46
ES.subsidies/1000		β_9	0	-1.38	-1.28	-0.40	-0.56	-0.55	-0.62

where O is the outputs (in Euros/hectare), I the inputs used, IC the intermediate consumption, S the amount of subsidies received (excluding environmental subsidies), ES the amount of environmental subsidies and $ES.O$, $ES.I$, $ES.IC$, $ES.S$ are interaction terms (environmental subsidies crossed with outputs, inputs, intermediate consumptions and subsidies respectively).

Data have been analysed on a yearly basis because the series are not stationary and thus a panel analysis would lead to unrealistic conclusions. Moreover we assumed that the relations between the various drivers of farm income evolve over time. This assumption is underlined by the sign of some estimators that vary from 1 year to the other. In particular, the constant is negative for most years but becomes positive for year 2004. Similarly, the marginal effect of the environmental subsidies on the output is negative or positive depending on the year considered. Analysis of regression (2) suggests that:

- The effect of output and subsidies on farm income does not vary much from 1 year to the other, although the output price and the producer support subsidies rates are totally different from the early 1990s to the mid-2000s: in the early 1990s, agricultural products have rather high prices that were drastically decreased in 1992 and then in 2000, while subsidies greatly increased (producer support shifted from price support to direct income support).
- There are significant differences for the effect of the inputs and intermediate consumptions drivers between the years. This suggests that there has been an evolution of the farms' combination of means and we can assume a modification in the jointness rates between commodity and non-commodity outputs within the farms.
- Some environmental outputs are subsidised, but the influence of the agri-environmental support programmes reduced since the mid-1990s, although the payments increased during that period. This suggest that despite environment is more and more subsidised along time (on our sample data, the environmental payments increased by a factor of 2.3 between 1995 and 2004), the reorganisation of the other drivers compensate their relative effect on farm income over time.
- More important is the effect of the environmental subsidies on the marginal effect of output, input, intermediate consumption and non-environmental subsidies on the farm income: the environmental subsidies moderate the marginal effect of the input, intermediate consumption and non-environmental ones on the farm income. Moreover, the environmental subsidies moderate the marginal effect of the outputs on the farm income in the early 2000s, but this effect reverses in 2003 and 2004, just as if after several years of environmental programmes, some of the farms have been able to reorganise themselves to take advantage of a higher degree of jointness between commodity and non-commodity outputs.

Even restricted to economic data, it is possible to conclude that the EU environmental policies have modified the way the farms combine their intermediate consumptions and the inputs they use in their profit function: there are links between the provision of environmental outputs and the evolution of the farm profit function.

The characterisation of these links deserves further investigation that can be performed at the regional level only because it requires a description of the non-commodity outputs supplied (and thus more precision in the data used).

Jointness at the Farm Gate in a Region

From a set of FADN farms in the Auvergne NUTS two region, we used the method developed by Perret (2006) to assess whether farms fulfil different functions. Once the existence of multifunctionality was determined, we analysed the origin of jointness in these farms and performed a qualitative assessment of jointness between commodity and non-commodity outputs at the farm scale. Using only expertise and FADN data it was not possible to analyse all the functions depicted in Table 2.3 at the farm scale. These functions were approached by a set of indicators:

- F2: farm-gate food provider:
 - ind 02 This indicator has the value one if the farm processes agricultural products into ready-to-sell food (and zero otherwise).
- F4: contribution to rural viability:
 - ind 7–1 Contribution to the maintenance of rural viability when the farm is located in a low density rural area. This indicator has the value one when the number of on-farm households is greater than two and the farm is located in a low-density area and the value zero when the number of on-farm households is less than two or if the information is not precise enough so that this indicator cannot be assessed.
 - ind 7–2 Contribution to the maintenance of rural viability when the farm is located in an area frequented by tourists. In this case, the role of farms is more important to the maintenance of scenery rather than in terms of providing employment (that already exist through tourism). This indicator has the value one when the farm, located in an area frequented by tourists, breeds cattle and the value zero if this is not the case or if the information is not precise enough so that this indicator cannot be assessed.
- F5: employment:
 - ind 9 Family employment. This indicator has the value one if total family employment on the farm exceeds one unit of farm employment, and the value zero if this is not the case.
 - ind 10 Farm employment. This indicator has the value one when paid labour minus seasonal employment is greater than 0.5 units of farm employment, and the value zero if this is not the case.
 - ind 11 Seasonal employment. This indicator has the value one when seasonal employment exceeds 0.2 units of farm employment and the value zero if this is not the case.

- F6: landscape:
 - ind 12–1 Contribution to open space. This indicator is a function of several variables, and has the value one when the share of on-farm forests, moors and low productive areas in total on-farm area and grazed land is below 5%.
 - ind12–3 Contribution to landscape patchwork. This indicator is derived using a scoring mechanism: the main crops are grouped together (cereals, corn, oil seeds, etc.) and each group is given a value of one when its area is greater than 10% of the total area, and a percentage of points for lower areas (for example, a group sharing 5% of the total area is assessed a score of 0.5 point). This indicator has the value one when the total score is greater than two and the value zero if less than two.
- F7: water quality:
 - ind 13 Water quality. The farm is considered to be contributing to good water quality when the total amount of organic nitrogen spread is lower than 70 kg N/ha and either (a) the share of agricultural area with bare soils in winter is lower than 30%, or (b) for a share of bare soils in winter comprised between 30% and 60%, the farmer joins a programme of nitrate or pesticides management, or (c) the share of organic farming is greater than 75%, or (d) for a share of bare soils greater than 60%, the share of organic farming is greater than 75%. When one of these conditions is met this indicator is given a value of one, otherwise a value of zero.
- F8: biodiversity:
 - ind 16 Management of ecologically rich habitats. This indicator has the value one when the farmer's share of low productive grassland is greater than 12.5% (when he uses collective pastures) and 25% when he does not use collective pastures.
 - ind 17 Diversity of crops. This indicator is derived using a scoring mechanism: each crop is assessed a score (see ind12–3 for details of calculation). When the total score is greater than three, ind 17 equals one.

Table 2.4 depicts the assessment of the above indicators on a subset of farms, in a presentation close to Table 2.1. Put differently, this corresponds to the identification of jointness which we regard as the precursor to the qualitative and quantitative assessment of jointness that will be explored below.

The Auvergne set of farms consists of a total of 354 individuals. A preliminary exploration of data, performed using principal component analysis (PCA), is depicted in Fig. 2.2. The analysis suggests that jointness exists between the supply of commodity outputs (variable PBRT0: total gross product) and the supply of non commodity outputs (indicators designed above). Moreover, the farms in this area are liable to sign a contract, named on-farm territorial contract, according to which the farmers are subsidised for the provision of non-commodity outputs: but, because the variable that depicts this contract, CTEXP, is orthogonal to the two first axis of the principal components analysis, we can consider that the signature of the contract has no influence on the degree of jointness in our set of farms.

Table 2.4 Identification of jointness for a subset of Auvergne farms

Economics	Social			Environment						
	Rural viability		Employment		Landscape			Biodiversity		Water
	IND71	IND72	IND09	IND10	IND11	IND121	IND123	IND16	IND17	IND13
0	0	1	1	0	0	1	1	0	1	0
0	0	0	1	0	0	0	1	0	1	0
1	0	0	1	0	0	0	1	0	1	0
0	0	0	1	0	0	0	1	1	0	0
0	0	0	0	0	0	0	1	0	0	0
0	0	0	1	1	0	0	1	0	1	0
0	0	0	1	0	0	1	1	0	1	0
1	0	0	0	0	0	0	1	0	1	0
0	0	0	1	0	0	0	1	0	1	0
0	0	0	0	0	0	1	1	0	1	0
0	0	0	0	0	0	0	1	0	1	0
0	0	0	0	0	0	0	1	0	1	0
0	1	1	1	0	1	1	1	0	1	0
0	0	0	0	0	0	0	0	0	0	1
0	0	0	1	0	0	0	1	0	1	0
0	0	0	0	0	1	1	1	0	1	0
0	0	0	0	1	0	0	1	0	1	0

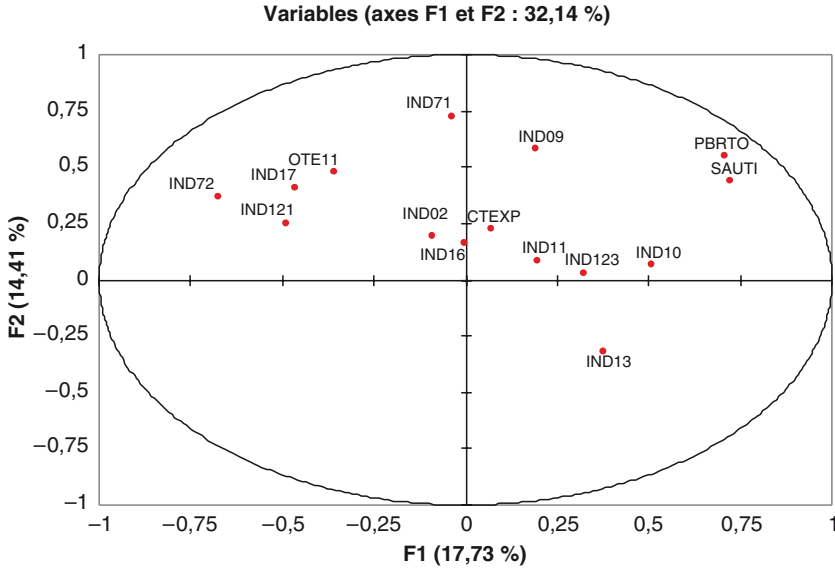


Fig. 2.2 Principal component analysis performed on the Auvergne farms set (axes 1 and 2)

Qualitative Assessment of Jointness

More sophisticated procedures are required to proceed with steps two and three of our framework (qualitative and quantitative assessment of jointness), so we turned to SEAMLESS-IF. SEAMLESS-IF does not directly assess the jointness in the production system between the supply of commodity and non-commodity outputs. The FSSIM-MP component represents the farmer's behaviour with regard to the possible relations between the production factors inside the production process of commodity outputs. Environmental non-commodity outputs are modelled as externalities (their supply is non-volunteer) or as constraints in the production process of commodity outputs (see Chapter 5 for more details).

The first simulations for some farms in four regions already suggest interesting insights about jointness at the farm level despite the lack of operational indicators. Figure 2.3 illustrates the modelled nitrate (NO_3^-) leaching with regard to farms income (per hectare) for some SEAMLESS-IF crop farms in Auvergne. When the sample of farms contains more than a few individuals, the relationship between both variables is not that simple.

Figure 2.4 depicts the marginal effect of environmental subsidies on farm income for FADN farms in the Auvergne region, for 2000 and 2004. The estimated coefficient is similar to coefficient β_5 in Table 2.3, but estimated for each individual farm (in Table 2.3 it is estimated on the whole sample of FADN farms). It is obvious from the Figure that this marginal effect is not the same for the 2 years, but we can notice an increased effect for some farms and a decreased effect for others. Aggregating these individual

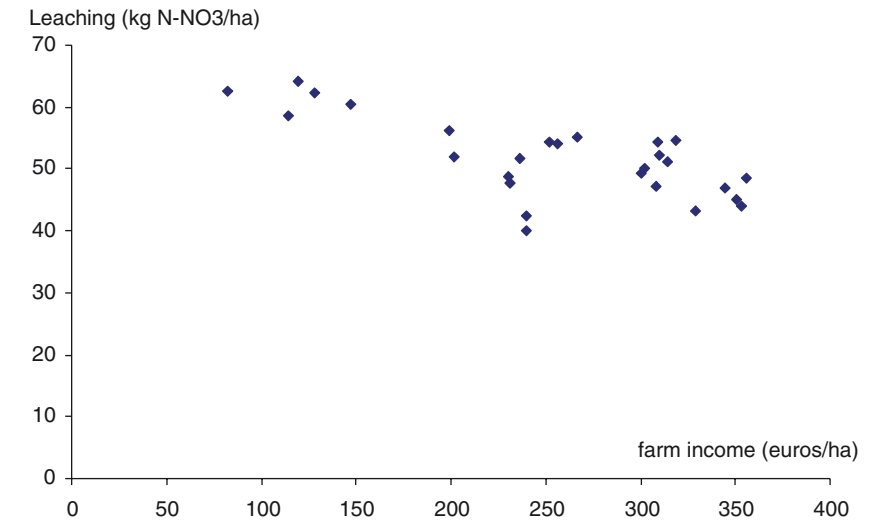


Fig. 2.3 Simulated N leaching depending on the farm income for some SEAMLESS-IF farms

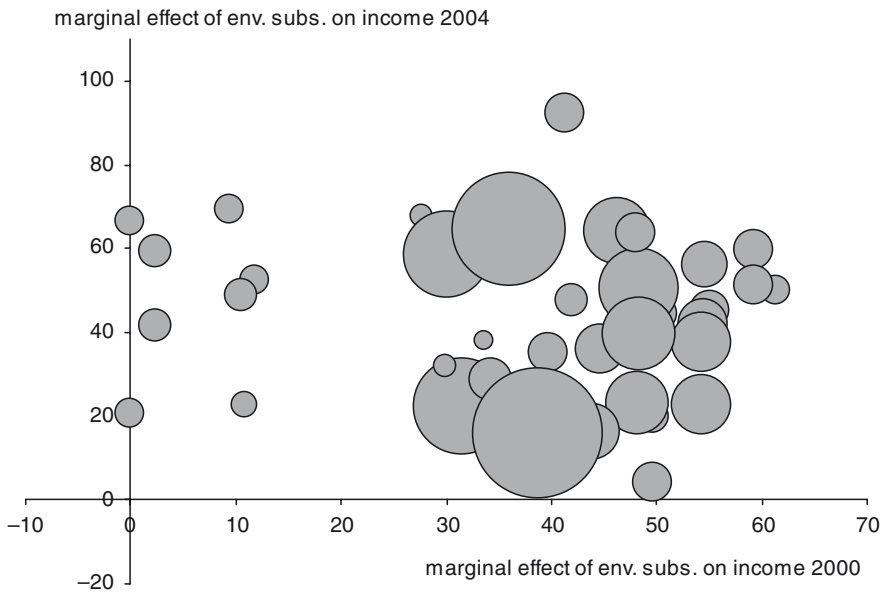


Fig. 2.4 Total marginal effect of environmental subsidies on farm income for FADN farm groups in Auvergne (the size of the dots represent the share of the total agricultural area for each group of farms)

variations at the regional level would require a calibrated procedure to assess in which sense positive and negative variations compensate (or not) each other.

Quantitative Assessment of Jointness

This section is a first attempt to quantitatively assess indicators of multifunctionality using SEAMLESS-IF. We opted for an estimation technique that is based on the assumption that was already derived from the outcomes presented in Table 2.4 which states that environmental subsidies are an estimator for the value of the subsidised non-commodity outputs. Unfortunately, such a proxy could not be found for non-commodity outputs that are not subsidized because of a lack of simulation results. The assumption that environmental subsidies are an estimator for the value of the subsidized non-commodity outputs enabled us to measure the share of modelled income that is due to the environmental subsidies (direct effect plus cross-effects on output, input and intermediate consumptions), for the years 2000 and 2004.

Figure 2.5 plots the difference of the 2000 and 2004 values for this indicator.

Analysing Figure 2.5 emphasises that regions that receive relatively high environmental subsidies on a per hectare basis (Finland, Austria, East-Germany)

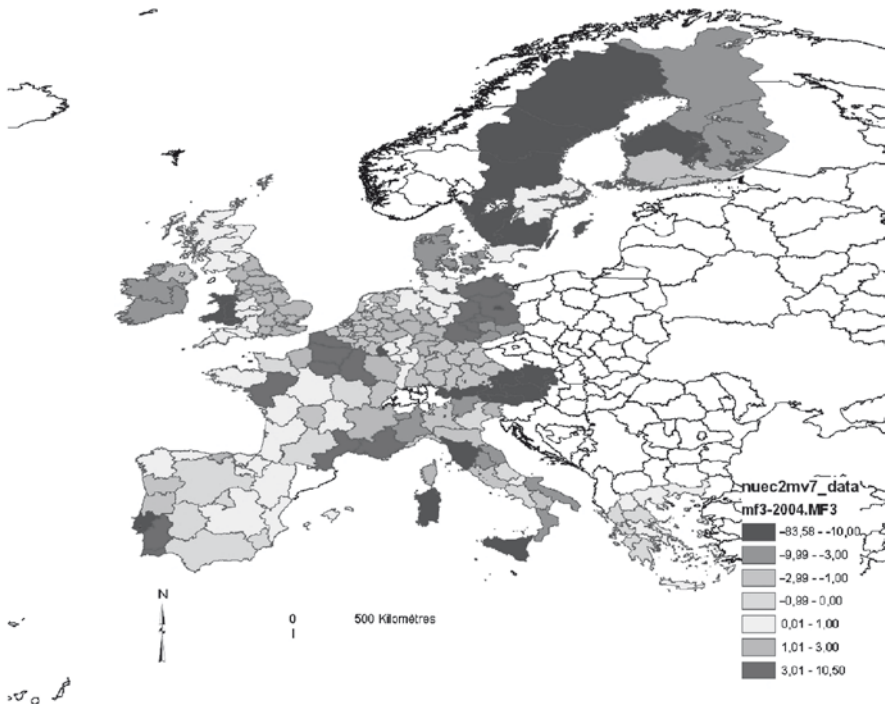


Fig. 2.5 Evolution of the total effect of environmental subsidies of the average farm income in each region between 2000 and 2004 (in blue decreasing effect and in green increasing one)

experience a relative decrease between 2000 and 2004 in the way these subsidies share their farm income, because of cross-effects with outputs, and mostly inputs and intermediate consumptions.

Conclusions

Although the concepts associated with the multifunctionality of agriculture are far from being consensual (see Cairol et al. 2006 for a description of the main concepts), we focussed in this chapter on one concept only, the joint supply of commodity and non-commodity outputs by farms. This is the definition of multifunctionality generally espoused by the EU; many other definitions of multifunctionality are self evident to some degree.

Based on this jointness definition, our novel assessment of indicators of multifunctionality relied on three sequential stages: identification of jointness, qualitative assessment of jointness, quantitative assessment of jointness. Identification of jointness was carried out at the level of the farm gate for both an EU sample and using a regional case study of Auvergne, France. FADN data for the EU sample covered only values for commodity outputs and their drivers and thus enabled only a rough comparison of the evolution of the production structure of the farms including insights on how they combine their different activities. By comparison, using FADN data for the regional case study permitted the assessment of which functions different farms fulfil using De Groot's (2006) classification of functions fulfilled by natural and semi-natural ecosystems. Qualitative assessment of jointness examined the relationship between farm income and nitrogen leaching for a subset of farms in four regions but problems with data availability make it difficult to authoritatively comment on the degree of jointness. However, for the Auvergne case-study it was possible to show how the marginal effect of environmental subsidies on farm income is not constant over time. Moving to assessing the final stage in our framework, quantitative assessment of jointness extended the approach used to identify jointness at the farm gate level for an EU sample, constrained by problems of data availability already noted with this sample. However, under the assumption that environmental subsidies are an estimator for the value of subsidised non-commodity outputs it was possible to show that regions that receive relatively high environmental subsidies on a per hectare basis experience a relative decrease between 2000 and 2004 in the way these subsidies share their farm income, because of cross-effects with outputs, and mostly inputs and intermediate consumptions.

Although the results outlined in this chapter serve to illustrate that multifunctionality of agriculture is far from being negligible, a comprehensive assessment of this phenomenon in terms of both functions and spatial scales covered by such an analysis is still beyond the bounds of possibility because of problems with data availability and model capabilities. Given the prominence placed on the multifunctionality concept by the European Commission, it is imperative that this situation improves in order to more fully and robustly assess this concept. Nevertheless, and

as noted in the introduction to this chapter, because the current state-of-the-art in terms of multifunctionality research is limited, from a quantitative point of view the work presented here is an important contributor to this research area.

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