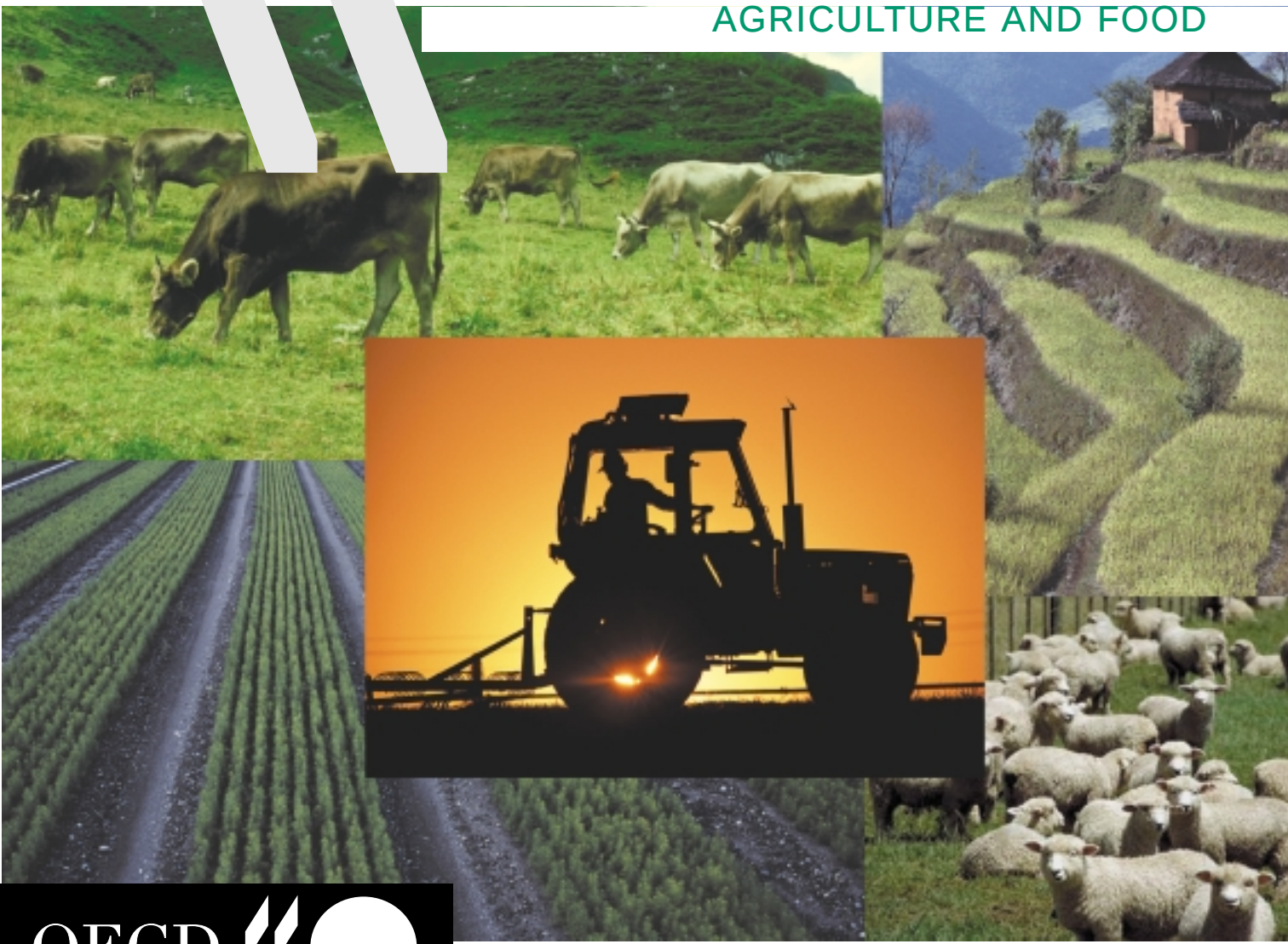
Multifunctionality

TOWARDS AN ANALYTICAL FRAMEWORK

AGRICULTURE AND FOOD



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FOREWORD

This is the final version of a study that was carried out under the 1999-2000 Programme of Work of the OECD's Committee for Agriculture. It contains the results of the first phase of the work on multifunctionality and aims to provide a conceptual basis for policy discussions. It focuses on production, externality and public good aspects of multifunctionality.

The principal authors of this report are Leo Maier and Mikitaro Shobayashi. Professor Boisvert of Cornell University is the author of Annex 2 and part of Annex 1. Catherine Moreddu and Jennifer Fellows also contributed to the preparation of this report, as did other staff in the Directorate for Food, Agriculture and Fisheries.

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Part I

SUMMARY AND CONCLUSIONS

Background

The OECD has over a long period analysed the non-commodity outputs (Box I.1) of agriculture, including its environmental impacts and its contribution to rural employment, and has undertaken substantive work in these areas. The introduction of the concept of multifunctionality by Agriculture Ministers at their meeting of 5-6 March 1998 added a further perspective to this discussion. The Ministerial Communiqué (OECD, 1998*a*) recognises that beyond its primary function of supplying food and fibre, agricultural activity can also shape the landscape, provide environmental benefits such as land conservation, the sustainable management of renewable natural resources and the preservation of biodiversity, and contribute to the socio-economic viability of many rural areas.

The shared goals set out by Ministers take account of the multifunctional character of agriculture but also aim for the sector to be responsive to market signals and further integrated into the multilateral trading system. Agro-food policies should strengthen the intrinsic complementarities between the shared goals and ensure that the growing concerns regarding food safety, food security, environmental protection and the viability of rural areas are met in ways that maximise benefits, are most cost-efficient and avoid distortion of production and trade.

The discussion of multifunctionality in the OECD and elsewhere has been beset by the problem that the concept of multifunctionality is not well defined and prone to different interpretations. The Secretariat therefore focussed in its initial work on elaborating a common terminology, identifying the key policy issues and developing a framework for analysis that would be acceptable to all Member countries and which would eventually clarify the meaning of the term "multifunctionality" and the way it is used in Member countries. The reactions to this early work reinforced the impression that Member countries have fundamentally different opinions and positions concerning the definition of multifunctionality, its utility for the agricultural policy debate and its implications for policy reform.

Nevertheless, the discussions converged on three distinct but connected sets of issues, which came to form the nucleus for the development of a work programme on multifunctionality. The first of these concerns the production relationships underlying the multiple outputs of agriculture, and the externality and public good aspects of these outputs. The second comprises methodological and empirical issues related to the measurement of the demand for non-commodity outputs, criteria and procedures for specifying domestic policy objectives, and mechanisms for evaluating progress. The third set of issues concerns the policy aspects of multifunctionality, including its implications for policy reform and trade liberalisation.

It was decided to begin with an analysis of the production, externality and public good aspects of the various non-commodity outputs of agriculture. This work should shed light on the supply and demand characteristics of the positive and negative outputs of agriculture and explore agricultural and non-agricultural ways of supplying the non-commodity outputs demanded by society. The results should provide the analytical basis for discussing, in a second step, the implications of multifunctionality for agricultural policy reform and trade liberalisation.

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Box I.1. **A note on terminology**

In drafting this report, a number of decisions concerning terminology had to be made. Multifunctionality has been the subject of very little economic analysis and there is no established terminology to describe its key elements. There are instances where several terms are available to describe a certain aspect, but none of them is perfect for the purpose in question.

An example is the use of the terms ***commodity*** and ***non-commodity*** outputs. In previous reports on multifunctionality, the terminology ***food*** and ***non-food outputs*** was used. The reason was that food production is generally the primary function of agriculture and the outputs that are jointly produced with food, such as the agricultural landscape, are non-food outputs. Yet, it was pointed out that on a significant portion of farmland, the primary products are non-food outputs, including flowers, fibres, renewable energy or raw materials for industrial production. In such cases the agricultural landscape would not be a by-product of food, but of a non-food output.

As an alternative, the terms ***market*** and ***non-market goods*** were considered. This would allow food and non-food raw materials to be subsumed under one term, but it would create another problem. One of the major objectives of the work is to assess the degree to which the non-food outputs of agriculture are marketable or non-marketable. To make a distinction (*a priori*) between market and non-market goods would amount to prejudging the outcome of the analysis.

Eventually, it was decided to use the terms commodity and non-commodity outputs, which do not suffer from either of the problems mentioned above.

The terms ***by-products***, ***side-effects*** and ***multiple outputs*** are similar in certain respects, but they are not all equally appropriate in a given context. For instance, one can safely assume that the negative effects of agriculture on the environment are unintended side-effects or by-products. An attractive landscape can also be a side-effect if it is the accidental result of food production, but if the farmer is aware of its value and willing to integrate landscape considerations into his or her production decisions, it may no longer be appropriate to call it a by-product or a side-effect.

The analysis of multifunctionality favours a perspective that recognises the integrated nature of the outputs (although it should be recognised that the degree of integration differs significantly among them). For this reason, the term multiple outputs is generally preferred, as it allows the inclusion of intended outputs and not merely unintended side-effects. However, the term multiple outputs has a slightly positive connotation and may be considered less appropriate when negative effects of agriculture, such as water pollution, are examined. To circumvent this problem, the term multiple outputs is replaced by ***multiple effects*** when negative impacts are discussed.

Another distinction concerns the terms ***multiple outputs*** and ***joint products***. A major goal of the work is to examine to which extent the multiple outputs of agriculture are joint products. The term joint products implies some inter-connectedness among the outputs that derives from the agricultural production process. ***Jointness***, as used in these reports, includes private and public goods.

The aim in drafting these reports was to keep the terminology simple and the text readable, and to focus on what is important: a clear description of the analytical issues. The terminology may not be perfect, but it will evolve as the discussion advances and new insights are gained.

There are strong complementarities between the work on multifunctionality and other work carried out in the Agriculture Directorate [on sustainable agriculture (Box I.2), agri-environmental policy, agri-environmental indicators, structural adjustment, farm household income, income risk management, the Policy Evaluation Matrix, decoupling, and trade] and in other parts of the Organisation, notably the Territorial Development Service (work on rural amenities and on rural indicators) and the Environment Directorate (work on biodiversity). There are also links with the OECD horizontal activity on sustainable development. The work on multifunctionality builds on these efforts, while trying to address the commodity and non-commodity outputs of agriculture within a unifying framework that reflects the way in which these outputs are generated and in which they impact on producers, consumers and taxpayers.

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Box I.2. **Multifunctionality and sustainability**

One question that has arisen in the discussions leading up to this work is how multifunctionality relates to sustainability. Sustainable development, and sustainable agriculture in particular, have been the subject of numerous conferences and discussions over the last ten years, and have been enshrined as guiding principles in several international agreements and action plans. The OECD itself has carried out a considerable amount of work on sustainable agriculture (for example, OECD, 1995*a*).

Sustainability refers to the use of resources, human, natural and man-made, in ways that allow current generations to satisfy their needs without jeopardising the capacity of future generations to meet theirs. As such, sustainability is a resource-oriented, long-term and global concept. It is resource oriented because we do not know which use future generations will make of the resources and which economic activities they will engage in; it is, by definition, long-term as it involves the interests of future generations; and it is inherently global as long-run sustainable resource use in a sector, country or a region can hardly be achieved if resource use in other sectors, countries or regions is non-sustainable.

Multifunctionality refers to the fact that an economic activity may have multiple outputs and, by virtue of this, may contribute to several societal objectives at once. Multifunctionality is thus an activity-oriented concept that refers to specific properties of the production process and its multiple outputs.

The concept of sustainability is essentially ***goal-oriented***, implying that resources should be used in such a way that the value of the entire stock of capital (including its option value) does not diminish and an indefinite stream of benefits can be obtained. The goal-oriented element may not always be evident, such as when the purpose of the exercise is to explore whether a particular type of agriculture is currently sustainable or not. But there is always an underlying assumption that the ultimate objective is to achieve sustainability. If an economic activity is not compatible with sustainable resource use, there is a problem that needs to be addressed. By comparison, if an activity is not multifunctional, there is no imperative to make it multifunctional. According to the working definition proposed in this report, multifunctionality is a ***characteristic*** of the production process that can have implications for achieving multiple societal goals.

It could be argued that this distinction is somewhat artificial. Sustainability is not an exclusively goal-oriented concept; it can also be used in a "positive" context. Similarly, multifunctionality can be given a "normative" aspect, as in paragraph 15 of the 1998 OECD Ministerial Communiqué, which lists as one of the adopted policy principles to "... preserve and strengthen the multifunctional character of agriculture...". Paragraph 13 stipulates that "... agro-food policies should ... [allow] agriculture to manifest its multifunctional character..." (OECD, 1998*a*).

The work plan on multifunctionality and the work on sustainable agriculture carried out in the OECD reflect these differences in perspective. The sustainability work examines the reasons why some current agricultural practices are not sustainable and explores the possibilities for corrective action. The work on multifunctionality emphasises the joint production and (both positive and negative) externality and public good aspects of the multiple outputs of agriculture, and their implications for policy formation.

Structure of the report

This report presents the results of analytical work on multifunctionality carried out in the OECD. They should provide the basic elements for future policy analysis. Part II addresses the production aspects of multifunctionality. In particular, it explores the production relationships that distinguish multifunctional activities from other economic activities; assesses the extent to which multifunctional characteristics are present in agriculture; and examines how such characteristics can influence the provision of commodity and non-commodity outputs, both within agriculture and relative to non-agricultural provision. Special attention is given to the possibility of cost savings due to the joint provision of outputs ("economies of scope"), and to the problems that arise if the joint outputs are generated in the wrong composition or proportion, if they differ in their geographical dimension, or if the beneficial effects are accompanied by harmful effects that can not be dissociated from the activity.

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Part III examines the precise nature of the positive and negative externalities and the public goods generated by agricultural activities, and considers policy approaches that address under- or overprovision due to market failure. Since the externality and public good characteristics of the non-commodity outputs are determined by the way in which the benefits and costs of the outputs are distributed in society, this work has links to demand analysis. A wide range of market and policy options is considered in the analysis, and their usefulness for correcting market failure is assessed as a function of the externality and public good aspects of the non-commodity outputs. Consumption links (complements and substitutes) among the outputs are also analysed and some policy issues that arise when multiple outputs are consumed together are highlighted. The importance of incorporating both positive and negative externalities is stressed throughout this report.

Annexes 1 and 2 provide a thorough discussion of the concept of joint production and its applicability to multifunctionality. Annex 3 reviews how issues that are similar to multifunctionality are treated in other economic sectors. The review is part of an effort to ensure that key issues are treated consistently across sectors. There is no presumption that agriculture is the only economic activity with multifunctional characteristics (Box I.3). Annexes 4 to 7 include technical material that complements the analysis of externalities and public goods.

Box I.3. **Multifunctionality: a specificity of agriculture?**

If multifunctionality is first and foremost a characteristic of an economic activity, then the question arises why this issue has become policy relevant in agriculture and not also in other parts of the economy. It is unlikely that the existence of jointly produced outputs should be so heavily concentrated in agriculture that it confers a special status on this sector. Whatever definition of "output" is adopted, many economic activities have, in addition to their intended output (which constitutes their *raison d'être*), other (often unintended) outputs or effects. Thus, the mere existence of multiple outputs that are inter-connected does not in itself distinguish agricultural from non-agricultural activities.

Similarly, the fact that some of the outputs are externalities or public goods, does not explain why debate on the concept of multifunctionality has not spread beyond agriculture. One can think of many cases where non-agricultural activities produce side-benefits that are non-excludable and non-rival (public goods). Hence, based on the presence of joint outputs, some of which are public goods, there is no reason to belief that multifunctionality is a specifically agricultural phenomenon. In fact, many issues that are conceptually similar to those discussed under the heading of multifunctionality in agriculture have also been addressed in other economic sectors, albeit under different headings and in different policy contexts.

Most of the relevant examples of joint production found in the literature review (Annex 3) are in forestry, with some additional applications to the fisheries sector and to household production. The examples from ***forestry*** are particularly interesting and relevant, as there are many similarities between agriculture and forestry regarding the provision of private and public goods, the importance of land as an input, the role of biological processes in production, the close relationship with the environment, and the impact on the rural economy. It is notable that joint production has entered the policy debate specifically in agriculture and forestry – the two major land-using activities in OECD countries.

A frequently asked question in these studies is whether joint provision of goods and services is cheaper (or more costly) or results in a higher (or lower) quality output than separate provision. Joint provision usually receives a favourable rating in situations where there is a high degree of complementarity among the outputs and where synergy effects can be increased, and conflicts reduced, through appropriate management decisions. A cautious evaluation and interpretation of experience in other economic fields can benefit the work on multifunctionality in agriculture and ensure that the main issues are addressed in consistent ways across different sectors of the economy.

But there are also a number of questions that need to be addressed in agriculture, which may not be of equal importance in other sectors, and these factors might explain why multifunctionality has become policy relevant especially in agriculture. Some of these may relate to characteristics of agriculture as an industry, such as the geographical dispersion of farm enterprises, and others to the political decision making process and the high levels of support and protection that continue to be provided to the sector.

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The division of the work into production aspects on the one hand and externality and public good aspects on the other is, however, somewhat arbitrary. The two sets of issues are closely linked from a policy perspective and neither can be treated without reference to the other. Part I therefore tries to bridge this divide by synthesising the lessons that can be drawn from the two analytical pieces, which are presented in Parts II and III.

Questions of measurability of the non-commodity outputs and demand estimation, although important for policy formation, are not explicitly covered in this report, as they form part of the second cluster of the work.[1] However, Part III on externalities and public goods implicitly acknowledges the measurement difficulties by stressing policy options that do not require demand estimation. In addition, Annex 1 mentions the implications of measurability problems for policy analysis.

A "working definition" of multifunctionality

The term "multifunctionality" has been used with various meanings in the agricultural policy debate, depending on the country and on the context in which it has arisen. While it is not the primary purpose of this report to develop a precise definition of multifunctionality (although such a definition may subsequently be established on the basis of the analysis), it is nevertheless necessary to adopt a "working definition" that provides an anchor for the discussion and defines the angle from which to approach the analysis.

Such a working definition needs to encompass the core elements of multifunctionality that have been recognised by Member countries. The key elements of multifunctionality are: *i*) the existence of multiple commodity and non-commodity outputs that are jointly produced by agriculture; and *ii*) the fact that some of the non-commodity outputs exhibit the characteristics of externalities or public goods, with the result that markets for these goods do not exist or function poorly. Before any attempt can be made to draw policy-relevant conclusions, the different elements that are put forward as pertaining to the multifunctionality of agriculture need to be examined in the light of this working definition.

This study makes reference to specific non-commodity outputs of agriculture to illustrate key points of the discussion.[2] These examples are not meant to constitute an implicit list of non-commodity outputs that are part of multifunctionality. Rather, the aim is to explore how various non-commodity outputs that have been cited in previous discussions in the OECD, fit into the proposed framework of analysis. The examples are kept short, and are often accompanied by cross-references to other work carried out in the OECD. This is especially true with regard to environmental outputs, which have been the subject of considerable work in the Joint Working Party of the Committee for Agriculture and the Environment Policy Committee.[3]

The inclusion of rural employment and food security in the discussion of multifunctionality has been controversial. Clearly, rural employment related to agriculture is an input either of commodity production or wider agro-food industries, and cannot be considered as a non-commodity output of agriculture or as an externality. Nonetheless, it may have impacts on society, which might be considered as externalities (for example, slowing the migration from rural to urban areas). The nature of the relationship between commodity production and rural employment is examined in Part II. The relevance of the analysis of possible externality and public good aspects of rural employment conducted in Part III then depends on the outcome of the analysis in Part II, in particular the degree to which there is jointness and possibilities for non-agricultural provision. The main issues associated with food security lie in its link with domestic production as opposed to alternative supply sources, as discussed in Part II. The impact of domestic production on food security could be either a positive or a negative externality of domestic production, as discussed in Part III.

This working definition associates multifunctionality with particular characteristics of the agricultural production process and its outputs. Alternative interpretations that are sometimes encountered in the public debate liken multifunctionality to an objective rather than to a characteristic (Box I.4). This other approach will not be considered in the analysis presented here.

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Box I.4. **Multifunctionality: a characteristic or an objective?**

There are essentially two approaches to the analysis of multifunctionality. One is to interpret multifunctionality as a characteristic of an economic activity. The particular characteristic that makes an economic activity multifunctional are its multiple, interconnected outputs or effects. These outputs can be positive or negative, intended or unintended, complementary or conflicting, reinforcing or offsetting. Some of the outputs are valued in existing markets, whereas others may elude the market mechanism.

Multifunctionality, interpreted in this way, is not specific to agriculture; it is a property of many economic activities. There are numerous ways in which economic activities can be multifunctional. A certain activity may be multifunctional or not, but there is no implicit notion that it should be multifunctional. This view can be termed the "positive" concept of multifunctionality.

The second way of interpreting multifunctionality is in terms of multiple roles assigned to agriculture. In this view, agriculture as an activity is entrusted with fulfilling certain functions in society. Consequently, multifunctionality is not merely a characteristic of the production process, it takes on a value in itself. Maintaining a multifunctional activity or making an activity "more" multifunctional, can become a policy objective. This view can be termed the "normative" concept of multifunctionality.

The analysis in this report is based on the "positive" concept of multifunctionality. The positive approach chosen by the Secretariat does not exclude policies that "… allow agriculture to manifest its multifunctional character…" (1998 Ministerial Communiqué, OECD, 1998*a*). Moreover, relating multifunctionality to economic characteristics of the agricultural production process and its outputs, provides a framework for discussion that allows a wide range of producer, consumer and taxpayer concerns to be addressed.

Putting the emphasis on the "positive" approach does not exclude a discussion of the "normative" concept of multifunctionality, both approaches being recognised in the Agricultural Ministers Communiqué of 1998. By placing multifunctionality in a "normative" context, the focus of the discussion would shift towards the societal objectives associated with agriculture in the various countries, including equity and stability objectives. The normative aspects of multifunctionality could thus be suitably addressed in the context of empirical work on multifunctionality and policy implications.

The fact that an activity produces multiple inter-connected outputs can acquire economic relevance if this characteristic influences the way in which scarce resources are used in the economy to meet the demands of society. Moreover, the multifunctional characteristic can become policy relevant if, among the multiple outputs generated, there are some that are welfare-enhancing or welfare-reducing but for which no private markets exist. If, in such a case, a policy action is deemed necessary to internalise an externality, the characteristics of the activity involved have implications for the design and the implementation of the correcting action.

Policy context

The policy context for the work on multifunctionality is provided by Member countries' commitments to further progressive reductions in domestic agricultural support and border protection, and a shift away from policy measures that encourage higher levels of food production and input use, towards measures that are less distorting of markets and trade. At the same time, there is a growing awareness of the positive and negative non-commodity outputs of agriculture among rural and urban citizens, and governments are increasingly looking for ways to ensure that the non-commodity outputs of agriculture correspond in quantity, composition and quality to those demanded by society.

Some Member countries are concerned that reductions in production-linked support and trade liberalisation may, through a decline in food production, reduce some of the positive non-commodity outputs of agriculture that are jointly produced with food and for which no markets exist, below the levels desired by society. Conversely, there are fears on the part of the trading partners that those countries might try to safeguard their non-commodity outputs through the continued protection of their domestic

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food markets, or even expand these outputs through measures that lead to increased food production. Underlying the debate on multifunctionality are some of the same considerations as the discussion of "non-trade concerns" that has evolved in the context of multilateral trade negotiations. These "non-trade concerns" can have important effects on trade and on producers in other countries.

The standard policy recommendation in situations where a combination of private and public goods is produced, is to let market forces freely determine the level of production, consumption and trade of the private goods, while at the same time addressing any underprovision of public goods and any positive or negative externalities through targeted and decoupled policy measures. Moreover, each public good objective or externality should be addressed through a separate policy instrument that influences the target variable directly. This standard recommendation corresponds to the well-known result from the theory of economic policy that, in order to simultaneously achieve a set of objectives, the number of policy instruments has to be equal to or greater than the number of goals (Tinbergen, 1952).

The challenge for the work on multifunctionality is to test the validity of the standard policy recommendation against the additional aspects introduced by multifunctionality: the simultaneous consideration of the various positive and negative effects of agriculture, and their joint production, externality and public good aspects. ***The eventual goal is to establish principles of good policy practice that permit the achievement of multiple food and non-food objectives in the most cost-effective manner, taking into account the direct and indirect costs of international spillover effects. On a broader scale, the work on multifunctionality is part of an ongoing effort by the Secretariat to address domestic non-trade concerns, including equity and stability issues, and trade liberalisation in mutually consistent ways.***

Summary of production aspects

Key concepts and questions

The principal issue on the production side of multifunctionality concerns the nature and degree of jointness in the production of commodity and non-commodity outputs. If production were non-joint, the non-commodity outputs could be supplied independently of agricultural commodities and domestic non-trade concerns could be pursued irrespective of trade considerations.

Jointness adds two new elements. First, any change in commodity production, be it market-led or policy-driven, entails a change in the levels of the non-commodity outputs that are jointly produced with commodities. Secondly, jointness can create possibilities for ***economies of scope***, that is, cost savings that are generated through the joint provision of several outputs as opposed to their separate provision.

Much of the analytical work on the production aspects of multifunctionality has focused on these two elements. Regarding the first element, if there are linkages between the commodity and non-commodity outputs, policy reforms in the commodity sector will affect the non-commodity outputs. Conversely, measures aimed at achieving non-food objectives will have implications for commodity production and trade. ***One of the major thrusts of the work has been to establish the extent to which the non-commodity outputs of agriculture are linked to or can be dissociated from commodity production. This has important implications for policy targeting and decoupling.***

The second consideration concerns possible cost savings due to joint production. Economies of scope arise if something inherent in the production process makes it cheaper to provide two or more outputs jointly rather than separately. The second major line of investigation has therefore been oriented towards the factors that determine whether there are economies of scope in the joint provision of commodity and non-commodity outputs by agriculture.

Another question concerns how the production linkages are influenced by site- and area-specific conditions. Territorial aspects, including differences in the spatial dimensions of the non-commodity outputs, have also been part of the analysis.

Finally, an important issue on the supply side of multifunctionality is whether some non-commodity outputs can be supplied at a lower cost by non-agricultural providers. In this context it is important to know whether the non-commodity outputs can be separated from agricultural production

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and resource use, and whether there are economies of scope that confer a cost advantage on agricultural or on non-agricultural providers. The analytical work has addressed these and other factors that influence the cost of agricultural and non-agricultural provision.

The results of the analytical work on the production aspects of multifunctionality do not allow conclusions to be drawn in terms of specific policy actions or measures. This will be the subject of future policy work, where additional factors that influence the relative merits of alternative market and policy approaches will be considered.

The nature of jointness in agriculture

The joint product relationships that characterise the non-commodity outputs of agriculture are extremely varied, including different types of technical interdependencies and shared or common resources, and linkages which defy easy classification in a joint production framework (Box I.5).

Production of commodity and non-commodity outputs is rarely observed in fixed proportion in practice. There is usually considerable scope for adjustments in the bundle of commodity and non-commodity outputs in response to changes in relative prices and policy incentives. In the case of environmental outputs, improvements can often be achieved through changes in farming technologies and practices. Some environmental outputs and landscape elements are separable in land use from

Box I.5. **The sources of joint production**

Joint production refers to situations where a firm produces two or more outputs that are interlinked so that an increase or decrease of the supply of one output affects the levels of the others. Three reasons for jointness are frequently distinguished: *i*) technical interdependencies in the production process; *ii*) non-allocable inputs; and/or *iii*) allocable inputs that are fixed at the firm level.

Technical interdependencies are at the origin of many of the negative non-commodity outputs of agriculture, including soil erosion, chemical residuals and nutrient leaching. Greenhouse gas emissions and problems of animal welfare are also associated with technical or biological characteristics of the production process. Positive effects due to technical interdependencies include, for instance, the pest-controlling effects of certain cropping patterns used in integrated pest management, and the impacts of crop rotations on nutrient balances and soil productivity.

The second type of jointness arises where multiple outputs are produced from the same input (non-allocable input). The classical example is the production of mutton and wool which are jointly obtained from raising sheep. The production of meat and manure, or the association of landscape with particular production systems (terraced paddy fields, Alpine pastures with cows, fields of sunflower), are other examples of joint products caused by non-allocable inputs. However, while these outputs are joint, they are rarely produced in fixed proportions and those proportions can be modified by using different production methods. Many output linkages, including those between game and timber or between food and landscape, can either be attributed to non-allocable inputs (they are produced on the same land) or to technical interdependencies.

Jointness can also be caused by allocable fixed factors. Such factors are available to the firm in a fixed amount and are allocated to the various outputs in the production process. An increase or decrease in the production of one output changes the amount of the factor available for the supply of the others, thus creating a linkage among the outputs. This source of jointness has attracted a lot of attention among agricultural economists because farmland and self-employed labour are allocable fixed factors. For the analysis of multifunctionality, however, it may be less important than the other two sources of jointness.

The overall jointness effect is often due to a combination of different sources, the relative importance of which can be difficult to assess. Moreover, there are outputs that are mentioned in the discussion of multifunctionality but which do not correspond neatly to the three sources of jointness. One of these is the contribution of agriculture to rural employment, which is linked to agricultural labour use. Another is the contribution of agriculture to food security, where the linkage is with food itself, which is a primary output, and a tradable good, whereas other multifunctional outputs are non-tradable.

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commodity production, and certain cultural heritage values can be completely dissociated from farming activities.[4] Agricultural employment is linked to commodity production, but developments in part-time farming and non-agricultural employment on the farm have changed the relationship between agriculture and rural viability. Food security is basically about consumption, but trade can allow the place of production to be dissociated from the place of consumption, at least to some extent.

Commodity and non-commodity outputs can be complements or substitutes in production depending on the underlying production relationship. Reducing a negative externality caused by a technical interdependency may lower commodity supply, whereas increasing a positive externality may expand it. Where non-commodity outputs compete with commodities for land, an increase in the non-commodity output will generally imply a reduction in commodity production.

Providing support to commodity production with the aim of achieving certain non-commodity objectives is likely to cause undesirable effects with respect to other non-commodity outputs. Addressing the non-commodity outcomes directly instead of focussing on commodity production will steer the agricultural activity in a direction of greater non-commodity benefits and smaller trade-offs in line with society's preferences. Direct incentives for the provision of non-commodity outputs will lead to the strongest possible dissociation of the non-commodity outputs from commodity production, and the smallest trade distortions, within the limits imposed by the underlying production relationships. Policy targeting increases precision and reduces distortions in commodity markets, but the gains will have to be weighed against any increases in transaction costs.

Since many of the non-commodity outputs of agriculture are, in one way or the other, linked to agricultural activities or resource use, achieving domestic non-commodity objectives will have some repercussions – positive or negative – on commodity production. Unavoidable trade effects and their welfare implications in other countries have to be taken into account when considering the costs and benefits of pursuing domestic non-commodity objectives. International spillover effects should also be taken into consideration in analysing the merits of alternative policy approaches.

The links between the commodity and non-commodity outputs have to be seen in a dynamic context. The intensity of agricultural production can be changed to modify the relationship between commodity and non-commodity outputs. New information, technologies and farmer experience create new ways of using a farm's resources and may influence the bundle of non-commodity outputs generated in the process. Agricultural research and development, in combination with farmer training, are potentially effective ways of modifying the linkages that determine the non-commodity outputs of agriculture. The degree of jointness between outputs may change in the future.[5]

The spatial, scale and time dimensions of non-commodity outputs

The costs of providing non-commodity outputs and the quality of these outputs can differ substantially within and across countries. Moreover, each non-commodity output has its particular territorial scale. Differences in site productivities and scale dimensions, in combination with spatial variations in the demand for non-commodity outputs, suggest that there will be no single response to multiple non-trade concerns that is optimal for all areas. On the contrary, spatial and scale differences reduce the usefulness of market and policy approaches that can not be implemented using area-specific or local criteria. Ignoring differences in site productivities and scale dimensions of non-commodity outputs can lead to local over- or underprovision of these outputs.

If the various functions of agriculture were completely separable, each non-commodity output could be addressed at the appropriate geographical level. However, jointness in production requires that multiple outputs be considered simultaneously. This can make it difficult to develop an approach that preserves the advantages of scale-specific solutions and permits differences in site productivities of non-commodity outputs to be taken into account. One way to proceed would be to identify dominant land uses for different areas based on the non-commodity outputs that are most in demand in these areas or that can be provided most efficiently under the local conditions, and to explore whether scale similarities allow several non-food concerns to be addressed on the same scale. In this context it is also important to identify the appropriate administrative level at which market or policy responses should be organised.

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Apart from the spatial dimension, the non-commodity outputs also have an important time dimension. While it has not been possible to address this dimension in detail in the analysis, questions concerning the length of time it takes for a non-commodity output to be produced, the pattern of development it follows during that period, the speed at which farming practices and systems can be adjusted, and whether a non-food concern is permanent or temporary, have been raised. The different time dimensions of the non-commodity outputs need to be taken into consideration in policy analysis.

N*on-agricultural provision*

The issue of agricultural versus non-agricultural provision of non-commodity outputs revolves around three questions: can the supply of non-commodity outputs be dissociated from agricultural production; to what extent are non-commodity outputs that are supplied by non-agricultural activities substitutes for those supplied by agriculture; and how can the demand for the non-commodity outputs be satisfied with the least resource cost to the domestic and international economy?

Regarding the possibilities for non-agricultural provision of non-commodity outputs, the picture that emerges from the analysis is rather complex. For non-commodity outputs that are tied to agricultural land, including some ecological and amenity services, provision by non-agricultural groups or enterprises is only possible if these are granted access to the land and if the functions they perform do not conflict with the agricultural activity. These conditions are most easily satisfied in cases where the commodity and non-commodity outputs are separable in land use. If this separation is not feasible, there will only be limited possibilities for farmers and non-agricultural providers to perform different functions side by side.

With respect to services that are not tied to agricultural land, there are few or no technical limits to non-agricultural provision. This concerns, for instance, the viability of rural communities or the maintenance of historical buildings in rural areas. Agriculture can no longer be counted on for vigorous employment creation, but in areas where no feasible economic alternatives exist, a slowdown of employment loss in agriculture can alleviate depopulation problems. In areas where non-agricultural employment is a realistic option, there may be some questions as to whether the replacement of agricultural employment by non-agricultural activities entails a loss of traditional lifestyles, customs and values, but a certain amount of change will be acceptable, while the most valuable traditions can be perpetuated in other ways.

Regarding food security, the issue is foremost one of food supplies from current domestic production versus supplies from foreign sources, from food stocks and from the activation of production potential in times of crisis. Non-agricultural contributions to food security include macroeconomic policies that raise the general income level and improve the affordability of food and measures that increase access to food, including through the development of a stable transportation and distribution system. Maintaining domestic food production above market levels for reasons of domestic food security creates costs for taxpayers, consumers and foreign suppliers and may impact negatively on global food security. Whether food security can be entirely ensured by alternatives to domestic food production depends on the contingency cases. Food security is neither simply a joint product of domestic food production nor simply a joint product of agricultural trade.

A special situation arises in areas where farming becomes unprofitable but the continued provision of some of the non-commodity outputs provided until now by agriculture is considered to be essential. In this case, it is an open question whether farmers are better placed than others to provide these outputs. Agricultural incomes may be small and declining and may not allow farmers to accept a lower remuneration for the supply of the non-commodity outputs than their non-agricultural competitors. Efficient outside providers may thus start to compete with farmers for land based on the direct incentives provided for the supply of non-commodity outputs. Potential quality differences in the non-commodity outputs supplied by farmers as compared to those supplied from non-agricultural sources, and their effects on consumers' valuation, is an issue that may need to be considered.

In sum, the analysis of the production aspects of multifunctionality suggests that the various positive and negative non-commodity outputs of agriculture differ substantially in the way they are related to the agricultural activity and to each other; the degree to which they can be de-linked from

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commodity output; their dependence on site-specific factors; the area over which they extend; and the possibilities for non-agricultural provision. Because of such differences, it is unlikely that a set of non-food objectives could be achieved by concentrating the corrective action on commodity production and letting the non-commodity outputs adjust. Such a path of action would invariably result in a situation where some of the non-commodity outputs are over- or undersupplied, and it would ignore the possibilities for achieving the desired adjustment through direct incentives with smaller impacts on commodity markets and trade.

Summary of externality and public good aspects

If all non-commodity outputs were private goods for which functioning markets exist, private transactions would ensure that resources are used efficiently and that supply and demand are balanced in all markets. Moreover, as shown in Part II, if production is non-joint, including the case where cost effective substitutes for non-commodity outputs exist, the non-commodity output can be supplied independently of commodity production. Therefore, both the lack of markets and jointness between production and the externality are necessary for any discussion of policy implications to be warranted.

Part III, which concerns externality and public good aspects of multifunctionality, does not examine whether given non-commodity outputs meet the above criteria because it is conceptual in nature. In fact, in order to allow the overall conceptual analysis to be made without waiting for an empirical analysis of individual production relationships, some degree of jointness between commodity and non-commodity outputs was assumed.

Part III examines exactly when and how markets fail due to externalities, and shows that non-commodity outputs that constitute positive externalities do not necessarily cause market failure. Theoretically, a positive externality causes market failure because producers do not take the benefits of the externality to society into account and therefore under-provide the good that generates it. In reality, market failure is more complicated, depending on how the demand for the externality is distributed. For example, suppose that a certain externality is produced in some fixed proportion to commodity output irrespective of the location or cost of that commodity production, but that demand is fully met by the amount that is produced jointly by the lowest cost producers. In this case, no market failure occurs because the quantity of the externality that society demands can be fully met without an increase in the supply of the commodity.

If there is trade and domestic prices fall, the market failure resulting from the change in the positive externality will be different than where there is no trade. Whether the result is a net loss or gain in welfare depends on many parameters. Gains come from the private cost savings resulting from the elimination of high cost farms and higher consumer satisfaction due to increased consumption. The possible loss is the decrease in production of the positive externality because of lower domestic production.

Taking negative externalities into account reduces the possibility of market failure because a decrease in supply of a positive externality may be offset by a decrease in the negative externality. Possible consumption relationships between externalities might also affect the outcome. The existence of some negative externalities may actually reduce the demand for positive externalities, thus reducing the risk of market failure.

The assumption that output price decreases cause a reduction in production should also be carefully examined in a more dynamic framework. Production levels may be maintained through increases in productivity on the part of efficient farmers. Farmers could switch to producing a more profitable commodity, which also produces the desired positive externality. These possibilities of course reduce the risk of market failure arising from a fall in supply of a positive externality caused by an output price fall.

It is important to understand that how benefits of externalities are associated with production could be one the factors affecting the degree of market failure, although most theoretical examples assume constant marginal benefits. Externalities that are site specific (discontinuous marginal benefits)

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or those for which the value of additional units falls as the total supply increases (decreasing marginal benefits) are less likely to be associated with market failure than those with constant marginal benefits (under the assumption that the total benefits are the same). Some externalities that are discussed under multifunctionality are very likely to belong to these categories. Whether market failure actually occurs or not should be tested empirically.

There is some controversy concerning the appropriateness of including food security and rural employment as aspects of the multifunctionality of agriculture. Production relationships must first be examined extremely carefully, to determine what the links with domestic agricultural production are and to explore the potential for more cost-effective non-agricultural provision. Only if (domestic) commodity production is found to be the most efficient provider, is it necessary to pose the question concerning externalities and public goods. Rural employment related to agriculture is just an input and can never be an externality of commodity production. Rural employment may, however, have impacts on society such as preventing migration of the population into cities (Similarly, fertiliser may cause an externality but is not itself an externality). If these impacts, which could be positive or negative, are not incorporated into market prices of commodities, they could be defined as externalities. With respect to food security, domestic production could affect (positively or negatively) the risk of shortfalls of food supplies, and this is often not reflected in market prices of commodities. These impacts on food security can therefore be externalities (positive or negative) of commodity production. Whether the positive impacts are greater than the negative ones (*e.g.* domestic production may mean that a country is particularly vulnerable to a production shock caused by weather because it has failed to diversify supply sources through imports) is an empirical question.

P*ublic goods*

Even if some non-commodity outputs are positive externalities that cause market failures, government intervention is not necessarily the best option. There are various ways to narrow the gap between social and private costs, depending on the specific public good characteristics of these non-commodity outputs. Many options would require no or very limited government intervention such as to facilitate market creation. A detailed classification of public goods is therefore needed. Otherwise there is a risk that goods as disparate as toll roads, national defence, community-owned natural resources, municipal fire protection services and fisheries would be discussed together without acknowledgement of the extent to which their different public good characteristics should lead to different policy conclusions.

Possible policy failures associated with incorrect estimation of the demand for public goods also strengthen the need for a detailed classification of public goods. If such errors are likely, provision arrangements that do not require demand estimation, including market provision, might be preferable to government provision, even if these alternative arrangements could also cause inefficiency (*i.e.* underprovision). Transaction and administrative costs associated with various provision mechanisms need to be included.

Six categories of positive externalities have been established based on their characteristics as pure or impure public goods. Each category would require completely different (or, sometimes, no) policy intervention.

A rough classification of major externalities from a public good point of view is proposed for discussion (Box I.6). Although this classification needs to be empirically tested paying sufficient attention to factors such as technical and institutional aspects of exclusion mechanisms (*e.g.* property rights), it indicates the possibilities that many externalities belong to categories that require no or very limited government intervention. Only a few are classified as pure public goods or open access resources, which are difficult to provide optimally without government intervention. On the other hand, many are classified as common property resources or club goods, which are more manageable without government intervention (or with very limited roles of government in encouraging clubs and providing information, etc.) than pure public goods and open access resources. The possibility that many externalities could be classified as local public goods also widens the range of available policy options.

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Box I.6. **Illustrative categorisation of public goods**

Pure Public Goods (*e.g.* national defence): Because of non-excludability and non-rivalry, governments usually supply these goods. This is likely to result in over-provision due to difficulty in estimating real demand. Voluntary provision, which is the only private option, is on the other hand likely to result in under-provision. Whether the inefficiency associated with over-provision by the government is smaller than the inefficiency associated with under-provision by voluntary means is an empirical question. Examples could be: non-use values of landscape; natural habitat; and biodiversity.

Local Pure Public Goods (*e.g.* municipal fire protection service): Benefits are restricted to small jurisdictions. Over-provision by the government or under-provision by voluntary provision are likely to be less serious than in the case of pure public goods. Examples could be: flood control; positive impacts of rural employment; and use values of landscape.

Open Access Resources (*e.g.* fisheries in ocean): Because of non-excludability and rivalry, these goods tend to be overexploited. Converting these into community property resources is an option to achieve efficiency. Otherwise, government intervention may be required. Examples could be: food security; and use value of landscape by visitors.

Common Property Resources (*e.g.* community irrigation): Because of rivalry and excludability of outsiders to the community, these goods could be efficiently managed by a community as long as it can establish rules for the use of the resources. Examples could be: groundwater recharge; and use values of natural habitat and biodiversity.

Excludable and Non-Rival Goods (*e.g.* uncongested highways): The private sector could provide these goods by charging users, but this would lead to inefficiency because potential users with a positive willingness to pay are excluded. However, private provision might be better than government provision when the possibility of over-provision by government is taken into account. These goods become club goods when there is congestion. Examples could be: non-use values of natural habitat and biodiversity if some institutional arrangements like environmental trusts could be established.

Club Goods (*e.g.* golf club): Because of their excludable and congestible nature, these goods are likely to be provided by the private sector or the public sector financed by user fees. Examples could be: non-use values of natural habitat and biodiversity if some institutional arrangements like environmental trusts could be established.

The dynamic nature of these non-commodity outputs as pure or impure public goods should also be stressed. The public good nature of certain externalities may change over time and some may even become private goods. Analysing policy options without taking these dynamic aspects into account could lead to unnecessary or harmful intervention by government.

Consumption relationships between externalities could also make their preservation without government intervention more likely. For example, the risk of underprovision of a pure public good could be reduced through voluntary provision or the market if it has a complementary consumption relationship with an impure public good or a private good.

Consumption relationships among externalities must also be examined to determine whether the externalities are causing market failures. This is because demand could vary depending on whether the externalities of interest are substitutes or complements in consumption. The likelihood of consumption interlinkages among negative and positive externalities will also affect the overall analysis.

A club providing multiple impure public goods sharing common characteristics (multi-product club) could be an option to avoid trying to estimate demand for multiple externalities. Members of the club would decide whether to join the club based on the cost (*e.g.* the membership fee) and the benefit of joining the club. The benefit of joining the club indicates their willingness to pay for using the multiple externalities simultaneously, which reflects substitution or complementary relationships among them.

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Stability and equity issues associated with the provision of different impure public goods are also potentially important in the context of future policy discussions. The most efficient arrangements for providing some impure public goods may not be optimal from a stability and equity perspective.

Various institutional arrangements for providing public goods (*e.g.* voluntary provision, central government provision, local government provision, provision through taking advantage of joint-production, club provision, community provision, etc.) may have different degrees of stability. The termination of provision of a given public good not only causes its underprovision (or no-provision), but could lead to a greater overall efficiency loss than the case where the provision of a different public good is terminated.

Multifunctionality could have domestic or international equity, or income distribution, implications. At the domestic level, equity issues are also much more complicated in the case of multifunctionality than in the case of a single product because, in addition to the fact that the multiple goods are related, each good (externality) has different equity implications. For example, food security (as long as it is not achieved through price support) might favour the poor more than the rich, because the rich can buy food even if prices rise due to a shortage. On the other hand, rural amenities might favour the rich more than the poor because the demand for rural amenities usually increases with income. There are two issues relating to equity or distribution in the context of multifunctionality, which are: *i*) how multifunctionality affects beneficiaries (the benefit implication); and *ii*) how the costs of preserving multifunctionality would or would not affect income distribution patterns (the cost implication).

Trade can improve all countries' welfare because of the existence of comparative advantages. The existence of negative and positive externalities associated with traded goods, along with any policies implemented to internalise them, could affect income distribution between the countries trading in those goods. This might lead to cases where trade does not increase all countries' welfare. How income distribution patterns actually change in response to trade and externalities is an empirical question, depending largely on the amount and nature of externalities in each country and the effect on the terms of trade for a given commodity of domestic policies to internalise the externalities.

Multifunctionality may have different effects in developing countries than in developed countries, although the analytical framework developed in this work could in principle be applied to both groups. Most of the differences between developing and developed countries with respect to multifunctionality are of degree not of nature. Such differences in degree may concern the levels and patterns of demand for non-commodity outputs, the institutional framework required for market creation and voluntary provision, transaction costs and the capacity of public administrations. However, they might have policy implications related, in particular, to domestic and international income distribution issues.

From an analytical framework to policy implications

The analyses of production, externality and public good aspects of multifunctionality undertaken in Parts II and III complement one another in that they treat respectively supply and demand aspects. The conclusions emerging from each element need to be combined in order to proceed to a discussion of the policy implications of multifunctionality. For example, examining the public good characteristics of non-commodity outputs requires information on how they are produced and how they are consumed. Determining the marginal benefits and costs of an externality requires an understanding both of supply (how it is jointly produced with a commodity) and of demand (how it is valued by society).

The work on production relationships and that on externality and public good aspects can also be interpreted as providing an analytical framework that defines a series of questions which should be posed sequentially in order to arrive at policy insights. More specifically, the answers to the questions will provide guidance on the appropriate policy responses, if any. Because of complicated inter-linkages, the questions may not always lend themselves to unambiguous answers. But they do provide a framework that will help keep the discussion sharply focused on the key issues that have been identified. They allow the elimination of cases in which policy interventions are not warranted while identifying others in which intervention may be beneficial and give some guidance as to the nature of the policy interventions that

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are likely to be most efficient. And, importantly, this analytical framework ensures rigorous, objective and consistent consideration of identified non-commodity interests and outputs.

The conceptual framework proposed would begin by examining whether a non-commodity output is jointly produced with a commodity and if so, whether it can be released from this jointness. If production is non-joint, the non-commodity outputs can be supplied independently. Similarly, if production of a non-commodity output can be separated from the production of a commodity output without any cost, the non-commodity output can be supplied independently. If this is the case, there may be no policy link between the goal of agricultural trade liberalisation and the goal of pursuing domestic non-commodity concerns. Policies that target only the supply of non-commodity outputs can be established independently of agricultural production. However, it is still necessary to devise policies that would allow the non-commodity outputs to be sustained efficiently but this would not affect trade.

There are many ways to relax or weaken the linkages between commodity and non-commodity outputs. Changes in farming technologies and practices, for example, can reduce the degree to which environmental outputs are linked with commodity production. There are also various possibilities for lower cost non-agricultural provision of non-commodity outputs.

There may also be many non-commodity outputs, however, that cannot be released completely from jointness with commodity production. Non-commodity outputs that are jointly produced with commodities are by definition externalities but they do not always cause market failures. In this case it is necessary to examine whether the non-commodity outputs in question are causing market failures. If not, there is no policy issue, either from a trade or domestic policy perspective.

In fact, some examples of situations where positive externalities do not cause market failures have been identified. For example, supply of a non-commodity output from farmers whose production cost is lower than the market price may be sufficient to meet demand. In this case, there is no inefficiency even though the benefit of the externality has not been internalised in producers' decision making. Taking negative externalities into account could also reduce the risk of market failure associated with positive externalities.

There may still be non-commodity outputs for which both jointness and market failure have been established. In this situation it is necessary to determine if there are non-governmental options to minimise market failures. When market failures associated with externalities arise, measures are required to provide incentives to incorporate social effects into production decisions. The analysis to date suggests that there are various options for providing these incentives, depending on the public good characteristics of the externalities. For some types of public goods, non-governmental options may be the appropriate strategy.

Applying the proposed analytical framework enables identification of potential policy issues that could conflict with the goal of trade liberalisation. In summary, the questions to be addressed are:

- Is there a strong degree of jointness between commodity and non-commodity outputs that can not be altered, for example, by changes in farming practices and technologies or by pursuing lower cost non-agricultural provision of non-commodity outputs?
- If so, is there some market failure associated with the non-commodity outputs?
- If so, have non-governmental options (such as market creation or voluntary provision) been explored as the most efficient strategy?

Finally, and only if the answer to all these questions is "yes", then the most efficient interventions will be defined by the nature of the jointness that exists on the supply side and by the different public good characteristics of the non-commodity outputs on the demand side. Various options, including central government provision, local government provision, provision through taking advantage of consumption relationships, club provision, and community provision should be carefully examined. Transaction costs, including administrative costs associated with various options should also be taken into account. Some of these options might eventually require a very limited role for the government. Stability concerns, equity concerns and international spillover effects may also affect policy choices.

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It is recognised that the information requirements implied in answering this series of questions may be onerous, and that completely unambiguous answers may not always be forthcoming. Availability of information could itself affect policy choices.

It should also be noted that it may not always be possible to answer the three questions sequentially. The answer to the third question may emerge only after all the costs and benefits associated with possible options are compared. It might then be necessary to revert to the first question, for example, if agricultural provision is eventually found to be more costly than non-agricultural provision of non-commodity outputs.

Even with these practical difficulties, the framework (*i.e.* an in-depth exploration based on the three-questions) can serve as a tool to help policy makers to understand the main issues identified in this analytical work. The application of the framework is important in order to avoid policy developments that are ineffective, inefficient and costly, and that risk to conflict with international obligations. A full consideration of the costs of international spillovers of policies aimed at domestic non-commodity objectives needs to include, in addition to the market impacts caused by such policies, the positive and negative externalities created in other countries as a result of trade effects.

NOTES

1. Demand assessment in the context of multiple outputs was one of the subjects of the OECD workshop on valuation issues, organised by the Territorial Development Service, the Agriculture Directorate and the Environment Directorate in Washington, DC, on 5-6 June 2000 (OECD, 2001*a*).
2. Most of the examples are taken from agriculture or from non-agricultural activities that compete with agriculture in the provision of non-food outputs. The agricultural focus reflects the role assigned to the Secretariat by Agriculture Ministers regarding the achievement of the shared goals for the agro-food sector, and the work programme of the Committee for Agriculture.
3. This agri-environmental work is well advanced and has covered subjects such as: policies for sustainable agriculture (OECD, 1995*a*); the link between farm forestry and the environment (OECD, 1995*b*); the environmental benefits from agriculture (OECD, 1997*a*); the environmental effects of land diversion schemes (OECD, 1997*b*); the links between agricultural trade, trade liberalisation and the environment (for example, OECD, 1997*c*, 2000*a*, 2001*d*); a summary of policy issues in agriculture and the environment (OECD, 1998*b*); the environmental effects of agricultural policy reform (OECD, 1998*c*); co-operative approaches to sustainable agriculture (OECD, 1998*d*); policies for sustainable water management in agriculture (OECD, 1998*e*); the role of reference levels for the remuneration of environmental services provided by farmers; criteria for the development of least-distorting agri-environmental policies; and a classification of agri-environmental measures. A workshop on sustainable farming technologies was held in July 2000 (OECD, 2001*b*). On the empirical side, a series of agri-environmental indicators is in the process of being developed (OECD, 1997*d*, 1999*a* and 2001*c*).
4. These conclusions refer to "technical" separability. Separability of a service from food production does not imply that farmers cannot be the least-cost providers of this service.
5. Some of these issues were addressed by the OECD Workshop on *Sustainable Farming Systems and Technology*, organised by the Joint Working Party of the Committee for Agriculture and the Environment Policy Committee and which took place in the Netherlands in July 2000 (OECD, 2001*b*). The OECD conference on Agricultural Knowledge Systems Addressing Food Safety and Environmental Issues, which took place in January 2000, also dealt with some of these issues (OECD, 2000*b*).

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Part II

THE PRODUCTION RELATIONSHIPS UNDERLYING MULTIFUNCTIONALITY*

Introduction

Like many economic activities, agriculture generates multiple outputs. It produces food and fibre, shapes the farm landscape, creates employment in rural areas, affects ecosystems and biodiversity, water, air and soil quality, and the well-being of farm animals. The multiple positive and negative outputs of the agricultural production process contribute to or detract from societal goals – the viability of rural areas, environmental quality (including biodiversity and land conservation), food security, sustainability, animal welfare, and cultural heritage. Other economic activities can also contribute to these goals, including through the direct provision of such outputs.

This part focuses on the way in which the multiple outputs of agriculture are generated. In particular, it explores the elements that distinguish multifunctional activities from other economic activities, assesses to which extent these characteristics are present in agriculture, and examines how such characteristics can influence the provision of commodity and non-commodity outputs, both within agriculture and relative to non-agricultural provision. Special attention is given to the possibility of cost savings due to the joint provision of outputs, and to the problems that arise if the joint outputs are generated in the wrong composition or proportion, if they differ across locations or regions, or if the beneficial effects are accompanied by harmful effects that can not be dissociated from the activity.

The part begins with an outline of the key questions that arise on the production side of multifunctionality. It then moves on to an exploration of the technical and economic aspects of joint production and their application to multifunctionality. The nature of jointness in agriculture and its implications for the supply of non-commodity outputs and local and regional differences in the non-commodity outputs are examined. Finally, the possibilities for non-agricultural provision of these outputs are addressed.

What are the key questions?

According to the working definition of multifunctionality proposed in Part I, the central characteristic of multifunctional economic activities is the joint production of multiple outputs, some of which exhibit the characteristics of externalities or public goods. This part focuses on the first aspect of the definition – the joint production aspect of the multiple outputs of agriculture.

The characteristic of jointness in production has economic relevance as it can influence the way in which scarce resources are used in the economy to meet the demands of society. However, if all outputs were private goods for which well-functioning markets exist, private transactions would ensure that supply and demand are balanced and resources are used efficiently.

The policy relevance of multifunctionality is linked to the second part of the definition: the fact that some of the multiple outputs are externalities or public goods. If there are welfare-enhancing or welfare-reducing outputs for which no markets exist, there will, in the absence of corrective measures,

* This part benefited from the comments of an outside reviewer, Professor Richard N. Boisvert of Cornell University, United States.

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be no signals that tell farmers how much of these outputs to produce. The outputs will still be generated, as they are supplied jointly with agricultural commodities, but it would be sheer coincidence if their level, composition and quality corresponded to those demanded by society.

Agricultural policies that raise commodity production also influence the level of non-commodity outputs because of jointness. As long as there are no mechanisms that reward farmers for the external benefits and hold them accountable for the external costs of their activities, there is no guarantee that agricultural support policies affect non-commodity outputs in the desired direction. Commodity-linked support and protection may either compound or mitigate under- or oversupply of non-commodity outputs, but does not address the basic problem, which is the non-internalisation of external effects. In all cases, when trying to identify the most cost-effective policy, all the costs and benefits, domestic and international, should be taken into account. Complex inter-relationships mean that a given intervention will have impacts that differ in magnitude and in direction on demand and supply of a range of outputs. Costs associated with information gathering, with administration, with compliance and monitoring of compl iance are all part of the equation.

These considerations raise a number of policy questions. What are the most appropriate means of ensuring that there is no under or oversupply of the non-commodity outputs, taking into account joint production relationships? If there is a need for government action to correct the signals currently provided by markets and policies to producers, which form should this action take? Do governments have sufficient information to ensure that their intervention will be beneficial both to communities in regions directly affected and to society overall? How have the high levels of support for agriculture that are provided in many OECD countries, shaped the non-commodity outputs? And how can policies for domestic non-trade concerns be developed that are consistent with countries' commitments to undertake further negotiations towards the long-term objective of reducing agricultural support and border protection?

To address these policy issues, the production, externality, public good, demand and trade aspects of the multiple outputs of agriculture all need to be taken into consideration. To keep the focus on the production aspects, a number of assumptions are made in this part concerning the other aspects. These include that the non-commodity outputs are measurable, that a demand for them exists, and that this demand is known. Moreover, it is assumed that ways of providing direct incentives or disincentives for the provision of the non-commodity outputs exist.[1] Some of the questions that are avoided by making these assumptions are addressed in Part III report (policy approaches for externalities and public goods); others were discussed in connection with the second part of the work plan on multifunctionality (measurement issues, demand estimation) (OECD, 2001*a*).

The key issues on the production side of multifunctionality are related to the nature and degree of jointness of the multiple outputs of agriculture. If production were non-joint, the non-commodity outputs could be supplied independently of agricultural commodities. Under the assumptions made above, appropriate direct incentives or disincentives for the provision of the non-commodity outputs (targeted measures) could be provided that would ensure that these outputs are supplied at desired levels, irrespective of changes in commodity production. There would be no policy link between the goal of agricultural trade liberalisation and the goal of achieving domestic non-food objectives.

Jointness complicates the picture in two major ways. First, any change in commodity production, be it market-led or policy-driven, entails a change in the levels of the non-commodity outputs that are jointly produced with commodities. Conversely, the introduction of a direct incentive or disincentive for the provisions of a non-commodity output has implications for commodity production. In fact, ***all outputs that are linked through the production process adjust if one of them changes***.

The "correlations" between the outputs could give rise to attempts to pursue several non-food objectives by influencing only one or a small number of outputs and letting the others adjust. In particular, there could be efforts to maintain a certain level of the non-commodity outputs by controlling commodity production, especially if direct incentives for the provision of the non-commodity outputs are difficult to implement or costly to provide. Such a course of action might be tempting if all of the non-commodity outputs generated in this way contribute equally towards societal goal. The situation will be different if some of the non-commodity outputs conflict with regional, national or global societal objectives.

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A strategy for pursuing non-food objectives based on commodity-linked measures implies interference with commodity markets, and thus creates domestic and international inefficiencies in these markets. The costs of these inefficiencies are a key factor in determining whether the non-food objectives cannot be achieved at a lower overall cost through targeted measures. However, other factors, including transaction costs, also have to be taken into consideration.

Unless there is a fixed one-to-one relationship between commodity and non-commodity outputs, a measure targeted at a non-commodity output will change the relative composition of the output bundle (through affecting the farmer's profit-maximising or cost-minimising production decision). The magnitude of this change depends on how rigidly the non-commodity outputs are linked to commodity supply. If there is some flexibility in the linkage and the direct incentive or disincentive is large enough, it may be possible to sever the link between commodity and non-commodity outputs (decoupling).

The rigidity of the production relationship depends, among other factors, on the farming systems and technologies employed by farmers. The fact that a number of production techniques are usually available to farmers, introduces a certain amount of flexibility, even if the links between commodity and non-commodity outputs are rigid for any given technique. Over time, new information, technologies and farmer experience create novel ways of using a farm's resources. The impacts of these developments on the degree of jointness constitute an important issue in the analysis of multifunctionality.

The policy implications of these considerations are straightforward. The more the non-commodity outputs can be dissociated from commodity production, the greater the possibilities for achieving domestic non-food objectives with no or minimal disturbances of commodity markets and trade. The more easily the non-commodity outputs can be adjusted relative to each other, the more likely a set of non-food objectives can be achieved with only small unwanted trade-offs.

The second complication introduced by jointness concerns the possibility of cost savings through the joint provision of several outputs as opposed to separate provision (***"economies of scope"***).[2] This issue does not arise where the outputs are so firmly linked that there is no way of providing them individually. But for many of the non-commodity outputs of agriculture the linkage with commodity production is such that separate provision may be possible.

Economies of scope have several ramifications regarding the efficiency of resource allocation. One concerns the geographical (or ***spatial***) pattern of production. Because of spatial differences in natural and economic conditions, the costs and benefits of non-commodity outputs differ from farm to farm and across regions. There is a need to examine which commodity and non-commodity outputs can be most cheaply produced on the same land or farm. Which ones generate a greater benefit, or can be supplied at a lower cost, if they are concentrated in certain areas? How do natural endowments, farm structures and consumer demand influence regional comparative advantage in the provision of non-commodity outputs? How big must the gains from regional specialisation be to justify "breaking the link" between commodity and non-commodity outputs, and assigning different production priorities to different areas?

Another ramification of economies of scope concerns the question of ***agricultural versus non-agricultural provision of non-commodity outputs***. Some non-commodity outputs of agriculture can also be provided by non-agricultural suppliers. These outputs include, for instance, ecological services that are not linked to commodity production, or goods for which non-agricultural substitutes exist, such as rural employment creation. In some cases, the provision of ecological services may conflict with commodity production. For which of these non-commodity outputs, and under which conditions, does jointness confer a cost-advantage on agriculture relative to non-agricultural provision? On the other hand, non-farm enterprises can also benefit from economies of scope. In which situations is this case, and can it give non-farm enterprises a cost-advantage over agriculture in supplying competing outputs?

In a broader sense, the issue of agricultural versus non-agricultural provision of non-commodity outputs revolves around three questions: can the supply of non-commodity outputs be dissociated from agricultural production; to what extent are non-commodity outputs that are supplied by non-agricultural activities substitutes for those supplied by agriculture; and how can the demand for the non-commodity outputs be satisfied with the least resource cost to the domestic and international economy?

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Virtually all of the questions raised in this section are in one way or the other related to the nature of jointness. The first step in analysing jointness is by exploring its various causes. This is done, in a generic way, in the following section. The results are subsequently applied to agriculture to examine the nature of jointness in this sector and the implications it has for the supply of non-commodity outputs.

Joint production and its application to multifunctionality[3]

There are various definitions of joint production, but in essence they all refer to situations where a firm produces two or more outputs that are interlinked. A key characteristic of jointness is that an increase or decrease of the supply of one output affects the levels of the others.

Three reasons for jointness are frequently distinguished. Outputs can be interlinked because: *i*) there are technical interdependencies in the production process; *ii*) the outputs are produced from a non-allocable input; and/or *iii*) the outputs compete for an allocable input that is fixed at the firm level.

Many of the commodity and non-commodity outputs of agriculture are joint products because of technical or biological linkages inherent in the production process. Economist have used the term ***technical interdependencies*** to describe situations where increases or decreases in the level of one output influence the supply of the other outputs without any change in input allocation to these outputs.

One consequence of technical interdependencies is that the marginal productivities of the inputs used in the production of one output depend on how much is produced of the others. Two outputs are technically ***complementary*** if an increase in the supply of one raises the marginal input productivities in producing the other; they are technically ***competing*** if the reverse holds (Beattie and Taylor, 1985).

In agriculture, technical interdependencies would also have to comprise biological interdependencies. Examples of technical interdependencies include the two-way benefits obtained from the joint production of honeybees and fruit trees, or the pest-controlling effects of certain cropping patterns used in integrated pest management. The impacts of crop rotations on nutrient balances and soil productivity could also be considered to be technical interdependencies over multiple planting periods.

Technical interdependencies are also at the origin of many of the negative side-effects of commodity production, such as the impacts on water and soil quality through soil erosion, chemical residuals and nutrient leaching. Similarly, greenhouse gas emissions, animal well-being and the visual effect of farm buildings on landscapes, are side-effects of food and fibre production caused by the technical characteristics of the production process.

The second source of jointness, ***non-allocable inputs***, concerns situations where multiple outputs are obtained from one and the same input. The fisheries industry provides a good example of non-allocable inputs. Water and the nutrients it contains are non-allocable to individual fish species (except where fish are farmed), with the result that a single fishery usually provides many different types of fish.

The classical example from agriculture is the production of mutton and wool, which are jointly obtained from raising sheep. Meat and hides, meat and bone-meal, milk and meat (from cows), or meat and manure, are other examples of joint products obtained from non-allocable inputs. The production of milk or meat and landscape where cattle graze on Alpine pastures could also fall into this group. In fact, specific farming systems are often perceived as combining the production of a commodity output with a particular type of landscape. Other examples include fields of sunflower in bloom, vineyards, and terraced rice paddy fields. However, while these outputs are joint, they are rarely produced in fixed proportions and those proportions can be modified by using different production methods.

Non-allocable inputs and technical interdependencies are closely related as sources of jointness. In fact, some authors regard non-allocable inputs as a facet of technical interdependencies. Multiple outputs obtained from non-allocable inputs often have biological links, which can alternatively be viewed as technical interdependencies. The links between honeybees and fruit trees, game and timber, or landscape and food can either be attributed to non-allocable inputs (the outputs are provided on the same piece of land) or to technical interdependencies resulting from the production process.

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The third source of jointness is due to ***allocable fixed factors***. These are factors that are available to the firm in a fixed amount and which are allocated to the various outputs in the production process. An increase or decrease in the production of one output changes the amount of the fixed factor available for the supply of the others. As a consequence, the marginal productivities of the variable inputs used in the production of the other outputs also change, thus creating a linkage among the outputs.

This source of jointness has attracted a lot of attention among agricultural economists because farmland and self-employed labour are by and large fixed allocable factors.[4] Most farms produce more than one output, the land and labour allocated to the production of a particular output can generally be distinguished, and the amount of these factors available to the farm is often fixed, at least in the short run.

Time is an important element in analysing jointness created by allocable fixed factors. While in the short run farmers may find it difficult to expand land, labour or even capital goods, in the long run all factors are variable at the farm level. Farmers can buy or rent land, increase or reduce the involvement of family members in the farm enterprise, and adjust their capital stock. The same flexibility is not given at the regional or national level, where the amount of farmland is usually fixed over longer periods.

Jointness created by allocable fixed factors, notably land, affects the way in which commodity supply responds to price changes (as reflected by the own- and cross-price elasticities of supply). Much of past research on jointness in agriculture has focused on this issue. For the analysis of multifunctionality, however, output linkages generated by allocable fixed factors are probably less important than those created by the other two sources of jointness mentioned above. In fact, the possibility of allocating the production of commodity and non-commodity outputs to different parcels of land, is a sign of a high degree of output separation (or a low degree of jointness) in the context of multifunctionality.

The classification of the sources of jointness into three categories is a useful pedagogical device but it does not always correspond to the complexities of practical situations. The overall jointness effect is often due to a combination of different sources – technical interdependencies, non-allocable inputs, and allocable fixed factors – the relative importance of which can be difficult to assess.

Moreover, there are cases of jointness that are important for the analysis of multifunctionality but which do not fit neatly into this classification. Some of the impacts of agriculture that have been associated with multifunctionality can be more easily treated within the context of joint production than others. Among the latter is the contribution of agriculture (or for that matter, of any other economic activity in rural areas) to the viability of rural areas, which is related to the employment and income effects of the activity. From the perspective of multifunctionality, agricultural employment is an input of the farming activity, which may have beneficial impacts on rural viability, although historical data indicate that, due to technical and structural change, agricultural employment has actually been decreasing over time even though agricultural production has increased. Another issue that is difficult to treat in this framework is the contribution of domestic food production to food security.

The analysis of joint production can also be approached from the cost side. Jointness can yield economies in production (or economies of scope) if something inherent in the production process makes it cheaper to provide two or more outputs jointly rather than separately. The cost savings are generally due to technical interdependencies or to non-allocable inputs. The existence or non-existence of economies of scope depends on specific cost parameters and is therefore an empirical question (Leathers, 1991).

The concept of economies of scope was originally discussed in the context of a firm. Economies of scope occur if it is less costly to produce two or more commodities in a single firm than to have them produced by different (specialised) firms. Cost savings from adding an extra product to the production plan, as compared to its separate provision, were used to explain the existence of multiproduct firms.[5]

To be relevant for the analysis of multifunctionality in agriculture, the concept of economies of scope needs to be extended in two ways: *i*) by including non-commodity outputs, and *ii*) by extending the definition of jointness beyond the firm unit. The basic question is whether the joint provision of commodity and non-commodity outputs by agriculture can procure economies of scope, where jointness

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Box II.1. **What is the appropriate unit of analysis?**

When the term multifunctionality is used in the policy debate, it is usually with a sector-wide meaning, referring to agriculture as being (or not being) multifunctional. This general use of the term obscures the fact that the positive and negative contributions of agriculture to the economy occur at different levels, ranging from the farm enterprise to the regional and national (and even global) levels. If the goal were to explore only one particular element of multifunctionality, the unit of analysis could be chosen according to the scale at which the particular output is generated.

When the various food and non-food effects of agriculture are considered simultaneously (as is the case in this part), the unit of analysis can not be chosen on the basis of a single non-commodity output. In this case, a pragmatic solution is to use the farm enterprise – the unit where the decisions are made that shape the bundle of commodity and non-commodity outputs of agriculture – as the point of reference, and to explore, in a second step, the complexities introduced by the different geographical scale associated with the multiple non-commodity outputs.

The discussion of multifunctionality raises questions that extend beyond traditional commodity-centred analysis. Many of these questions relate to farm-level links between management decisions, commodity supply, input use, farming technologies, and non-commodity outputs. These links also determine the adjustments in the output bundle that take place in response to changes in market and policy signals, and which are key to the development of appropriate strategies for multifunctionality. In this context, direct incentives or disincentives for the provision of the non-commodity outputs would have to be implemented at the appropriate scale (targeted measures).

can refer to the provision of multiple outputs on the same piece of land, on the same farm, or in the same region (see Box II.1 for a note on the unit of analysis). Obviously, any evaluation of economies of scope has to include the costs of unwanted side-effects that are created by the joint provision of outputs.

The issue of economies of scope arises only if there is a choice between separate and joint provision of the outputs. In the context of multifunctionality, a criterion for separable provision could be whether the commodity and non-commodity outputs of agriculture can be produced on different parcels of land. If this is the case, the cost implications of producing the outputs separately (on different parts of the farmland) versus managing the entire land (of a farm, region or country) for multiple outputs can be explored. While this question has hardly been examined by agricultural economists, it has received a great deal of attention in forestry economics (Box II.2; a review of the forestry literature is provided in Annex 3).

Even if complete separability of land use is not feasible, it may still be possible to achieve cost reductions or value increases by strengthening the provision of non-commodity outputs in areas where they can be supplied most cheaply or where the demand for them is particularly high. Farms are likely to adopt a set of production activities and methods that maximise their profits under the prevailing market and policy conditions (dominant techniques). If relative prices or policy incentives change, farms will adjust their activities and move towards new dominant techniques with different bundles of associated non-commodity outputs. Regional differences in cost conditions or "site productivities" can lead to a pattern of dominant land uses where the relative emphasis in the provision of non-commodity outputs varies from region to region. Such regional specialisation can be reinforced by regionally targeted policy incentives that respond to differences in demand conditions.

Another aspect of multifunctionality concerns the relationship between supply and demand in the case of jointly produced goods. To achieve a balance of supply and demand, the goods have to be demanded in the same proportion as they are supplied (and *vice versa*). For non-food outputs that are private goods, the balance will be ensured through the market mechanism. If an increase in food production due to a change in relative prices leads to an increase or decrease in the supply of a jointly provided non-food output, the price of this output will adjust until demand matches supply.

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Box II.2. **Joint production – the example of forestry***

The example of forestry is particularly interesting for the discussion of multifunctionality in agriculture. There are many similarities between agriculture and forestry regarding the provision of private and public goods, the importance of land as an input, the role of biological processes in production, the close relationship with the environment and the impact on the rural economy.

Like agriculture, forestry can provide certain environmental and amenity values in addition to its primary output, timber. The question that has occupied forestry economists concerns the most efficient way of supplying non-timber outputs in the quantity and quality demanded by society, while taking full account of the market opportunities for timber production. While there is no doubt that the timber and non-timber outputs are to a certain degree intertwined, it is not always clear whether it is more efficient to manage a given forest simultaneously for timber and non-timber outputs, as opposed to separating the timber from the non-timber functions and managing different parts of the forest in different ways.

The problem is essentially one of whether the joint provision of goods and services is cheaper or results in a higher quality output than their separate provision. Joint provision requires managing each forest stand for multiple outputs, whereas disjoint provision implies a spatial differentiation of the forest into areas with intensive timber production and areas where environmental and amenity values dominate the management decisions.

The studies carried out by forestry economists project a mixed picture. In some situations management of an entire forest for multiple outputs maximises the net value of timber and non-timber production. In others, a better result can be obtained if the relative emphasis on timber and non-timber outputs changes throughout the forest while the overall plan remains one of joint provision. But there are also cases where a spatial segregation of the timber from the non-timber functions increases the value of both types of outputs. Several factors, including technical and biological linkages between the timber and non-timber outputs, regional and local environmental conditions and the structure of demand for the non-timber services, determine which management approach is most appropriate in a given situation.

* Annex 3 reviews applications of joint production theory in the forestry economics literature.

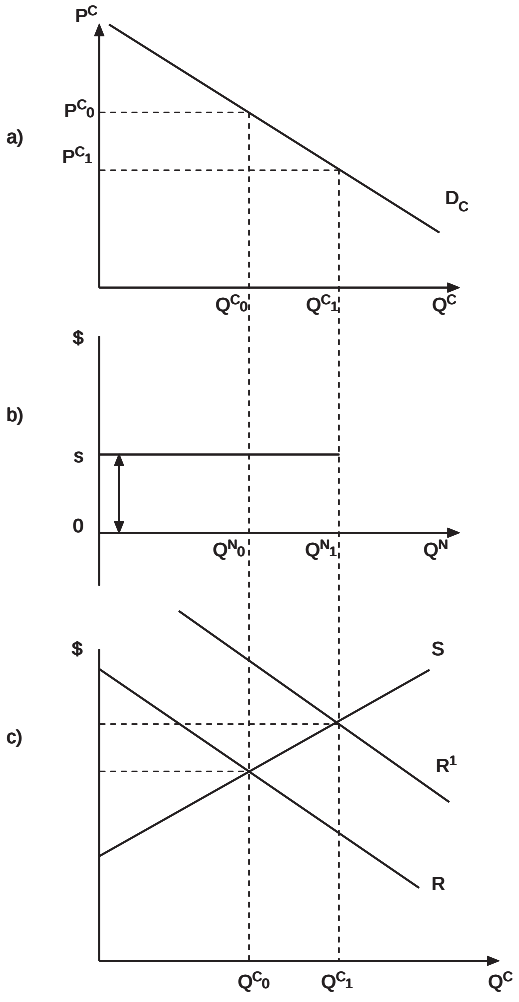
In the case of multifunctionality, the output bundle includes private and public goods. If commodity production under market conditions provides enough of the jointly produced non-commodity outputs, there will be no problem. If, however, society is willing to pay for additional amounts of the non-commodity outputs, the market outcome will not be socially optimal.

Figure II.1 provides a simplified model of the way markets and policies may interact in such a case. The downward sloping curve in panel a represents the demand for the commodity output. The horizontal axis in panel b measures the supply of a non-commodity output. Panel c shows the supply curve of the agricultural commodity (S) and the average revenue curve (R), which is the vertical sum of the individual market demand curves. Assuming that there is no market demand for the non-commodity output, the average revenue curve is identical to the demand for the commodity output (DC). To keep the illustration simple, it is assumed that the commodity and non-commodity outputs are produced in fixed proportions.

In the market equilibrium, the output bundle includes Q^C_0 units of the commodity output and Q^N_0 units of the non-commodity output, and the price of the commodity output is P^C_0. If, in this situation, the quantity supplied of the non-commodity output is below its socially optimal level, an incentive can be provided to farmers to increase its supply. Such an incentive could be provided, for instance, in the form of a payment per unit of the non-commodity output of size *s*, as is reflected in panel *b* of Figure II.1. This would shift the average revenue curve from R to R^1 in panel *c*, and yield a new equilibrium with larger amounts of both outputs (Q^C_1, Q^N_1). The price of the commodity output would decline to P^C_1 for the market to clear.

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Figure II.1. **A simplified model of supply and demand for joint products**



Source: OECD.

The example above referred to a "positive" non-commodity output. The same figure can be used to discuss the adjustments that would occur in a case where the non-commodity output is a negative externality. Since the farmers ignore the social cost of this externality, it is likely that it will be produced at a level that exceeds the socially optimal one. This situation can be rectified, for instance, through a tax on the externality (negative *s* in panel *b*), which would shift the average revenue curve inwards in panel *c*. In the new equilibrium, the outputs would be smaller and the price of the commodity output higher.[6]

This simple market model can be extended by including several non-commodity outputs at the same time, to show the trade-offs that would occur if, for instance, two non-commodity outputs were inversely related or if they were produced in different (yet fixed) proportions.

The model remains nevertheless very limited, as the fixed-proportion assumption is rarely met in practice. In general, changes in relative prices and policy incentives alter the relative composition of the commodity and non-commodity outputs. In fact, the degree to which output substitution is technically feasible, and the cost implications of changing the output mix in favour of particular non-commodity outputs, are key issues in the analysis of multifunctionality.

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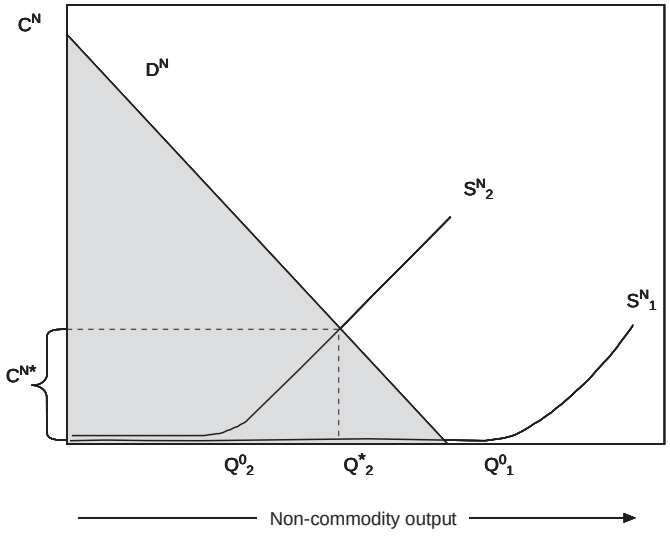
Figure II.2 illustrates the importance of these issues. The figure shows the cost implications of achieving a socially optimal level of supply of a jointly produced non-commodity output under different economic conditions. S^N_1 and S^N_2 represent the supply curves of the non-commodity output in the two situations; D^N represents the demand curve expressing society's preferences for the non-commodity output; and C^N represents the cost of achieving a given level of the non-commodity output. The non-commodity output is assumed to be a public good for which no market exists.

In the first situation, the amount of the non-commodity output that is produced jointly with the agricultural commodity under market conditions, is represented by Q^0_1. Any provision of the non-commodity output beyond this level creates extra costs for farmers which are not covered by market revenues. Farmers would supply more of the non-commodity output only if specific incentives were provided. In the situation shown in the figure, the demand for the non-commodity output is below the amount supplied under market conditions. In this case, the non-commodity output demanded by society is jointly supplied with commodity production at no additional cost.

In the second situation, the level of the non-commodity output provided under market conditions is Q^0_2, which is smaller than in the first situation. Any amount beyond Q^0_2 can only be provided at additional costs, as indicated by the curve S^N_2, which slopes upwards at this point. The socially optimal supply of the non-commodity output is achieved where the supply curve S^N_2 intersects the demand curve D^N. This level (Q^*_2) is above the market level. To generate this supply of the non-commodity output, farmers have to adjust their production plan. This will lead them away from the profit-maximising resource allocation under market conditions. The cost incurred by the farmer of making the necessary adjustment is represented by the distance C^N*.

The same analysis can be applied to situations where the non-commodity outputs of agriculture are associated with external costs rather than external benefits. In such a case, a policy issue arises only if the level of a non-commodity output exceeds the socially optimal levels. The corrective action may involve a disincentive for the production of the non-commodity output, with the size of the disincentive corresponding to the cost of making the necessary production adjustment.[7]

Figure II.2. **Optimal supply of a jointly produced non-commodity output**



Source: OECD.

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The shapes of the marginal cost curves (S^N_1 and S^N_2) of the non-commodity output in Figure II.2 reflect the ease with which the composition of the output bundle can be adjusted, including the trade-offs that occur in moving to a different production configuration. The importance of these curves for optimal supply decisions suggests that there might be a need for a closer examination of the various cost components, including international spillover effects, and of possible ways of reducing these costs, as a basis for policy analysis in the next stages of the work on multifunctionality.

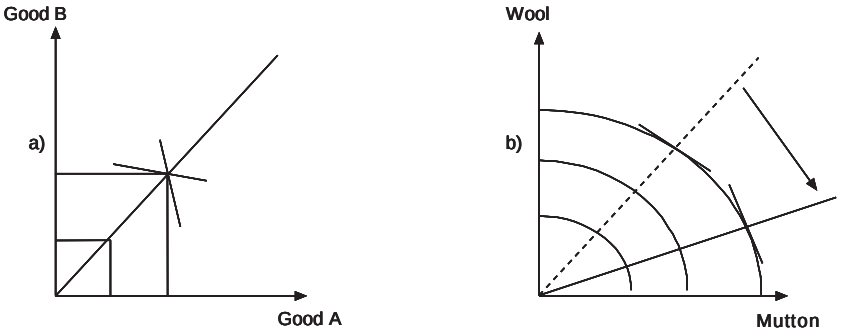
Agriculture is a highly supported and protected industry in many OECD countries (OECD, 2000*a*). As a result, the current level of non-commodity outputs is different from what it would be under market conditions. Policy reforms that reduce support and border protection improve the efficiency of commodity markets and will either increase or decrease jointly provided non-commodity outputs. Figure II.2 can be used to considered this issue.

Figure II.3 provides an alternative presentation of output substitution. Panel a reflects a situation where jointness is due to an invariable physical or biological link so that the outputs can only be produced in fixed proportions, an extreme case that is not often observed in reality. The straight upward sloping line shows the combinations of outputs A and B that can be achieved by successively expanding production. An illustrative example that comes fairly close to this situation is mutton and wool, even though here also the proportions of those joint outputs can be modified extensively by using different production methods.

However, the link between mutton and wool is not entirely inflexible, as the farmer has the choice between different breeds of sheep that produce the two outputs in different proportions. The feeding regime may also influence the outcome. An increase in the price of mutton relative to that of wool will induce the farmer to change the "technology" or the "farming practice", thereby moving to an output combination that includes relatively more mutton and less wool (the solid line in panel *b*). The slopes of the tangent lines to the convex curves reflect the relative prices of mutton and wool in the two situations. The solid lines in Figure II.3a and 3b represent two different output expansion paths corresponding to two different (but constant) relative prices.

In cases where jointness is caused by a rigid technical link, the way the outputs change together is predetermined. It then does not matter which of the outputs is targeted to bring about a change, the adjustment will follow along the same path.[8] In all other cases, the relative composition of the output bundle can adjust within a certain range, and the bundle that is produced in a given situation is determined by the relative prices (or, more generally, by the relative production incentives, including incentives for the production of public goods).

Figure II.3. **Joint production, relative prices and output composition**



Source: OECD.

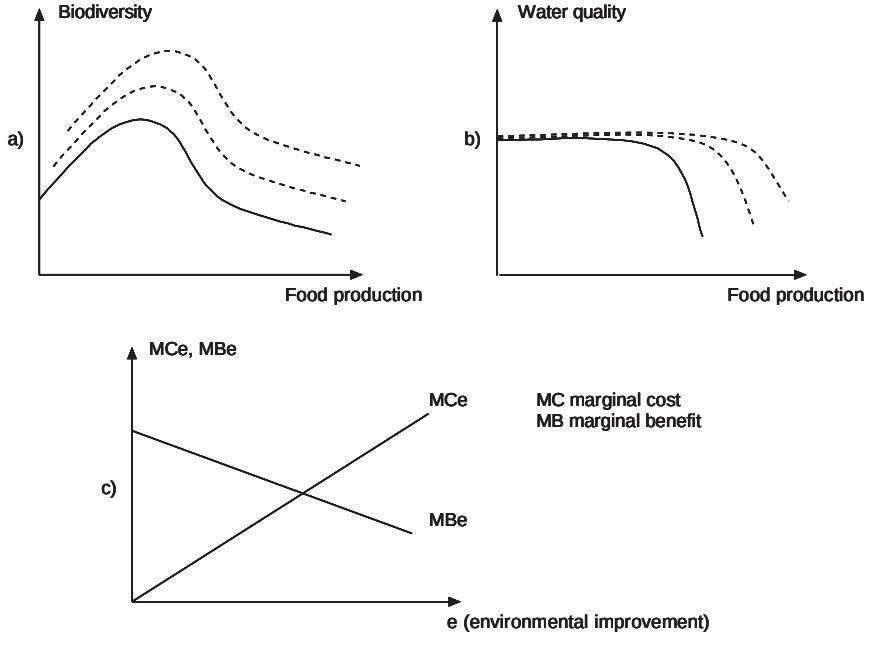
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Of particular interest for agriculture are situations where the non-commodity output is a public good that adjusts as commodity production varies in response to market fluctuations or policy reform. Figure II.4 provides an example of such a case. The solid lines in panels *a* and *b* reflect the combinations of commodity and non-commodity outputs in a situation where no market or other incentives are provided for the non-commodity outputs, and food production varies in response to changes in commodity prices. The non-commodity outputs are joint products associated with least-cost commodity production.

The two examples of non-commodity outputs shown in the figure are biodiversity and water quality. Although these examples are for illustrative purposes only, and the shapes of the curves are hypothetical rather than empirical, an interpretation could be attempted. Panel *a* shows an initial increase in biodiversity as commodity production expands from a low level. This might be conceivable if partial land clearings and the introduction of domestic plant and animal species increase habitat diversity and the feed base, and generate a more diverse fauna and flora. The relationship turns negative above a certain level of commodity production, as the continued expansion of cultivated land and the increased intensity of input use may again reduce biodiversity. Panel *b* reflects an analogous relationship between water quality and commodity production.[9]

If this level of environmental quality is not sufficient, a higher level can be achieved by altering the way commodities are produced or by engaging in specific non-commodity activities. The environmental improvements represented by the dotted lines involve a shift away from the least-cost input combination. The marginal costs of environmental improvements are shown by the upward sloping curve in Figure II.4c. The optimal improvement is given where the marginal cost is equal to the marginal benefit of the improvement (the intersection of the two curves).

Figure II.4. **Some hypothetical production relationships**



Source: OECD.

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While exploring in greater depth the relationships between commodity and non-commodity outputs, Annexes 1 and 2 extend the analysis presented here to include several positive and negative non-commodity outputs at the same time.

The nature of jointness in agriculture

This section examines the key characteristics of jointness in agriculture. The main questions are:

- In which respect are the multiple outputs of agriculture joint products?
- In which way and to what extent are the non-commodity outputs of agriculture linked to farming technologies and practices, and to farm input use?
- How are the non-commodity outputs linked to commodity production, and how do they respond to changes in commodity output?
- What are the possibilities of altering the output mix and the trade-offs among the outputs involved?

The examples of non-commodity outputs discussed in this section serve an explanatory purpose and should not be interpreted as an attempt to establish a list of outputs that should or should not be included in a definition of multifunctionality. If it is deemed necessary to establish such a list, this could be done at a later stage taking into account the results of the analytical work.

The non-commodity outputs of agriculture are not outputs in the conventional sense. Most of them are the result of specific aspects of the agricultural production process. They can be associated with the level of input use (the employment effect of agriculture); be tied to commodity composition and farming practices (the impact on landscape and agricultural biodiversity); be linked to the intensity of intermediate input use (water quality, biodiversity); or be related to food production itself (global food security). Externalities can be either positive or negative depending on the reference level (Part III). Some are closely tied to agricultural production, while others, such as the establishment of wetlands or the creation of wildlife habitat on farmland, compete with agricultural production for land and other resources.

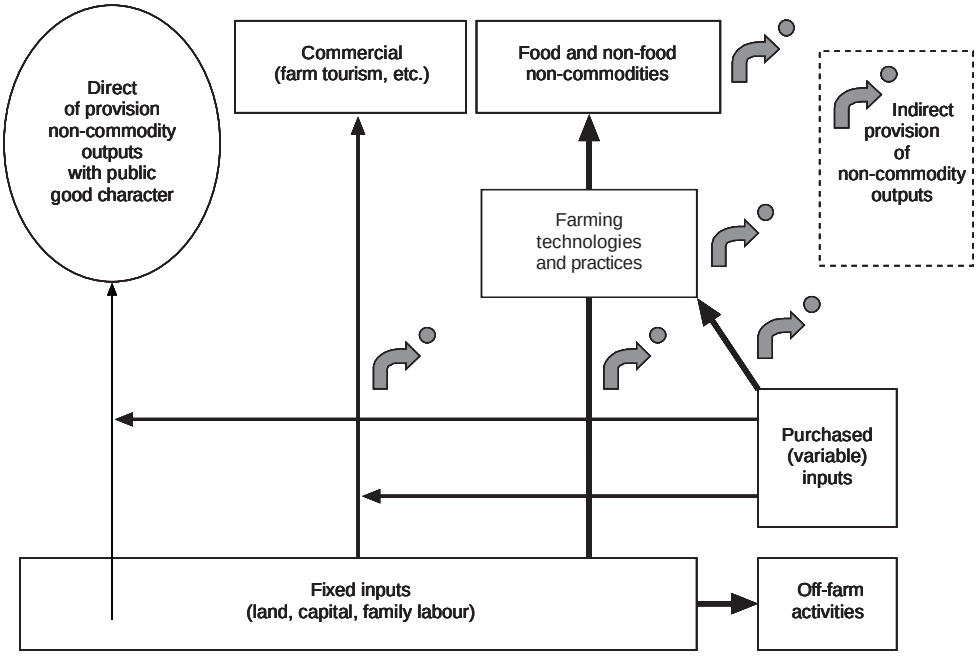
Figure II.5 provides a simplified model of agricultural production and resource allocation on the farm, and shows how the bundle of commodity and non-commodity outputs is generated. The fixed resources available to the farm (land, family labour, and fixed capital goods other than land) can be allocated to produce food and other commodities; they can be used to provide commercial services, such as farm tourism; or they can be used to supply non-commodity outputs with a public good character, such as certain ecological improvements or the preservation of farm structures with a cultural heritage value. These non-commodity outputs do not directly involve commodity production, but they are nevertheless joint products because they are generated from the same pool of fixed resources.

The major use of fixed resources, however, is for commodity production.[10] To produce agricultural commodities, fixed inputs are combined with purchased intermediate inputs in ways that are determined by relative prices, policies, and the farming technologies available to farmers. Commodity production generates non-commodity outputs at every stage of the production process (the arrows in Figure II.5) due to shared inputs, competition for fixed inputs, and a wide array of technical and biological interdependencies. Jointness due to allocable fixed factors is responsible for the direct provision of non-commodity outputs while indirect provision results from jointness due to technical interdependencies and non-allocable inputs.

Table II.1 illustrates, in a simplified way, examples of how non-commodity outputs of agriculture are related to different elements of the production decisions. The linkages indicated in the table illustrate the complexity of joint product relationships. It should be emphasised that the table is neither complete nor detailed enough to describe specific real-world situations. In some cases (*e.g.* food security), the non-commodity output would have to be defined more clearly to fully identify the production linkages. Moreover, the table does not include non-agricultural provision of non-commodity outputs.

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Figure II.5. **A schematic representation of economic activities on the farm**



Source: OECD.

In spite of its shortcomings, Table II.1 permits one important conclusion to be drawn: each non-commodity output of agriculture is linked to several aspects of commodity production and/or to other activities on the farm. The rate of soil erosion, for instance, is linked to input use (the cultivation of fragile lands and the machinery used for soil cultivation and harvesting), farming practices and technologies (crop rotation and tillage practices), commodity composition (the plants grown on the land) and specific measures to protect soils (protective cover crop).

Conversely, each element of the production process affects several non-commodity outputs. For instance, farm buildings and structures, including those for housing animals, form part of the countryside and are an important determinant of animal welfare. Grazing livestock can enhance the countryside but they can also cause problems for soil and water quality and reduce plant diversity if stocking densities are too high. The crop composition impacts on the visual impression of the countryside and determines the amount and quality of feed and refuge available to game and farmland birds. Purchased intermediate inputs, such as mineral fertilisers, pesticides, lime, feedstuffs, antibiotics and hormones can have various positive and negative non-commodity effects regarding soil fertility, water quality, biodiversity, food safety and animal welfare.

There are usually several ways of influencing the provision of a non-commodity output, with different impacts on commodity supply, depending on the aspect of the production process that is targeted. For instance, if a technical interdependency is at the root of jointness, a change in the technical relationship is the most direct way of changing the supply of the non-commodity output.

Some non-commodity outputs may be difficult to influence. For example, to change the amount of employment created by agriculture, significant changes in production or farming systems would have to be made. Other outputs can be influenced more easily, requiring only an adaptation of farming practices. Examples of the latter include the damage to nesting farmland birds caused by cutting grass, or the link between tillage practices and soil erosion.

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Table II.1. **Examples of production relationships for selected non-commodity outputs**

Non-commodity effects	Commodity production				Commercial non-food activities	Direct provision of public goods
	Fixed inputs	*Variable inputs*	*Farming technologies and practices*	*Commodity outputs*		
Landscape	Farmland area; land use patterns; farm buildings and structures		Silos, glass-houses, livestock housing, irrigation	Crop composition (structure and colour of the landscape)	Buildings and facilities for farm tourism	Maintaining farm buildings, flower meadows
Species and ecosystem diversity	Land use patterns	Use of agro-chemicals	Animal stocking densities, soil cultivation and harvesting techniques	Crop composition	Leased access to specific eco-systems	Wetland and other habitat creation, shelterbelts, wildlife feed and corridors
Soil quality	Cultivation of fragile soils		Crop rotation, stocking densities, tillage practices, irrigation	Crop composition, cover crops		Permanent cover crops
Water quality	Cultivation of erodible soils	Pesticide and fertiliser use	Manure storage and spreading, irrigation, livestock concentration	Crop composition, cover crops (erosion)	Leased access to clean rivers and lakes	Permanent cover crops, buffer zones
Air quality	Cultivation of erodible soils	Pesticide use	Manure storage and spreading, tillage practices	Crop and livestock composition, cover crops (erosion)		
Water use			Irrigation	Crop composition		
Land conservation	Cultivation of fragile land		Soil cultivation techniques, paddy fields	Crop composition		Permanent cover crops, afforestation
Greenhouse gases	Land use patterns	Mineral fertilisers	Tillage practices	Crop and animal composition		Permanent grass cover, afforestation
Rural viability	Demand for farm labour (in the short term)				Extra income on the farm	
Food security	Maintaining production capacity (land, livestock)	Maintaining production capacity (seed production)	Practices that reduce the risk of pests and other disasters	Storage for food security	Wholesale and marketing sectors	Maintaining land fertility, seedbanks
Cultural heritage	Maintaining farm buildings and family traditions		Traditional farming practices	Food as part of cultural heritage	Rural customs as a tourist attraction	Maintaining buildings, structures and rural customs
Animal welfare	Animal housing	Animal feed	Transportation and slaughter practices, access to outdoor areas			

Source: OECD.

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One important factor that is not represented in Table II.1 is the farm structure (although there are linkages between farm structure and farming technologies and practices, and the latter are represented in the table). Some of the non-commodity outputs of agriculture are related to structural characteristics of the sector. The agricultural settlement pattern, for instance, has implications for agricultural landscapes. Industrial-type concentration of animal production can create problems for manure management. Structural characteristics of agriculture are often the result of historical processes and respond only slowly to changes in technology, economic conditions and government policies.

In the following, a brief characterisation of the production linkages of different non-commodity outputs is attempted. At first, the way in which each non-commodity output represented in Table II.1 is linked to economic activities on the farm and how it responds to changes in commodity production, is examined. It is assumed that the changes are only caused by increases or decreases in the price and level of production of the commodity. Considered simultaneously, the adjustments of the non-commodity outputs to changes in commodity production reflect the implications of a strategy for multifunctionality based on influencing commodity production.

In a second step, the scope for adjustment in the output bundle that could be achieved by introducing direct incentives or disincentives for the non-commodity outputs, is discussed. The entire discussion is based on a fairly general knowledge of the agricultural production process. The non-commodity outputs of agriculture are influenced by many factors and the way they respond to price and policy incentives will ultimately be an empirical question. The conceptual discussion in this section can only provide an introduction to this subject.

Agricultural landscape and cultural heritage values

Agricultural landscape consists of a combination of natural and man-made features. The natural features comprise the physical character of the surface (land elevation and inclination, rock formations, lakes, rivers, coastlines), natural vegetation and climate. Man-made features include the spatial distribution of arable land, grassland and forests relative to uncultivated land, farm buildings and yards, terraced hillsides and paddyfields, stone and wood shelters, hedges and walls, fishponds, and farm forests. Modern animal housing facilities, silos for grain storage and maize silage, and feed mixing installation are equally part of the agricultural landscape. For a discussion of landscape indicators see OECD (2001*b*).

Agricultural landscapes are usually interspersed with non-agricultural features, including wilderness, historic monuments or other cultural heritage elements, the density of which can vary substantially within and across countries. Small villages may also be perceived as being part of the rural countryside.

In terms of geometric elements, rural landscapes are composed of a combination of area, line and point features. The colour composition of the various elements contributes to the overall picture. The material landscape may give rise to different visual impressions and aesthetic appreciation on the part of the observer. The same landscape can mean different things to different people. This element of perception makes it difficult to define, classify and value landscapes.

The visual features of a landscape have to be seen in conjunction with facilities that increase the landscape value to potential users. These include access paths, hiking trails, picnic areas and nature discovery trails. Information about the local flora and fauna and on-site descriptions of historical buildings can further enhance the amenity value of the landscape. The visitor is likely to take agricultural and non-agricultural features into account in forming his/her appreciation of the landscape.

The speed at which the rural landscape was transformed from one shaped by hunter-gatherers to one dominated by commercial agriculture, differs enormously among OECD countries. In some countries this transformation took place over thousands of years, whereas in others it was accomplished in a much shorter period. Although today the major driving forces are common to all Member countries, historical developments may have inspired different notions of what a "traditional" landscape looks like. Rural landscapes continue to change in line with economic developments, but consumer perceptions and preferences may not always evolve at the same rate or in the same direction.

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While agriculture may, in many cases, have increased the diversity of the landscape as compared to natural areas, this increase in diversity may not be seen by everybody as an enhancement of landscape quality. If the point of reference for the valuation of landscape is a more or less undisturbed natural landscape, then agricultural activity may be perceived as interfering with the natural landscape. What constitutes an improvement in the rural landscape depends to some extent on cultural values, and it is difficult to qualify developments as positive or negative independently of the cultural context.

Agricultural production affects landscapes through a combination of decisions regarding land use, commodity composition and farming practices. Structural changes, including the relocation of farmsteads or barns out of villages into the surrounding countryside and the consolidation of land parcels into larger plots, also impact on the landscape. The intensification of agricultural production over the last decades has in many areas reduced landscape diversity due to the simplification of farmland structures and land use patterns, reductions in cropping diversity, the removal of trees, hedges, ponds and other landscape features that pose obstacles to mechanisation, and the appearance of industrial-type farm buildings that contribute negatively to the landscape. To the extent that production-linked support has contributed to this development, it has also influenced the agricultural landscape.

While consumer tastes may to some degree adjust to incremental changes in landscape brought about by changes in market conditions and support policies, there may also be a demand for maintaining certain landscape features or making active landscape improvements. In this context, the ease with which landscape provision can be (at least partially) separated from commodity production becomes important. Many of the point and line elements of the landscape can be provided or maintained independently of food and fibre production. This applies to agricultural structures, such as stone walls, but also to historical monuments and other cultural heritage features. On the other hand, the large-area elements of agricultural landscapes are usually dominated by and closely linked to food and fibre production.

Maintaining or actively improving the landscape can be achieved through direct incentives for the creation of desirable landscape features that are not (or no longer) supplied jointly with commodity production, or for the elimination of undesirable features that are generated jointly with food and fibre. In many cases, improvements in the landscape may be achieved most effectively by focusing on point features or small-scale area elements. Examples include incentives for creating high-value features on strategic sites, and disincentives for the construction of unsightly farm buildings. Problems with unsightly constructions could be addressed through the building code and zoning restrictions, while the maintenance of historical farm buildings and structures could be organised in line with cultural heritage rules.

Large-area elements that are no longer provided through commodity production are more difficult and costly to maintain. This issue arises where agriculture ceases to be profitable and cultural perceptions are such that abandoning farmland to nature or converting it to residential or commercial uses is regarded unfavourably by society. Some large-area elements, such as grassland, could still be maintained through direct incentives, but even minimal grassland management by farmers or non-farm enterprises will generate a certain amount of grass which can be fed to farm animals. The appearance of the landscape in arable areas is, for a large part of the year, linked to the presence of crops in the fields and there will, in general, be no way of preserving the same landscape features without maintaining a minimum of agricultural activity to the extent that the land would need, at least, to be sown. Complete decoupling of large-area elements from commodity production will only be possible where a more substantial altera tion of the landscape, such as the conversion of farmland to golf courses, afforestation, or replanting with natural vegetation, is both acceptable and economically feasible. To consider these issues, the preferences of society for alternative types of land cover would need to be examined.

Sometimes farmers are considered to be the guardians of rural customs and traditions and of an age-old way of life. However, farm life has evolved like any other way of life and the rural customs and traditions that have entered into the folklore, especially in tourist areas, often reflect the way of life of other times. The rural customs and traditions continue to be passed on to future generations through the farming population but they can also be perpetuated through clubs and cultural associations whose non-farm members share a profound appreciation of traditional rural values.

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E*nvironmental outputs*

The relationship between agriculture and the environment has been the subject of considerable work in the OECD, notably in the Joint Working Party of the Committee for Agriculture and the Environment Policy Committee (OECD, 2001*b*, *c*; 2000*b*; 1999*a*; 1998*a*, *b*, *c*, *d*; 1997*a*, *b*, *c*, *d*; 1995*a*, *b*). Only a brief discussion of agri-environmental relationships, with an emphasis on the joint production aspects, is therefore provided in this subsection.

The results of previous work in this area suggest that agriculture has multiple positive and negative environmental effects, and that these are strongly linked to land use and farming practices. Regarding ***land use***, negative environmental effects can result from the cultivation of fragile soils, which can lead to unsustainable rates of soil erosion, loss of biodiversity and a reduction in the water-controlling and flood-preventing capacity of the land. There can also be off-farm impacts in terms of reduced groundwater recharge and water pollution through the deposit of eroded soil in rivers and lakes. Certain land use systems, such as paddy field production, can be very effective in controlling soil erosion and water flows. The crop composition also can have implications for soil quality, biodiversity and agricultural ecosystems. For example, arable farming generally bears a greater risk of soil erosion than grass-based production.

F*arming technologies and practices* are equally important for the environment. Inappropriate cultivation and harvesting methods, including heavy machinery, can lead to soil degradation or compaction. Minimum- and conservation-tillage reduce soil exposure to wind and water erosion. Rotational cropping and cover crops can enrich the soil with nutrients and organic matter. Inappropriate use of agro-chemicals (excessive dosage, inappropriate technology, bad timing) can cause water pollution and damage to species and ecosystem diversity. To reduce the risk of environmental damage special practices, such as integrated pest management, have been developed. The environmental effects in the animal sector are largely determined by grazing practices, stocking densities and manure storage and spreading techniques.

Farming systems that are particularly respectful of the environment, such as organic farming, are, for the most part, based on production techniques that are specifically adapted to biological cycles and risks. For example, less intensive production may lead to higher levels of some environmental outputs. In some areas in OECD countries, high-value ecosystems have developed that are dependent on traditional forms of agricultural land use and farming practices (*e.g.* low-intensive dryland pastures).

Greenhouse gas emissions from agriculture are also influenced by land use and farming practices. Nitrous oxide emissions are primarily related to nitrogen fertiliser use, methane emissions to ruminant livestock and paddyfield production, and carbon dioxide emissions to forest clearings and the conversion of grassland to arable land. Where farmland is afforested or permanent grassland expanded, long-term carbon stores are created.

With respect to ***water use***, the amount of water diverted to agriculture is linked to the irrigated farmland area. Irrigation increases land productivity and enables agriculture to expand into dryland areas that would otherwise not be suitable for cultivation. But excessive levels of water withdrawal can create pressure on the environment by reducing the water resources available for sustaining aquatic ecosystems, lowering the groundwater table and depleting aquifers. Inappropriate irrigation methods can provoke soil salinisation and water logging, and increase nutrient levels in rivers and lakes.

Irrigation requires substantial investments in dams, canals and special equipment, and the energy costs of operating irrigation systems are relatively high. If all these costs had to be borne by farmers and water were priced at market rates, irrigation would be much less widespread than it is. In practice, however, a large part or all of the investment in irrigation structures is paid for by governments, and often the operating expenses are also subsidised. Moreover, farmers usually pay a lower price for water than other users. Agricultural water use is thus strongly influenced by irrigation subsidies.

Some of the environmental outputs of agriculture can be the result of activities on the farm that do not involve commodity production. The clearest case of separation of environmental outputs from commodity production is given where the two functions are performed on separate pieces of land. An

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example is the supply of feed for wildlife and birds, as separate plots of land can be set aside for this purpose. Alternatively, this function can be performed in conjunction with agricultural production, provided that suitable crops are grown and patches of land are left unharvested. This example shows that there can be alternative ways of integrating an environmental objective into the farming activity. The way an ecological service is best provided will also depend on whether farmers have the necessary expertise to provide the service or whether input from wildlife and ecology experts is required, especially if the ecological service is of a more complex or specific nature.

In some cases, land use separation may be a necessity. This concerns, for instance, the creation of wetlands or the restoration of complex ecosystems on farmland. Other examples of land use separation include buffer zones around lakes or along waterflows to reduce nutrient leaching from adjacent fields, and the creation of windbreaks, wildlife corridors and wooded islands to improve wildlife habitat and ecosystems and increase the diversity of landscapes.

Even if separate pieces of land can be allocated to the provision of environmental outputs, complete separability from commodity production may not be possible. As long as the environmental goods compete with commodity production for farm resources, there will be some degree of jointness in production. The provision of environmental outputs usually implies less commodity production in such cases. However, environmental improvements that reduce commodity production in the short run may increase the productive capacity of the natural resources in the long run.

The environmental benefits and costs of farming are often not reflected in market returns. This applies to external effects as well as to those affecting the farmers' own resources. For instance, farmers should have a considerable self-interest in maintaining or improving soil quality, as the soils form an essential part of the productive capacity of their resources. Nevertheless, the methods of cultivation may not always reflect the conditions for sustainable resource use, either because farmers are not fully aware of the adverse long-term effects of soil degradation on land productivity, because they do not take these effects into account in their decisions in the same way as other, more short-term considerations or because they face conditions – *e.g.* linked to land tenure – that can result in non-sustainability.

Changes in commodity prices and production-linked support affect commodity supply and may lead to adjustments in farming practices, but the environmental outcomes of such changes may not correspond to the environmental objectives of society. The environmental outputs of agriculture are linked in different ways to commodity production, and while some may adjust in the "right" direction, others may not. Moreover, the effects of agriculture on the environment depend on local environmental conditions, and the demand for environmental services also differs across areas. An environmental strategy for agriculture based on influencing the incentives for commodity production ignores these factors.

By comparison, direct incentives or disincentives targeted to environmental outcomes or to the specific elements of the production process that trigger these outcomes, can be adapted to local and regional differences in environmental conditions and demand. This is, by now, widely recognised for negative environmental effects concerning, for instance, soil and water quality and land conservation. Improvements in bio- and ecosystem diversity and wildlife habitat can also be achieved more effectively through direct actions than indirectly through changes in commodity production. When considering the cost-effectiveness of alternative policies, additional factors, such as transaction costs, should be taken into account.

Taking low-profitable land out of agricultural production can raise questions concerning the environment that do not arise with simple changes in the level of commodity production. If agricultural cultivation is discontinued without there being a viable economic alternative, some form of conservation management may be necessary during a transition period to prevent degradation of the land. This may, for instance, concern paddy fields in mountainous areas, terraced vineyards, orchards or olive groves on steep hillsides, and alpine or highland pastures, where the changes to the natural environment caused by agriculture are irreversible.

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In such cases, adaptive measures could be implemented to avert environmental damage. A policy based on price support to prevent agricultural land from being taken out of production is unlikely to have the desired effect in exactly the desired location and may actually prevent the full range of adjustment possibilities from being explored. In addition, it would affect production in non-marginal areas, with associated trade effects. An example of a direct incentive for land conservation is provided by the Japanese rice paddy field diversion programmes. Under these programmes, farmers can be paid for maintaining and flooding idled paddies to prevent a loss of the flood-controlling function and the productive capacity of the fields (OECD, 1997*b*).

Rural viability and the contribution of agricultural employment

One of the often cited non-commodity outputs of agriculture is its contribution to the economic and social viability of rural areas and communities. How agriculture, among other activities, contributes to rural viability through the use of inputs, including labour and land, is considered in this section.

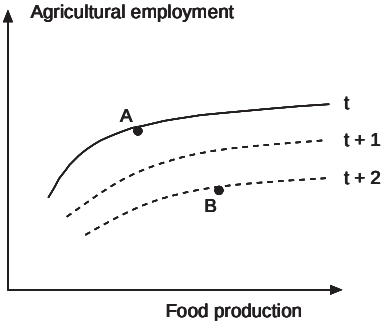
In broad terms, rural viability is related to the "attractiveness" of life in rural areas to both rural and urban populations (for a discussion of rural viability indicators see OECD, 2001*b*). There is no unique way of defining or measuring the "attractiveness" of rural areas but important aspects of rural viability that have been discussed include the level of income and the possibilities for employment and income creation in these areas, the physical infrastructure, the social capital, the quality of the environment, and rural amenities,[11] including landscape.

Agriculture contributes to rural viability through its employment and income generating effects and through the provision of agricultural landscapes and other rural amenities. Conversely, any negative environmental effects of farming, including water and air pollution, or the construction of unsightly buildings, reduce the attractiveness of rural areas as living and working places.

The major impact of agriculture on rural viability is through the creation of employment and income, which permit farming populations to stay on the land and participate in the economic and social life of rural communities. The focus of this subsection is on employment issues. Other aspects of rural viability, including rural landscape, environmental quality and cultural heritage, are addressed in other sections.

The level of agricultural employment is determined by the demand for labour in commodity and non-commodity production. The relationship between agricultural employment and the level of commodity production is positive in a completely static framework, *i.e.* an increase in commodity production will, *ceteris paribus*, increase the demand for labour in agriculture, as is indicated by the solid curve in Figure II.6. However, technological and structural change mean that over time the relationship is generally negative.

Figure II.6. **Commodity production and agricultural employment**



Source: OECD.

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Persistent increases in labour productivity in recent decades have allowed agriculture to reduce its labour force while increasing food supply (point B relative to point A in Figure II.6). The price of labour has increased relative to the price of capital goods and other purchased inputs, causing a substitution of capital for labour and a shift to less labour-intensive farming practices. The rise in the relative price of labour has induced researchers to develop further labour-saving technologies, thus reinforcing the downward trend in agricultural employment.

In fact, farm employment data covering the 1980s show annual decreases in the agricultural labour force ranging from 1.5 to 4% for all but four OECD countries. In two countries agricultural employment remained more or less stable, and only in two (Canada and the Netherlands) did it slightly increase. Within countries, the decline of the agricultural labour force was higher in the significantly or predominantly rural regions than in the predominantly urbanised regions. Where growth occurred, it was highest in the predominantly urbanised regions, and a considerable part of it was due not to core agricultural activities but to fisheries, gardening and landscaping (OECD, 1996).

Non-agricultural employment increased in almost all rural areas during the same 10-year period. As a result, agricultural employment declined even more in relative terms than in absolute terms. Even among the most rural regions in OECD countries, there are few where the agricultural labour force accounts for more than 25% of total employment.[12]

Regarding the future, the current advances in biotechnology, telecommunications and other areas of technology with applications to agriculture, and the possibilities for further structural change in the sector, suggest that agricultural labour productivity will continue to increase. Gains in labour productivity will maintain pressure on farm employment. The importance of agriculture as a motor of rural employment creation will be even smaller in the future than it is at present. Providing incentives for commodity production may slow down this process but may not be able to reverse the trend.

The economic base of the farming population can expand in ways that are efficient and non trade distorting. These include farm tourism, value-adding transformation of agricultural raw materials, and direct distribution of products through farmers' markets. Employment possibilities may also be created by facilitating shifts to more labour-intensive production methods, such as organic farming, where this is in line with market developments and does not lead to inefficiencies; improving the telecommunications infrastructure to facilitate farm-based telework; and promoting integrated rural development to create off-farm opportunities for part-time farmers. To some extent, new employment opportunities for farm-based populations in rural areas may also depend on the development of the demand for non-food services provided by agriculture.

A substantial part of farm family income in OECD Member countries now comes from non-agricultural activities on and off the farm. The emergence of part-time farming with its mixed income pattern and its close link to the wider economy has changed the structure of agriculture in many countries. The link between agriculture and the viability of rural communities is no longer adequately reflected in agricultural employment and income data. In most rural areas agriculture is only one of many sources of employment, and this applies increasingly to the farm family itself.

Regarding the wider agro-food sector, employment in industries upstream and downstream of agriculture has remained fairly stable or has even increased, but data on the degree of rurality of these industries are scarce. The data that are available indicate that while a significant part of the agricultural input supplying, processing and marketing industries are located in rural areas (almost half in the case of US and Canadian farm input industries), these industries tend to be concentrated in areas with a lesser degree of rurality, where they are often a more important source of employment than agriculture (OECD, 1998*e*). There are a number of uncertainties regarding trends in rural employment and the location of agri-food industries, and projections for the future are difficult make. Rural development is a dynamic process, involving changes in demographics, institutions, technology and markets. The key issue is how to formulate policies that best accommodate these changes.

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Food security

Food security is often mentioned in the context of multifunctionality. The purpose of this subsection is to examine how food security relates to the definition of multifunctionality developed in this report. The discussion focuses on the supply-side aspects of food security and in particular on the fact that food security, unlike other elements of multifunctionality, is associated with a tradable good (food). The public good aspect of food security is addressed in Part III.

According to the definition endorsed at the World Food Summit in 1996, food security exists when all people, at all times, have physical and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life. Food security, on a global scale, requires that sufficient food of an acceptable quality is produced, and that everybody has access to it. Access includes the ability to afford food and a well-functioning transportation and food distribution system. The ability to afford food depends on income as well as on the price of food. A country's attitude to food security may vary according to their income level, and the quality of their transportation and distribution systems.

Potential threats to food security include reductions in food supply due to political, technical or natural events (wars, radioactive fallout, floods, droughts, plant and animal diseases) or long-term declines in the productive capacity of agriculture (reduced availability of water, desertification, soil erosion, climate change); increases in the global demand for food (world population growth); chronic or sudden problems of affordability (poverty, currency devaluations, economic crises); and disruptions of the trading, transportation and distribution systems due to natural disasters or political causes (floods, earthquakes, strikes, wars, trade embargoes, export restrictions). Some of the threats to food security are associated with temporary events, others with long-term developments. Many of them are unpredictable.

A direct way of addressing problems of food security is by addressing their causes. Where poverty poses a threat to food security, economic reforms that foster economic growth and reduce poverty could be a solution. Sound macroeconomic policies might be the only durable and effective response to food security problems caused by economic crises and currency devaluations. Commitments by food exporters to supply food also in periods of production shortfalls would alleviate fears by net food importers of not having access to food in tight world market situations. Diversification of the sources of supply would make food importers less exposed to regional supply disruptions. The risk of crop failure can be reduced by using pest, drought and frost-resistant crop varieties and farming practices that increase the resilience of food production to natural pressures. Concerns over long-term increases in global food demand could be addressed by strengthening research into sustainable food production. And short-term unexpected supply shortfalls could be overcome through public stockholding.

Agricultural trade enhances national and global food security by increasing the sources of food supply and lowering food prices in importing countries, stimulating food production in countries that have a natural or structural advantage in agriculture, and increasing overall economic growth rates through a more efficient allocation of resources. However, disruptions of trade due to political events can never be entirely excluded and there will always remain a residual threat to food security, which will be perceived differently by countries depending on their situation. However, it is likely that events that would prevent access to food imports would also have repercussions on access to imported inputs necessary for domestic production. In fact, in countries where agricultural production is heavily reliant on imported inputs, including energy, a high level of domestic food production may be a misleading indicator of food availability in a crisis situation in which imports of these inputs are also disrupted. To this extent, securing co-operation and harmonious trade relationships is crucial to food security.

Net food importers are generally more concerned about food security than net exporters. A net food importer may see only limited scope for addressing sources of food security problems that lie outside its borders, and may find itself faced with a situation of uncertainty and risk concerning access to food. It might attempt to increase domestic production or keep production at a higher level than would otherwise be the case, to reassure its consumers. This raises the question how current food production in a country is linked to domestic and global food security. Similarly, there are questions regarding the perception of risk attached to domestic production versus imports and its variation between countries.

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Domestic production can alleviate the risk of food shortages related to insecure food supplies from abroad and protect against difficulties in financing food imports in the wake of severe economic crises. However, maintaining food production above market levels may increase the instability of domestic supply if resources of marginal quality are drawn into agriculture, and increase the risk of crop failure. It may also discourage food production in other countries where natural conditions are more favourable and where the risk of supply shortfalls is smaller. While national food security may be enhanced, global production may become less diversified and the stability of global food supplies may be reduced.

The benefits of maintaining domestic production at higher levels than would be the case with a freer market must be evaluated against the national and global efficiency gains that free trade often results in. Domestic production must be considered in conjunction with food imports. The most efficient solution probably lies in a combination of domestic production, storage and imports, proportions varying according to costs and benefits attached to the various options, risk being taken into account. The possibility of maintaining production capacity by low intensity farming could also be part of a long-term food security strategy. Current food production could be allowed to adjust to the market level, while additional capacity for food production would be maintained at a level considered to be sufficient for food security. The goal would be to preserve food production capacity in a way that corresponds to the dietary needs of the population in a crisis situation, while reducing dependency on imported inputs to a minimum. At the farm level, this would imply a reduction in the resources devoted to current food production while paying greater attention to capacity maintenance according to a contingency plan. However, ceasing production may reduce production capacity if arable land is permanently diverted to other purposes or if human resources, in the form of knowledge and expertise, are lost.

Animal welfare

Animal welfare is an ethical concern associated with the principles of human care in the use of farm animals. The usual premise is that animals can be used to benefit humans but such use carries certain obligations for their care (Blandford and Fulponi, 1999). Attempts to establish references based on which animal welfare can be defined or measured, have typically involved some notion of the physiological and behavioural needs of the animal species, in particular regarding feed, housing and animal care.[13] No internationally agreed definitions or standards exist, but many Member countries have passed legislation and enacted specific measures to protect the welfare of farm animals.

Animal welfare is closely linked to meat, milk and egg production, as most farm animals are raised for this purpose. The main aspects of agricultural production that influence animal welfare are the buildings in which the animals are housed, access opportunities to outdoor areas, and feeding, transportation and slaughter practices. Animal welfare is thus primarily related to production methods and associated investments in buildings and equipment. Milk, meat and eggs can be produced with different levels of animal welfare, although the cost of production will also differ.

The trend towards large-scale operations in animal production, which has been more important for non-ruminant farm animals than for ruminants, has accentuated concerns about animal welfare. Large-scale operations account now for a substantial part of pig, poultry and egg production in many OECD countries, and tendencies in this direction are noticeable in other livestock branches. Considerations such as optimising the use of space in animal housing facilities, preventing massive losses from pests and diseases, and reducing injuries to animals from aggressive behaviour provoked by confinement in small spaces, have become key management parameters. Limiting the movement of farm animals to improve feed conversion ratios, using chemical substances that increase meat or milk yields, and reducing transportation costs, have also been part of cost-minimising strategies.

Animal welfare is largely independent of the level of agricultural support. Problems with animal welfare have arisen in the production of cattle and sheep (transportation, veal crates) which receive relatively high levels of support in most OECD countries, as well as in the production of low-support livestock (battery hens). Changes in production-linked support are unlikely to have a substantial impact on animal welfare. If problems of animal welfare are to be addressed, this could be done more

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effectively through measures that are directed at the production methods that cause the problem such as regulations to impose minimum standards or incentives to adopt animal-friendly production methods.

Spatial and scale issues

This section provides a brief discussion of issues of space and scale and their relevance to the debate on multifunctionality. The main questions are:

- How important are site-specific differences in the joint production relationships?
- What is the spatial dimension of the various non-commodity outputs?
- How do spatial factors influence the cost of supplying non-commodity outputs?

There are two distinct reasons why the spatial factors need to be taken into consideration in an analysis of multifunctionality. First, there are geographical (site-specific, local, area-specific, regional, national) differences in the link between the commodity and the non-commodity outputs, as well as in the valuation of the non-commodity outputs by consumers. For instance, some areas are better suited for the provision of ecological services, or are less vulnerable to erosion, than others. The demand for rural amenities may be stronger around urban agglomerations than in other parts of a country. Such spatial differences may require site- and area-specific specialisation in the provision of non-commodity outputs.

Secondly, there are differences in the geographical scale of the non-commodity outputs. This concerns the extension of the outputs beyond the point where they are generated and the scale on which they are perceived and valued by society. For instance, emissions of greenhouse gases from agriculture are global in their effect, whereas the impact of farm employment on rural viability is primarily felt at the local level. For landscape, the relevant scale depends on the topography of the region, but in most cases a rural landscape of interest to visitors will extend over the land of several or many farms.

Spatial and scale differences in the production relationships of the non-commodity outputs raise important questions as to which geographical and administrative level is most appropriate to address domestic non-trade concerns. A related question is to what extent problem-scale solutions imply regional specialisation of non-commodity supply, including different dominant land uses for different areas.

Spatial differences in production relationships

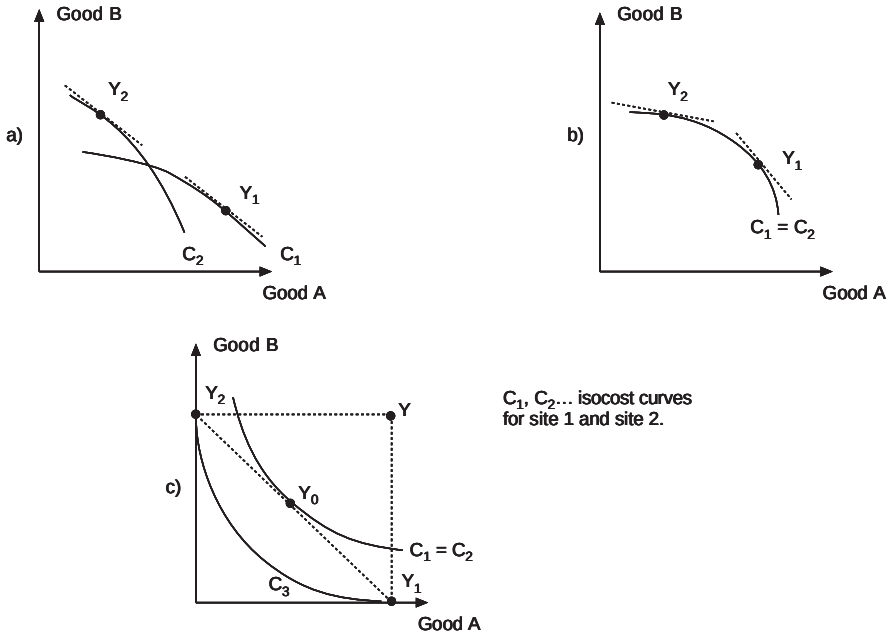
There can be significant geographical differences in the output bundles generated by a given farming activity. Depending on soil type and climatic conditions, for example, a certain level of fertiliser use per hectare will not have the same effect on the environment everywhere. Free-ranging cattle that contribute positively to the landscape in one area may, at the same stocking density, cause soil erosion and degrade the countryside in another area. And the effort spent on preserving the food production capacity of farmland may have different pay-offs in terms of food security in times of crisis. For simplicity, site-specific characteristics that affect the generation of commodity and non-commodity outputs are summarised by the term "site productivity".[14]

Figure II.7a illustrates how site-specific productivity differences can influence the optimal output mix. The two curves in the figure represent combinations of the outputs (A and B) that can be achieved with a given expenditure in two different locations (site 1 and site 2). The way these isocost curves are drawn implies that an increase in the provision of one good can only be achieved by reducing the other if the costs are to be kept constant. This might be the case, for instance, for an output bundle composed of a food commodity (good A) and ecosystem quality (good B), if ecosystem improvement requires a reduction in the intensity of land use. Other production relationships would result in different curves.

The relative marginal valuations of the two goods are represented by the slope of the dotted lines. The optimal output combinations at the two sites are given by points Y_1 and Y_2. Optimal production at site 1 includes relatively more of good A than of good B, and the reverse is true for production at site 2.

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Figure II.7. **Implications of site-specific productivity and value differences for non-commodity supply**



Source: OECD.

The two output bundles reflect the differences in site productivity. But even if the site productivities are the same in both locations (identical isocost curves), different output bundles may be optimal if a good is valued more highly in a one location than in the other (Figure II.7b).

Concave isocost curves as the ones shown in Figures II.7a and II.7b can give rise to different output bundles if site productivities differ and/or if the relative values attached to the outputs are not the same in various locations, but in general they favour output bundles that include at least some amount of each of the outputs. If the trade-offs among the outputs are very large so that a unit of one good can only be produced if a substantial amount of another is sacrificed, cost-efficient production of multiple outputs may require a stronger or even complete specialisation. This is reflected in Figure II.7c where it is cheaper to produce output bundle Y through complete specialisation. Site 1 produces only good A and site 2 only good B. The same total output could be generated if both sites produced a mix of both goods (two times Y_0), but the total cost of production would be higher (two times C_1 as opposed to two times C_3).

Even though there are no differences in site productivity (the isocost curves for the 2 sites are the same in Figure II.7c), large trade-offs between the outputs favour site-specific specialisation. The large trade-offs are reflected by the convex shape of the isocost curves. In practice, there will be limits to specialisation because of jointness. Complete specialisation is only possible where the various outputs are separable in land use. For some environmental services, such as wetland creation, this may be the case. Separation of land use is also possible, for instance, where the trade-off is between producing food, and idling land and maintaining its production capacity for food security purposes.

In other cases, the possibilities for specialisation are more restricted. For instance, some types of wildlife habitat in dryland areas may be dependent on low-intensive forms of agriculture. To preserve such habitat may require spatial separation of intensive and low-intensive forms of agriculture.

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However, a certain amount of commodity production will still take place in the low-intensive areas. Many ecosystem, habitat and landscape services may benefit from a certain amount of regional specialisation due to site-productivity differences.

The magnitude of the differences in site-productivity within OECD countries is an empirical question. As regards the positive and negative effects of agriculture on the environment, it is by now widely recognised that site- and area-specific factors need to be taken into account in any solution. Concerning food security, some of the implications of differences across countries in the cost of producing food have been discussed in the previous section in connection with the contribution of agricultural trade to food security. With respect to the other non-commodity outputs, a further exploration of this issue might be useful. Site- and area-specific information about the production or cost structures[15] of the commodity and non-commodity outputs, and about the valuation of these outputs by consumers, is necessary to determine spatially optimal production patterns.

T*he spatial extension of non-commodity outputs*

The term "scale" is used in this section to describe the geographical or spatial extension of non-commodity outputs. A fungible private good, such as wheat, does not have a spatial scale; it can be produced somewhere and sold elsewhere. But many of the non-commodity outputs of agriculture have a distinct spatial scale. This can be a single farm, all farms in a valley or in a water catchment area, or the agricultural sector of a country. The scale that is relevant for surface water pollution can be different from that of groundwater pollution, and the relevant scales for landscape and rural employment may also differ. Some effects, such as water and air pollution, or impacts related to bird and wildlife habitat, can transcend country borders. The effects of greenhouse gas emissions are, by their nature, global.

There are also indirect spillover effects into other countries that are created through the trade impacts of policies used to achieve domestic non-food objectives. Trade impacts influence not only the supply and demand of agricultural commodities in other countries, but also associated non-commodity outputs. The potentially negative impact on global food security of maintaining a high level of domestic food production for national food security, has already been mentioned. Derivative non-food effects in other countries occur also with respect to the environment, landscape or rural employment.

It may be useful to distinguish between the scale that is related to the creation ("supply") of a non-commodity output and that which is attached to the valuation ("demand") of the output. In some case these scales do coincide. An example is aquifer depletion through excessive agricultural water use. The impacts on the water level of individual water withdrawals for irrigation occur on the scale of the aquifer, and the problem of water depletion manifests itself on the same scale. In this case it should be clear to all affected parties that a problem-scale solution would imply addressing irrigation on the scale of the aquifer.

In other cases, the "supply" and "demand" scales may differ. Examples include landscape and rural employment, where farms impact locally but the objectives are usually defined on a larger scale. Ecosystem protection, flood and erosion control, and preservation of the productive capacity of farmland for food security purposes, are other examples where the contributions of farmers are local, but the outcome is measured on a larger scale and depends on the combined actions of a smaller or greater number of farmers. The challenge is to find the relevant scale at which supply and demand can be arbitrated in the most efficient way. This applies to market creation, negotiation between producer and consumer groups, as well as policy intervention.

It is not always easy to find the most appropriate scale on which to address a non-trade concern. Multifunctionality introduces an additional complexity, as it requires that several non-trade concerns be considered together. Many of the positive and negative non-commodity outputs of agriculture are associated with different geographical scales. A solution that addresses all of them on the same scale may provide the wrong signals for those outputs for which this scale is not appropriate.

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A grouping of non-commodity outputs based on scale similarities may, however, be feasible. Landscape, ecological and habitat values, for instance, are often spatially connected and could be addressed on the same scale. In areas that are separated by natural divides, such as mountain valleys or small islands, the relevant scales of environmental, landscape and rural economy outputs may coincide.

Agricultural versus non-agricultural provision of non-commodity outputs

It is in society's interest that the demand for non-commodity outputs is satisfied with the least resource cost to the domestic and international economy. The least-cost providers can be farmers or non-agricultural suppliers, provided that the supply of the non-commodity outputs can be dissociated from agricultural production. This chapter explores the possibilities for and the limits to non-agricultural provision of non-commodity outputs. The main questions are:

- Which non-commodity outputs of agriculture can also be provided by other economic activities?
- To what extent are the non-commodity outputs provided by non-agricultural activities perfect substitutes for those supplied by agriculture?
- In which areas and under which conditions can non-agricultural activities provide non-commodity outputs cheaper than agriculture?

The discussion in this section focussed on the positive non-commodity outputs of agriculture. Negative impacts, such as environmental pollution or problems of animal welfare, are unwanted side-effects of commodity production which are, by their nature, specific to agriculture. Such problems would not exist in the absence of commodity production. They can be reduced only through changes in agricultural practices and through better management. However, when comparing agricultural provision of a positive externality to non-agricultural provision, potential negative externalities arising from the latter should be taken into account.

The term "non-agricultural provision" of non-commodity outputs refers to economic activities that do not involve the production of agricultural commodities. Such activities can be carried out by individuals from outside the agricultural sector but also by part-time farmers. Many farmers are not fully employed in agriculture and are engaged in non-agricultural activities on and off the farm.

Of the non-commodity benefits of agriculture that can also be supplied by non-agricultural activity, perhaps the most obvious one is ***rural employment***. It is evident that agriculture is only one of several sources of rural employment and that its contribution has declined in importance over the years. The driving forces behind the decline in agricultural employment are common to all OECD Member countries and, unless a major reversal in the underlying economic and technological trend occurs, agriculture can hardly be counted on for the creation of additional jobs in rural areas.

Most of the new jobs in OECD economies are created in knowledge-intensive industries and in the service sector, including tourism. The question is whether rural areas can capture part of this new employment. The growing inconveniences of urban life and the increasing demand for environmental quality, space and low-priced land and housing, may make rural areas more attractive to businesses. Improvements in the transport infrastructure and the telecommunications industry, have made rural areas less isolated than they were in the past. The emergence of telework should mitigate the handicap of rural areas posed by distance and facilitate job creation. However, the economics of agglomeration are poorly understood and there may also be new factors that favour job creation in urban areas.

The decline in farm labour and the increase in non-agricultural employment in rural areas entails a separation between the place of residence and the place of work that did not exist on the farm. Businesses in rural areas are frequently located in country towns, and village dwellers who are employed by these businesses, have to commute from their villages. Improvements in commuting facilities can be part of rural development strategies aimed at maintaining village life.

In the small number of areas where agriculture's share in total employment is still very high, the question arises whether stabilising agricultural employment can be the least-cost way of preserving the economic viability of rural communities. Stabilising agricultural employment in rural areas involves

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government expenditures or, in the case of price support, costs to consumers and foreign producers. Employment stabilisation in agriculture has opportunity costs in terms of the employment that could be created with the same amount of money in another sector. Supporting agricultural employment therefore only makes sense if it is cheaper to maintain a job in farming than to create one outside of agriculture, or if agricultural employment is valued more highly than non-agricultural employment. A comparison of alternative employment strategies for rural areas thus requires a thorough analysis of the costs of maintaining or creating jobs in specific areas, alongside an analysis of the accompanying benefits, including those related to the multiple non-commodity outputs provided by agriculture.

Agricultural and non-agricultural employment may not be identical in their effects on rural communities, but they may be reasonably close substitutes. Any type of employment provides side-benefits that are not reflected in market returns or salaries. A manufacturing or service job in rural areas will have the same effect on the rural population as agricultural employment and a similar, if not greater, effect on rural income. But agriculture's contribution to the rural economy could be regarded as being broader, including, for instance, the preservation of traditional customs and farm buildings. On the other hand, many manufacturing and service industries may offer better prospects for future growth, and a rural area that builds up human capital and physical infrastructure for such activities may be in a better position to take advantage of its development potential in the long run.

A special case is employment creation through non-food activities on the farm, in particular farm tourism. Farm tourism illustrates the economic interdependencies that can exist between various non-commodity aspects of agriculture. The provision of an attractive landscape by agriculture can create demand for farm tourism, which in turn allows farmers to capture part of the social benefits associated with landscape provision. The link could even be extended if the extra income generated by farm tourism reduces the decline in the agricultural population and thus contributes to the viability of rural areas.

Farm tourism is an area where farmers are in direct competition with non-farm commercial enterprises. An attractive landscape is only one element of the package of leisure goods sought for by tourists. In most cases, farmers who expand into farm tourism have to upgrade existing accommodation or build new living quarters, and expand the range of services they can offer. They also need to commit labour resources to the tourist activity. Whether farmers are able to compete with non-agricultural suppliers of tourist services depends on cost-factors (the size of the investment required to adapt existing facilities to tourist standards; spare capacity in terms of lodging and family labour), the quality of farm-specific services (access to landscape and nature; existence of high-value landscape and ecosystem features; availability of home-made food; access to farm animals; proximity to services that can not be supplied on the farm), and the preferences of vacationers for farm-specific rural amenities.

Farm tourism is one way of internalising the social benefits associated with agricultural landscape provision, but not the only one. Alternative ways of internalisation, including through access fees, tourist taxes, or the redistribution of revenues from tourism to landscape providers, will be discussed in connection with the policy cluster of the work on multifunctionality.

L*andscape* provision by non-agricultural enterprises concerns primarily the management of land that is no longer used for agricultural production. Where cultivated farmland is part of the landscape, the possibilities for non-agricultural provision are limited. However, it is conceivable that some forms of landscape management on farmland be carried out by non-farm enterprises or community groups that have a special interest in the landscape benefits. Active management of farmland for landscape value may require changes to agricultural activities. Such changes can be initiated in various way, including market creation, financial incentives, or the purchase of easements or development rights by conservation groups.

The provision of ***environmental benefits*** is similar to landscape provision in that it comprises both agricultural and non-agricultural land. Ecosystems and wildlife habitat, for instance, often extend over large areas, including cultivated land but also unproductive areas on farm property or adjacent land, such as wooded islands, hedges, wetlands, forests and nature parks. Whether environmental benefits can be supplied through non-farm activities depends on the way in which they are related to agricultural production. Environmental outputs that are separable in land use from commodity production are more

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amenable to non-agricultural provision than outputs that are tied to cultivated farmland. Access to farmland can be a key issue for non-agricultural provision of environmental services.

Farmers may have a competitive advantage in certain types of nature management, as they know the environmental properties of their land and may be able to integrate the necessary tasks into the overall farm management plan. This advantage will be greater the more closely the environmental benefits are linked to the agricultural activity. However, some environmental improvements may require expert knowledge and might be better performed by nature and conservation groups. The management of animal and birdlife in farmland areas could also be entrusted to non-farm groups.[16]

A special situation may occur in areas where agricultural use of farmland has become unprofitable but the continued provision of some of the services provided until now by agriculture is considered to be essential. In this case, it is an open question whether farmers are better placed than other providers to perform these functions. On the one hand, farmers have the equipment and knowledge that may be required to provide the services, and they can count on additional income from commodity production. But the agricultural income may be small and declining and may not allow farmers to accept a lower remuneration for the supply of environmental outputs than their non-agricultural competitors. Where the value of land in agricultural production approaches zero, efficient outside providers may start to compete with farmers for land based on the direct incentives provided for the supply of environmental services. However, potential quality differences in the non-commodity outputs supplied by farmers as compared to those supplied from non-agricultural sources, and their effects on consumers' valuation, also need to be given consideration.

Regarding ***food security***, the problem presents itself somewhat differently. The choice is not between agricultural and non-agricultural activities but between domestic food production and food supplies from alternative sources. The alternatives include public stocks, food imports and unused production potential that can be activated in times of crisis. Food imports can be regarded as substitutes for domestic production in their effects on food security, although if there are perceived to carry greater risk, they are a less than perfect substitute. However, domestic production may also be prone to risk of shortfall. Domestic production can be less reliable than imports, especially compared to a situation where a country has diversified its sources of import supplies. Public stocks can also satisfy food needs in a crisis situation, but for a limited time period. Stockholding is expensive (but so is support to production) and there is a direct trade-off between the cost of stockholding and the length of time the supply from stocks will last. Food supplies from the activation of dormant production potential may come forth only after some time.

The effectiveness of solutions to food security concerns depends on the contingency cases envisaged and the risks attached to them. Stockholding and a diversification of the sources of imports will usually be sufficient for short-term disruptions of supply lines from certain parts of the world. Preserving a certain domestic production potential will be more adequate for cases where a severe and prolonged destabilisation of international markets, including the international transportation system, occurs.

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NOTES

1. This assumption does not imply that direct incentives or disincentives are the most efficient way of achieving the non-food objectives. In order to make such a judgement, other factors, including the transaction costs associated with direct measures, have to be taken into consideration.

2. This concept was introduced by Baumol *et al.* (1981).

3. See also Annexes 1 and 2 for a discussion of joint production.

4. See, for instance, Asunka and Shumway (1996); Ball (1988); Chambers and Just (1989); Leathers (1991); Lynne (1988); Moschini (1989); and Shumway *et al.* (1984, 1988).

5. Risk diversification is another reason for the existence of multiproduct firms. As governments reduce their involvement in agricultural markets, risk management may also become more important for agriculture.

6. Negative externalities may have particularities related, for instance, to cumulative effects, threshold levels and irreversible damage, which may not be found in the case of positive non-commodity outputs, and which would need to be taken into consideration in a more sophisticated model.

7. The terms incentives and disincentives are used in a general way and do not imply any judgement about who is to bear the burden of the corrective action.

8. However, if one of the outputs is a private good and the other a public good, then targeting the public good may be associated with higher transaction costs than targeting the private good.

9. This relationship consists of an aggregation of two curves, one describing the relationship between food production and the use of potentially polluting agro-chemicals and manure, and the second the relationship between the use of agro-chemicals and manure and water pollution (the "damage function"). The latter includes site-specific climatic and environmental factors, including the nutrient retention capacity of soils, which influence the impact of nutrient use on water quality.

10. This applies to farmland, buildings and machinery, but perhaps not any more for farm family labour. Part-time farmers already outnumber full-time farmers in several OECD countries.

11. Rural amenities are: unique natural and man-made features that are strongly associated with specific territorial attributes and the value or utility of which is linked to the provision of enjoyment or pleasure; associated with consumer rather than productive value; and can be consumed not only in the immediate area but also outside the area with or without the aid of media (OECD, 1999*b*, p. 9).

12. Exceptions are Greece and Portugal, where the average employment share of agriculture in predominantly rural areas was close to 40% in 1990. For some countries with a large agriculture sector, such as Mexico, Poland and Turkey, a breakdown of the labour statistics by degree of rurality is not available.

13. As has been pointed out by Blandford and Fulponi (1999), genetic modification of a farm animal can make it difficult to define what the physiological and ethological nature of the animal are.

14. This term is used in Bowes and Krutilla (1989).

15. This information can be obtained by analysing production relationships or by analysing cost relationships. Production and cost curves contain the same information about the production system, provided that farmers minimise costs in their activities.

16. This is often the case with hunting game. The task of gamekeeping is frequently performed by local hunting clubs whose members include individuals from the farm and non-farm communities.

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Part III

EXTERNALITY AND PUBLIC GOOD ASPECTS OF MULTIFUNCTIONALITY*

Introduction

Background

The preliminary discussions of multifunctionality of agriculture in OECD meetings[1] to date have led, as stated in Part I, to an understanding that analysing the production relationship between commodity and non-commodity outputs, along with their externality and public good aspects, is essential to the development of a conceptual framework to further explore the concept.

This part focuses on externality and public good aspects while production relationships are discussed in Part II. That is, Part II considers questions that relate mainly to the supply side while this part looks at those on the demand side. Analysing the production relationship can provide a conceptual framework to analyse how multifunctionality is being or could be supplied in different policy environments. Analysing externality and public good aspects, on the other hand, can provide a conceptual framework to analyse how the benefits of multifunctionality are being and could be distributed in and by society. Any policy discussion on externalities requires an analysis of the type and amount of demand that exists for each externality that is jointly produced with a marketable good. The reason for discussing externality and public good aspects together is that externalities alone are not necessarily a source of market failure. Only those externalities with public good characteristics may require policy intervention.

Approach

This part will highlight two different dimensions that are relevant to the discussion of the externality and public good aspects of multifunctionality. The first dimension is to analyse, in a rigorous and in-depth manner, the externality and public good characteristics of each individual non-commodity output. The second dimension is to focus on issues that arise when several non-commodity outputs are taken together.

With respect to the first dimension, the terms "externalities" and "public goods" are often invoked to justify government intervention (*e.g.* taxes, subsidies, regulations, price support). For example, one of the main arguments for government intervention is that social optimality can be achieved by bridging, through subsidies (for positive externalities) or taxes and regulations (for negative externalities), the gap between social and private costs generated by externalities. A similar argument to justify government intervention in the case of public goods is that people do not reveal their willingness to pay for the provision of public goods, because of their preference for free-riding.

There are, however, various kinds of externalities and public goods,[2] each of which may require different types of policies to address the market failures associated with them. These policies do not necessarily imply government intervention at all. Moreover, a policy to address one type of externality (or public good) may not be useful for another type. On occasion, in fact, it may cause actual damage. It is therefore critically important to differentiate between the different types when more than one externality or public good is under discussion, as is the case with multifunctionality.

* This part benefited from the comments of an outside reviewer, Professor John Boland of the John Hopkins University, United States.

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The second dimension of the discussion relates to the fact that multifunctionality is composed of multiple non-commodity outputs (a working definition of multifunctionality is presented in Part I). An appropriate policy to address multiple non-commodity outputs might be different from a policy to address individual non-commodity outputs. For example, the simultaneous demand for several non-commodity outputs might be different from the sum of the individual demand for each one if they are substitutes or complements for one another. It might also be possible to propose more efficient and effective policies than simply combining individual policies by taking these consumption relationships into account. It is also possible that policies to provide non-commodity outputs may have complicated effects on stability and equity of provision, since these policies may have a different effect jointly than they would individually.

In considering these two dimensions, this part tries to show the link between the conceptual analysis and policy formulation. Although policy implications are to be discussed at a future stage of the work on multifunctionality, emphasising policy relevance at this point can provide a firm basis for constructive and efficient policy discussions. The conceptual issues explored in this part lead to the second and third questions proposed in the Summary and Conclusions (Part I). Exploration of the issues embodied in these questions is an essential prerequisite to the discussion of policy options.

Although for the sake of convenience the theoretical analysis in this part concentrates on positive externalities, this does not imply that negative externalities can be excluded. Overall efficient policy solutions can be determined only when all positive and negative externalities are fully taken into account. Moreover, negative externalities may affect the value of positive externalities when there are specific consumption relationships among them (*e.g.* the demand for preserving natural habitat might be smaller when over-use of fertiliser is also observed). It should also be borne in mind that experiences in many countries show that internalising negative externalities is not straightforward. Attention should be paid to spatial variation in the landscape, temporal variation in weather, and differences among production technologies.

Focusing on the demand side requires that some assumptions be made on the supply side. One of these is that the externalities discussed in this report have joint-production relationships with commodity outputs. Another assumption is that joint-production (*i.e.* with agriculture) of non-commodity outputs has been evaluated as more efficient than other alternatives, specifically non-agricultural provision of these non-commodity outputs. These are the subjects of in-depth analysis in Part II. The first question defined in Part I is designed to lead to empirical testing of these assumptions. It is important to note that if production is non-joint, or there are lower cost providers of non-commodity outputs than agriculture, there is no policy link between the goal of agricultural trade liberalisation and the goal of safeguarding domestic non-food concerns. The discussion in this part therefore becomes irrelevant.

Organisation of this part

The externality and public good aspects are analysed in the first sections. A basic definition of externalities is provided, followed by a proposed classification for non-commodity outputs. Basic theories on how markets fail (or why markets do not fail) in each category are then reviewed. The following subsections emphasise the need to undertake comprehensive analysis and to incorporate negative externalities, which will be required to understand the overall impacts on efficiency of the various types of externalities. A subsection categorising the major non-commodity outputs follows.

The section covering public good aspects also starts with definitions and a classification system. It then analyses, through an in-depth and rigorous approach, how markets do or do not fail with special attention to comparing market failures with policy failures. It also categorises all major externalities and demonstrates that there is wide variation in the extent to which the outputs of agriculture exhibit public good characteristics. The second dimension of the analysis, that is the fact that multifunctionality relates to multiple externalities, is also dealt with. The subsection which follows discusses stability and equity issues associated with multifunctionality and includes a conceptual analysis on international income redistribution. A brief discussion from the perspective of a developing country is also included in this section. The final subsection analyses potential impacts on policy choices of availability of information for concerned parties.

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Externality aspects

Externalities alone do not justify policy intervention. There are many cases where externalities are neutral in terms of economic efficiency.

Definitions and classifications

General definition: this report will use the following broad definition for externalities:[3]

"An external economy (diseconomy) is an event which confers an appreciable benefit (inflicts an appreciable damage) on some person or persons who were not fully consenting parties in reaching the decision or decisions which led directly or indirectly to the event in question" (Meade, 1973).

The basic problem with externalities is that a good generating a positive externality tends to be under-provided because the market cannot incorporate the benefit to society generated by the positive externality. If the good generates a negative externality,[4] then over-provision is likely. Producers of the good determine the level of production that maximises their profit while a higher or lower level of production might be necessary to maximise social welfare. This means that there is a divergence between producers' interests and society's interests. Policies to correct this "market failure" basically require that producers be given incentives to incorporate the benefits into their decision-making process when producing the good, or be taxed (or regulated) to incorporate the costs. In this case, an externality is "internalised". Box III.1 provides some basic terms and analytical tools that are useful for discussing more complicated issues associated with externalities.

An assumption made in the following theoretical analysis is that price decreases will reduce production of commodity outputs. This might lead to a reduction in positive externalities associated with that production although many other factors, especially complicated relationships between externalities and production, would also have an impact. This assumption will be reviewed later in this section in a more dynamic framework. If it is possible that the production level along with the associated positive externalities could be preserved even if agricultural prices decrease, then this assumption could lead to incorrect conclusions.

Classification: Positive externalities as defined above can be divided into categories based on the type of market failure they induce. First, externalities without opportunity costs in production should be differentiated from those with opportunity costs. Opportunity cost in this context refers to the costs that producers incur to produce the externalities. They are either in the form of increased costs associated with the increased inputs needed to produce the externalities, or reduced net profits associated with a reduction in the activities that generate the externalities. Externalities without opportunity costs in production can be further divided into several sub-groups based on the shape of their marginal benefit curves (Box III.1 contains an explanation of marginal benefits). There are five such sub-groups: constant, increasing, decreasing, discontinuous, and zero marginal benefits (Figure III.1).[5] These marginal benefits are expressed also as the vertical difference between social cost and private cost (Box III.1 and Figure III.2).

Classification of positive externalities

Type I:	Externalities without Opportunity Costs
Type II:	Externalities without Opportunity Costs: *a*) Constant marginal benefits as commodity output increases *b*) Increasing marginal benefits as commodity output increases *c*) Decreasing marginal benefits as commodity output increases *d*) Discontinuous marginal benefits as commodity output increases *e*) Zero marginal benefits as commodity output increases

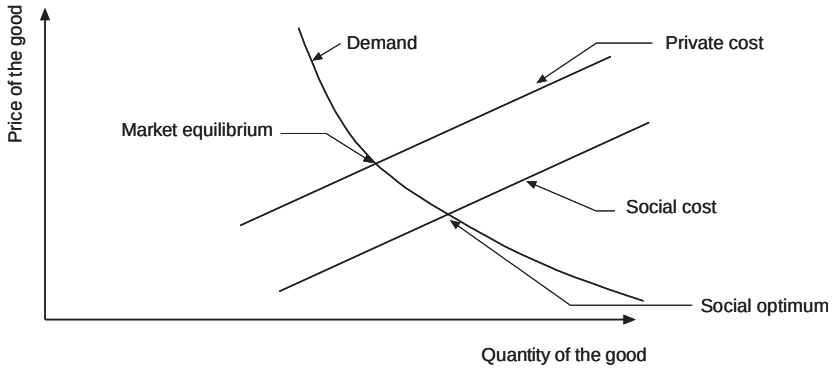
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Box III.1. **Basic terms and analytical tools for discussing externalities**

***a*) *Private vs. social costs*:** One of the most effective ways to discuss the divergence between producers' and society's interests is through the concept of private and social costs. Private costs are the costs that producers incur to produce a good that generates an externality. Social costs are obtained by subtracting the social benefits of the positive externality from the private cost (or by adding the social costs, in the case of negative externalities). This reflects the true cost to society of producing the good when there is an externality. (Net) social costs are, therefore, lower than private costs if the externality is positive. Both private and social costs are usually expressed in marginal terms. Private (marginal) costs are the costs required to increase production by one unit while social (marginal) costs are the difference between the private (marginal) costs and the (marginal) benefits of the externality (if it is positive) resulting from the increase by one unit of the product generating the externality.

***b*) *Graphical analysis using private and social costs*:** The two costs can be illustrated by a graph showing the relationship between the price and the quantity of the good in question. The market equilibrium lies at the intersection of the private cost curve and the demand curve of the good. However, a socially optimal point would lie at the intersection of the social cost curve and the demand curve of the good. As the graph below indicates (an example of a positive externality), the good should be produced in greater quantity than the market equilibrium because the true cost of producing the good is smaller than what producers face (*i.e.* the private cost curve). This graph will be a powerful tool to analyse how and when markets "fail" under more complicated situations than in this example.



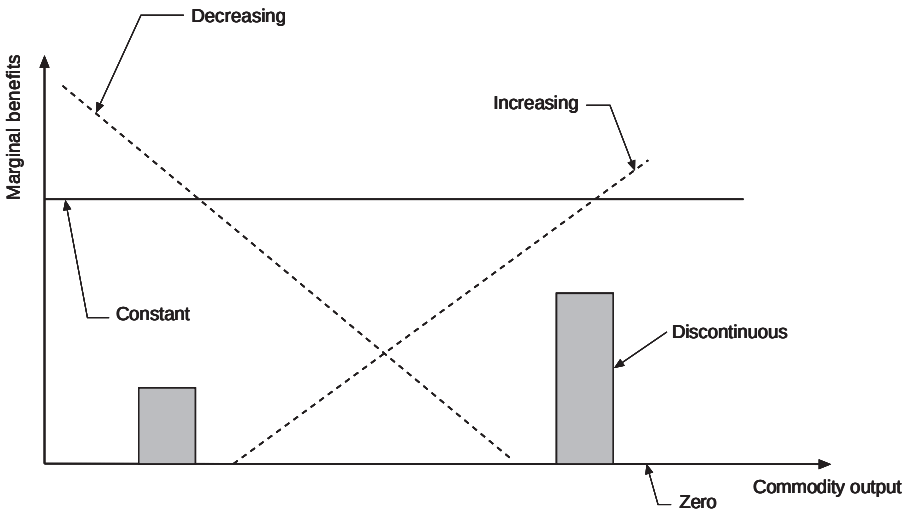
***c*) *Are "internalised" externalities still externalities*?** Externalities can be internalised through policies that bridge the gap between private and social costs. These policies make producers incorporate the social cost when they make production decisions. They include the creation of markets for externalities, including bilateral transactions, and the provision of subsidies to or imposition of taxes on producers (these subsidies and taxes are called "Pigouvian" subsidies and taxes, after Pigou, the economist who developed the theory).

The definition of externalities used in this report means that those externalities that are internalised through markets are no longer called externalities. For example, a positive externality would not be an externality anymore once it is traded in the market because the beneficiaries of that externality are implicated in the production decision through the market. An example that does not fall in this category is the case where a market failure is corrected by Pigouvian subsidies. Such an externality still falls under the above definition.

***d*) *Technical externalities and pecuniary externalities*:** Technical externalities are externalities that cannot be taken into account by the market, including through bilateral negotiations, while pecuniary externalities are externalities that can be adjusted in markets. Pecuniary externalities, therefore, do not cause market failure. The definition in the report categorises pecuniary externalities as externalities although, as stated above, technical externalities cannot be classified as externalities once they begin to be traded in the market. Pecuniary externalities are reflected in market prices that are endogenously determined, which fits the definition of externalities. In other words, pecuniary externalities typically result from the market correctly expressing the consequences of changed demands. The concept of pecuniary externalities will be needed in the discussion of rural employment. An example of a pecuniary externality is when the development of a high-tech industry increases wage rates for computer engineers, which can be adjusted through labour markets.

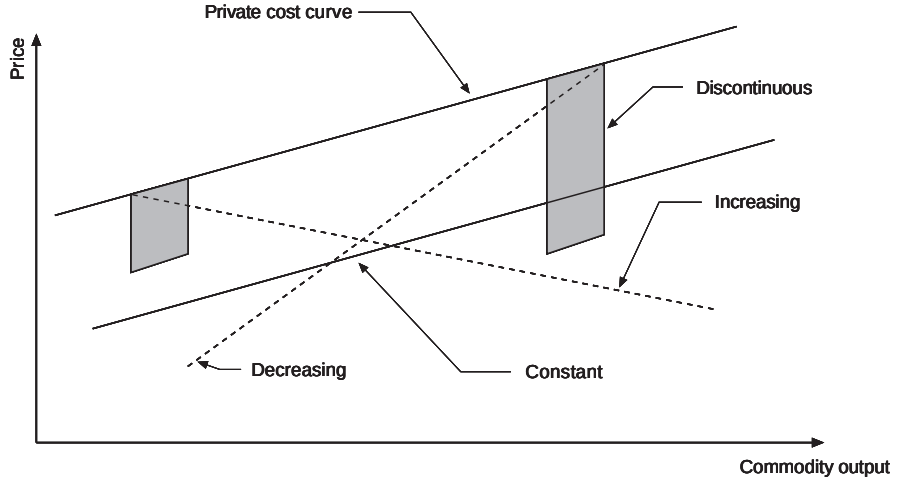
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Figure III.1. **Classification of positive externalities (marginal benefit – commodity output curve)**



Note: Lines for these types are drawn as social cost curves. The divergence between the private cost and the social cost is the marginal benefit of an externality (see Box III.1 for marginal benefits). When the private cost and the social cost curves are parallel, the externality has a constant marginal benefit.
Source: OECD.

Figure III.2. **Classification of positive externalities (social cost curves in commodity output-price graph)**



Note: Lines for these types are drawn as social cost curves. The divergence between the private cost and the social cost is the marginal benefit of an externality (see Box III.1 for marginal benefits). When the private cost and the social cost curves are parallel, the externality has a constant marginal benefit.
Source: OECD.

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Whether the benefits are linear or non-linear does not matter from a conceptual point of view for the purpose of this part. It should, however, be stressed that most externalities probably exhibit more complicated, non-linear shapes. The shape depends on various factors, including the production relationship between a given commodity output and the externalities, and social demand for the externalities. It is also possible for some marginal benefits to become marginal costs once commodity output exceeds a certain level. In this case the social cost curve intersects with the private cost curve. When considering the area where private cost is below social cost, an analysis of these externalities should be the same as for negative ones, although the total (not marginal) value of the externalities may still be positive.

Externalities with and without opportunity costs: The production of externalities with opportunity costs is essentially the same as the production of two (or more) products under jointly constrained inputs. Producers of externalities with opportunity costs make explicit decisions on the allocation of input resources between the production of commodities and of externalities (see Box III.2 for a detailed discussion on whether externalities with opportunity costs should be classified as externalities). If farmers use more labour than under normal farming practices to improve an agricultural externality, for example, the improvement is considered to be a positive externality with an opportunity cost equivalent to the cost of hiring the extra labour. Another example is when rice farmers reduce the use of chemical fertiliser so that their paddy fields can be used as habitat for certain fish species, which may benefit the society. In this case, providing natural habitat is a positive externality with an opportunity cost equivalent to the farmer's reduction in income because of lower production due to the decreased use of fertiliser.

In theory, the optimal combination of the two products (*i.e.* a commodity output and an externality) is obtained when the opportunity cost for producing an externality (*i.e.* the marginal cost for producing one unit of the externality) is equal to the relative price of the two goods (*i.e.* the marginal benefit to be obtained by increasing production of the externality by one unit). Many countries are adopting policies[6] to pay for some environmental externalities (either increases in positive externalities or reductions in negative externalities), implicitly assuming that the total social benefits from these (incremental) changes in externalities are equal to or exceed the cost of producing or reducing them. Who should pay the costs depends on where the reference level lies.[7]

Externalities without opportunity costs, on the other hand, are generated automatically without producers deciding to allocate resources to them. Economic inefficiency associated with these externalities arises only when there are divergences between marginal social costs and marginal private

Box III.2. **Are externalities with opportunity costs externalities?**

Farmers intentionally control the level of externalities when the externalities have opportunity costs. This report still refers to these as externalities because of the definition being used. It is possible for producers to choose a level of externalities with opportunity costs without other affected parties being consulted (as in the case of regulation). However, it is also true that some economists define an externality as an ***unintended*** side effect of an activity (Dorfman, 1993).

The utility of including these intended externalities is that it simplifies the conceptual discussion of multifunctionality. For example, suppose farms originally provide landscape without farmers using any extra resources for it. Then, in response to a change of (say) regulations, the farmers change their farming practices and use extra resources to further improve the landscape. We would refer to this situation simply as "farmers increase the supply of externalities by using extra resources", instead of saying that "farmers generate externalities and also provide some environmental services in addition to the normal externalities by using extra resources to produce the services". The latter description would be more appropriate when discussing, for example, the reference level.

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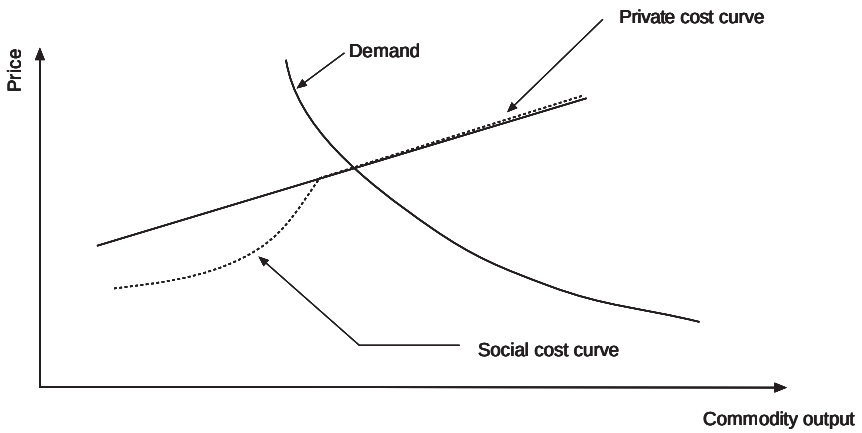
costs at the market price of the product generating the externalities. There are several policy instruments available to bridge this gap. It should again be stressed that negative externalities could offset positive externalities, thus reducing the gap between marginal social costs and marginal private costs.

It should, however, be stressed that policies should simply close the divergences at the market price. For example, if there is no divergence between social and private costs at the market price, then there is absolutely no need for policy intervention, at least from an efficiency point of view, even if there is a substantial divergence between the two costs at an output level that is below the market equilibrium (Hyman, 1990) (Figure III.3). In this case, producers of the externality would continue producing the externality without being remunerated.

S*ub-groupings of externalities without opportunity costs*: As the above discussion indicates, the shape of the divergence between social and private costs is critical when discussing market failures and their policy implications. It is therefore necessary to have sub-groups in the category of "Externalities without Opportunity Costs" corresponding to the shape of the divergence between the social and private cost curves. The case of constant marginal social benefits has the most ordinal shape in the theoretical analysis of externalities, although it might be quite rare in the real world since there is usually asymmetry between commodity and non-commodity production. It could be used as a benchmark for the conceptual analysis. The case of decreasing marginal social benefits incorporates the general characteristic of demand for many types of goods, which is "the more you have, the less you are willing to pay for additional units". A typical example is food security, which will be discussed later. The case of increasing marginal social benefits, on the other hand, reflects those cases where the physical quantity of an externality increases as agricultural production increases (*e.g.* in the case where less favoured areas produce more externalities than production-efficient areas), and the increase in quantity outweighs the general trend of decreasing marginal values. The case of discontinuous marginal social benefits occurs with site-specific externalities where marginal benefits occur only in the areas where the externalities are generated.

Zero marginal social benefits represent a special case, two of which deserve note here. The first is the externality whose quantity is not linked to the level of agricultural production. That is, even if the level of agricultural production in a country dropped by half, the quantity produced of the externalities would remain the same. The second case is where there is no social or private demand for an externality. It could be argued that these cases should not be considered as agricultural externalities because the first one could exist without agriculture (non-jointness in production), and the second one

Figure III.3. **Positive externalities where government intervention is unnecessary**



Source: OECD.

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contradicts the general definition of externalities.[8] Although jointness issues are fully discussed in Part II, this part will retain the category as a reminder that the possibility of non-jointness should always be considered. Obviously, there is no market failure associated with these externalities.

Market failures associated with externalities: analytical basis

Sharing a common understanding on when and how markets fail for each type of externality is essential to avoid the risk of introducing unnecessary government intervention for externalities that do not cause market failure. There are some situations where markets do not fail, especially in the case of externalities without opportunity costs. It is also important to distinguish between closed economies (*i.e.* without trade) and open economies (*i.e.* with trade) since the two cases can be completely different. This section first discusses a universal condition for market failure and then considers how each type of externality can lead to market failure in both open and closed economies.

Universal condition for market failure (failure to achieve social optimality): Market failures associated with all types of externalities occur when a market cannot be established between producers and consumers of the externality (this is obvious from the definition itself). Market in this specific context includes bilateral transactions between parties concerned based on clearly defined property rights. The existence of externalities alone is not the source of the market failure, a point that will be addressed in the next section on public goods.[9] As well, the lack of a market for externalities does not necessarily lead to market failure. For example, as stated above, there would be no market failure if an externality is associated with a production level of a commodity output that is smaller than the market equilibrium (Figure III.3). Non-existence of markets for externalities is therefore a necessary, but not sufficient, condition for market failure.

Market failure specific to each type of externality: In addition to the universal necessary condition for market failure, each type of externality has to meet different conditions in order to cause market failure. The degree of market failure for each type also varies.

***Externalities with opportunity costs* (Type I):** These market failures occur when markets cannot be established (universal condition) or when markets can be established (externalities are excludable in consumption) but the externalities are non-rival[10] in consumption. Regarding the first case, without policy intervention giving producers incentives to produce the externalities, there could be under- or, most likely, non-provision of the externalities. In such a situation, provision would be possible only through voluntary contributions by producers, which is unlikely to happen on a significant scale.

An example of the second case is that of a farmer who uses resources to improve the landscape and then sells the view by charging visitors at the farm entrance.[11] If there were no congestion, it would be economically efficient to accept all visitors with a positive willingness to pay. The farmer, however, would charge a fee to cover the cost of the resources required for creating the landscape, which would eliminate some potential visitors whose willingness to pay is smaller than the admission price but is still positive.

If a market can be created for an externality and the externality is rival in consumption, there should be no market failure regardless of whether or not there are imports of the agricultural product linked with the externality. In fact, according to the definition of externalities developed in the previous paragraphs, they would not be considered externalities at all once markets were created for them. The optimal set of prices and quantities for both the agricultural products and the externalities lies at the point where the marginal value of the externality is equal to its marginal cost of production.

The best policy when a market cannot be created is to provide producers with an incentive to produce the externalities at the level they would produce if there were a market. If the price of an agricultural product decreases because of imports, the incentive would become relatively larger, which would mean that producers would produce more of the externalities and less of the commodity output. An illustrative example of this adjustment process is the case where farmers produce both a commodity output and landscape by explicitly putting resources towards producing them. Suppose the farmers are currently being compensated for landscape production and that the compensation increases with the volume or quality of the landscape. In this case, farmers would shift resources from agricultural

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production to landscape production, because the commodity output price decrease makes it more lucrative to produce landscape. This adjustment process would work well as long as the incentive correctly reflects social demand for the externalities. It would, however, be difficult to accomplish, as will be shown in the next section.

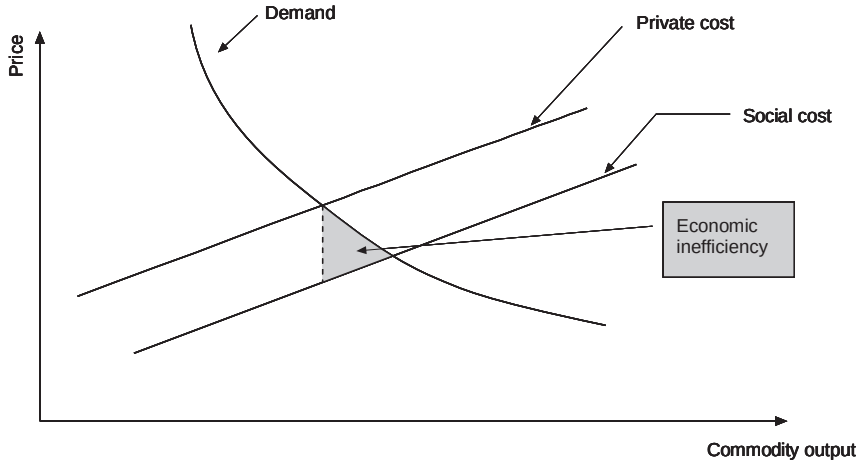
Addressing these issues might not conflict much with trade liberalisation if encouraging or preserving the production of this type of externality does not encourage farmers to produce more commodity outputs.[12] In fact, most of these policies would encourage farmers to reduce levels of production for commodity outputs. However, detailed analysis would be required to understand where and when this is the case.

***Externalities without opportunity costs* (Type II)**: We start by reviewing the most standard case, with no imports, and then expand the discussion to other types of market failure, where there are imports and a consequent decrease in the price of the imported good.

Static case with no imports: Economic inefficiency in this most standard case can be represented as the underproduction of the good generating the externalities, assuming that the good is efficiently supplied through competitive markets and that there are no trade barriers. The (net) social cost is less than the private cost by the value of the externalities. The level of market failure is usually expressed as the area of the triangle made by the demand, social cost and private cost curves (Figure III.4; this figure assumes that the demand for an externality associated with the production of the agricultural product is constant). As discussed, the non-existence of a market for the externality is a necessary condition for market failure.

However, there are some cases where markets do not fail even if there is a demand but no market for the externality. First, as discussed, if there were no divergence between the social and private cost curves at the point where the private cost curve and the demand curve intersect there would be no market failure. As discussed earlier, the existence of negative externalities could reduce the divergence caused by positive externalities. Externalities with decreasing and discontinuous marginal values could produce this situation depending on where social costs intersect with private costs. Secondly, if the demand for a commodity output is perfectly inelastic with respect to price (which is unlikely in reality), there is no efficiency loss (Figure III.5). In this case, the production level is fixed regardless of the social and private costs.

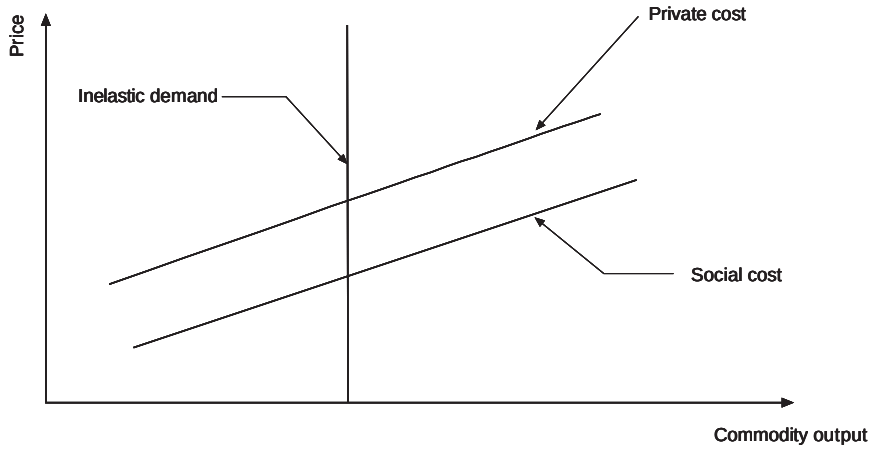
Figure III.4. **Economic inefficiency caused by positive externalities (without imports)**



Source: OECD.

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Figure III.5. **No efficiency loss when demand is perfectly inelastic to price**



Source: OECD.

When the demand for a commodity output is relatively price inelastic[13] and the demand for a (positive) externality decreases as the quantity increases (as will be discussed later in this section), these externalities are unlikely to be major policy issues. Policy intervention might even be harmful in these cases at least from an efficiency point of view. For example, a policy that encourages the creation of a market for these types of externalities (*e.g.* by correctly defining property rights) could cause economic inefficiency if the externality shows non-rivalry in consumption, as is the case for externalities with opportunity costs. All those with a positive willingness to pay for the externality should receive the service, but the market for the externality might prevent this. It is therefore efficient that no action be taken in these cases for the provision of the externalities.[14]

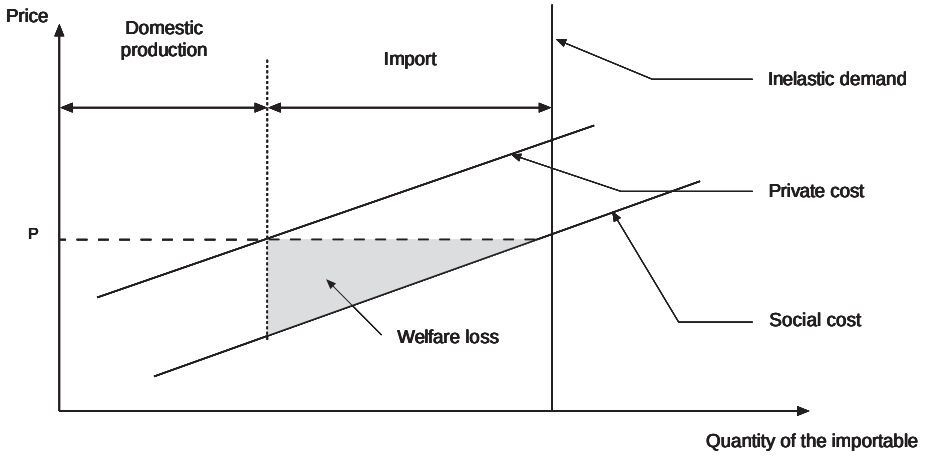
There are, however, some cases where positive externalities could be a policy issue even when there is no exogenous pressure reducing domestic production; some indigenous factors could reduce positive externalities in the long run. First, if the demand for a commodity output generating a positive externality decreases, the production level as well as the associated externality would also decrease. The decrease in demand could be caused, for example, by the country's importing substitute goods or just a change in consumption patterns due to income changes.[15] Secondly, an increase in agricultural productivity could reduce the amount of land required to meet demand, which would eventually reduce the externality associated with the land. Unit yield increases can take place, for example, due to land improvements including the introduction of irrigation and the development of bio-chemical technologies.

There are also many cases where positive externalities could be regional policy issues. Production levels in a certain region could change without the country's total production being changed, which would also affect the level of the externalities associated with the production in the relevant regions. This could cause welfare losses in some regions and gains in the other regions, and also cause some distribution problems as will be discussed in the next section.

Static case with imports: Positive externalities without opportunity costs could be major policy issues when there is trade, again assuming that the good is efficiently supplied through competitive markets and that there are no trade barriers. This is mainly because the economic inefficiency associated with these externalities is not related to the price elasticity of demand, and is only determined by the marginal values of the externalities. This can be illustrated using an example when the demand for a commodity output is inelastic to price. In this case, there is no inefficiency involved

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Figure III.6. **Economic inefficiency caused by positive externalities (with imports)**



Source: Revised from Corden (1997).

when the country does not import the product, as explained above. On the other hand, there is inefficiency when the country imports some of the product. This occurs because, although the country should produce more from a social point of view, it actually produces less and incurs the cost of imports (import price times that part of the imported quantity that would not be imported if a production decision were made from a social point of view). Again, negative externalities could offset some or all of this inefficiency associated with positive externalities. Figure III.6 explains this in more detail.

When domestic prices decrease due to imports:[16] Positive externalities without opportunity costs might cause net welfare losses or gains when domestic prices decrease due to imports, although the result depends on many parameters. The simplest way to calculate whether it would result in losses or gains is to measure each loss and gain separately. Possible gains are observed both on the production and consumption sides. The production side gain is the private production cost saving resulting from the elimination of high-production cost farms from production. The consumption side gain is higher consumer satisfaction due to increased consumption (if demand is price elastic). The possible loss is the decrease in production of positive externalities because of lower domestic production. If there are negative externalities associated with commodity production, the gain due to the decrease in negative externalities should be incorporated in this exercise. The overall welfare changes can be measured by the difference between the gains and the losses (Annex 4 contains a more detailed discussion).[17] Externalities with increasing marginal benefits may be more likely to cause inefficiency than those with constant, decreasing and discontinuous marginal benefits, although this would depend on the exact shape (including where social costs intersect with private costs), impact of the price decrease on production, and absolute value of marginal benefits, and on some other factors. For example, in a country where production costs are relatively high compared to international prices, domestic price decreases due to imports may affect production substantially and, as a result, the externalities (both positive and negative) associated with production.

***Market failures under five subcategories of externalities without opportunity costs*:** Based on the above discussion, Table III.1 presents a rough sketch of how likely markets are to fail for each subcategory under each of the conditions described above. This table is based on the assumption that the total value of the externality is the same for each case and provides information on the relative degree of market failure for each subcategory. The shape of the social cost curves would need to be known to determine if they actually cause market failure or not. This table is therefore intended only as a basis

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Table III.1. **Sketch of how likely markets are to fail**

	Static case without imports	Static case with imports	When import prices decrease
Constant marginal benefit	(Market failure would be) Minor	Medium	Minor
Increasing marginal benefit	Minor	Large	Medium
Decreasing marginal benefit	None or minor	Minor	None or minor
Discontinuous marginal benefit	None or minor	Minor or medium	None or medium
Zero marginal benefit	None	None	None

Note: The degree of market failure is based on a very strong assumption that the total benefits are the same for all externalities.
Source: OECD.

for understanding that the shape of the social cost curves is important in examining whether there is market failure or not. In practice, there are likely to be cases where the relative degree of market failure is different from what is presented in this table.

Revising some assumptions

The discussion of market failure has so far been based on assumptions, some of which need to be reviewed so that this report can provide a more rigorous conceptual framework for the policy discussion. Relaxing these assumptions is likely to reduce the degree of market failure assumed in the above table. The major assumptions that need to be reviewed concern: *i*) the effects of agricultural price decreases on agricultural productivity, and the production level; and *ii*) the externalities that may be associated with resources released from agricultural production. Each of these assumptions is examined in the following paragraphs.

***Price changes might increase productivity*:** The implicit assumption made so far is that a price decrease does not affect farmland productivity. This static result may have to be reviewed in a more dynamic perspective paying attention to adjustment processes caused by price decreases or other factors. In fact, productivity might improve in response to a price decrease, and hence positive externalities associated with production might be preserved. For example, efficient producers with high productivity may buy or rent those lands that would otherwise be abandoned by less efficient farmers due to the decrease in price of the product. This would shift the private cost curve downward, production may not fall, and most of the positive externalities associated with production could be preserved. If this is the case, the efficiency loss could be much smaller than expected.

***Released resources may also generate externalities*:** The partial analysis used above implicitly assumes that the resources released from production of an agricultural product due to a price decrease do not generate positive externalities in other uses. There could, however, be many situations where this assumption does not hold. For example, a price decrease affecting output A could force some producers to shift resources to the production of output B. If the demand for output B is price elastic, then the total production of output B could be increased, which would in turn lead to increased externalities associated with the production of output B.[18] The overall effect of the price change on social welfare is judged by comparing the welfare gain (that is, the net change in the externality associated with the increase in production of B and the increase in the consumer surplus associated with lower prices of A and B) with the welfare loss associated with the decrease in the externality associated with output A.

Another example indicating the need for a more general analysis is the case where an externality can be provided by other methods, or substituted for by other goods.[19] In this case, even if there seems to be an overall welfare loss due to the price decrease, the loss could be offset by providing a substitute. More specifically, the net benefit of providing the substitute could be greater than the overall welfare loss caused by the price decrease. The costs to provide substitutes should be incorporated in the comparison.

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When the assumption holds that price decreases will lead to a reduction in production as well as in the supply of linked positive externalities, identifying production areas that would actually go out of production is crucial for our understanding of when (why) and how much markets fail. The degree of market failure depends on how the externalities are generated at and around the current market output level. If these production areas are correctly identified, then policies suitable for addressing the externalities associated with them can be selected. For example, as discussed in previous paragraphs, there may be no need for policy intervention in the case where the production areas most likely to exit do not generate any externality, even if other areas involved in production of the output concerned are generating substantial externalities.

Identifying these areas, however, may not be as straightforward as the above discussion suggests. For example, a farm household where most of the income comes from off-farm employment could better accommodate a price decrease than a farm household that depends totally on agriculture, even if the two farms have exactly the same unit production cost. The real private costs might, therefore, become known only when the price decrease actually forces some farmland out of production, which should be empirically tested.

This difficulty in estimating these marginal production areas affects policy analysis when the marginal values of externalities are not constant. A typical example is the case of discontinuous benefit reflecting site-specificity. In this case, failure to pinpoint production areas could lead to policy failures, which would cause welfare loss either through the loss of positive externalities attached to the actual areas that go out of production or through the provision of unnecessary support for areas that could continue production.

Taking negative externalities into account

As indicated earlier in the text, negative externalities must be taken fully into account along with positive externalities in formulating actual policies. Overall efficiency losses or gains under both static and dynamic conditions can be determined only when all externalities are accounted for in the analysis. Failure to incorporate negative externalities could create a substantial bias against achieving social optimality in policy design. The theoretical framework for positive externalities discussed in the previous paragraphs can be applied to negative externalities by simply changing the sign of externalities, although there is some asymmetry between positive and negative externalities that should also be noted here.

One difference concerns efficiency changes when the prices of imported goods fall due to trade. As discussed above, there could be either efficiency gains or losses in the case of positive externalities, while there is an unambiguous efficiency gain in the case of negative externalities if the other conditions do not change. The only source of potential welfare loss in the case of positive externalities is from lower production of those externalities. In the negative externality case, decreased production of negative externalities would necessarily also increase welfare. For exporting countries, the converse would hold. A price increase due to trade would lead to welfare gains in the case of a positive externality while there is ambiguity in the case of a negative externality (see the subsection on international income distribution for a more detailed discussion).

Another difference between positive and negative externalities can be observed in the case of externalities with opportunity costs. Negative externalities with opportunity costs of production could not exist, since no one would produce "bads" by sacrificing resources that could be used to produce "goods."

A further difference between positive and negative externalities is that there could be a need for policies to alleviate negative externalities without opportunity costs even if there is no divergence between private and social costs at the market equilibrium. In Figure III.3, it was shown that in some cases the private cost curve may intersect with the demand curve at a higher level of production than where the social cost curve diverges from the private cost curve. In the case of positive externalities, there is no need for policy intervention as the externality will continue to be produced and benefit society. However, in the case of a negative externality, there may be a need for policy intervention if it is possible to reduce the amount of negative externality produced, for example, by changing production technology. In this case,

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social welfare is improved as long as the benefits from the reduction of the externality outweigh the costs. Although this could also be the case if positive externalities are increased, under actual policy conditions it would be an issue only in situations with negative externalities.

The asymmetry in the case where there is no divergence between private and social costs at the market equilibrium could be greater when the social cost associated with negative externalities (*i.e.* the social demand for reducing negative externalities) is very high. If the jointness in production between commodity outputs and negative externalities is fixed, then there could be a situation where production of the commodity output would stop completely. For example, if there is a market for trading the rights to dispose of negative externalities, then all of the rights could be bought, and the production of commodity outputs producing these negative externalities could stop. In the case of positive externalities, the production of commodity outputs would continue, regardless of the level of social demand for the related non-commodity output.

A related difference between negative and positive externalities occurs when a market for the externalities cannot be created, even in the presence of well-defined property rights. In these cases, given jointness of production, some level of externality will be produced along with the commodity. For a positive externality, the lack of market may not lead to a need for policy intervention, as shown above. However, for a negative externality, it could be that the preferred level of production is lower than that occurring in the absence of a market, or even zero. Thus, in a static case with negative externalities, lack of markets can create a situation where social costs are not properly addressed. Reasons for the failure of a market to exist can be high levels of transactions costs, including a lack of information.

As long as externalities occur, information on negative externalities should be collected so that it can be determined whether or not any policy is required. However, in the case of positive externalities, unless positive externalities decline due to a decrease in commodity production or demand for them increases, the need for policy intervention is unlikely.

The differences between negative and positive externalities simplify the analysis in some cases, while making it more complex in others. While, for negative externalities, there is no need to consider opportunity costs associated with the production of the externality, nor to consider welfare loss in the case of a lowering of externality levels, there may be a need for policy intervention where, for positive externalities, this would not be the case.

Incorporating negative externalities is also critically important if these negative externalities have specific consumption relationships with certain positive externalities. As will be discussed later in this part, some consumption relationships between positive and negative externalities would require complicated analysis rather than simply adding the costs associated with negative externalities to the private costs. For example, it is likely that the demand for groundwater recharge would be much smaller in a case where a negative externality associated with the use of chemical inputs exists than in the case with no negative externality. Overall welfare in this example would not simply be a sum of the positive and negative effects. That is, the negative effect might itself change (decrease) the demand for the positive effect. Table III.2 below illustrates some possible consumption relationships between positive and negative externalities, although the empirical evidence remains to be examined.

Review of major non-commodity outputs

A very rough and illustrative outline of the characteristics of major non-commodity outputs as externalities is presented here for discussion (Table III.3). At this stage, it would be very difficult and also of little use to categorise major non-commodity outputs into the externality types proposed in this report due to lack of information and also the site specificity that governs most of the non-commodity outputs. Moreover, the real shapes of non-commodity outputs as externalities can be obtained only after in-depth analysis on production relationships and also demand for non-commodity outputs. In actual policy discussions, the classification of each externality should be determined separately from this conceptual sketch. This outline will therefore try to provide a conceptual framework shared by each major non-commodity output, which will be useful for future discussion on multifunctionality. Supplemental notes for some externalities follow this sketch.

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Table III.2. **Illustrative consumption relationships between positive externalities and a negative externality**

Sub-Groups	Main components (positive externalities)	Likelihood of a negative (environmental) externality (*e.g.* pollution from the use of fertiliser) affecting the preference for a positive externality
Environment and Rural Amenities	Natural habitat	Likely
	Biodiversity	Likely
	Landscape	Likely
	Cultural Heritage	Unlikely
Land Conservation	Flood control	Unlikely
	Groundwater recharge	Very likely
Food Security	Food security	Likely
Rural Viability	Positive effects of rural employment	Unlikely

Source: OECD.

Use values and non-use values: Some agricultural externalities may have both use and non-use values,[20] which is taken into account in this section. That is, an externality with a use value is differentiated from the same externality with a non-use value. For example, landscapes are generally believed to have both use and non-use values. Some people may put a value on agricultural landscapes although they do not have any plan to use (visit) them while others want to keep them because they do. In this case, the use value externality may often be site specific while the non-use value externality may not be site specific.

E*nvironmental benefits* (*natural habitat*, *bio-diversity*): These are agricultural externalities that have both use and non-use values. Most of the use values could be categorised as Type I or Type II-d (Discontinuous), while some of them may be Type II-e (Zero). Type I externalities include those that are managed under most of the current environmental policies. Type II-d (Discontinuous) reflects strong site specificity and Type II-e (Zero) represents those cases with no direct relationship to agricultural production. Most of the non-use values are likely to be in Type II-c (Decreasing) if they are not for specific sites, Type II-d (Discontinuous) or Type II-e (Zero).

Table III.3. **Sketch for major non-commodity outputs from externality points of view**

	Environment	Rural amenities	Land conservation	Food security	Rural viability (positive effects of rural employment)
Type I with OC	X	X		X	X
Type II-a Constant MB					
Type II-b Increasing MB					
Type II-c Decreasing MB	X	X		X	
Type II-d Discontinuous MB	X	X	X		X
Type II-e Zero MB	X	X	X		

OC: Opportunity costs.
MB: Marginal benefit.
Source: OECD.

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Rural amenities (landscape, cultural heritage): These are also partly agricultural externalities, some of which have been internalised by creating markets for them. They also have both use and non-use values. It is likely that most of them have similar characteristics to environmental amenities from an externality point of view. Most of the use values could be categorised as Type I or Type II-d (Discontinuous). The non-use values are most likely Type II-c (Decreasing) or Type II-d (Discontinuous).

Land conservation (flood control, groundwater recharge, soil conservation, landslide prevention):[21] These are agricultural externalities that probably only have use values with strong site-specificity. Most of them could therefore be categorised as Type II-d (Discontinuous). Some of them could also be Type II-e (Zero) because flood control capacity, for example, can be retained without cultivation in some cases.

Food security: This is one of the most controversial cases. Can food security be considered as an agricultural production externality, where there is a proven linkage to domestic production and no lower-cost substitutes? This section tries to apply an overall definition of externalities to examine if this is the case. Whether domestic production is the most efficient provider of food security is a question to be answered in the context of the discussion in Part II.

First, domestic production has an impact on the probability of a country's facing a food shortage when it cannot import food. Domestic production could reduce this specific probability, for which there might be social demand. This social demand, however, is not reflected in the market prices of agricultural products. Market price is determined only by the demand for current consumption of the food product and supply, since non-excludability of the consumption of "food security", as will be discussed in the next section, prevents it from being incorporated into the market price. Food security through domestic production could, therefore, be associated with a positive externality in the case where a country cannot eliminate the risk of losing access to sufficient imported foods (or reduce it below the risk associated with domestic production).

In a different scenario, domestic production could create negative externalities related to food security. Maintaining domestic production could reduce the likelihood of a country's diversifying the sources of food supply, especially through trade. It could, therefore, lead to food shortages in the case of a shortage in domestic production. In other words, imports can also contribute to food security, and can be a more efficient provider of food security. "The contribution of agricultural production to national food security, while probably positive, needs to be looked at as one part of a diversified portfolio of strategies – including, not least, trade". Domestic production might also slow down the process of improving productivity through structural adjustments in the agricultural sector. This delayed structural adjustment could eventually have a negative impact on national food security because it could weaken the country's capacity to establish a sustainable supply system.

Whether the value of positive externalities from domestic production (or negative externalities associated with imports) is greater than the negative externalities (or positive externalities associated with imports) is an empirical question, depending on various factors. These factors would include expected probabilities of shortages in domestic production versus shortages in imports, and also how much value is placed on food security.

Food security has both use and non-use values. The use value is for the current generation while the non-use value is for future generations (bequest values,[22] see below). Both could be categorised as Type I or Type II-c (Decreasing). Type I reflects the possibility that a country may be able to preserve the potential production capacity without maintaining current production levels (*e.g.* preserving farmland without production).

Rural viability (possible positive effects of rural employment): The inclusion of rural employment in an examination on multifunctionality is also controversial. First of all, it should be stressed that agricultural employment is an input in commodity production. Similarly, employment in industries upstream and downstream of agriculture is just an input of the wider agro-food sector. Rural employment related to agriculture therefore cannot be considered as an externality at all. Regional or sectoral distribution of the labour force is, at least in theory, adjusted in labour markets according to changes in the price of outputs. For example, if labour were released from one sector in a region due to a decrease in the

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output price, it might reduce the wage rate in this sector, and in the region. This would induce other sectors to move into the region. Another example of the adjustment process is that the released labour would move to other regions where other sectors require additional labour. These are typical examples of pecuniary externalities, which can be efficiently dealt with in the labour market.[23]

If there is no social cost or benefit associated with regional redistribution of labour, there should be no major policy issue associated with maintaining rural employment. If this is the case, it would not make any difference, for example, if, following a price decrease in the good using the labour, a region loses a part of its population due to the emigration of its labour force. Or, high unemployment rates in rural areas would imply the same social cost as for similar unemployment rates in urban areas, in which case common employment policies could be applied to both rural and urban areas.

However, there may be some cases where specific patterns of regional distribution of the population generate benefits (or costs) to society, and where those benefits or costs are not incorporated in wage rates. In these cases, rural employment related to agriculture may have unintended positive or negative externalities through contributing to maintaining rural population although rural employment related to agriculture itself is just an input. A parallel is the use of fertiliser and water pollution. Fertiliser is an input, and itself not an externality of commodity production. However, the use of fertiliser could have negative impacts on water quality, which means that commodity production has negative externalities through the use of fertiliser. Similarly, commodity production might have positive or negative externalities through the use of labour. Whether agriculture is the most efficient supplier of rural employment or whether agricultural employment is linked with commodity production is a separate issue to be discussed in the context of production aspects. In fact, as the analysis of production aspects of multifunctionality contained in Part II indicated, it seems highly questionable that agriculture is the most efficient supplier of rural employment in most OECD countries.

There are various economic aspects related to the positive externalities that might be associated with rural employment,[24] which could partly explain why some countries have explicit objectives related to the distribution of the population. First, rural employment through the preservation of population in rural areas could contribute to reducing congestion in cities. Congestion can generate both financial costs for the government (*e.g.* the provision of infrastructure) and economic costs. Secondly,, rural employment in a region could have unintended positive impacts on rural communities by preserving per capita costs of public services by municipal governments or formal or informal social organisations within local communities. This is because even if the population declines, most of the costs of providing public services will not decrease (*e.g.* education, health, sanitation, etc.) and there could be some minimum level of local population needed to maintain community activities. Wrede (1997) argues that in order to secure an efficient distribution of the population, the social net benefits of additional individuals have to be equalised across regions. Finally, some countries may wish to maintain a rural or remote population for national defence purposes.

On the other hand, artificially[25] keeping labour in the agricultural sector in a region could also have a negative impact. Other sectors in other regions[26] are deprived of the possibility of using that labour more efficiently and may suffer larger costs of providing certain public services.[27] The degree of negative externality would depend on the overall employment situation[28] and the quality of labour required in other sectors.

These impacts of rural employment have both use and non-use values. That is, use values for the current generation and non-use values for future generations (bequest values). Both the use and non-use values are likely to be either Type I or Type II-d (Discontinuous) reflecting strong site specificity.

Animal welfare: The fact that agricultural production has negative effects on animal welfare creates a negative externality for some people. They feel bad when they know that agricultural production imposes suffering on livestock. Consumer concerns regarding animal welfare are considered to be how these negative externalities can be minimised.

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Animal welfare should therefore be discussed in the context of negative externalities. It should also be noted, as discussed previously in this section, that negative externalities should always be taken into account when policies to address multifunctionality are discussed so that overall efficiency, incorporating all positive and negative externalities, can be ensured.

Public good aspects

This section discusses public good aspects of non-commodity outputs under the assumption that they are externalities causing market failures. As analysed in Part II on production aspects, there might be various possibilities that provision of non-commodity outputs could be de-linked from commodity production. In this case no major policy issue related to trade arises. Analysis of public good aspects of non-commodity outputs would be policy relevant only if they are externalities (*i.e.* joint production of commodity outputs). As also discussed in the previous section, externalities may not cause market failures depending on how the benefits and costs associated with externalities are spread in society. If there is no market failure, no policy issue arises. The analysis of public good aspects will therefore be useful only when non-commodity outputs are externalities of commodity production and are causing market failure. This is summarised as the second question in the analytical framework proposed in Part I.

An elaborate classification of public goods is needed because the economic analysis and practical management of public goods is different for the different types (Dorfman, 1993). A lack of clear and detailed distinctions would imply, for example, that toll roads, national defence, community-owned natural resources, municipal fire protection services and fisheries should be discussed together using a single principle.

Possible policy failures associated with estimating the demand for public goods also strengthen the need for a detailed classification of public goods.[29] Each public good may require different mechanisms to correctly estimate people's willingness to pay. This could be important if the failure to estimate the demand for public goods caused inefficiencies that spread, through trade of the goods generating these public goods as externalities, to other countries or over generations.

Transaction and administrative costs are also important factors that need to be addressed in discussing the provision of public goods, especially in the context of future policy discussions. Transaction costs may be high because of non-exclusion and non-rivalry, because additional information is needed or because negotiation between many agents is necessary (Zilberman and Marra, 1993). Transaction costs may also vary depending on the public good in question.

D*efinitions and classifications*[30]

P*ure public goods*: Pure public goods are goods that meet both of the following criteria:

N*on-excludability*: A good is non-exclusive if it is physically or institutionally (*e.g.* through laws) impossible, or very costly, to exclude individuals from consuming the good. That is, we ***cannot*** exclude anyone from using the good.

N*on-rivalry*: A good is non-rival when a unit of the good can be consumed by one individual without diminishing the consumption opportunities available to others from the same unit. That is, society ***should not*** exclude anyone from using this good because there is no additional cost to accepting another user.

In practice, it is very difficult to find a good that strictly meets these criteria. For example, national defence, which is often presented as a good example of a pure public good, may not entirely meet the criteria.

I*mpure public goods*: Therefore, most goods that are not private (*i.e.* rival and excludable in consumption) are impure public goods. Although the best way to provide these impure public goods depends on conditions specific to each good, it is still useful for further policy discussion to categorise these goods in a general way.

Classification of goods based on the concepts of rivalry and exclusion: Because pure public goods and private goods are defined by the existence or non-existence of excludability and rivalry, impure public goods, which lie between the two, are classified according to the degree of excludability and rivalry. The

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Table III.4. **Classification of pure public goods, impure public goods and private goods**

	Non-Rival	Congestible	Rival
Non-excludable	Pure public goods (*e.g.* national defence)	Type II Open access resources (*e.g.* fisheries)	Type II Open access resources
(*Benefits involve only a small jurisdiction such as municipality*)	Type I Local pure public goods (*e.g.* municipal fire protection services)		
(*Excludable only to outsiders of a community*)		Type III Common property resources (*e.g.* community owned irrigation)	Type III Common property resources
Excludable	Type IV (*e.g.* toll road without congestion)	Type V Club goods (*e.g.* golf club)	Private goods

Source: OECD.

following classification table (Table III.4) was made by revising the one proposed by Randall (1980).[31] Although the cells of the table do not necessarily match the terms often used in policy discussions for various impure public goods (*e.g.* club goods, common property resources, etc.), the terms are presented for those who may prefer to use them.

Characteristics and optimal provision of each pure and impure public good[32]

Pure public goods: There are two fundamental problems associated with the provision of pure public goods. First, voluntary provision, which is the only private option available because non-excludability prevents providers from charging user fees, tends to lead to under-provision of goods. This is because people are believed to free ride on others' contributions to the provision of pure public goods. Secondly, even if a government decides to provide pure public goods, it is often difficult to estimate people's true willingness to pay for the good (*i.e.* the marginal value of the good to them). This is partly because they are not forced to do so, unlike the case of private goods in a market. There is, therefore, a substantial risk of policy failure associated with the over- or underestimation of the willingness to contribute to the provision of a pure public good.

The question of whether the inefficiency associated with the market failure (*i.e.* the under provision of pure public goods by voluntary provision) is greater than the inefficiency associated with the policy failure[33] (*i.e.* under- or overprovision of pure public goods because of the government's failure to correctly estimate demand) is empirical, not theoretical. There are also some examples where the usual free-rider theory cannot be applied (Annex 6). These examples indicate the possibility of voluntary provision achieving Pareto optimality, although the issue of the transaction costs of organising voluntary provision needs to be overcome (Box III.3).

***Type I Impure public goods (Local public goods)*:** The only characteristic differentiating local pure public goods from pure public goods is that a local pure public good benefits only a small jurisdiction such as a municipality or town.[34] This also affects the degree of both the market failure and the policy failure associated with the provision of pure public goods. First, a Pareto optimal level of voluntary provisioning could be more likely for local pure public goods than for pure public goods. The size of the local population is smaller than the entire population and in many cases people put more value on local public goods than general public goods simply because local ones are physically closer to them. Secondly, people tend to reveal their willingness to pay for local pure public goods more correctly than for general public goods, if local tax revenue finances the local public goods.[35] Although they may not decide where to live based only on the level of local taxes and services (provision of local public

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Box III.3. **Notes on some basic terms for discussing public goods**

Pareto-optimality for a pure public good

Pareto-optimality refers to an allocation of resources where no single individual can be better off without making someone else worse off; this is a useful benchmark for analysing economic efficiency. For Pareto-optimality of a pure public good the following condition must be met (Samuelson Condition).

$$\sum_{i=1}^{n} \text{MRS} = \text{MRT}$$

where MRS is the marginal rate of substitution between a pure public good and a private good, MRT is the marginal rate of transformation between these two goods, and n is the size of the population.

In short, the Samuelson condition states that the sum of the individual demand (*i.e.* the marginal value) of the population for a pure public good must be equal to the marginal cost of producing the pure public good. This is the basis for many theoretical and empirical analyses in the field of public finance, including the development of the contingent valuation methodology, where the total demand for a public good is obtained by adding up individual demands.

Underprovision of pure public goods

Underprovision refers to situations where the level of provision is below what the Samuelson condition requires. The problem, as stated in the main text, is that the level that meets the Samuelson condition is usually unknown to policy makers due to lack of information on individual preferences. It is therefore difficult to estimate the degree of underprovision.

goods), they tend to be forced to think of the combination of taxes and services more seriously than in the case of pure public goods. In the extreme case, as Tiebout (1956) suggested with his famous notion of "voting with your feet", people may relocate. This could provide an accurate proxy of their willingness to pay for the services.

Again, whether voluntary provision would be preferable to government provision depends on various factors, which makes it an empirical question. However, it should be stressed that the degree of market or policy failure can be much smaller in the case of local public goods than for pure public goods.

***Type* II (*Open Access Resources*):** Congestion and rivalry, which are the only features differentiating these goods from pure public goods, are the sole source for possible overexploitation of the resource, the "tragedy of the commons".[36] A good is congestible if the consumption of a unit of the good negatively affects other users' utility, but does not reduce the amount of the good to be consumed by the others by one unit. When one additional person uses the resource, then the total welfare change would be the difference between the value that that individual puts on the resources and the increased congestion cost imposed on the other users. In terms of total economic efficiency, resources with congestion or rivalry should be used in such a way that the marginal cost associated with congestion is equal to the marginal benefit of using the resources. However, when each individual tries to maximise his utility without taking into account the congestion cost imposed on the others,[37] it could lead to overexploitation of the resource.[38]

If resources were truly open to all, policy intervention would not be very effective because of non-excludability (or the lack of property rights). However, there are very few resources where this is the case, even if many appear to be non-excludable at first glance.

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Type III (*Common property resources*): Common property resources are different from individual property right regimes in the sense that common property resources are open to everyone in a community, while perfect excludability holds for individual property right regimes.[39] Formal or informal rules that govern the behaviour of community members have been proven to be one of the most efficient instruments to allocate congestible resources among community members. Establishing these rules is therefore critical for open access resources to become common property resources. For example, if a rule as to how each community member should behave in the case of congestion were established in the example above, then the use of the resource could be optimised at the community level.

Type IV (E*xcludable and non-rival*): The private sector or financially autonomous public enterprises, which can be financed by user fees because of excludability, provide most of these goods. Examples are toll roads, public transportation and parks that are at lower than their carrying capacity. Efficiency losses are associated both with provisioning and operating decisions. Efficiency losses due to provisioning decisions tend to result in under-provisioning because providers would take into account only those who can pay the prices determined by the capacity for providing the public good, while the capacity is in turn determined by the expected number of users. An efficiency loss due to operating decisions results from the elimination of users whose willingness to pay is positive. Natural resources already in existence with non-rivalry in consumption tend to face this problem.

Type IV inefficiency may be smaller than that caused by policy failures associated with government provision; market provision of these goods could be a second best solution.[40] Market provision could at least force users to reveal their true willingness to pay, which is often difficult in the case of government provision.

Type V (*Club goods*): The core definition of club goods is that they are excludable and congestible in consumption. Thus, there could be overexploitation or congestion with open use. However, the characteristic of excludability means that it is possible to achieve social optimality through a certain combination of the numbers of users and the size of the resources. This is the basis for achieving economic efficiency through forming clubs. Transaction costs associated with clubs may also be important as they are for other types of public goods.

There are some characteristics that distinguish pure public goods from club goods, in addition to excludability and congestion (Sandlerm and Tschirhart, 1997). First, clubs must be voluntary, which is not the case for pure public goods. In some cases, for example, the provision of pure public goods may harm some recipients (*e.g.* defence to a pacifist). Secondly, the entire population (or the population of a region in the case of local pure public goods) is the recipient of a pure public good. In the case of club goods, there may be non-members. Thirdly, decisions must be made regarding membership and the quantity of the good provided for club goods, while only the provisioning decision need be considered for pure public goods. Lastly, "under a wide variety of circumstances, clubs can achieve Pareto-optimal results without resorting to government provision" (Sandler and Tschirhart, 1997).

In the context of economic analysis, clubs are useful concepts mainly when goods show both excludability and congestion in use. Although clubs can be established if goods show only excludability,[41] analysing these clubs does not provide useful policy implications. For example, creating clubs under Type IV (*i.e.* excludability and non-rivalry) is financially possible with many actual examples in the real world, but they are inefficient because they exclude some of the potential users with a positive willingness to pay. Clubs for goods that exhibit rivalry and excludability, on the other hand, do not make sense in many cases because the optimal membership size of a club would be one.[42, 43] The only exception is when the supply of the good shows decreasing average cost. In this case, collective consumption can reduce an individual's share of the total cost. Most public utilities fall into this category. In the case of agricultural externalities, decreasing average costs (*i.e.* a large initial investment) are not expected to occur often. Therefore, this case will not be covered in this report.

Categorising agricultural externalities under multifunctionality from a public good point of view

U*se values and non-use values*: In categorising major agricultural externalities under multifunctionality, use values and non-use values are discussed separately, as described in the

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previous section. This is very important, especially when the two values exist for different categories of public goods. A more detailed classification of the two values follows (OECD, 1999*b*):

Use values	*Use values*:	Use values represent the value associated with actual use.
	Option values:	Option values (and quasi-option values) represent the value of having the ability to make choices in an uncertain future[1].
Non-use values	*Existence values*:	Existence values represent the value that humans attach to the simple fact of a resource's existence.
	Bequest values:	Bequest values represent the value that humans attach to the possibility of maintaining a resource for future generations.

1. Siebert (1998) discusses that "for a risk-averse agent, the option price, *i.e.* the willingness to pay for keeping up an option, exceeds the expected consumer's surplus".

Source: OECD.

A classification is proposed for discussion in Table III.5, followed by a description of the analysis for each externality. It should be noted that this proposed classification tries to provide a rough sketch rather than a fixed classification, and that there could be many examples which differ from this classification. The purpose of this classification is to illustrate the idea that non-commodity outputs have different characteristics. Some characteristics, while theoretically valid, may not be significant in practice (*e.g.* exclusion mechanisms may not work well in some actual situations). This idea, therefore, should be tested using actual examples. The basic rules used in this report are: *i*) the classifications

Table III.5. **Classification of pure public goods, impure public goods and private goods (Sketch)**

	Non-Rival	Congestible	Rival
Non-Excludable	**Pure public goods** • Landscape (non-use value) • Natural habitat (non-use value) • Biodiversity (non-use value)	**Type II** **Open access resources** • Food security • Landscape (use value by visitors)	**Type II** **Open access resources**
(*Benefits involve only a small jurisdiction such as municipality*)	**Type I** **Local pure public goods** • Flood control • Soil conservation • Land slide prevention • Landscape (use value by residents) • Cultural heritage (non-use value: region-specific) • Positive effects associated with rural employment		
(*Excludable only to outsiders of a community*)		**Type III** **Common property resources** • Groundwater recharge • Natural habitat (use value) • Biodiversity (use value)	**Type III** **Common property resources**
Excludable	**Type IV** • Natural habitat (non-use value) • Biodiversity (non-use value)	**Type V** **Club goods** • Food Security (if special arrangements were made) • Natural Habitat (non-use value under special conditions) • Biodiversity (Non-use value under special conditions)	**Private goods** • Landscape (use value by visitors if exclusion can be made) • Cultural heritage (use value of historical buildings) • Food security (use value by farmers)

Source: OECD.

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should be based on a normative approach; and *ii*) minor possibilities of grouping goods into certain categories are ignored. The normative approach means that the classification should retain the definition of each type rather than discussing how each externality is grouped in practice. This approach could contribute to generating policy implications at a later stage. Regarding the second rule, the analysis needs to avoid ending up with all externalities being categorised as all types of goods, which would not provide any useful policy implications. In fact, it is possible that most goods could be categorised into all groups if we considered every minor possibility. As pointed out earlier, both technical and institutional aspects of exclusion mechanisms need to be carefully reviewed when testing the classification empirically.

Landscape: Landscape has various values with different characteristics. Differentiating use values consumed by residents of an area where a specific landscape site exists from those consumed by visitors could provide some useful policy implications at a later stage. The use value for residents is the value that residents give to consuming (most probably by looking at the landscape) in their daily life, while the use value for visitors is the value that visitors give to visiting the site from time to time. The use values for residents could be categorised as local pure public goods since the benefits accrue only to residents, and non-rivalry and non-excludability within the geographical area hold. The use values for visitors could be either open access goods[44] or private goods depending on the possibility of establishing exclusion mechanisms (*e.g.* a landscape that can be enjoyed only by those with transportation maintains excludability by charging fees for parking spaces; a similar example is a landscape that can be enjoyed only by those who stay in a hotel because the landscape is too huge to be seen in a day) since they are at least partially rival in use.[45]

Most non-use values of landscape, on the other hand, could be pure public goods since non-excludability and non-rivalry hold perfectly (OECD, 1999*a*).[46] More detailed analysis could lead to differentiating non-use values consumed by residents (bequest values for future generations) from those consumed by the general population (existence values and bequest values). The first one would be site-specific while the second one could be both site-specific and general landscape (*i.e.* agricultural landscape in general) depending on whether a specific site is somehow unique and can be distinguished from other landscapes by the general population.

With some exceptions where the general population attaches a special value to a specific site,[47] use-values are likely to be dominant over non-use values for an individual landscape site.[48] This is partly supported by the fact that the willingness to pay to conserve a particular landscape decreases with increasing distance from the site (OECD, 2001*a*). This general tendency is accelerated if the marginal value for general landscape decreases as quantities increase.[49] The deterioration of agricultural landscape in an area means a lot to those who live there but may affect the general population very little or not at all, as long as they know there is an abundance of farmland and associated landscape available elsewhere.

If the above holds and the use value for residents is greater than the cost to preserve (or provide) the landscape in question, there is a possibility that the landscape could be preserved (or provided) by the local government or by local voluntary provision. The local government knows that the landscape will be enjoyed by the general population, but may be accepting of free-ridership on its preservation of the landscape. This is a typical example of the privileged game described in Annex 6. There are also many examples where farmers themselves take initiatives to preserve the environmental conditions of their lands by forming co-operatives (OECD, 1998*a*). Transaction costs to organise voluntary provision, however, could be a major issue reducing the possibility of voluntary provision. The issues associated with transaction costs could also be discussed in the context of advances in information technology.

Preserving landscape as a local public good might, however, cause problems associated with income distribution, since the demand by residents for use values is dependent on income in the region. This could lead to an unbalanced distribution of landscape across the country. Policy failure at the local level could also have a negative impact on income distribution. This aspect is discussed later in this section.

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Cultural heritage: This has also both use and non-use values. Typical use values are those that benefit visitors of historical and cultural places related to agriculture. Many of them could be private or club goods since exclusion mechanisms can be easily established (*e.g.* admission at the entrance of a building) and they are congested or rival in consumption (*e.g.* historical buildings can easily become crowded).

Most non-use values may be related to traditions and customs associated with agriculture, which are categorised mainly as local or general pure public goods because they are non-excludable and non-rival.[50] They could be local pure public goods when these traditions and customs are region-specific. Although people living in the other regions may put values on these region-specific traditions and customs, these values are most likely to be appreciated mainly by regional residents. Traditions and customs could be pure public goods when they are appreciated commonly by the country's general population.

Biodiversity and natural habitat: These two externalities also have both use and non-use values (for example, see King and Wainger, 1999), which lists categories of ecosystem services). Use values are mainly fishing, hunting, bird watching, and also providing learning and research opportunities. Some of these values could be categorised as common property resources because they are rival (fishing, hunting) or congestible (bird watching, learning and research opportunities) in consumption and at least weak excludability is guaranteed[51, 52] for outsiders because these resources lie on private properties (*i.e.* agricultural land).[53] In some countries, however, laws do not allow land-owners to prevent access to their lands.

Some non-use values could be pure public goods since non-excludability and non-rivalry are perfectly met. There might be some special exceptions where they are categorised as Type IV or club goods (OECD, 1999*b*). Typical examples of Type IV and club goods are environmental trusts, in which information on biodiversity or natural habitats can be given only to the trust members. Although benefits stemming from members' contributions to preserving biodiversity or natural habitats are non-excludable and non-rival in consumption by the general population, non-use values attached to the knowledge that some biodiversity and natural habitats exist may sometimes be excludable,[54] especially when general access to the areas concerned is difficult or costly.[55] Regarding non-rivalry, congestion will not occur in most cases, except where members feel negatively affected by an increase in membership size (*i.e.* when keeping the information within a limited community would make them feel better). Voluntary provisioning under Type IV would likely be sub-optimal but could be the second-best solution.

Unlike landscape, most of the non-use values that could be provided under Type IV or club good arrangements, and some of the non-use values categorised as pure public goods, might be site specific. The reasoning here is that non-use values for biodiversity and natural habitats are often attached to specific species while non-use values for landscape are often for general images of agricultural landscape.

The strong site-specificity[56] for non-use values could make the case of biodiversity and natural habitat different from that of landscape in the sense that the use values may not necessarily outweigh the non-use values.[57] If "clubs" represented the non-use values, then it might be feasible for them to co-operate with a community that manages common property resources (*i.e.* use values) to find optimal solutions. If non-use values are just pure public goods with substantial demand attached to a specific site, then strategic behaviour might dominate the reactions of both local communities and the government (*i.e.* local communities would be inclined to free ride on the government).

Flood control, soil conservation and land slide prevention: These are typical examples of pure local public goods. Areas that benefit from these are restricted to certain hydrological and geographical boundaries with no or minor spillover effects in the surrounding regions. There should be no non-use value for these services because the benefits accrue to limited areas as use values.

It is less complicated to estimate demand for these services than in the case of the other local pure public goods described in this report. The demand estimation process does not require knowledge of individual utility functions. The demand for these services can be estimated either by valuing the damage that would occur if the services did not exist in an area, or by estimating the cost of

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implementing alternative policies to substitute for them. Although some uncertainties in the estimation process would remain (*e.g.* probability of flood occurrence, hydrological mechanisms in which agricultural land plays a role, valuation of properties protected by these services, etc.), the demand estimation is much more reliable than for the other local pure public goods.

These characteristics of the services make it easy for municipalities to have direct contracts with farmers to preserve these functions. If a municipality can identify areas that benefit and the quantity (in monetary terms) of the benefits, it could estimate the costs and benefits.[58] If it finds that the benefits exceed the costs, then it may want to contract with farmers to preserve them.[59]

In fact, there is some empirical evidence for this type of arrangement. For example, some municipalities in Japan subsidise farmers to continue rice farming[60] so that declining flood control capacity associated with the decline of rice farming near cities can be reversed (OECD, 2001*a*).

Groundwater recharge: This is a classic example of a common property resource with excludability for outsiders, some formal or informal rules for insiders, and congestion (*i.e.* decline of groundwater levels). Most OECD countries have various types of institutional and legal arrangements by which groundwater resources are managed as common property resources. For example, governments regulate individual withdrawals from groundwater, especially for industrial use. Farmers form water users' associations that consequently exclude non-members from using groundwater (individual pumping may be too costly). Municipalities or municipal parastatals usually supply drinking water, which also contributes to the exclusion of individual users.

Groundwater could be an open access resource if there were no such institutional arrangements. In fact, some OECD member countries experienced the "tragedy of the commons" before these arrangements were made. This led to, for example, rapid declines in groundwater levels in some industrial areas in some countries, or in the western agricultural lands in the US Many developing countries that have not established such arrangements are suffering from the tragedy of the commons. The agricultural sector's production capacity has been reduced due to increased salinity linked to over-pumping of groundwater by individual farmers in Pakistan, for example. Attempts are being made currently to encourage farmers to install community-owned joint-tubewells instead of individual tubewells so that the open access regime can be converted into a common property regime (World Bank, 1994*a*).

Under a common property regime, direct negotiations between the suppliers and beneficiaries of the groundwater recharge services, could be relatively easily arranged. The suppliers are farmers, and the number of beneficiaries may be small enough for them to co-operate in negotiating with farmers on preserving the service of groundwater recharge. An example of a similar arrangement is that some municipalities and water users' associations are providing cash or labour grants to those managing forestry upstream.

Food security: It should be noted again that whether or not domestic production is the most efficient supplier of food security should be tested in the context of production relationships. A policy issue arises if it is established that domestic production contributes to food security and that market conditions does not provide the required level of domestic supply. Food security could be classified as an open-access resource with non-excludability and congestion.[61] It is definitely congestible in consumption; *i.e.* the larger the population enjoying the externality, the smaller is the assurance that individuals can have it (this aspect differentiates food security from national security). It is non-excludable in consumption, although there could be some possibility of making it excludable, as will be shown. A fall in the risk of food shortage can be enjoyed by anyone as long as they have access to food through markets. Current consumption is, of course, rival. Again, it should be stressed that exclusive reliance on domestic production could also have negative impacts on food security by limiting the source of supplies. This aspect should be fully taken into account in policy discussions.

Food security could in theory be an excludable club good, which is more manageable than open access resources, if consumers had direct contracts with food suppliers. A very much hypothetical example could be where consumers have contracts with farmers to buy domestic products at higher prices than imported products with the assurance that they would have access to the domestic products

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in case of a food shortage. Establishing consumers' groups could reduce the transaction costs and make these arrangements more realistic. Income distribution problems, however, would be attached to these arrangements,[62] since the poor cannot buy the "insurance".

The analysis of possible arrangements to convert open access regimes to other, more manageable ones, needs to pay careful attention to how each society perceives food security. In fact, many societies consider food security[63, 64] as one of the most important government responsibilities. In these societies, the hypothetical arrangements listed above, for example, might generate a severe "public bad". Social instability would result in the case of a real food shortage because consumers who didn't buy "insurance" might not accept the lack of food. This could happen because people regard food security as a "public good" regardless of whether it meets the neo-classical criteria (non-excludability and non-rivalry). They believe that the government should provide the goods they consider as "public goods".[65]

Possible positive impacts of rural employment: As discussed in the previous section, there are two major issues with respect to the possible beneficial effects of rural employment. These are the preservation of per capita costs of public services in local municipalities and the reduction of urban congestion. From the public good perspective, these two issues are local pure public goods and pure public goods. The value of preventing an increase in the costs of providing local public services is a local pure public good since the benefits are non-excludable and non-rival only within certain geographical boundaries. The value of preventing congestion in cities is, on the other hand, a pure public good because the potential benefits could accrue to all congested cities. Both values are site specific. Again, it should be noted that rural employment itself is not an externality; it just has external effects on society.

Values that are pure public good in nature may be small considering recent trends in rural and city conditions in OECD Member countries. For example, agriculture's share of total employment in all OECD Member countries was smaller than 10% in 1990, with the exception of a few countries (OECD, 1996), indicating that the pressure of the agricultural population on urban populations is becoming negligible.

The structure of agriculture in most OECD countries also rules out the possibility that agricultural employment could reduce urban congestion. Moreover, the dominance of part-time farmers in some OECD countries[66] reduces the risk of farmers migrating to cities even if they quit farming. Situations in some developing countries whose economies depend heavily on agriculture may be different, as discussed in the following section.

Values that are pure local public goods in nature may be relatively substantial although they depend on site-specific conditions. The figures show that in most OECD countries, the share of agriculture in total employment in predominately rural regions[67] is twice or three times as large as at the national level. It should, however, be noted that even in predominately rural regions agriculture's share of employment is less than 20% in most OECD countries. Agricultural employment could have value as a local pure public good only if the agriculture's share of total regional employment is dominant.

The importance of analysing consumption relationships

Analysing consumption relationships among pure and impure public goods is essential to policy discussion in at least three ways. First, the demand for multifunctionality composed of several goods might depend on the consumption relationships between the goods. Secondly, "multiproduct" clubs could be efficiently established to preserve some of the multifunctional components that are impure public goods. The third aspect is related to the theory of joint-products[68] recently developed in the field of public finance. The application of this theory could lead to establishing policies that overcome the free rider problem if goods have specific consumption relationships. This would encourage the voluntary provision of these goods.

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The demand for multifunctionality composed of pure and impure public goods: Analysing the consumption relationship is important for estimating the social demand for multifunctionality composed of several public goods [Santos (2000) provides a more detailed discussion]. For example, if two multifunctional goods are complete substitutes in consumption, then the total demand for them would be smaller than the sum of the individual demands, assuming that demand decreases as the quantities increase. For example, suppose the demand for a 100 ha landscape is USD 10 and USD 15 for a 200 ha landscape. Then, suppose a natural habitat is a perfect substitute for a landscape and the demand for a 100 ha natural habitat is USD 10 and the demand for a 200 ha natural habitat is USD 15. Then, the demand for multifunctional goods in a certain area composed of 100 ha landscape and 100 ha natural habitat would be USD 15 because people are indifferent to the combination of these two products since they are perfect substitutes.

If, on the other hand, they are complete complements, then the individual demand for each of these goods would be zero because only joint consumption of both goods would generate social utility.[69]

Negative externalities should also be taken into account when the consumption relationship is discussed. There could be strong relationships in consumption between some negative and positive externalities. It is likely that some negative externalities would not only reduce social welfare but also reduce the demand for certain positive externalities. For example, the demand for food security from domestic production could be much smaller in a case where domestic production generates substantial negative environmental externalities (*e.g.* overuse of fertiliser) than a case where domestic production generates no negative externalities. This would imply that smaller amounts of positive externalities under good farming practices with minimum negative externalities would generate greater benefits to society than large amounts of positive externalities combined with substantial amounts of negative externalities.

One way to overcome the problems associated with estimating the demand for multifunctionality composed of several goods that are related through consumption is to directly value multifunctionality. For example, an estimate survey could be designed, similar to the contingent valuation method (CVM), so that people could indicate their willingness to pay for the joint externalities, instead of how much they would pay for each good individually. This process automatically takes into account the consumption relationship (Santos, 2000), although it could also aggravate problems associated with applying CVM to a demand estimation of a single product.

This method, however, could not be applied to most externalities under multifunctionality because they have different natures as pure, impure public or private goods. Take, for example, multifunctional benefits composed of a local pure public good (*e.g.* use values of landscape by local residents) and a pure public good (*e.g.* non-use values of biodiversity). Beneficiaries of the two goods are different, but there could be some consumption relationship between the two goods. In this case, the suggested approach cannot be applied even from a theoretical point of view.

Forming multiproduct clubs: The discussion in the above paragraph suggests that if we can establish a club providing multiple impure public goods sharing common characteristics, then the club may not need to know the consumption relationship between these goods. Members of the club would decide whether they would join the club based on the cost (*e.g.* the membership fee) and the benefit of joining the club. The benefit of joining the club indicates their willingness to pay for using the multiple externalities simultaneously, which reflects substitution or complementarity relationships among the externalities.

Multiproduct clubs are prevalent in the real world. For example, political jurisdictions provide law enforcement, highways and fire protection, and a country club contains a golf course, tennis courts, a swimming pool, and a clubhouse (Cornes and Sandler, 1996). Obviously, these clubs provide impure public goods with a common character. For example, political jurisdictions in the above example provide local public goods, while the country club provides "club" goods. In these cases, the club does not need to know how much a member would be willing to pay for using each facility separately, and try to estimate the demand for using all facilities through a careful analysis of the consumption relationship between the use of each facilities. Instead, it simply asks a member how much they would pay for using the combination of facilities.

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A typical example of these multiproduct clubs in the context of the multifunctionality of agriculture could be community supported agriculture (CSA) (Box III.4). The main objectives of CSA are to "develop a regional food supply and strong local economy; maintain a sense of community; encourage land stewardship; and honour the knowledge and experience of growers and producers working with small to medium farms". These objectives are all related to regional interests and could be considered as local public goods or club goods. In this case, members don't have to decide how much they are willing to pay to help CSA to achieve each individual objective; they simply decide how much they will pay to achieve all the objectives as a group.

***The joint-product theory and its possible application*:** The essence of the theory[70] is that voluntary provision of a (pure) public good could be made if another good that is jointly produced with the public good and can be provided through the market or through voluntary provision is complementary in consumption to the public good. Suppose agricultural production in an area generates both natural habitat that is a public good, and green tourism that is traded in the market. If the natural habitat and green tourism are complementary in consumption, then buyers of the green tourism would pay more if the provision of natural habitat increases through the contributions of others. The payments for green tourism could be used to support agricultural production (assuming that farmers are operating the green tourism), which in turn could increase the provision of the natural habitats. This behaviour is the opposite of free riding, where individuals reduce their contribution when others' contributions increase.

A similar illustration applies to landscape. As discussed in the previous section, landscape in general has use-values for residents and non-use values for the entire population. The former has a local pure public good nature while the latter has a pure public good nature. Suppose complementarity in consumption between these two values exists. In this case, local residents may place greater use-value on the landscape in their area if they know that the non-use value for the general population is large (*i.e.* local residents may value the landscape more when these landscapes are also appreciated by the general population). If the landscape in this area is preserved or strengthened from the increase in use-values by the local residents (for instance through the local political system), then it would automatically increase the non-use value for the general population. This hypothetical process provides some thoughts on the possibility that the provision of local public goods could at least partially incorporate the demand for pure public goods that are jointly produced with a local public good.

Box III.4. **What is community supported agriculture (CSA)?**

CSA is an innovative and resourceful strategy to connect local farmers with local consumers, to develop a regional food supply and a strong local economy, to maintain a sense of community, to encourage land stewardship, and to honour the knowledge and experience of growers and producers working on small to medium farms. CSA is a unique model of local agriculture which began 30 years ago in Japan. A group of women concerned about increasing food imports and the corresponding decrease in the farming population initiated a direct growing and purchasing relationship between their group and local farms. This arrangement is called "teikei" in Japanese, which translates as "putting the farmers' face on food". The concept travelled to Europe and to the US, where it was given the name "Community Supported Agriculture" at Indian Line Farm, Massachusetts in 1985. As of January 1999, there are over 1 000 CSA farms across the US and Canada.

CSA is a partnership of mutual commitment between a farm and a community of supporters, which provides a direct link between the production and consumption of food. Supporters cover a farm's yearly operating budget by purchasing a share of the season's harvest. CSA members make a commitment to support the farm throughout the season, and assume the costs, risks and bounty of growing food along with the farmer or grower.

(*Cited from University of Massachusetts*, 1999)

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Box III.5. **Conservation, amenity and recreation trusts (CARTs) in UK**

"Collectively, CARTs have a combined membership of nearly four million (although this double-counts individuals who are members of more than one trust), a staff of some 4 500, and a financial turnover (calculated from 1990 accounts) of over 110 million pound sterling per year. They therefore constitute a significant sector within the UK economy, and particularly within the field of public goods provision. Their total turnover, for instance, was 50% than the total expenditures of the Nature Conservancy Council and the Countryside Commissions for England and Wales and Scotland combined in 1990. The land-holdings of CARTs by 1990 were over 1.3 million acres, or around 2.7% of the land area of the UK The National Trust, the largest Trust in the country, owned 59 1000 acres in 1994, of which 42% is agricultural land" (Dwyer and Hodge, 1996).

Another example of the joint-product theory is the analysis of charity, which has a huge potential for being extended to the voluntary provision[71] of environmental goods (*e.g.* environmental trusts. See Box III.5 for a review of the growing importance of environmental trusts in the UK).[72] Charity has been referred to as a pure public good. However, Sugden (1985) demonstrated that under certain assumptions if charities were pure public goods, charities that depended on contributions from a large number of donors could not exist, although in fact such charities do exist. "Posnett and Sandler (1986) viewed charitable contributions as giving rise to a pure public output (*i.e.* the good done for the recipient) and donor-specific private outputs" (Cornes and Sandler, 1996). The latter may represent tangible benefits, such as theatre tickets, or intangible benefits, such as a warm glow.

Analysing the consumption relationships between the relevant public goods is therefore crucial for understanding the possibility of voluntary provision. There could be a large number of combinations in terms of consumption relationships among multifunctional public goods especially if we take into account both use and non-use values of externalities. The analysis, however, should focus only on those that are complementary in consumption, which would probably reduce the number of combinations.

Other issues associated with multifunctionality: stability and equity

"Key issues in the literature on public goods provision are stability, efficiency and equity/fairness" (Bag, 1999) although the discussions so far in this report have dealt only with efficiency issues. This section provides some basic concepts related to stability and equity, which could be important when we discuss multiple products as in the case of multifunctionality. Some unique problems, resulting from the fact that agriculture may generate several types of externalities with different public good natures, may complicate the analyses of these issues much more than single product cases.

Stability

As discussed, there could be various institutional arrangements for providing public goods such as voluntary provision, central government provision, local government provision, provision through taking advantage of joint-production, club provision, community provision, etc. Each arrangement has merits and demerits depending on the situation to which it is applied. For example, as discussed, local government might be more suited to providing local pure public goods than central government, while forming clubs may be more appropriate for providing club goods than governments. Choosing the best arrangement for providing public goods, taking into account the character of the public goods, is essential for designing policies.

It should also be stressed that the stability of each institutional arrangement needs careful attention, especially if the degree of stability of different arrangements varies. Pareto optimality achieved under several institutional arrangements could be lost, for example, by termination of

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voluntary provision of a public good under multifunctionality, while the arrangements for providing the other public goods are left unchanged. The termination not only causes underprovision (or no-provision) of the public good in question, but could lead to a greater overall efficiency loss than the case where the provision of a different public good is terminated.

However, there have been very few theoretical[73] and empirical analyses on stability related to the provision of public goods. For example, voluntary provisioning could be volatile.[74] The provisioning arrangements could be highly affected by fluctuations in individual contributions even if the demand for the public goods does not change, due to the temptation to free-ride. This could be a problem, especially when a good cannot be recovered once it is lost. One possible mechanism to avoid such instability would be to establish funds so that annual expenditure for providing public goods could be equalised through average annual contributions.[75]

Government provisioning at both national and local levels would likely preserve greater continuity once the initial provision level is determined. It is also possible, however, that government provisioning could be subject to change due to political processes that require balancing policy issues in all sectors. For example, implicit vote-trading (referred to as logrolling[76] in political science) may adversely affect the supply of a public good, although the population's demand for that good is unchanged.

The provision of common property resources could be stable as long as the community itself is stable. However, once the community faces a disturbance, supply could decrease, mainly because the common property regime becomes an open access regime. For example, a community managed fishing pond could cause overexploitation of fish (the tragedy of the commons) once the community loses a management rule.

E*quity*[77]

The analysis of the public good and externality aspects of agricultural production has been based on a efficiency framework. That is, the concern has been with evaluating the implications of non-commodity joint outputs on policy and market efficiency. However, their implications for equity are also important: "While some would prefer to exclude distribution since it falls outside the more manageable Paretian realm, this would leave the fiscal model in an incomplete state" (Musgrave, 1999).

The question of distribution is not easy to approach mainly because economic theories are in general not suited for discussing "optimal" income distribution. It is not within the scope of this report to analyse various proposed methods of dealing with distributional equity. There are, however, a number of possible ways to evaluate equity Gaertner (1994) at least from a theoretical point of view.

Pareto-optimality does not provide any information on equity or income distribution ;it guarantees only that resource allocation is efficient for a given income distribution pattern. A different income distribution pattern would lead to a different Pareto optimal solution. Analysing the trade-off relationship between equity and efficiency is therefore one of the important tasks in analysing the provision of public goods. This is especially true because the demand for public goods is in many cases related to income levels.

Equity issues are much more complicated in the case of multifunctionality than in single product cases. This is because, in addition to the fact that many goods are related, each good (externality) has different equity implications. For example, food security might favour the poor more than the rich, because the rich can buy food even if prices rise due to a shortage.[78] On the other hand, rural amenities might favour the rich more than the poor because the demand for rural amenities usually increases with the income of the beneficiaries.

When the international distributive implications of the existence and provision of non-commodity outputs are added, the water is further muddied. When there is no externality associated with production of tradable goods, basic trade theory states that each country could be better off by moving from trade restrictions to free trade.[79] International income distribution may not, therefore, be a major issue[80] in this case although the effects of free trade on domestic income distribution could be important (*e.g.* income distribution between sectors, industry, and consumers, or regional income

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distribution, etc.). However, if there are some externalities associated with the production of tradable goods, there could be various patterns of effects of free trade and policies internalising externalities on international income distribution. In this case, international income distribution may have to be closely looked at.

The equity issues with respect to non-commodity outputs in this section can therefore be divided into two areas, domestic implications and international implications. The discussion on domestic implications is further divided into two parts, which focus on who would benefit from the provision of non-commodity outputs and who would bear the costs associated with the provision of these non-commodity outputs. In the sections that follow, some of these implications will be outlined. While the implications have been separated for the sake of clarity, in any evaluation of policy there would be a need to consider all three types.

Domestic implications: There are two issues relating to domestic equity or distribution in the context of multifunctionality. The first question is how multifunctionality affects beneficiaries (the benefit implication). More specifically, understanding how different types of multifunctionality composed of different sets of externalities affect various types of beneficiaries is essential for analysing equity implications. The second issue is how the costs of preserving multifunctionality would or would not affect income distribution patterns (the cost implication). If beneficiaries bear the entire cost, then a cost sharing arrangement might not cause problems associated with income distribution.

Benefit implications: As discussed in the previous section, there could be various combinations of multifunctional goods that could satisfy Pareto optimality (*i.e.* non-inferior solutions; Annex 5). Unless the demand for all products is valued in the same way (*e.g.* in monetary terms), the choice between the combinations would be dominated mainly by equity considerations, and not by efficiency considerations.

These equity considerations have two dimensions: income distribution among individuals, and income distribution between regions. An example of income distribution among individuals is when a combination of multifunctional goods places a greater value on food security than on landscape. This might favour low-income groups more than the opposite scenario.[81] This is because the high-income population could bear higher food prices and is willing to pay more for amenities. Consequently, they feel that they place a greater value on landscape than on food security.

As can be seen, analysing how the demand for each non-commodity output would change as income changes (*i.e.* income elasticity of demand) is critical to a discussion of the distributional implications of multiple products, as occurs with multifunctionality. Although there is very limited data on this (OECD, 1998*b*), a rough illustrative sketch will be presented here to encourage discussion on the issue (Table III.6).

Table III.6. **Illustrative income elasticities of demand for various non-commodity outputs**

	As income increases, demand would	As income increases, demand would change
Environment (preserving a specific species)	Increase	Very much
Land conservation (recharging water for a municipality composed mainly of apartment residents)	Increase	Slightly[1]
Rural amenities (preserving an ordinary landscape)	Increase	Moderately
Food security	Decrease	Moderately
Rural employment (in a region where the local tax rate is uniform)	Decrease[2]	Moderately

1. The demand for municipal water would be income inelastic if there are no gardens.
2. If the tax rate is uniform, disposable income would increase as income increases, which would cause a decrease in demand for the preservation of agricultural employment in a region.

Source: OECD.

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An example of the implications for regional equity is when a certain multifunctional characteristic is concentrated in certain regions only. Placing a greater value on this characteristic would mean favouring these regions. Another possibility for regional distribution problems is if the provision of a public good is determined only by the regional population's willingness to pay. In this situation, provision of the good would be concentrated in areas with high incomes.

***Cost implications*:** Who bears the cost of providing public goods probably has the largest impact on income distribution as well as on economic efficiency. Although there are a number of combinations of provisioning mechanisms and types of goods, some of them deserve specific mention in this section.

The provision of local pure public goods may be the most complicated case. For example, financing the provision of local public goods from the country's general tax revenue could help to adjust any inequities in distribution; that is, it would help a local government with poor financial capacity to provide a local pure public good. However, it could also induce local governments to free ride on general tax revenue by overestimating the demand for the local pure public good. Financing the provision of local public goods from local tax revenue would reduce the risk of free riding, but could create a distribution problem. Financing the provision of local pure public goods through voluntary contributions could have the same effect on efficiency and equity as does local government provision. Financing the provision of local pure public goods through voluntary contribution managed by a central institution (*i.e.* the central institution distributes the voluntary contributions) would cause free riding unless the distribution rules include incentives for each region to contribute (Konrad, 1998).

The provision of common property resources would have to face the same trade-off between equity and efficiency as local pure public goods. If the goods are provided only by voluntary contributions from community members, efficiency could be achieved, but equity might be sacrificed. If the provision of the goods were supported by local or central government financing, the free-rider problem would arise, although equity concerns might be better addressed.

The provision of club goods by clubs might balance equity and efficiency concerns if the goods are not specific to a region. This arrangement could avoid favouring specific regions and would not induce club members to free ride on other sources of financing.

The question of who bears the cost of the provision of public goods could also affect income distribution between generations. For example, suppose a government tries to preserve an agricultural landscape as a rural amenity through budget contributions to farmers to continue generating landscape. In this case, preserving landscape would mainly benefit current generations with high incomes (assuming a high-income population is likely to have a greater demand for landscape than low-income groups). As well, this budget allocation might harm the poor of future generations if the resources could have been used to increase their welfare (for example, by providing basic services like municipal water supply or education). For example, if the budget were used to construct public stockholding infrastructure, it could benefit the poor of both current and future generations (again, assuming that low-income populations have a greater demand for food security).

***International equity implications*:** Multiple non-commodity outputs may also have implications in terms of international distribution when there is trade in the goods generating them. As international income distribution issues are complex, a few simplified cases are presented so that an understanding of the basic nature of the issues can be developed. Understanding conceptually how income distribution changes in response to trade and domestic policies is a prerequisite for policy discussions at a later stage.

The impact of non-commodity output provision is discussed in the following two contexts: the impact of free trade on the international distribution of welfare, and the impact of domestic policies to internalise externalities on the international distribution of welfare. Although current trade policies (*e.g.* tariffs) could have various distributional implications, this report avoids discussing them to focus sharply on basic conceptual aspects. In the latter case, whether domestic policies could affect international prices of tradable commodity outputs is important. Scenarios under both small country and large country assumptions will therefore be examined.

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Income distribution from trade – basis for the discussion: Standard neo-classical trade theory shows that under certain conditions, all countries will gain from more trade. If this is the case, no major policy issue is expected to be associated with international income distribution. Although it is generally admitted that there are equity considerations that need to be taken into account in terms of the distribution of these gains at the national level, they are not specific to the debate on multifunctionality.

The impact of externalities on trade: no internalisation policy: In a situation where there are externalities associated with the production of tradable goods and no measure is taken to internalise these externalities, free trade may lead to gains or losses with respect to individual country welfare, and to the world as a whole (global welfare).[82] The type of externality will lead to different impacts on income distribution within countries, and consequently among countries. In Table III.7 the results of a illustrative analysis (a simple two country model) of the effects of a move from no trade to free trade are summarised and synthesised. The details of the analysis can be found in Annex 7.

Table III.7. **Effects of trade on international income distribution when there are externalities**

Case #	Externality in an importing country	Externality in an exporting country	Global welfare	Importing country's welfare	Exporting country's welfare
1	None	None	Increase	Increase	Increase
2	Negative	Negative	Increase or decrease	Increase	Increase or decrease
3	Positive	Positive	Increase or decrease	Increase or decrease	Increase
4	Negative	Positive	Increase	Increase	Increase
5	Positive	Negative	Increase or decrease	Increase or decrease	Increase or decrease

Note: Welfare increases or decreases as both countries move from trade restriction to free trade.
Source: OECD.

Table III.7 shows how global welfare and the welfare of an importing and an exporting country would change responding to the movement from no-trade to free trade of two goods, one of which is generating either positive or negative externalities in both countries. For example, if the tradable good in both countries is generating social costs (negative externalities) because of the use of, for example, chemical fertiliser, free trade would increase the welfare of the importing country. This is because the welfare gain associated with the reduction of the negative externality due to the drop in production caused by imports would be added to welfare gains associated with free trade. On the other hand, the welfare of the exporting country may increase or decrease depending on whether the decrease in welfare associated with higher levels of the negative externality is offset by the increase in welfare from free trade.

The presence of externalities could lead to ambiguity in the discussion of income distribution among countries. As can be seen, the only cases where there is an unambiguous gain from trade in the presence of externalities that are not internalised is when the production of a good generates a positive externality in the exporting country or a negative externality in the importing one. When a good generates a positive externality in an importing country or a negative externality in an exporting one, then the individual country welfare may either increase or decline. The overall welfare effect depends on whether the consumption gains from trade are larger or smaller than the production-side losses from the decrease in positive externalities or the increase in negative externalities.

Because the presence of externalities might affect the direction and magnitude of the effects of trade on country welfare, it might also affect global welfare. Thus, the presence of externalities that are not internalised may be a source of departure from the general conclusion that trade is welfare improving.

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The impact of externalities on trade – with policies to internalise externalities: Policies to internalise externalities in all countries could reduce the ambiguity concerning international income distribution, at least from a theoretical point of view. When there are no terms-of-trade effects from internalisation policies (*i.e.* a small country assumption), and when externalities are appropriately internalised, the combination of policies and free trade are likely to improve both global and domestic welfare from when there is only free trade (no policies). When externalities are internalised appropriately, social cost is used to determine the level of production. Thus, all costs are taken into consideration avoiding the excess costs associated with situations where only private cost is used to determine production levels and levels of exports.

Policies to internalise externalities may have terms-of-trade effects when a country is large enough to affect world supply and prices (*i.e.* a large country assumption). If a large country imposes a policy to internalise a positive externality, its production of the good would increase, leading to increased global supply and a decline in the world price. The opposite occurs if the externality is negative; production declines, and the world price increases.

If all countries have appropriate policies to internalise their externalities, the effect on other countries within the international trading system of a change in policy in one country to internalise externalities would depend on the terms-of-trade effect. If the policies led to an increase in the world price, exporting countries would benefit, while importing countries would lose. With a decline in the world price, exporters would lose while importers would gain. The terms-of-trade effect would determine which country would gain or lose if the gains or losses associated with the change of production of externalities caused by policies are not large enough to outweigh the terms-of-trade effect. At the global level, overall welfare is increased by the policies, as, for the world as a whole, terms-of-trade effects cancel out (Corden, 1997).

If the exporting and importing countries have different externalities associated with the same good (*i.e.* one has a positive externality and the other a negative externality), the terms-of-trade effects of the policies might be moderated because they would offset each other. If the international price remains unchanged (or the change is small) due to this cancelling-out effect, both global and individual country welfare could be increased.

The above discussion is summarised in Table III.8, showing how welfare would change in response to measures taken by both countries to correctly internalise externalities. Free trade is assumed and each country is big enough that policies to internalise externalities could affect international prices.

The above analysis depends on all countries having appropriate policies to internalise their externalities. If only some countries internalise externalities, then the effect of non-optimal levels of externalities must be added to the terms-of-trade effect to understand the total welfare effect of the policies. In the case of a negative externality, production will decrease in the country with an appropriate policy. However, production will increase in the other country, which will increase the level of negative externalities. Depending on whether or not the gains from the decreased negative externality in the exporting country outweigh the losses from the increased negative externality in the

Table III.8. **Effects of policies to internalise externalities on the international income distribution**

Case #	Externality in an importing country	Externality in an exporting country	Global welfare	Importing country's welfare is likely to	Exporting country's welfare is likely to
6[1]	Negative	Negative	Increase	Decrease	Increase
7[1]	Positive	Positive	Increase	Increase	Decrease
8[2]	Negative	Positive	Increase	Increase	Increase
9[2]	Positive	Negative	Increase	Increase	Increase

1. Terms of trade effects are assumed to be large enough to outweigh the change of externalities.
2. Terms of trade effects are assumed to be small because of the cancelling-out effects.

Source: OECD.

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importing country, global welfare may increase or decrease. The welfare of the importing country when it does not implement policies would decrease more than in the case where it does. The opposite would occur when both countries have positive externalities and only the importing country implements policies to internalise them (Annex 7 provides a summary of how global and individual country welfare would change responding to the policies of one country to internalise externalities when the other country does not have such policies, given free trade).

Policy failure leads to similar results. If policies do not appropriately address the externality, there is potential for over- or underproduction of the externality, and the good with which it is associated. In this case, where there are terms-of-trade effects, welfare in the exporting and importing countries could be affected.

G*lobal public goods*: Another case where trade could affect international income distribution is when some of the non-commodity outputs in certain countries have a global public good nature. Global public goods can be defined as public goods where the "benefits extend to more than one group of countries and do not discriminate against any population group or any set of generations, present or future" (Kaul, Grunberg, and Stern, 1999). As in the case of national and local public goods, there could be both pure and impure global public goods. If some non-commodity outputs in a country are global public goods, then there would be asymmetry between the costs and benefits associated with the provision of these goods unless international cost sharing arrangements could be established. This could lead to distributional problems as well as efficiency problems (*i.e.* the undersupply of global public goods). Typical examples of global public goods are international economic stability, international security, the international environment, international humanitarian assistance, and knowledge (Stigliz, 1995). It is also possible that global public "bads" would cause similar distributional problems.

In practice, there may not be many non-commodity outputs with a global public good nature. For example, non-use values of some non-commodity outputs could theoretically be global public goods because people in one country may place some value on the fact that there are some special agricultural landscapes in another country. However, the value for persons not living in the country generating the non-commodity outputs are quite likely much smaller than the value given them by that country's population. In this case, these non-commodity outputs should not be classified as global public goods in most cases.[83] Although difficult to judge without undertaking empirical studies, it seems unlikely that many non-commodity outputs have the nature of global public goods. A possible example is that social stability preserved by agricultural employment in some developing countries may contribute to international security. Regarding negative externalities, a typical example would be rivers that cross international borders being polluted by agricultural activities in the relevant countries. Migratory birds are also an example. Commodity production may have positive or negative effects on them.

In the context of the current analysis of the provision of non-commodity outputs, it does not seem cost-effective to pay a great deal of attention to the issue of global public goods at this stage; the costs associated with the increased analytical complexity and the possibility that some non-commodity outputs are likely to be categorised as global public goods make their incorporation into the analysis unnecessary at this time. The issue may be taken up later in the policy discussions if it is shown that some non-commodity outputs are global public goods and that a more in-depth report of the concept should be made.

D*eveloping countries*: The analysis can also be conceptually applied to developing countries. Most of the differences between developing and developed countries with respect to the discussions on multifunctionality are those of degree, not of kind. However, the differences in degree might have policy implications. Some factors that could empirically differentiate developing countries from developed countries are therefore highlighted here to assist future policy discussions. Although broad generalisations should be avoided, discussions in this section focus on the differences between developing and developed countries in income, the degree of importance of agriculture in the total economy, and levels of institutional and financial capacity of the public sector.[84] How trade affects economic efficiency and income distribution in developing countries when there is no externality is beyond the scope of this report, and therefore is not analysed.

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A first factor that may be different between developing and developed countries is that there could be differences in demand patterns for non-commodity outputs that are linked with the differences in income and in the stage of development. For example, the social demand for preserving rural employment in developing countries might be much greater than in developed countries because keeping the rural population from migrating to cities could be important for social stability. Tight current account balances and limited foreign exchange reserves in many developing countries may lead to their placing greater value on self-sufficiency in basic foodstuffs than developed countries do. On the other hand, the demand for landscape in developing countries might be smaller than that in developed countries, reflecting high income elasticities of demand. These differences could have policy implications, especially from a domestic equity point of view. If non-commodity outputs in developing countries mainly benefit lower income groups, as implied by the above examples, reduction in the provision of these non-commodity outputs could worsen social inequality.

Secondly, compared with developed countries, developing countries may face higher transaction costs associated with the provision of non-commodity outputs, and this could affect policy choices. For example, creating markets for non-commodity outputs may be ruled out if defining property rights is difficult due to insufficient institutional capacity. Lack of transportation infrastructure may be an obstacle to encouraging use values of some non-commodity outputs. Lack of transportation and communication infrastructure might also prevent people from organising voluntary groups for preserving non-commodity outputs on a large scale. Although there are many success stories in which people in small communities or villages have worked together to supply and maintain local public goods in developing countries,[85] the lack of infrastructure could cause difficulties when these goods cover greater numbers of beneficiaries. The World Bank (1994*b*), for example, stresses the importance of "involving the ultimate beneficiaries directly, for example, through town meetings", which would require at least basic infrastructure if a large group of people were involved.[86]

Thirdly, in developing countries, high administration costs in the public sector due to insufficient management capacity could also affect policy choices, by favouring policies that require less administration. For example, if collecting taxes and distributing them as payments to internalise externalities would lead to high administration costs, then in some cases payments might not be the first-best option even when they seem to be so from a theoretical point of view. Also, many developing countries rely more on tariff revenue than on revenue from income tax, as compared to developed countries. It could be argued that non-commodity outputs can be efficiently provided through tariff revenue, if the distortionary effects of the tariff are balanced by the benefits from the non-commodity outputs (Feehan, 1988). High administration costs in the public sector could also favour voluntary contributions, especially community provision, if non-commodity outputs show a local public good nature. This should be discussed in parallel with the issue of high transaction costs associated with organising people, as described above.

Fourthly, intergenerational income distribution could be a more serious issue in developing countries than in developed countries in the case of non-commodity outputs that are considered to be income elastic with some strong empirical confidence. As stated previously, estimating the demand of future generations for non-commodity outputs is almost impossible, and therefore cannot usually be incorporated in policy discussions. However, demand for some non-commodity outputs could be shown through empirical evidence to be income elastic in many countries. It is likely that the demand for these non-commodity outputs would increase as the income of developing countries increases. In this case, policies trying to internalise these externalities (non-commodity outputs) based on the current demand would lead to a reduction in welfare for future generations especially if the current policies irreversibly reduce the level of provision of these outputs. The same logic could be applied to some negative externalities.

Lastly, as shown above, the existence of non-commodity outputs (externalities) and policies to internalise these externalities would have international income distribution implications. Future policy discussions may have to pay special attention to this issue by taking into account the possible public good nature of international equity (Kapstein, 1999).

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Availability of information and multiple non-commodity outputs

The provision of multiple non-commodity outputs requires a great deal of information on the part of consumers, producers, and policy makers. In order to establish effective policies for the provision of non-commodity outputs, it would be necessary to have information on such things as the production relationship, the consumption relationship, the demand for each non-food output and its range (local, regional or national), the income elasticity of demand, the stability of each institutional arrangement, and the possible alternatives for the provision of non-food outputs. However, in the real world, there are many occasions when there may be less than full information in these areas. In these cases, the existence of inadequate information has important implications for the analysis of multiple non-commodity outputs. It is important to distinguish between asymmetric information in which only some of the concerned parties have the information and a more general information problem due to uncertainties and high costs associated with the collection of information.

For marketed goods, as conventional economic theory states, the existence of asymmetric information might lead to production and consumption that is over or under optimal levels. This is because the price of a marketed good is based on all available information. With incomplete or asymmetric information, the price may not be the same as in an otherwise identical situation with full information.

In the case of non-marketed goods, the effect of inadequate information could be more complex, since not only supply and demand need to be evaluated, but also the means of provision. There are a number of ways in which the analysis of goods, and their provision, could be compromised due to the presence of inadequate information. Some possible issues regarding the demand and supply of non-market goods and the impact of inadequate information will be considered in the following paragraphs.

Availability of information and demand for non-commodity outputs: Availability of information can have an important effect on revealing demand for non-commodity outputs, at the individual level and at a society-wide level. Inadequate information can make demand much more difficult to evaluate, and thus increase the possibility of market or policy failure in the provision of a good.

An initial need in terms of demand evaluation is that individual consumers know their own demand for a given good. Even at this basic level, however, lack of information may have an impact. Detailed information about the good may not always be available, for example. In the case of some environmental benefits, it may be difficult for an individual to obtain and understand the necessary technical information.

Consumption relationships further complicate the issue of individual and social demand for public goods. While an individual may be able to evaluate his own demand for a given non-commodity output in isolation, when its consumption relationship with other goods is considered, demand evaluation may be much more difficult.

An example of some of the concerns mentioned above is where an individual may have a high demand for clean air, and initially, therefore, have a high demand for the maintenance of a given piece of farmland that acts as a carbon sink. However, there may be a degree of scientific uncertainty about the actual effects of the maintenance of that particular farmland, as well as the possibility that if the farm is replaced by a factory there will be increased employment. Finally, it may also be possible to provide the environmental benefit in some other way. Thus, while demand for a given output may be high, because of production and consumption uncertainties and interrelationships demand for the farmland becomes much more difficult to determine, even at the level of the individual. At the level of society, these difficulties are compounded.

Regarding asymmetric information, there may be a need for decision makers to estimate total demand by society for a given good. Even supposing that it is possible for individuals to estimate demand, evaluating total social demand could be very difficult, as many studies using CVM or other methodologies have shown.

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Availability of information and supply of non-commodity outputs: The implications of the effect of inadequate information for the provision of non-market goods could be significant, both in terms of whether the good is supplied in optimal quantities, and in choosing the most efficient way to provide it. The following examples show many issues on the supply side could be associated with asymmetric information.

Different policies may be required to provide a good in the case of inadequate information as opposed to a situation where there is full information. For example, suppose that a non-commodity output has both a club good and a pure public good nature, and that sharing the cost to preserve the output between the club and the government would be the best strategy if all information were available. If information on the public good nature were missing, the best strategy might be to have the club pay the full cost, because cost-sharing with the government when there is a lack of information might not only lead to over provision, but also to free riding by the club. Also, in a case where government provision is the best choice in the presence of full information on demand, in the absence of such information, private provision may be the optimal choice. That is, lack of information has implications for the estimation of total demand, which in turn has implications for the optimal method of provision of a public good.

Incomplete knowledge regarding cost structures also seems likely to have an impact on the provision of positive externalities with opportunity costs. It might be in the provider's interest to exaggerate the cost of the provision of a good, which would lead to overall economic inefficiency. One method to get a more accurate idea of the cost of providing a non-commodity output could be an auction system, whereby potential providers would bid for a contract to supply a given output. Since the lowest price bid would win, an auction could provide an incentive for providers to reveal their costs more accurately (see, for example, Latacz-Lohmann and Van der Hamsvoort, 1997).[87]

There are also implications in terms of deciding who will provide the good in question. The optimal provider of the good may also depend on available information. One example is a situation where horizontal or vertical spillovers across local jurisdictions may indicate a need for provision of a local public good by the central government. Where a local government has more knowledge of local preferences than the central government, it may, in fact, be more efficient for the public good to be provided by the local government (Aronsson and Wikström, 1999).

It should also be considered that the local government may have incentives to alter its provision of the good, which may create a situation where it is better for the federal government to provide the good, despite its less complete knowledge of local conditions. Ulph (1998) provides the example of environmental regulations, where local governments may have an incentive to set lower than optimal standards for strategic reasons. In this particular case, it is concluded that the federal government should set uniform standards despite different cost structures across the set of local governments.

Implications for transaction costs: Inadequate information also has implications in terms of transaction costs. That is, while the information on demand or provision costs may be theoretically available, it may be that the costs of obtaining it are so high that it cancels out the benefit from the provision of the good. From this point of view, a means of provision of a non-market good should also be evaluated as to its effectiveness in obtaining and disseminating information. In this context, the impact of different types of information technologies may prove to be of interest. The type of information dissemination method available could have a direct effect on the optimal choice of action for providing a non-commodity output. Changes in technology may lead to changes in best strategies.

The main impacts that inadequate information has on the analysis are that it increases the difficulties involved in estimation of demand, and affects the choice of method of provision. The degree of information available must therefore always be borne in mind when making policy decisions. The evident importance of information, and the difficulties encountered in its partial or total absence, also point to a possible need for policies that act to overcome inadequate information. That is, a policy that provides more information to the various actors may be more valuable than a policy that provides less, all else being equal.

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NOTES

1. December 1998 meeting of the Committee for Agriculture and June 1999 meeting of the Working Party on Agricultural Policies and Markets of the Committee for Agriculture.
2. For example, Ver Eecke (1999) claims there are 13 definitions of public goods.
3. This definition could include both technical and pecuniary externalities, which will be discussed later.
4. As Bromley (1997) pointed out, differentiating between negative and positive externalities is not straightforward; nonetheless, this study uses the terms negative and positive externalities since they can still serve as the basis for conceptual discussions.
5. This five-group classification does not provide any practical guidance for policy-making unless the absolute marginal values of externalities are obtained. The classification, however, can still be useful in discussing how and when markets fail due to externalities.
6. These policies include: payments to farms (*e.g.* cost-sharing payments); taxes/charges on farm inputs; regulatory measures with compensation, etc. .
7. "Environmental reference levels are the levels of environmental performance, in terms of ecological, habitat and amenity outputs of any economic activity to be attained through the use of appropriate production practices at the producer's expense". For example, if the current situation is below the reference level, then farmers should bear the cost of raising their farming practices to the reference level.
8. For example, "non-production-linked environmental outputs".
9. "The inefficiency can persist if non-exclusiveness and non-rivalry are involved but in that case it is attributable to non-exclusiveness and non-rivalry, not to externality" (Randall, 1980).
10. Non-excludability and non-rivalry are detailed in the next section.
11. Assuming that viewing the landscape requires going through the entrance.
12. These policies could, however, make less efficient farmers continue cultivation although they might otherwise have been forced out of the production. This aspect of these policies may especially create problems if the policies are to pay for labour devoted to the production of externalities that otherwise would have been idle. In this case, the payment would just increase farmers' income.
13. Some simulation models use 0.1 or smaller as price elasticity of demand for a price inelastic commodity output. Then, even if a positive externality associated with the food production has a value equal to 10% of the production cost of that food product, the additional food product to be produced to meet the social demand for the externality would be just 1% of the production level at the market equilibrium.
14. If a positive (negative) externality is below (above) the reference level, the positive (negative) externality should be increased (decreased) to the reference level. However, this process can be explained under the framework of Type I.
15. A typical example is rice consumption in Japan. There is a study showing that the income elasticity of rice demand in Japan has been negative since 1970 (Mitchell *et al.*); the demand for rice in Japan decreases as income grows.
16. Exporting countries are discussed below in the section dealing with international income distribution.
17. This is related to the definition of trade distortion.
18. If the demand for output B is price inelastic, then the total production of B would remain unchanged. The production of B by the producers of A would lead to the elimination of less efficient producers from the production of B.
19. Although this issue is discussed in Part II and this part is based on the assumption that there are no lower cost suppliers, it is touched on here to stress the importance of examining alternative non-agricultural provision.
20. This will be detailed in the next section on public goods.

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21. Terraced farming in mountain areas may have positive externalities on soil conservation and land slide prevention although it should be tested whether terraced farming is better than other land use including forest.
22. It should be noted that bequest values are values placed by the current generation on food security for future generations. The discussion in this part does not intend to incorporate the demand by future generations (see also footnote in Annex 5).
23. Most pecuniary externalities are reflected in the prices of factor markets.
24. We should be careful about double-counting the externalities. For example, preserving agricultural population in a region could also contribute to preserving landscape; however, that effect should be accounted for as the landscape externality.
25. As stated, naturally released labour has only pecuniary externalities that could be adjusted in the labour market.
26. Even if there is a mismatch in the quality of labour between agriculture and the other sectors that have the potential to move to the region, it may still be possible for farmers to move to other sectors in the other region.
27. Per capita cost could be reduced if the entire population in a region moved to other regions and there were no need for providing public services to the region at all.
28. For example, Findeis and Jensen (1998) discuss the case of the US where "the problem is that there are not enough jobs that can provide an adequate income. Given this weakness, it is unreasonable to expect that rural areas, in particular, can provide any more than poverty-level employment for those willing (and needing) to work".
29. Policy failures will also be detailed in this section.
30. There has been substantial confusion as to the definition of public goods. The most serious one is whether impure public goods should be called public goods. Another one is the interchangeable and confusing use of the terms public goods and common property resources. The distinction between open access resources and common property resources is also ambiguous in many papers.
31. Randall proposed a 2X3 matrix (excludable and non-excludable *vs.* rival, congestible, and non-rival)
32. It is strongly recommended that Annex 4 be consulted for more detailed discussion on this because detailed classifications are essential for constructive policy discussions.
33. There could be various reasons for policy failure. This report focuses mainly on the failure to correctly estimate the demand for public goods. These policy failures are often also referred to as government failures (OECD, 1994).
34. Political and economic jurisdictions do not necessarily coincide. Olson (1969) defines that when these jurisdictions coincide, "fiscal equivalence" results. If they do not coincide, there may be sub-optimality in the provision of local pure public goods (Cornes and Sandler, 1996).
35. If local public goods are financed by the country's general tax revenue, then there is a strong possibility that municipalities will free ride on general tax revenues by overestimating the demand for their local public goods. Fiscal federalism (*i.e.* the separation of taxation and expenditure functions among levels of government (Hyman, 1990) should therefore apply to both the collection of taxes and the provision of public goods, in order to ensure that local public goods are provided efficiently. Inequity resulting from fiscal federalism, however, might also have to be considered.
36. The tragedy of the commons usually refers to the use of natural resources (especially renewable natural resources). However, all kinds of goods with open access and congestion in use share the problems of the tragedy of the commons.
37. A person who starts using the resource would also have to bear the congestion cost, which would be incorporated into the decision-making process. However, the total congestion cost for all of the users would be much greater than the congestion cost that the single person would have to bear.
38. There could be various other types of misuses of the resource in addition to this example. For instance, if a good is rival and non-excludable, the people who obtain use of the resource by chance are probably not those with the greatest willingness to pay for it.
39. Ostorm (1990) states that "the term 'common pool resources' refers to a natural or man-made resource system that is sufficiently large as to make it costly (but not impossible) to exclude potential beneficiaries from obtaining benefits from its use".
40. The second best is the best allocation of resources that is obtainable when various constraints preclude attaining true economic efficiency (Nicholson, 1985).
41. Cornes and Sandler (1996) provide the following definition of a club. It is broader than simply the provision of excludable and congestible goods, although in their economic analysis they refer to a club good as an excludable and congestible good:

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"A club is a voluntary group of individuals that derives mutual benefit from sharing one or more of the following: production costs, the members' characteristics, or a good characterised by excludable benefits."

42. "If a consumer experiences any consumer surplus from the apple, the forgone utility from giving up half of his apple exceeds the gains from sharing its costs and optimal club size is one" (Mueller, 1985).
43. As the degree of congestion increases, club goods may be provided more efficiently as private goods [see Reiter and Weichenrieder (1999) for more details].
44. CVM studies conducted by some OECD countries reveal that landscapes perceived as overcrowded have a lower willingness to pay (OECD, 2001*a*).
45. Visitors might be more sensitive to congestion than residents.
46. Non-use values could also be club goods as in the case of biodiversity, which will be discussed later in this section.
47. The Alps could be a typical example.
48. If a non-use value for the general landscape is divided for a specific site.
49. It may be reasonable to assume that landscape has most of the characteristics of a normal good including decreasing marginal value.
50. Some unique traditions or customs could be used as a tourist attraction, which are private or club goods.
51. If policing costs too much to a community, then these resources will be open access resources.
52. "Community" in this context is a community including both farmers and local residents rather than farmers' communities.
53. They could be private goods if commercial fishing or hunting is possible.
54. Dwyer and Hodge (1996) states that "it is common for them (environmental organisations) to offer some private benefits such as a magazine, an educational service, certain unique kinds of consumer products, or preferential access to their properties".
55. It should be noted that modern information technology could lead to difficulties in establishing these exclusion mechanisms.
56. King and Wainger (1999) provide good examples on how site specificity determines the value of each site.
57. This is partly because the site specificity does not guarantee decreasing marginal social utility.
58. These are in economic terms, not in financial ones.
59. This may not necessarily mean that farmers would be asked to continue farming; they could simply maintain flood control capacity without farming. The precise arrangement would depend on the cost/benefit analysis.
60. The association of flood control capacity with rice farming should be tested using the first question defined in the analytical framework.
61. A notable exception is food security for producers themselves, which could be classified as a private good (it is excludable and rival).
62. See Allen (1999) for issues on income distribution associated with food security.
63. Busch and Lacy (1984) state that ancient civilisations rose and fell based upon their ability to maintain a secure, stable food supply.
64. Food security is used in its general sense in this context; *i.e.* food security by all possible measures that include, of course, trade.
65. This is related to the fact that society sometimes perceives public goods as social justice (Heilbroner and Galbraith, 1987).
66. "In 1990, at the national level, full-time work was more important than part-time farming only in Canada, Ireland and United Kingdom" (OECD, 1998*c*).
67. The share of regional populations living in rural communities is more than 50% (OECD, 1996).
68. The joint-product theory in this context is different from the theory of joint production in the field of production theories.
69. If consumers' preferences for the externalities are "separable", then, each demand could be added (Deaton and Muellbauer (1993) provide a definition of separable preferences).
70. The original theory has a much wider meaning than that of encouraging voluntary provision.
71. Voluntary contributions are reaching substantial amounts in some countries. For example, voluntary money donations including the value of donated time in the US in 1989 amounted to almost 2% of GDP (Schiff, 1990).
72. Private land trusts in the US could be another example. There are 730 000 acres of farmlands protected by various conservation easement programs, half of which are by the private land trusts (Wiebe *et al.*, 1997).

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73. For example, Glomm and Lagunoff (1999) made an analytical study on how individuals would make location decisions over one of two hypothetical communities. In one community, (local) public goods are provided by voluntary contributions by the residents and in the other one these goods are provided by involuntary contribution (*i.e.* through tax). The result of the study shows that under certain conditions individuals would select the involuntary provision mechanism in the long run.
74. The growing number of environmental trusts in UK, for instance, cannot necessarily prove the stability of voluntary provision because most of them are quite "young" [the median age is nine years (Dwyer and Hodge, 1996)].
75. If a public good is provided through infrastructure development (*e.g.* public roads), then one-shot voluntary contributions to the investment project could realise the provision of that good, which could avoid the stability problem. However, in the case of multifunctionality, the need for investment projects is unlikely.
76. For a detailed discussion on logrolling, see Mueller (1989).
77. The distributional impact of agricultural policies on farmers' income is a separate issue. A discussion of this issue can be found in OECD (1999*c*).
78. Assuming that there is no difference in the degree of risk aversion between the rich and the poor. It might be possible that the degree of risk aversion itself is affected by the level of income, which may lead to the situation where food security would favour the rich more than the poor (*i.e.* in the case where the rich are more risk averse).
79. Although this could be guaranteed only on some strong assumptions including that full employment is achieved, etc.
80. As long as free trade could benefit all countries, possible issues associated with international income distribution could be smaller than the cases where some countries benefit and the other countries lose.
81. Assuming that landscape and food security can be traded off.
82. A discussion of the definition of trade distortions in the context of global welfare can be found in OECD (2001*b*).
83. It should, however, be noted that as information technology improves and global travel increases, both use and non-use values for various amenities may become increasingly global.
84. This section also avoids an explicit definition of "developing countries", although the discussions implicitly assume they are those countries with the lowest per capita income.
85. Typical examples of these local public goods are village roads, drinking water from wells and small scale irrigation systems.
86. Gender issues may have to be highlighted when voluntary organisations are discussed. For example, depending on whether there is some gender-related difference in participation in the voluntary sector, women in some countries who already suffer from overwork in their production activities might face additional loads by joining voluntary organisations.
87. This cannot be applied to the case of externalities without opportunity costs.

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Annex 1

A NOTE ON THE CONCEPT OF JOINTNESS IN PRODUCTION*

Introduction

It could be argued that the subject of joint production is among the most neglected in production economics (Shumway *et al.*, 1984). Nonetheless, a number of definitions of joint production are found in the literature. Some of the alternative definitions describe slightly different phenomena, while others attempt to distinguish among the various causes of joint production (Leathers, 1991).

As the multifunctional attributes of agricultural production are increasingly recognised, it becomes important to understand the extent to which characterising multifunctionality within a joint production framework can clarify the concept, inform the agricultural policy debate, and ultimately influence policy reform. With an expanding capacity to model the complexities of agricultural production systems, the ability of agricultural economists to understand the causes of joint production and multifunctionality at an empirical level has never been greater.

The discussion in this annex begins by briefly reviewing economists' historical interest in the subject of joint production. Next, some definitions are provided. The implications of joint production for agricultural supply and price formation are then examined using an example of two private goods. This example sets the stage for expanding the notion of joint production to encompass non-commodity outputs of agriculture, particularly those with an externality or public good dimension for which no markets exist.

Historical background

Throughout the literature, joint production is defined to encompass all production situations in which two or more outputs or products are technically interdependent (Shumway *et al.*, 1984). The classic definitions of joint products offered by earlier authors such as Marshall (1959) and Carlson (1956) refer to things which cannot be produced separately, but are joined by a common origin. The examples provided include wool and mutton from sheep; wheat and straw; or oil and meal from soybeans. These products are often thought to represent one extreme of the definition: production in fixed proportions, although in reality even here the proportions can vary within narrow ranges. At the other extreme, there are joint products for which the proportions can vary more widely and do so in response to relative price changes.

While there are some obvious examples of joint production in agriculture, other joint products are less apparent. If it were not for the fact that "jointness" in production affects decisions at the firm level, interest in the topic would have remained largely academic.

At its most fundamental level, the notion of joint production was introduced in an attempt to explain the existence of multiproduct firms (Baumol *et al.*, 1981). By assuming free entry and exit of firms, the authors are able to show that multiproduct firms will exist only if joint production is less expensive than separate production.[1]

In an early empirical study to understand domestic and foreign demand for soybeans, Houck and Mann (1968) were among the first to articulate how joint production relationships affect product supply and price determination.

More recent efforts have been directed primarily at studying the implications of joint production and resource use for estimating complete systems of agricultural supply and factor demand (Shumway *et al.*, 1984; Leathers, 1991). The notion of joint production is also important in understanding the extent to which one can identify output-specific input requirements (Paris and Howitt, 1998; Lence and Miller, 1999).

Since much of the emphasis of these papers is on the implications for modelling supply and factor demand systems, these analyses are based on the assumptions that all outputs are private and that markets exist for all inputs and outputs. Where there are well-defined markets for the joint (private) outputs (*e.g.* wool and mutton, or meal and oil from soybeans), output supply and factor demands respond to relative prices as they do in situations where production is non-joint. The nature of the response is affected by the joint production relationship, but private markets still function efficiently. In this case, joint production is neither a necessary nor a sufficient condition for the need for policy intervention.

* This annex is based on a contribution by Professor Richard N. Boisvert of Cornell University, United States, who acted as an outside reviewer for Part II of this report (on the production aspects of multifunctionality).

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This is not the case when joint production encompasses those multifunctional outputs that are either positive or negative externalities or public goods. After defining precisely the conditions giving rise to joint production, we address these issues directly.

Definitions and nature of joint production

A *formal definition*

Since joint production encompasses all production situations in which two or more outputs or products are technically interdependent, joint production of outputs, Y_j (j = 1,…, m), and inputs, X_i (i = 1,…, n) can be described by an implicit transformation function:

$$F(Y_1,\dots, Y_m; X_1,\dots, X_n) = 0 \quad (1)$$

to which the restrictions implying non-joint production do not apply. The most commonly quoted conditions for non-joint production are due to Lau (1972, p. 287):

***Condition* 1.** The production function is nonjoint in inputs if there exist individual production functions F_i such that:

$Y_i = F_i(X_{il},\dots, X_{im})$ and $X_j = \Sigma_m X_{ij}$ imply $F(Y_1,\dots, Y_m; X_1,\dots, X_n) = 0$.

***Condition* 2.** The production function is said to be nonjoint in outputs if there exist individual input requirement functions, G_j such that:

$X_j = G_j(Y_{lj},\dots, Y_{mj})$ and $Y_i = \Sigma_n Y_{ij}$ imply $F(Y_i,\dots, Y_m; X_i,\dots, X_n) = 0$.

While the two conditions provide the mathematical conditions for when there are no technical economies or diseconomies in the production of multiple outputs or the use of multiple inputs, they are not easy to interpret. They say little about what forms of the implicit transformation relation, F, correspond to a joint production setting. Rather, the definition speaks to conditions that imply non-joint production, and provides only information about those functions for which jointness can not apply. Further, these definitions offer little by way of understanding the causes of jointness. Therefore, to understand the nature of joint production, it is best to outline the conditions that give rise to joint production, and then restate the conditions for jointness in terms of cost and profit functions.

T*he causes of joint production*

In essence, joint production is given where two or more outputs produced by a firm are interlinked. These interlinkages arise because:

i) there are technical interdependencies in the production process;

ii) outputs are produced from a non-allocable input; or

iii) outputs compete for an (allocable) input that is fixed at the firm level.

In reality, the three sources of product interlinkage may occur in various combinations and proportions, but for ease of exposition, each is discussed separately.

When the interlinkage between the outputs is caused by ***technical interdependencies*** in the production processes, production of either output depends not only on the amount of the factor allocated to this output, but also on the level of the other output. This can be written as follows:

$$Y_1 = F^1(Y_2, X_1);\ Y_2 = F^2(Y_1, X_2);\quad X_1 + X_2 = X \quad (2)$$

Interdependencies of this type arise if an increase in the level of one output affects the marginal productivity of the factor used in producing the other output. If the marginal productivity increases, the two outputs are ***technically complementary***; if it declines, the outputs are ***technically competing*** (Beattie and Taylor, 1985). Alternatively, there are no technical interdependencies if the input requirement responds to a single output (Shumway *et al.*, 1984).

Jointness caused by technical interdependencies implies the presence of economies or diseconomies in production. An example of technical interdependencies might be the joint production of honeybees and fruit trees, where the trees depend on insect fertil isation but also provide feed for the bees.

The case of product interrelationships that may be the most relevant for the analysis of multi-functionality is where ***non-allocable inputs*** are used in the production of multiple outputs, that is, where the outputs are obtained from one and the same input.[2] Denoting the non-allocable input by Z, we have:

$$Y_1 = F^1(Z);\ Y_2 = F^2(Z) \quad (3)$$

The classical examples, production of mutton and wool obtained from feeding sheep, and oil and meal from crushing soybeans, fit this category nicely, as does the production of meat and landscape by grazing cows on pasture.

In the third case, the amount of the factor used in the production of each output can be distinguished from the amount of the same factor used in the production of the other outputs, but the total amount of the factor available to the enterprise is fixed (***allocable fixed factor***). An example would be a farm producing several commodities from a fixed land base.

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For the single input, two-output case, the production relationships can be represented in the following way:

$$Y_1 = F^1(X_1); \quad Y_2 = F^2(X_2); \quad X_1 + X_2 = X \tag{4}$$

Although the factor can be allocated to the various production activities, where each activity is represented by a production function, the outputs are interconnected. An increase in the production of one output reduces the amount of the fixed resource available for the production of the other output, and *vice versa*. As a consequence, the marginal productivity of a variable factor used in the production of an output is likely to be influenced by a change in the production of the other output.[3]

Many authors argue that this case of an allocable fixed input is especially representative of agriculture. Most farms produce more than one product, the amount of land allocated to a particular product can virtually always be determined, and the land available to the farm is often fixed in the short or medium run.[4] However, when this argument is made, the discussion focuses primarily on private outputs for which there are established markets. The same argument may not apply for many of the non-food multi-functional characteristics of agricultural production. We return to this issue below, but before doing so, it is useful to characterize these three joint production situations in terms of the firm's cost structure.

The nature of joint costs

Leathers (1991) relates the notion of joint production to cost and profit by appealing to the notion of ***economies of scope***, which can be defined in a somewhat simplified manner for our purposes in the following way. For any group of outputs, $Y_1,\ldots, Y_m$, there are economies of scope if:

$$C(Y_1) + C(Y_2) + C(Y_3) + \ldots + C(Y_m) > C(Y_1,\ldots, Y_m) \tag{5}$$

That is, if there are economies of scope, the cost of producing the m products jointly, $C(Y_1,\ldots, Y_m)$, is less than the cost of producing the products separately.

This way of looking at joint production focuses directly on the technological interactions among outputs. In case *i*) from above, there are cost complementarities in production where the increase in the production of one good leads to a reduction in the cost of the other. In case *ii*), the interaction occurs because the two products share some fixed cost or common origin (*e.g.* the sheep in the case of wool and mutton or the soybean in the case of meal and oil).

These conditions, however, do not address directly the situation when joint production occurs due to an allocable input that is fixed in the short run. Here, Leathers (1991) establishes that joint production will occur if and only if joint production is at least as profitable as non-joint production of either product.

This latter condition is especially important for multifunctionality, when some of the non-food inputs are in the form of public goods or externalities for which there are no markets, or whose social value is ignored by the farmer in any production decisions. If there is no public policy intervention to internalize the externality, joint production will clearly be less expensive (or at least no more expensive) than separate production. Here the farmer does not have to deal with the social benefit or cost of the non-commodity output. There is a natural level of animal waste or nutrient pollution associated with the profit maximizing input levels to produce the animal or crop products. If production methods or input levels must be changed to reduce the output of these non-commodity outputs (or eliminate them altogether, implying non-joint production), profits will fall. Clearly, joint production is more profitable. At the other extreme, if the social value or social cost of a non-commodity output were sufficiently large, the condition for separate production may obtain if the farmer is rewarded sufficiently for the non-commodity output's value or is forced to absorb its substantial cost.

As demonstrated in Annex 2, the nature of the economic interdependence is hidden in this circumstance because the value of the public good, be it positive or negative, is not recognized explicitly as are the prices and costs of the other inputs and outputs. This is a major source of concern in attempts to identify the joint production relationships between commodity and non-commodity outputs from agriculture. Agricultural data bases rarely, if ever, contain sufficient information to document the levels of these public good outputs; to articulate the technical relationships with the production inputs; and to predict changes in their levels due to changes in input and output prices or policy incentives. These issues are addressed more directly below.

Jointness, dual indirect profit functions, price response, and output supply for many outputs

Following Shumway *et al.* (1984), we use Lau's terminology to restate the conditions for non-jointness in terms of indirect profit functions.

Non-jointness in outputs

A necessary and sufficient condition for non-jointness in outputs is that the profit function be additively separable in input prices of the form:

$$\pi = \Sigma_n \, r_i \, H_i(p/r_i) \tag{6}$$

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where π is profit, H_j is the individual profit function for the jth input, r_j is the jth input price, and p is the vector of output prices (Lau, 1972, p. 288). From duality theory, we know that the input demand function for factor j is the partial derivative of this profit function with respect to its price, $r_j - \partial\pi/\partial r_j$. Further, because the H functions are additively separable in the case of non-jointness, each one depends only on one input price, implying that:

$$\partial^2\pi/\partial r_i \partial r_j = \partial X^*_j/\partial r_i = 0 \ (j \neq i) \tag{7}$$

Therefore, non-jointness in outputs implies that the demand for any input does not respond to changes in another input's price.

Correspondence with interdependence among inputs

Relative to our discussion above, jointness in outputs implies that the above expression is non-zero; when examined in pairs, inputs are either economically complementary or economically competitive.

Most agree that non-jointness in outputs occurs rarely in agriculture, a contention that is confirmed by overwhelming empirical evidence from numerous studies of agricultural factor demand (*e.g.* Ball, 1988). From this discussion, it is fair to conclude that for agriculture, most, if not all inputs are economically interrelated in the sense that demands for any single factor are affected by changes in the prices of all other factors. Whether the effects are in a positive or negative direction is an empirical question. Since these inputs are used in the production of multifunctional outputs, these interdependencies have policy significance. The interrelationships between the various commodity and non-commodity outputs from agriculture, have to do with whether or not production is joint or non-joint in inputs. They have policy significance as well.

Non-jointness in inputs

According to Lau (1972, p. 288) a necessary and sufficient condition for technology to be non-joint in inputs is that the profit function be additively separable in output prices of the form:

$$\pi = \Sigma_m \, p_i \, F_i \, (r/p_i) \tag{8}$$

where F_i is the individual profit function for the ith output, p_i is the ith product price, and r is the vector of input prices. Following logic similar to that above, the partial derivatives of this indirect profit function are the individual output supply equations. Since non-jointness implies the F_i's are additively separable in output prices, non-jointness in inputs is equivalent to:

$$\partial^2\pi/\partial p_i \partial p_j = \partial Y^*_i/\partial p_j = 0 \ (i \neq j) \tag{9}$$

In words, this suggests a situation in which the supply of an agricultural good is affected by changes in its own price, but not by the prices of other goods.

Correspondence with interdependence among products

Again, drawing a parallel from the discussion above, jointness in inputs implies that the above expression is non-zero, and the supply of agricultural goods is affected by other output prices. When examined in pairs, outputs are economically complementary, economically competitive, or economically independent.

For example, if, on a farm or at the market level, the supply of corn responds to soybean and wheat prices, jointness is implied. This suggests that jointness is probably descriptive of the supplies of most agricultural commodities since many conventional supply models (*e.g.* Shumway *et al.*, 1984; Williams and Shumway, 1998; Weaver, 1983; Chambers and Just, 1989; Ball, 1988, and Ball *et al.*, 1997); report "statistically significant" non-zero coefficients corresponding to Equation (9).

It is equally clear that there is joint production between most commodity and non-commodity outputs either because allocable inputs are fixed in the short run, or joint products come from non-allocable inputs. Some obvious examples in addition to those mentioned above include:

- commercial fertiliser inputs leading to the joint production of one or more crops and fertiliser leaching or runoff which potentially creates quality problems in surface and/or ground water;
- fixed land inputs leading to the joint production of several competitive commodities, landscape amenities, and soil erosion;
- labour leading to joint production of commodities and rural economic viability through direct and indirect rural employment generated from labour employed on the farm;
- chemical inputs leading to joint production of commodities and residuals released into the environment affecting wildlife populations and the health of farm workers or consumers of fresh farm products; and
- small farms using organic inputs leading to joint production of commodities, visual amenities from small scale production technologies, and responding to some food safety concerns for consumers.

In all but the second example, the same units of a single input contribute to commodity and non-commodity outputs. There is no way to separate the inputs' contributions to each. They all are "text book" cases of jointness in production due to a non-allocable input and/or to a fixed allocable input.[5] Further, it is unlikely that the joint

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production occurs in fixed proportions. Finally, when taken together on a diversified farm or agricultural sector, these and other joint production relationships clearly occur simultaneously. It is for this reason that models of joint production to report the policy implications of a multifunctional agriculture must accommodate more than two outputs, and allow for the case where some of the non-commodity outputs are competitive and others are complementary with the commodity outputs. Contrary to some notions of multifunctionality that acknowledge only the positive joint non-commodity outputs (such as cultural and landscape amenities, contributions to rural vitality, and food safety), it is critical from a policy standpoint that we also recognise explicitly those joint, but undesirable, non-commodity outputs (such as risks to health from chemical exposure and water contamination).

Now that joint production has been defined in several ways and its causes have been examined, it is important to understand the implications of jointness for output supply and price determination. It is the effect of joint production on these issues that have implications for the supply of multifunctional non-commodity outputs, both with and without policy intervention. This understanding is accomplished below by first discussing a conventional case of joint production when all goods are private goods. Next, we extend the analysis to accommodate externalities and public goods. To illustrate the major points most effectively, the discussion is couched in terms of simple supply and demand diagrams.

A conventional illustration of joint production

To illustrate the significance of joint production, let us consider the simple case of joint production where two products are generated in fixed proportions from one base commodity. Soybean oil and meal are good examples (Houck and Mann, 1968).[6] To obtain one of these items, the other must be produced as well, and once the annual crush of soybeans is known, the supplies of meal and oil are fixed.[7]

Since their supplies are bound together by these technical processing constraints, differing growth rates in demand produce unique price and production patterns. The two-dimensional diagrams in Figure A1.1 are a simplified version of the analysis by Houck and Mann (1968), but they illustrate the essential relationships.

The total demand for soybean meal at wholesale, D_m is shown in panel D. This could include both domestic and export demand, where p^m and q^m are the price and quantity of meal, respectively. Similarly, the total demand for oil, D_O, is in panel C; p^o and q^o are the price and quantity of oil, respectively. The units on the two quantity axes are the amount of meal and oil, respectively, that can be produced from a tonne of soybeans.

To reflect the technically fixed crushing yields for meal and oil, the q^m and q^o axes are lined up. Thus, the total demand functions for meal and oil are added vertically to form the average revenue function R in panel B. If we ignore any crushing margin to avoid unnecessarily complicating the diagram, this average revenue function becomes the crushing demand for soybean, q^s.[8] Let us assume, again for simplicity, that there is no export or other demand for beans. In this case, this average revenue curve represents the total demand for beans. The curve is then simply transferred to panel A as D_B in panel A so that the intersection with the supply curve for soybeans, S_B, can be determined.

In the market equilibrium, demand and supply of beans are at q^{s0} and p^{s0}. Demands for oil and meal are at q^{o0} and q^{m0}, and the prices are p^{o0} and p^{m0}, respectively. Houck (1964) shows that where joint products are produced in fixed proportions from a basic commodity, the price elasticity of demand for the basic commodity is the weighted average of the price elasticities of demand for the joint products. The weights are given by the proportion of the value of the basic commodity attributable to each product.

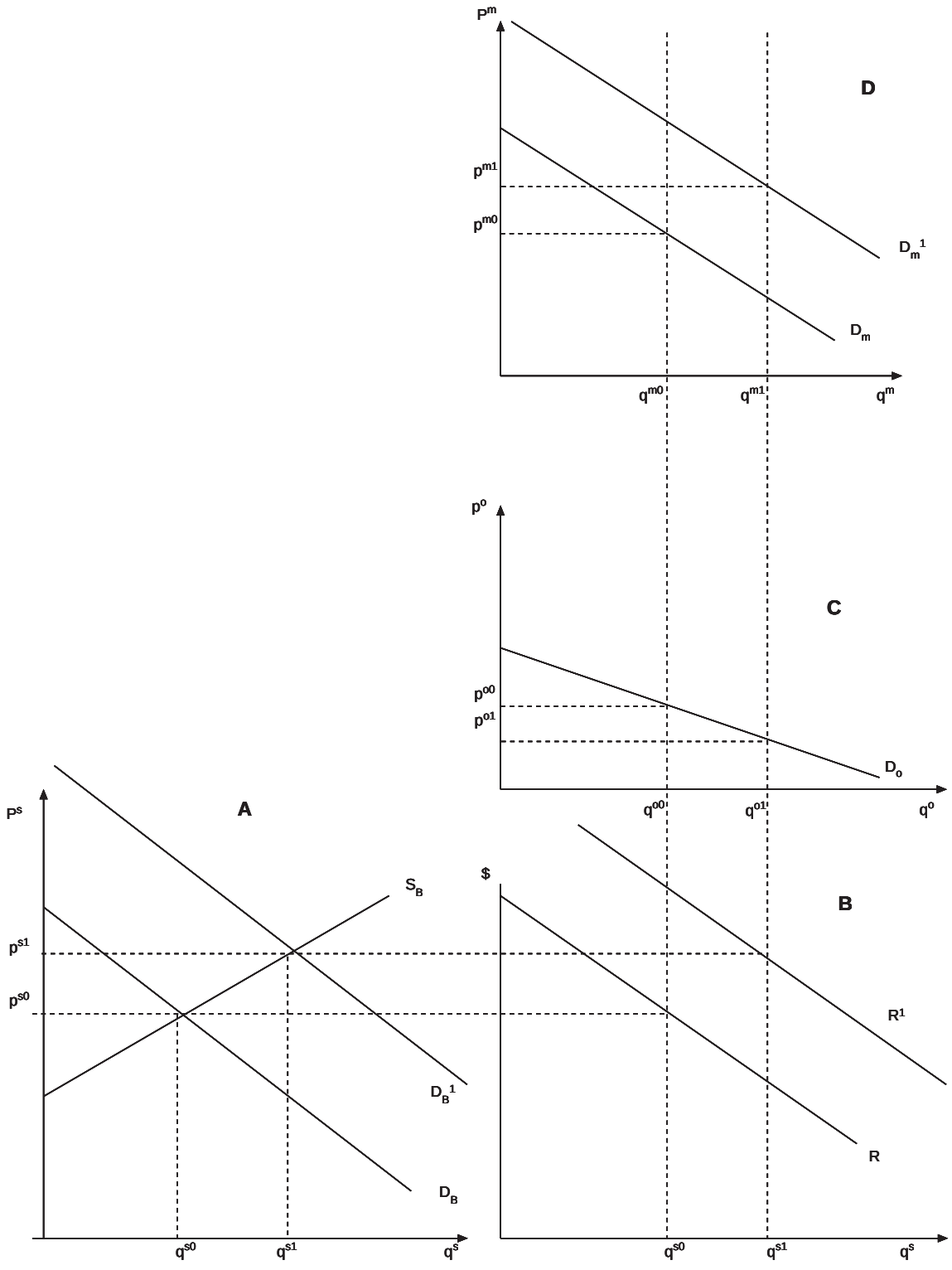
The implications of joint production are perhaps best understood by considering a shift in demand for one of the joint products. Suppose the demand for meal shifts from D_m to $D_m{}^1$. Because of the vertical addition of product demands, R shifts to R^1 and D_B shifts to $D_B{}^1$. The new equilibrium supply of soybeans is now higher – q^{s1}, at a price of p^{s1}. The demand (and supply) for meal is now higher as well, q^{m1}, and the new higher price is p^{m1}. Although nothing happened initially to the demand curve for oil, more supply is now available, q^{o1}. For the market to clear at this higher volume, the price of oil falls to p^{o1}.

An important lesson to be learned from this exercise is that, if products are produced jointly, a shift in the demand for one of the products can lead to a shift in the supply of the other, even though their markets are in no way related (*e.g.* the products are neither complements nor substitutes for one another in demand). Both markets clear because the prices in both markets can adjust appropriately. In the case where products are jointly produced, but the proportions can vary over some range, an increase in the demand for one product would still affect the supply of the other, but the magnitude of the effect would depend on the extent to which the proportions could change.

Now that the essential elements of joint production have been outlined, the analysis can be extended to encompass multifunctional non-commodity outputs. This extension is more straightforward with respect to some classes of non-commodity outputs than it is for others. It is important to emphasise that if markets exist for these non-commodity outputs, the markets will allocate production and inputs appropriately. In cases where markets do not exist, we can still examine the market clearing conditions, and illustrate how these might change if public policies are adopted to move the levels of the non-commodity outputs closer to what is optimal from society's point of view.

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Figure A1.1. **A simplified graphic model of markets for joint products**



Source: OECD.

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The multifunctionality case

Simple models of joint production with two outputs – one being a non-market externality

To see how the multifunctionality case can be cast into the joint production framework, the example of corn production is examined. In contrast to the situation above, the joint product is not a commodity but a ***negative externality***: an environmental residual in the form of fertiliser leaching and runoff. The other marked difference from above is that there is no market for this residual. Unless there are policies in place to provide incentives to do otherwise, farmers' decisions on how to produce corn are largely independent of the level of the fertiliser residual associated with the least-cost production strategy. The residual has no value to the farmer, and there is no consideration given to the residual's negative value to society.

The analysis proceeds as above. To simplify, it is assumed that the environmental residual is produced in fixed proportion with corn. This assumption is clearly a simplification of reality as fertiliser leaching and runoff may well increase with corn yield. However, the essential elements of the analysis are unaffected by this simplification. We can see that this situation conforms to the definition of joint production in the following way: any strategy to produce a given corn yield using production techniques to ensure a reduced (or zero) level of fertiliser leaching and runoff is more costly than the commonly used practices for producing the same yield but which also generate some fertiliser residual.[9]

A graphical representation of this situation is given in Figure A1.2. Total demand for corn is given in panel D. Panel C represents the level of the environmental residual. The supply of the residual is measured along the horizontal axis, but in contrast to the situation in Figure A1.1, there is no demand curve in panel C because there is no market demand for this residual. The axes in panels B, C, and D are aligned vertically to represent joint production. The vertical summation of the demands in panels C and D yields the average revenue curve R in panel B. Since there is no demand for the residual, R is equal to D_c. In the initial market equilibrium, corn supply is q^{c0}, and the market clears at a price of p^{c0}. The initial supply of the environmental residual is q^{e0}. If there were an increase in the price of corn due to an outward shift in the demand for corn, the supplies of both corn and the fertiliser residual would increase beyond q^{c0} and q^{e0}. Since this analysis is so similar to the one in Figure 1, it is not shown in the graphs.

It is more instructive to examine the implications of the environmental externality in this case. Since the farmer initially ignores the social cost of this externality, it is likely that q^{e0} will be above the socially optimal level of the environmental residual. The set of graphs can be used to examine the effect of a tax on this source of pollution. If each unit of the environmental residual is taxed at a rate of t (in panel C of Figure A1.2), then the average revenue from corn will be reduced by this much and the average revenue curve in panel B will shift down by the amount of the tax. The new equilibrium will be at a corn price of p^{c1}; production of corn and the environmental residual will be reduced to q^{c1} and q^{e1}, respectively. Because of the joint nature of production, the supply of corn falls despite the fact that there is no shift in the demand curve for corn. The market for corn still clears because the price of corn can rise.

This same diagram could be used to illustrate the case of a ***positive externality***. For example, consider the joint production of meat and landscape by grazing cows on pasture. To analyse this case, the graphs would have to be labeled differently. The top graph would represent the demand for meat, while the middle one would reflect the supply of landscape amenities, for which there is no market. The farmer would ignore the supply of landscape amenities in his/her meat production decisions. To encourage a greater supply of landscape amenities, a payment to the farmer could be made at a constant rate per unit of the amenity, somehow measured. This would be represented by a horizontal line above the axis in panel C above the horizontal axis. The distance between the origin and the line would reflect the level of the payment, which would be added to the farmer's average revenue (assuming that landscape amenities are produced in nearly fixed proportion to meat). As a result of the payment, the output of meat would increase, as would the supply of amenities. For the market for meat to clear, the price would have to fall.

A couple of things must be emphasized in both these examples. First, if the value of either the negative externality or the landscape amenities were known, the tax or payment could be set so that both the output of meat and the output of the non-commodity output would be at socially optimal levels.

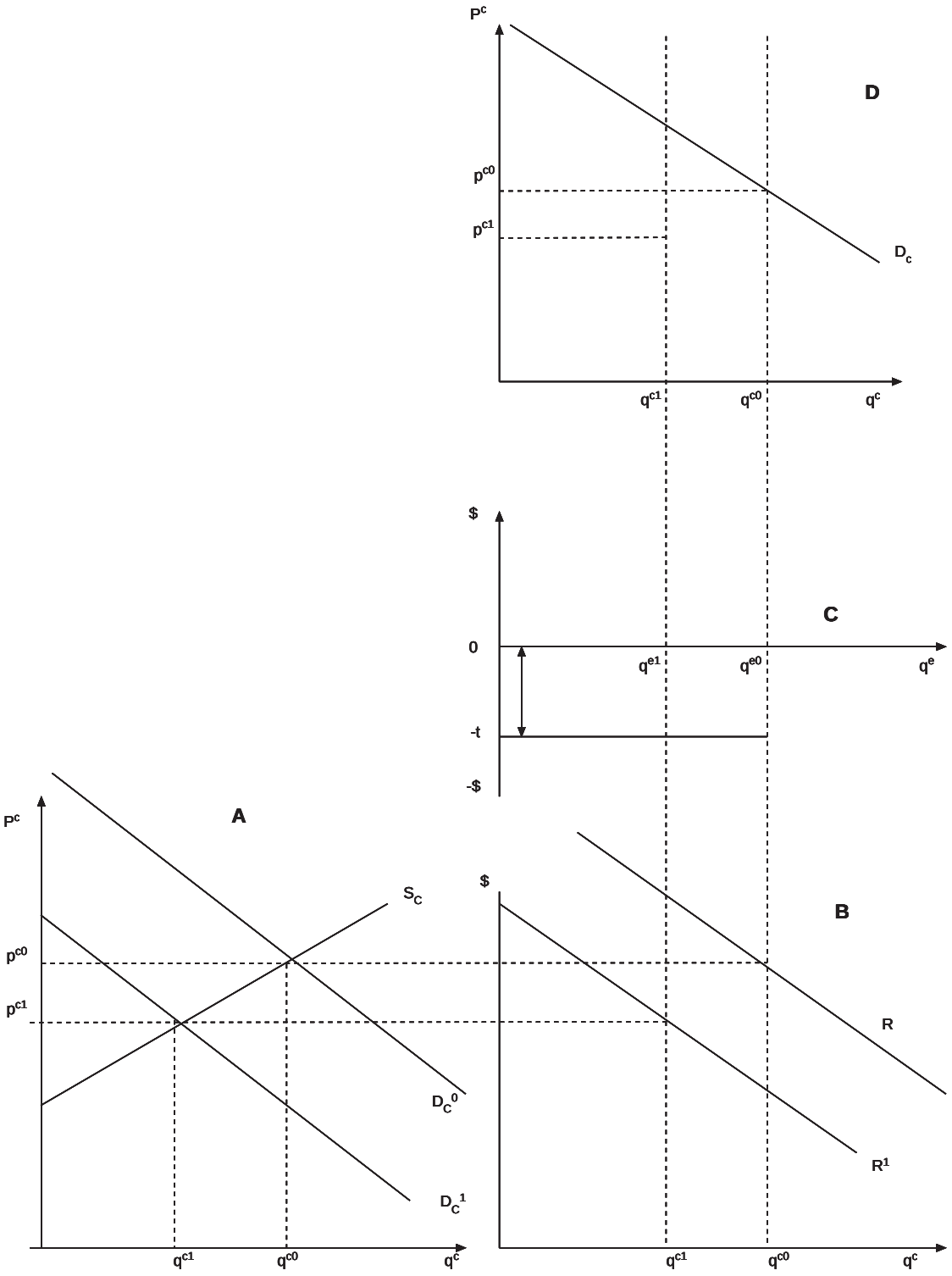
Second, in the case where the non-commodity output is a true non-exclusionary public good, the demand for the good is derived by the vertical summation of the demands across all individuals. Put differently, there is "jointness in consumption" since all people consume the same level of the public good. This is analogous to summing the demands for oil and meal.

The significance of having no markets for some outputs

These simple cases of joint production are instructive, both in introducing the concept and in highlighting potential difficulties in generalising too readily to more realistic situations. Thus, before moving on to situations where production is not in fixed proportions, a couple of final comments are in order. First, if the social value of

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Figure A1.2. **A simplified graphic model of markets for joint products, where one of the goods is an externality**



Source: OECD.

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either the negative externality or the landscape amenities were known, a tax or payment could be set so that non-commodity, multifunctional outputs would be at socially optimal levels. Further, since production is in fixed proportions with commodity outputs, it would be easy to calculate the optimal level of tax or payment, even though it is difficult to observe the actual non-commodity outputs. In this extreme case of production in fixed proportions, socially optimal levels of the externalities could also be achieved through appropriate taxes or payments on the commodity outputs themselves.

When, as is the more realistic case, commodity and non-commodity outputs do not occur in fixed proportions, it will be apparent that a tax or payment on the commodity output would no longer be the efficient mechanism for internalising the externality. The fact that non-commodity outputs are not easily measured or observed further complicates the situation, as does the case when both positive and negative externalities are produced simultaneously with commodity outputs.

General models of joint production for multiple (more than two) outputs

In generalising these ideas to more than two outputs, we must account for the fact that joint production is rarely, if ever, in strict fixed proportions. Fortunately, by relaxing this assumption, and by accommodating more than two outputs, we can still capture the critical aspects of joint production in a relatively simple model – one that includes two commodity outputs, and one positive externality and one negative externality.[10] If this were not the case, we could learn very little about the policy significance of joint production, and generalisations would be nearly impossible.

In our model (which is specified algebraically and analysed mathematically in Annex 2), we assume each of the two agricultural commodities is produced with only two inputs, land and a purchased input. In reality, of course, other inputs such as labour and machinery are involved in production, as are other purchased inputs. One interpretation of our model is that labour and machinery inputs are needed in fixed proportion to land, and that all purchased inputs are used in fixed proportion as well. Thus, the model accommodates substitution among major types of inputs, but not among inputs within a major group, and this level of complexity is not essential for our purposes, and the results do generalise to more than two inputs.

Similarly, we assume that an environmental residual, that damages the environment, is associated only with the purchased input used to produce commodity 1. Production of the residual increases exponentially with the application of the purchased input, but pollution declines if, *ceteris paribus*, production of good 1 becomes more land intensive. In this case, production of the environmental residual and good 1 is joint because they both require the non-allocable purchased input. There is no way to isolate the separate contribution of the purchased input between good 1 and the residual. Interestingly, the purchased input in this case is allocable between the two market commodities.

Landscape amenities are produced by land allocated to both commodities. Amenities rise with the amount of land in agricultural production, but they rise at a decreasing rate. In terms of the two commodity outputs, land is an allocable input, but it is non-allocable between both commodities and the production of landscape amenities. Thus, when the amenities are considered explicitly, production is joint as well.[11]

It can be tempting to conclude that some of the commodity outputs are involved in the actual production of non-commodity outputs because production is joint. There are undoubtedly a small number of examples of where this is true – the case of an intermediate product, for example, but this would be the exception, rather than the rule. Instead, as we have assumed in the algebraic model in Annex 2, it is more likely that conventional inputs, such as land, labour, capital, and purchased inputs, are combined to produce both commodity and non-commodity outputs. It is how these inputs are combined that leads to jointness in production, and the nature of the technical interdependencies is summarised empirically in the specific functions.

Clearly, the choice of "production" functions matters, but for other reasonable specifications, the qualitative results of our analysis would remain unchanged. They would differ only in degree.

The differences in production and jointness due to spatial variation in land productivity and vulnerability to erosion and leaching or aesthetic characteristics, for example, could also be accommodated in our analysis by changing the parameters of the four "production functions" (Equations 1a-4a) in Annex 2. A constant greater than unity, or a larger exponent on the purchased input variable in the function for the environmental residual would reflect more vulnerable soils, for example. For farmland in particularly scenic or culturally important areas, the exponent on the production function for landscape amenities might be considerably larger than the value we assigned.

Empirical estimates of production functions for commodity outputs date to the early 1940s as suggested above, but similar empirical relationships for non-commodity outputs are rare. Boisvert *et al.* (1997) provide one possible exception. They estimate environmental nitrate leaching and runoff from corn production for a broad range of soils and weather conditions.

Based on a careful report of the technical analysis in Annex 2, we are assured that all four outputs are joint products, a fact that is demonstrated by an *ex post* algebraic analysis of these four production functions. We are able

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to verify that as commodity outputs expand, the additional inputs needed in their production contribute jointly to an expansion in the non-commodity outputs, but not in the same proportion. This is the essence of jointness in inputs.

As output 1 expands along the profit maximising expansion path, the environmental residual increases proportionately more. The two goods are technical complements, but because the environment deteriorates with production of the residual, good 1 and the environment are technically competitive. As either commodity output expands, the supply of the amenity goes up less than in proportion to the commodity outputs. They are also technical complements.

The technical interdependence between joint commodity and non-commodity outputs is easily demonstrated in this way, but, in contrast to the case of jointly produced private goods (*e.g.* Case 2 in Annex 2), there is no evidence of any economic interdependence. It is only after one incorporates the social values or social costs of both non-commodity outputs into the farmer's decision model that this economic interdependence is revealed. Put differently, if farmers are not forced to account for the social costs and benefits of their production decisions, there is no economic linkage between the technically interdependent commodity and non-commodity outputs.

It is only after accounting for the social costs and values of these non-traditional outputs, that the indirect profit function becomes non-separable in all prices. The set of "prices" now, however, includes the conventional input and output prices, as well as the "social prices" for the two non-commodity outputs; the supply functions for all outputs (the derivatives of the profit function with respect to the prices) depend on this expanded set of "prices" also. Since the "social value" of conventional outputs and inputs are equal to the private values as reflected in market prices, we are now able to compare the economic implications of joint production of commodity and non-commodity outputs on an equal footing. Algebraically:

$$S^1 = \partial\Pi^*/\partial P_1 = S^1 (P_1, P_2, T_e, S_a, P_L, P_Z); \quad (10)$$

$$S^2 = \partial\Pi^*/\partial P_2 = S^2 (P_1, P_2, T_e, S_a, P_L, P_Z); \quad (11)$$

$$S^a = \partial\Pi^*/\partial S_a = S^a (P_1, P_2, T_e, S_a, P_L, P_Z); \text{ and} \quad (12)$$

$$S_e = \partial\Pi^*/\partial T_e = S_e (P_1, P_2, T_e, S_a, P_L, P_Z) \quad (13)$$

By examining the first-order conditions for profit maximisation for Cases 2 and 5 of Annex 2, we are also able to establish that the two commodity outputs are economically competitive, while both the amenities and environmental residuals are economic complements with commodity output 1. The environmental residual is economically independent of the second commodity output, while there is an economically complementary relationship between amenities and commodity 2. The two non-commodity outputs are economic complements as well. To reflect the fact that pollution increases with the level of the residual, the tax is really a negative price. (This means that the cross effect in Equations (16) and (19) below are negative, rather than positive, for these "complements".) Since environmental quality improves as the quantity of the residual falls, we could consider good 1 and the environment as economically *competitive*. Algebraically:

$$\partial^2\Pi^*/\partial P_1\partial P_2 < 0;\ \partial^2\Pi^*/\partial P_2\partial P_1 < 0; \quad (14)$$

$$\partial^2\Pi^*/\partial P_1\partial S_a > 0;\ \partial^2\Pi^*/\partial S_a\partial P_1 > 0; \quad (15)$$

$$\partial^2\Pi^*/\partial P_1\partial T_e < 0;\ \partial^2\Pi^*/\partial T_e\partial P_1 < 0; \quad (16)$$

$$\partial^2\Pi^*/\partial P_2\partial S_a > 0;\ \partial^2\Pi^*/\partial S_a\partial P_2 > 0; \quad (17)$$

$$\partial^2\Pi^*/\partial P_2\partial T_e = 0; \text{ and} \quad (18)$$

$$\partial^2\Pi^*/\partial S_a\partial T_e < 0;\ \partial^2\Pi^*/\partial T_e\partial S_a < 0 \quad (19)$$

In the algebraic models, we have assumed log-linear production functions for the two commodity outputs, and we assume decreasing returns to scale. If returns to scale are below 0.5 (between 0.5 and 1.0) output expands less than (more than) proportionately to price increases. In either case, input ratios remain constant as long as input prices remain unchanged.[12] Therefore, we also know that as output 1 expands as its price rises, the environmental residual increases disproportionately more than does output l. Using similar reasoning, we know that amenities increase less than proportionately to either output 1 or output 2 as these commodity prices rise. In contrast to the fixed proportion production of the simpler models above, these disproportionate cross price responses between commodity and non-commodity outputs are clearly more characteristic of reality.

The challenge is to grasp their general policy significance. Without loss of generality, we focus on commodity 1 (call it commodity C) and the two non-commodity outputs and depict the non-proportional price responses graphically. By examining "price" change in isolation, we learn why policies to internalise multiple externality must be operated simultaneously.

With the introduction of the tax on the environmental residual and the payment on landscape amenities so that the farmer is accountable for his actions' effects on society, we can think of their being a supply curve for each of the three outputs [*e.g.* Equations (10) through (13)]. Each supply curve gives the quantity of any good a farmer is willing to produce at all possible prices. Graphically, each supply curve is positioned differently, depending on the prices for the other goods. The supply curve for an output shifts out or back in response to an increase in the price of another good, depending on whether the two goods are economically complementary or competitive, respectively. To show all commodities' supply responses to a change in any price, we need three separate graphs.

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If we fix the amenity payment and the residual tax at zero, or any other level, the changes in the non-commodity outputs as the commodity output expands in response to an increase in its own price, mirror the technically joint relationships described above. By keeping this in mind, we are assured that our analysis neither presumes nor depends on the imposition of such tax or payment policies. Our main purpose is to create a vehicle for understanding these joint relationships from both a technical and an economic perspective.

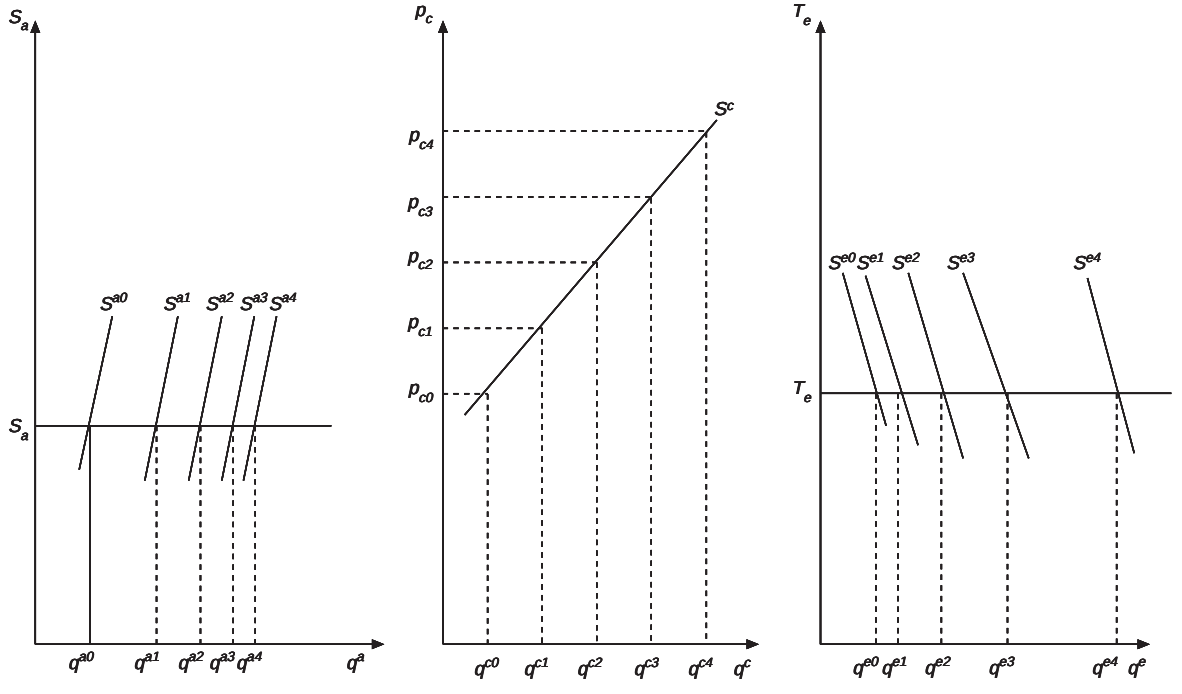
Response to commodity output price changes

Many things can cause the price of our commodity "C" to increase, including a shift in the demand for the product, or even the introduction of a price support. As the price increases from p_{c0} to p_{c4} in Figure A1.3, the quantity supplied increases from q^{c0} to q^{c4}. We have drawn linear supply curves for ease of exposition only, and to emphasise the non-proportional nature of the responses, even though the supply curves based on the algebraic model in Annex 2 would not be linear, nor would they be in reality. As output expands in response to a price increase, more land and purchased inputs are employed. This explains why both amenities and the environmental residual are complements to good "C" [*e.g.* Equations (15) and (16)], and why their supply curves (given fixed levels of T_e and S_a) shift to the right to a new position corresponding to each value of P_c. Since the tax on the environmental residual is the negative of the price to the farmer, the supply curves for each level of p_c are negatively sloped.

Based on the argument above and the analytical results from Annex 2, the environmental residual increases proportionally more than the increase in the quantity of commodity "C", while the amenities increase proportionately less.

If farmers are not held accountable for (or rewarded for) the social consequences of their production decisions, the supply curves would all shift, but after the adjustments the quantities of *a* and *e* would correspond to the quantities where their supply curves, if extended, would cross the horizontal axes. The changes in amenities and environmental residual in response to increases in P_c would remain disproportional, and they would be the natural but unplanned, outcomes of farmers' profit maximising behaviour. Since amenities are a desirable outcome, but the environmental residual is not, the level of amenities would move closer to the social optimum, but pollution would rise also in response to an increase in the price of "C". Further, even if both externalities were "positive", an

Figure A1.3. **Three joint products – effects of a change in the price of market good C**



Source: OECD.

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increase in the price of a single commodity would not generally lead to adjustments in the non-commodity outputs in socially optimal proportions.[13] This is a practical application of Tinbergen's (1952) time-honoured policy principle: we need at least as many policy instruments as there are policy objectives.

Response to non-commodity output tax

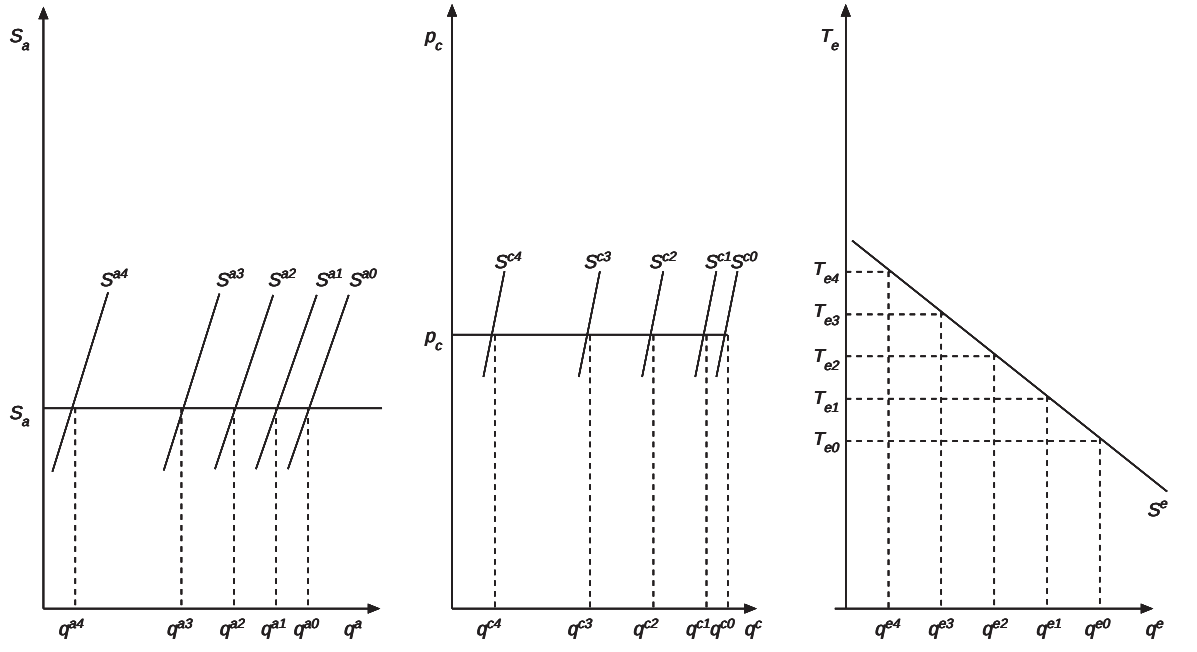
We gain further insights into the joint response of commodities by focusing on a systematic increase in the tax for the environmental residual. The tax shifts the supply curves for both complements, amenities and good "C" [Equations (16) and (19)]. Since the tax is effectively a negative price, their respective supply curves shift to the left as in Figure A1.4. Again, for given levels of the other prices, amenities and good "C" are reduced from q^{a0} and q^{c0} to q^{a4} and q^{c4}, respectively as the tax rises from T_{e0} to T_{e4}.

The chain of events can be summarised. As the cost of farming is increased due to the implicit tax on purchased inputs, fewer purchased inputs are used and, although production of "C" becomes more land intensive, some land is driven out of production (*e.g.* Peterson *et al.*, 1999). Commodity output falls; environmental quality improves; and the landscape amenities are reduced. The exact nature of the shifts is an empirical question, but, again, under reasonable empirical specifications, the expected changes in amenities and "C" are not likely to be proportional to the reductions in the environmental residual as taxes are increased to equal the marginal social cost of the environmental damage. Regardless, a single policy intervention to reduce agricultural pollution would work at cross-purposes in the provision of other important public goods.

Response to non-commodity output payment

Finally, we want to examine the effects of a systematic increase in the payment on landscape amenities, from S_{a0} to S_{a4} (Figure A1.5). This payment provides an incentive to use more land in production, and the supply of amenities will rise from q^{a0} to q^{a4}. As we know from Annex 2, the payment is also effectively a reduction in the price or cost of land that will clearly lead to an increase in the output of good "C". This change is effected by the systematic outward shift in the supply curve for good "C" [*e.g.* Equations (15) and (19)]. At a fixed price of "C", output expands from q^{c0} to q^{c4}, and the closer returns to scale in production are to unity, the more likely output "C" will expand disproportionately more.

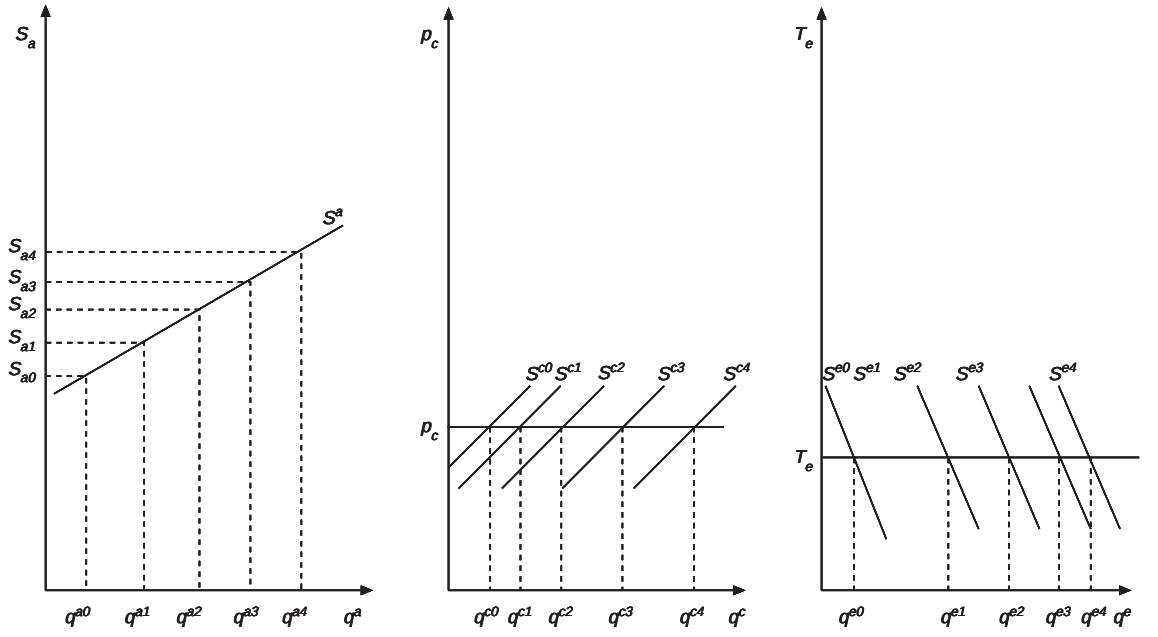
Figure A1.4. **Three joint products – effects of a change in the tax on the environmental residual**



 Source: OECD.

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Figure A1.5. **Three joint products – effects of a change in the payment for landscape amenities**



Source: OECD.

Further, the production of "C" becomes more land intensive as this cheaper input is substituted for the purchased input. Therefore, although the output of the environmental residual will still increase as the production of "C" expands (they are complementary outputs, but competitive in terms of environmental quality because of the damage caused by the environmental residual), it will increase disproportionately less as commodity production becomes more land intensive. For a fixed tax on the environmental residual, its supply curve will shift in response to the payment increase, and its production will increase from q^{e0} to q^{e4}. Again, due to the existence of a second non-commodity output, this single policy to expand the supply of landscape amenities works at cross-purposes with a desire to reduce pollution from agricultural production.

Some undeniable lessons

Despite the unavoidable abstractions in these models of multi-output joint production, we can bring away from the discussion some undeniable lessons about multifunctional agriculture. The first is a simple one, and it comes as no surprise at all: most production throughout agriculture is joint in both commodity and non-commodity outputs. Jointness in outputs in agriculture is pervasive, and any input demand is probably affected by prices of other inputs. The production of some commodity and non-commodity outputs is non-joint in inputs, but there are likely to be even more where there is jointness in inputs.

This latter case is probably the most interesting case for our purposes. It leads to the impossibility of identifying separate production functions for the outputs. When the social values or costs of the non-commodity outputs are accounted for explicitly in the farmers' decisions, the various joint products, that are technically interrelated for one or more reasons, are revealed to be economically interdependent as well. Some might be complements with one another; others might be competitive; and still others might exhibit a complementary range as well as a competitive range. A number of these situations have been mentioned above as examples, and every reader can most certainly think of others. The exact nature of the jointness in each case is an empirical question, and will most surely differ by region and technique of production.

Perhaps the best way to tease out the economic interrelationships between commodity and non-commodity outputs is to accommodate the social value or costs directly into the analysis. In doing so, we make transparent the complementary and competitive relationships, and the non-proportional response in commodity and non-commodity outputs to changes in prices, social values or costs, or policy instruments. The pure technically joint relations are perhaps less informative for policy because they don't reveal the nature of the response to policy incentives.

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Further, there are no simplistic policy solutions to effect the levels of agriculture's several multifunctional outputs, particularly those involving single policy instruments.

Along with the wisdom of co-ordinating the design and operation of policies to internalise multiple externalities, we also see the inherent efficiency of taxing or subsidising the non-commodity outputs at their social costs or values. Implementing these favoured policies of the environmental economist, however, can be illusive for many multifunctional outputs. Separate from the complexities in measuring the cost or value to society stemming from these non-commodity outputs (*e.g.* the non-market valuation question), it can be equally difficult to measure their relationships to productive inputs in agriculture, or for that matter even observe output levels. Without knowledge of these non-commodity output production functions and/or the ability to observe and monitor the non-commodity outputs at the farm level, it is impossible to know their response to changes in price signals of all kinds or to other types of policy initiatives. This problem is particularly acute in the case of non-point source pollution.

In these cases, one feasible alternative may be to focus the policy on the agricultural inputs most directly associated with the production of the non-commodity output (*e.g.* in our example, a direct payment on land or a direct tax or ban on the use of the purchased input). While multiple policy objectives can still be achieved through these means, Peterson *et al.* (1999) caution that the appropriate input payment or tax may differ substantially from the social value or cost estimated by contingent valuation or other non-market valuation methods. In a model not unlike the one described in Annex 2 applied to US agriculture, they show that the optimal land payment is about 50% larger than the social value of landscape amenities.

This divergence stems from the fact that the payment or tax now affecting farmers' decisions is only indirectly related to the social value of amenities and the social costs of the environmental residual. There is not a one-to-one correspondence between the inputs and the non-commodity outputs. In a slightly different context, Thomas and Boisvert (1995) highlight the differential effects due to controlling nitrate leaching through direct taxes or quantity controls on leachate, taxes or direct controls of nitrogen fertiliser application and sales of leachate permits.

There is a final note of caution. Most of the important implications regarding multifunctional outputs from agriculture are evident from this model with two commodity outputs and two public externalities – one positive and one negative – none of which occur in fixed proportions. However, the model is still relatively simplistic, and it is tempting to assume that the whole array of positive multifunctional attributes of agricultural production can be captured in the single positive externality that has been conveniently labelled landscape amenities. The same temptation might also extend to thinking that all negative multifunctional attributes can be captured by the non-commodity output called the environmental residual.

Regardless of how appealing this temptation seems at first blush, our results underscore exactly the opposite conclusion. Unless all multifunctional attributes occur in fixed proportions, it is not sufficient to focus only on the most pervasive externality, or combine all external values into a single index or "net" measure (Ollikainen, 1999), especially if the index includes items contributing to widely different social objectives.

Even within this stylised model, the significance and pervasiveness of the non-proportionality in the joint production of commodity and non-commodity outputs is evident. Clearly, there is no reason, for example, to expect the environmental problems from releases of chemical fertiliser to be proportional to those from animal wastes or the release of pesticides and other chemicals. The marked differences in the animal and crop production processes or techniques alone offer convincing evidence that agriculture's contribution to open space values are not proportional to its contribution to the vitality.

A final word on allocable fixed inputs and joint production

Throughout this discussion, much of the focus has been on the technological causes of joint production. And, it has been stated that perhaps the most important cause of joint production involving non-commodity outputs is in the case of a non-allocable input or condition.

However, in the case of private food outputs, there is general agreement that joint production due to an allocable fixed input is especially applicable to agriculture where the land base is fixed. Because of this widely held view, it is essential to examine if such a view is also as widely applicable in the case of jointly produced non-commodity outputs. Based on what we know about farmers' choices in the face of input constraints, it would be difficult to argue that the case is as compelling when externalities or pubic goods are involved. The rationale behind this conclusion is as follows.

The argument surrounding production of multiple goods in the face of allocable fixed inputs is well known, but is often described in other contexts. For example, the production plans obtained in a linear programming (LP) framework are diversified so as to make the most efficient use of fixed factors (Gass, 1985). One engages in as many production activities (simple or complex) as there are effective resource constraints, in an attempt to use scarce resources in the same ratios in which they are supplied. Efficiency of resource use is defined either in terms of profit per unit of resource or cost per unit of resource. In the first case, the collection of production activities is selected which maximises the combined profit from the fixed bundle of resources, while in the second case, it would be the collection of production activities that minimises the cost of producing a fixed output quantity.

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While this result has been known for many years, it is only relatively recently that it has been attributed to what has been defined as joint production in the short run. For the reasons explained below, it is difficult to see how this cause for jointness is necessary nor even appropriate when the non-commodity outputs are externalities or public goods for which there is no market.

This argument can be summarised, without loss of generality, by appealing to LP technology. Let us assume that there are only two binding constraints. Normally, this means that there will be two activities in the solution, unless there is one activity which dominates all others by using no more of any resource per unit of profit and less of at least one. If this is not the case, then the production plan is diversified with those activities which collectively are most efficient in the use of the two resources. However, as emphasised above, the farmer, in choosing his production portfolio, ignores the non-commodity outputs as they generate no revenue in the absence of public policy. Thus, if any of these public goods or external effects are a part of the farmer's portfolio of commodity and non-commodity outputs, it must be because there is a technical interdependency between them and one of the private goods generating profits for the farmer. Within the context of LP-fixed coefficient technology, the activities in solution would necessarily be "composite" activities producing some combination of both private and public goods in fixed proportions. If it were possible to produce some of these public goods separately, then there would also be separate activities in the model for them. However, these separate activities would never be in the solution because they would contribute nothing to a farmer's profit.

Based on this argument, environmental residuals and landscape amenities, for example, are, in a very real sense, technically interdependent joint products associated with commodity outputs. Because these private goods are produced jointly to make most efficient use of allocable inputs that are fixed in the short run, it could appear that the public goods or externalities are jointly produced for this reason.

This result is important as it warrants a distinction between the potential causes of jointness for non-commodity outputs that have direct cost or revenue implications for the farmer, and those that do not. This distinction may have implications for any empirical investigations that might be conducted.[14] It may be a mixed blessing, particularly in a policy context. For example, if the externalities or public goods generated by agriculture are suddenly taxed or remunerated, this will affect farmers' net revenues and the non-commodity outputs may indeed become jointly produced in the short run. But, in some cases, if the tax or payment is sufficient, separate production may be the most efficient solution in the long run.

Concluding remarks

It seems clear from this discussion that the concept of joint production is relevant for the analysis of multifunctionality. The importance of the various causes of jointness, however, may differ between situations where only private goods are involved and others where some non-commodity outputs involve externalities or public goods. There are at least three important reasons why jointness is relevant:

- Theory suggests that the behavior of a production system can be influenced by the source of jointness. It is, therefore, important to know the exact nature of the production relationships underlying the multiple outputs of agriculture, as otherwise inferences about the adjustment of the outputs to changes in market and policy incentives could be wrong.
- The provision of several goods by one firm (joint provision) can, in some cases, be cheaper than the separate provision of these goods. There is a need to examine whether joint provision of commodity and non-commodity outputs by farm enterprises has the potential to benefit from such cost savings.
- As a result of jointness, the number of production activities and methods operated by firms may be smaller than the number of outputs. If markets or policy incentives change, then firms will move towards a new collection of activities. In the context of agriculture, it would be interesting to know how farmers adjust their activities in response to changing incentives, and whether there are alternative combinations of activities and practices that would produce the bundle of goods and services demanded by society more efficiently.

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NOTES

1. One should not depend exclusively on this argument, however, to explain the existence of multiproduct firms. If one abstracts from the tendency to diversify production because of short-run resource constraints, diversification is also a common result of risk averse behaviour. Risk averse behaviour is thought to be pervasive in agriculture (Brink and McCarl, 1978; Buccola, 1982; Love and Buccola, 1991), and it may well be as important as short-run resource constraints in explaining a diversified agricultural industry. As governments gradually reduce their levels of support for agriculture, risk management may take on added significance in shaping the future of the industry and individual firms within it.
2. The case of non-allocable factors could also be discussed within the context of technical interdependencies. In fact, "jointness in inputs", which is given when an input simultaneously contributes to the production of several commodities, can be considered one of the reasons for technical interdependence.
3. It is clear that with an allocable fixed input, the amounts of the two goods that will be produced are not independent. The decision of how much of good 1 to produce will be influenced by the price of good 2 and *vice versa*. However, whether there are also cost complementarities that would make it cheaper to produce the two goods jointly (by one firm) rather than separately (in specialised firms), depends on specific cost parameters and is, therefore, an empirical question (Leathers, 1991). Brown *et al.* (1979) were among the first to study the cost structure of multi-product firms.
4. This applies also to the regional or national level where the amount of farmland can be considered fixed over even longer periods.
5. The products are interrelated technically, but, unfortunately, and in contrast to the situation when studying commodity outputs, we have never had the physical data needed to estimate such relationships. Further, since markets for these non-commodity outputs do not exist, data to identify the nature of the economic interrelationships by estimating multi-product indirect cost or profit functions do not exist either. More is said about these issues below.
6. Soybean production is usually not associated with serious environmental problems, although some environmental residuals may be generated.
7. Since neither of these products can be produced without the other, they also meet the formal conditions for joint production. With separate production impossible, the terms on the left-hand side of Equation (5) are infinite. The strict inequality holds; there are clearly economies of scope in the production of oil and meal.
8. Subtracting a crushing margin would just shift the average revenue curve down.
9. To make this conform to the strict definition of joint production one has to: *i*) add the costs of producing the same corn output and the same fertiliser residual separately, and *ii*) show that these costs exceed those of conventional corn production. Separate production of the fertiliser residual would, of course, never be done, but it is feasible. Thus, through this comparison, the sufficient conditions for joint production would be satisfied. A similar argument would apply to the joint production of fruit crops and chemical residue.
10. The concept of reference level, which provides a mechanism to determine if a given externality is positive or negative, has been developed in the OECD and is often applied in the context of the environment.
11. These assumptions clearly simplify reality, but they may approximate a corn-soybean operation in the mid-western part of the United States. On these farms, nitrate leaching and runoff from commercial fertiliser applications are problematic on corn production, but much less so on land in soybeans or forage crops. We also abstract from the fact that the amount of environmental residual is known to differ by soil type, as are yields. This would lead to a spatial diversity in both commodity and non-commodity outputs.
    To see how this model might be used to represent different non-commodity outputs, we could focus on the labour part of the input aggregate we have called "land" in the description above. Given this interpretation, the public good that is now joint with both goods could be the direct and indirect rural employment due to employment of labour in agriculture. Similarly, the purchased input could represent pesticide application on fruit crops, and the environmental residual could reflect health hazards to chemical applicators or to consumer exposure to pesticide residue. Since this residual declines with application of what now is a "labour" input,

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increasing the intensity of this input in the production of commodity 1 could reflect additional IPM scouting efforts to reduce pesticide use and improve the timing of its application.
Clearly, alternative interpretations of this simple model can embrace other dimensions of agriculture's multifunctional nature.

12. If production is best represented by a flexible production function or flexible multi-product indirect profit function that is not self-dual, production will remain joint, but it will be even more difficult to know the interrelationships between various outputs. What we can say is that these complex functions are extremely unlikely to suggest that any joint production occurs in fixed proportions. The possibilities for being able to represent both competitive and complementary outputs are enhanced, and the relationships can change depending on the levels of output. This type of function would be needed to reflect the type of transformation relation in Figure A1.3(c). We return to this issue below.

13. Depending on the nature of the joint production relationship and the shape of the total social benefit function for the public good, there could be cases in which an adequate level of the positive externality is achieved without government intervention. If, for example, the marginal social benefit of the public good declines as the output of the public good increases, its current level of joint production is sufficient with no government intervention at that point where the marginal benefit of an extra unit of public output has fallen to zero. In this case, the optimal policy would be a zero payment and the social outcome would mimic the private outcome. The conceptual analysis contained in Part III and summarised in Part I discuss the circumstances under which this situation might arise more completely.

14. The particular source that causes the interrelationships can influence which estimation procedures have to be used and the information that can be extracted from the empirical analysis. Because of the prevalence of firms in agriculture that produce multiple products and face a land constraint, much of the previous analysis has focused on the case where jointness is caused by an allocable fixed factor (Asunka and Shumway, 1996; Ball, 1988; Chambers and Just, 1989; Leathers, 1991; Lynne, 1988; Moschini, 1989; Shumway *et al.*, 1984, 1988. This focus may be less relevant for the analysis of multifunctionality.

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Annex 2

JOINT PRODUCTION IN FOUR OUTPUTS: TWO AGRICULTURAL COMMODITIES AND POSITIVE AND NEGATIVE EXTERNALITIES*

Introduction

In this annex, we describe a farm production situation in which two agricultural commodities are produced, along with landscape amenities and an environmental residual. The model is clearly an abstraction of reality, but it contains the essential ingredients to highlight the causes and effects of joint production. We go on to specify the model algebraically, and analyse the optimal conditions for five separate cases. For some cases, we assume that the farmer's profit maximising decisions explicitly account for resource constraints and/or for the social values of non-commodity outputs. These different cases essentially involve allocable fixed inputs and non-allocable inputs, and we are able to determine how each of these causes leads to joint production. It is also true that the nature of the joint production depends on assumptions of how the non-commodity outputs are generated. As is discussed above in the text, the way in which the outputs are generated has implications for policy design as well.

The farm production situation

In terms of the level of abstraction, we assume each of the two agricultural commodities is produced with only two inputs, land and a purchased input. In reality, of course, other inputs such as labour and machinery are involved in production, as are other purchased inputs. One interpretation of our model is that labour and machinery inputs are needed in fixed proportion to land, and that all purchased inputs are used in fixed proportion as well. Thus, the model accommodates substitution among major types of inputs. All that is lost in making this assumption is some rather unimportant information about substitution among inputs within a major group; this level of complexity is not essential for our purposes.

Similarly, we assume the environmental residual is associated only with the purchased input and land used to produce commodity 1, but land amenities are produced by land allocated to both commodities. These assumptions are again somewhat unrealistic, but they may approximate a corn-soybean operation in the mid-western United States. On these farms, nitrate leaching and runoff from commercial fertiliser applications are problematic in corn production, but much less so on land in soybeans. We also abstract from the fact that the amount of environmental residual is known to differ by soil type, as are yields. This would lead to a spatial diversity in both commodity and non-commodity outputs. The policy implications of this spatial diversity are significant, but are addressed elsewhere in the report.

In this model, we assume that there is an amenity value to land in each crop. To add to the complexity of the model, we could have assumed that the amenity values differ by crop, but again, this potential for spatial diversity is best addressed elsewhere.

On balance, these simplifying assumptions help isolate the causes and effects of jointness, and make it possible to examine situations of increasing complexity. If production is joint under these simple assumptions, production will remain joint if both external effects are associated with both commodities and differ spatially, but the causes would be less transparent.

The farm model

We begin by defining the following variables.[1] Let Y_1 = agricultural output 1; Y_2 = agricultural output 2; a = amount of landscape amenities; e = amount of environmental residual; L_1 = land input for agricultural output 1; L_2 = land input for agricultural output 2; Z_1 = purchased input in the production of output 1; Z_2 = purchased input in the production of output 2; P_1 = market price of output 1; P_2 = market price of output 2; P_L = land price; P_Z = price of purchased input; T_e = tax on the environmental residual; and S_a = payment on the landscape amenity.

Further, the commodity outputs and the two non-commodity outputs a and e are functions of input use:

$$Y_1 = L_1^{.6} Z_1^{.2} \quad (1a)$$

* This annex is taken from a contribution by Professor Richard N. Boisvert of Cornell University, United States.

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$Y_2 = L_2^{.4} Z_2^{.3}$ (2a)

$a = L^{.5}$; and (3a)

$e = Z_1^{.2}/L_1$; (4a)

where $L = L_1 + L_2$.

In these physical relationships, we can show that Y_j increases with the levels of both inputs ($j = 1, 2$), but at decreasing rates. The two functions are known as general Cobb-Douglas functions in which no output is forthcoming if either input is at a zero level. The marginal product of each input is positive, but decreasing, and there are decreasing returns to scale. These particular functions are chosen because they have been widely used in empirical production economics (*e.g.* Heady and Dillon, 1961) and have been used in many stylised aggregate policy analyses as well (*e.g.* Peterson *et al.*, 1999; Floyd, 1965; Gardner, 1987). These functions are also separable in both outputs and inputs. Therefore, we can begin our analysis with a system where production is non-joint. Then, by adding complexity to the model, we can study the causes of jointness explicitly.

To illustrate joint production between commodity and non-commodity outputs, we must also specify production functions for the two non-commodity outputs. In our model specification, amenities, a, increase with land used in the production of both commodities, but again at a decreasing rate (Equation 3a). For a given amount of land allocated to output 1, the production of the environmental residual, e, increases with Z_1 and at an increasing rate (Equation 4a). For a given amount of Z_1, the level of the environmental residual decreases as the amount of land increases. For example, e might be the leaching of nitrates in the groundwater from the application of chemical fertiliser. Clearly, as one applies more fertiliser to a fixed amount of land, leaching would increase, as would output. However, if a fixed amount of fertiliser were applied to more land, output would rise, but leaching would fall because the fertiliser intensity of production would fall.

Several cases

We analyse five separate cases of this farm situation to illustrate the causes and implications of joint production in this multiple output context. Each is increasingly complex is some way. In all five cases, we study the conditions that maximise net return from the production of the two commodities, but the cases differ in the following ways:

1. We ignore non-commodity externalities. This implies non-joint production.
2. We ignore non-commodity externalities, but impose an overall land constraint. This leads to interdependent production of the two commodities due to the jointness in inputs from an allocable fixed factor.
3. We consider only the environmental residual. This leads to economic interdependence between commodity 1 and the environmental residue, because of the non-allocable purchased input. Production of commodity 2 remains economically independent of good 1, and amenities are not considered.
4. We consider only the amenity externality. This leads to economic interdependence between the amenities and both commodities because of the non-allocable input. The environmental residuals are not considered.
5. Maximise net returns from production of two commodities, considering both non-commodity outputs. Here, all production is economically interdependent.

To demonstrate the five cases described above, we must formulate five separate decision models and determine the extent to which we can solve for indirect profit functions that are separable in various products. In the latter three cases, we assume that the non-commodity output is considered explicitly in making input and output decisions. The only way to represent this situation explicitly is to assign prices (*e.g.* taxes or subsidies) to these non-commodity outputs. Otherwise, there is no incentive for the farmer to consider these non-commodity outputs in making decisions, and the jointness between commodity and non-commodity outputs is not transparent.

Case 1. No external effects or allocated fixed factors

To determine the profit maximising levels of the two commodity outputs in this case, we:

$$\max \Pi = [P_1(Y_1) - P_L L_1 - P_Z Z_1] + [P_2(Y_2) - P_L L_2 - P_Z Z_2] \quad (5a)$$

Now, substituting the commodity production functions (1a) and (2a) into (5a), we have profit in terms of prices and inputs, and we can:

$$\max \Pi = [P_1(L_1^{.6} Z_1^{.2}) - P_L L_1 - P_Z Z_1] + [P_2(L_2^{.4} Z_2^{.3}) - P_L L_2 - P_Z Z_2] \quad (5a')$$

L_1, Z_1, L_2, Z_2

The first-order conditions for a maximum are:

$$\partial\Pi/\partial L_1 = .6\ P_1\ L_1^{-.4}\ Z_1^{.2} - P_L = 0 \quad (6a)$$

$$\partial\Pi/\partial Z_1 = .2\ P_1\ L_1^{.6} Z_1^{-.8} - P_Z = 0 \quad (7a)$$

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$\partial\Pi/\partial L_2 = .4\ P_2\ L_2^{-.6} Z_2^{.3} - P_L = 0$; and (8a)

$\partial\Pi/\partial Z_1 = .3\ P_2\ L_2^{.4} Z_2^{-.7} - P_Z = 0$ (9a)

These four equations are the standard results, where the values of the marginal products of each input used to produce the two commodities are equal to the input prices. Since only the input variables for commodity 1 are in the first two conditions, we can solve them simultaneously for optimal levels of L_1^* and Z_1^*. Similarly, we can solve the second two conditions for optimal levels of L_2^* and Z_2^*. Then, by substituting these optimal levels into the direct profit function above, we can derive an indirect profit function. This indirect, or dual profit function depends only on input and output prices, and the partial derivatives of the indirect profit function with respect to output prices are the output supply equations.

Rather than provide solutions to these systems, we can substitute directly into the general form of the indirect profit function for a Cobb-Douglas production function that was derived by Beattie and Taylor (1985). The indirect profit function is:

$$\pi^* = \{0.2\ [.6^{.6}\ .2^{.2}\ P_1\ P_L^{-.6}\ P_Z^{.2}\ ]^{1/.2}\} + \{0.3\ [.4^{.4}\ .3^{.3}\ P_2\ P_L^{-.4}\ P_Z^{.3}]^{1/.3}\} \quad (5a'')$$

The significance of this result is that this indirect profit function is the sum of two separate indirect profit functions, one for each of the commodities. The first depends only on the prices of the first good and the two inputs, while the second depends only on the prices of the second good and the two inputs. Thus, the indirect profit function is separable in inputs, and the two products are economically independent. That is, the partial derivatives of the profit function with respect to either output price is independent of the other output price – each output is a function only of its own price and the price of the two inputs. There are no cross price effects in commodity output supply.

Case 2. An allocable fixed input: land

Let us assume that the farmer still does not consider either of the non-commodity outputs in the decision process, but that there is an upper limit on land for farming. It is often argued that this is a common situation for many farms in the short run, and common to many regions or countries in the longer run. The farmer will now maximise profit subject to the land constraint. Assuming that all land is used, for simplicity, we solve the following constrained profit maximising problem:

$$\max \Pi = [P_1(L_1^{.6} Z_1^{.2}) - P_L L_1 - P_Z Z_1] + [P_2(L_2^{.4} Z_2^{.3}) - P_L L_2 - P_Z Z_2] \quad (10a)$$
$$L_1, Z_1, L_2, Z_2$$

subject to:

$L_1 + L_2 = L^*$.

Land is in fixed supply so the price, or rental value, of land, is ignored, although qualitatively the results do not change if a land charge is included (Moschini, 1989). To solve the problem, we form:

$$\max \Pi = P_1(L_1^{.6} Z_1^{.2}) - P_Z Z_1 + [P_2(L_2^{.4} Z_2^{.3}) - P_Z Z_2] - \lambda_L[L_1 + L_2 - L^*] \quad (10a')$$
$$L_1, Z_1, L_2, Z_2.$$

The first-order conditions for a maximum are:

$\partial\Pi/\partial L_1 = .6\ P_1\ L_1^{-.4} Z_1^{.2} - \lambda_L = 0$ (11a)

$\partial\Pi/\partial Z_1 = .2\ P_1\ L_1^{.6} Z_1^{-.8} - P_Z = 0$ (12a)

$\partial\Pi/\partial L_2 = .4\ P_2\ L_2^{-.6} Z_2^{.3} - \lambda_L = 0$ (13a)

$\partial\Pi/\partial Z_1 = .3\ P_2\ L_2^{.4} Z_2^{-.7} - P_Z = 0$; and (14a)

$\partial\Pi/\partial\lambda = L_1 + L_2 - L^* = 0$ (15a)

In contrast to the first-order conditions from Case 1, there are now five equations in five unknowns. The first four conditions equate the value of the marginal product of each input in the production of each commodity to the value of the input. For the purchased input, the conditions are the same as in Case 1. The values of the marginal products of land are equated to the Lagrangian multiplier for the land constraint, λ_L^*, instead of the rental price for land. Thus, in addition to finding optimal levels for the four input levels, we have to solve for the optimal level of λ_L^*, which is the marginal value of the constraint on land. This is the amount by which profits could be increased if there were another acre of land available.

In theory, we can solve these equations simultaneously for optimal levels of the inputs L_1^*, and Z_1^*, L_2^*, and Z_2^*, and for the optimal value of λ_L^*. However, one of these equations is linear in the land variables, while the others are exponential. The solution is algebraically complex, and even if a closed form solution exists, there is little to be gained by performing the calculations here. What is clear is that there is no way to solve for the optimal levels of inputs for producing commodity 1 independently of those optimal inputs needed to produce commodity 2, because λ_L^* is in both the first and third equations above.

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For this reason, the indirect profit function, derived by substituting the optimal levels of inputs into the direct profit function, necessarily involves both output prices and both input prices. The indirect profit function is no longer separable in the two output prices, implying that each of the partial derivatives of this indirect profit function (the output supply curves) with respect to each output price will contain both output prices. As expected, the short-run constraint on the allocable land input leads directly to the joint production. There are cross-price effects and the two products are economically interdependent.

Although we have not derived the indirect profit function for this case of joint production, we can establish that the two products are economic competitors. As a consequence of the land constraint, the product transformation curve resembles that in Figure 3(a) of the text.

To develop the argument for why this is so, we need to examine conditions (11a) and (12a).[2] These conditions equate the value of the marginal product of each input to the value or cost of the input. Therefore, if we raise the price of commodity 1, the marginal products of both inputs in the production of commodity 1 must decline to re-establish the equalities in conditions (11a) and (12a). For each condition taken individually, this is guaranteed for *ceteris paribus* increases in L_1 for (11a) and *ceteris paribus* increases in Z_1 for (12a). Further, we are also guaranteed that this remains true for the simultaneous adjustments in these inputs in both equations, because the inputs are technical complements. With the higher levels of both inputs, we know that output of commodity 1 increases as well.

In checking the marginal conditions for commodity 2, we know that some of the available land has shifted out of commodity 2 into commodity 1. The marginal product of land in good 2 rises, and to re-establish (13a), the amount of the second complementary input, Z_2, allocated to good 2, must decline as well. A similar argument would show that these reductions in input use also re-establish condition (14a). As the price of good 1 increases, therefore, its production increases at the expense of the production of good 2. The two goods are economically competitive.[3]

Technical interdependence with non-commodity outputs

Up to this point, the farmer is concerned only with the two commodities in making profit maximising decisions. Although not considered in making decisions, both the environmental residual and the landscape amenity are still produced. For a given set of input and output prices, once we solve for the profit maximising input levels, we can substitute them into Equations (3a) and (4a) to determine *ex post* the levels of these two non-commodity outputs. Thus, while these two non-commodity outputs are not economically interrelated to the two commodity outputs, they are clearly interrelated in a technical sense. Anytime certain inputs are used in the production of the two commodities, one or both of the non-commodity outputs are produced as well. In looking at Equations (1a) and (4a), for example, both commodity 1 and the environmental residual are produced from the same inputs of land and the purchased inputs, and in this sense, these inputs are non-allocable (cause (ii) of joint production from the text). Production of good 1 and the environmental residual, are therefore, technically interdependent, although this is not obvious in either set of first-order conditions to Cases 1 and 2. Similarly, landscape amenities are technically interdependent with goods 1 and 2 [Equations (2a) and (3a)] because it is impossible to determine which amenities are due to land allocated to the two commodities. This is also a variation on the notion of a non-allocable input.

Further, there are decreasing returns to scale in the two Cobb-Douglas functions for commodities 1 and 2. As output of either commodity expands, therefore, the use of both inputs increase in the same proportion to one another, but also more than proportionally to output. For expansions in output 1, it follows directly from Equation (4a), homogeneous of degree 1 in inputs, that the environmental residual increases proportionately more as well. Commodity 1 and the environmental residual are clearly technical complements in production, but production is *not* in fixed proportions. Environmental quality deteriorates with production of the residual, and is, therefore, technically competitive with output 1.

A similar, but somewhat more complicated, argument can be made for both commodities being technical complements with landscape amenities. The production of landscape amenities is assumed homogeneous of degree 0.5 in the sum of land in agricultural production. As long as returns to scale for both goods are greater than 0.5, the likely case empirically, amenities increase proportionally less than an equal and simultaneous proportional increase in the production of both agricultural commodities. If the production of only one good increases, the increase in amenities is clearly less than in proportion to output, and that proportion depends on the amount of land committed to the other commodity.

In summary, both commodity and non-commodity outputs in this analysis are modelled as relatively simple exponential functions of the two inputs, and are forms that for many years were thought to be adequate descriptions of agricultural production processes. Despite the stylised representation, it is easy to demonstrate that commodity and non-commodity outputs are jointly produced, but not in fixed proportions.

As discussed above, the more modern approach to modelling agricultural supply and demand systems relies on the specification of a flexible, multi-product, indirect cost or profit function. The translog function is such a function, and it has the Cobb-Douglas function as a special case. It follows, therefore, that under these more

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flexible, complex, and modern specifications, the case to be made for joint production of commodity and non-commodity outputs in non-fixed proportions is stronger still.

To investigate further these technical interdependencies, one could simulate this system by systematically changing the output price and solving for the levels of commodity and non-commodity outputs *ex post* at each new price. This strategy fails to reveal the economic forces that determine the interrelationships. To understand these forces, it is helpful to assume that farmers do consider the level of these non-commodity outputs in their production decisions by assigning prices (*e.g.* taxes or subsidies) to each unit of non-commodity output produced. In doing so, we can see how these taxes or subsidies on these externalities affect their production and how their output responds to changes in commodity prices and *vice versa* . In the case where the taxes and subsidies are set at zero, the analysis, as we see below, reduces to Case 1. For the technical analyses here, we ignore the issues surrounding the appropriate levels of tax or payment, or the feasibility of implementing such policies.

To proceed, we first consider each non-commodity output in isolation, and then we consider all four outputs simultaneously. We begin with the environmental residual.

Case 3. An environmental residual

In an effort to determine the profit maximising levels of output when the social cost of the environmental residual is assessed to the farmer, we have:

$$\max \Pi = [P_1(Y_1) - P_L L_1 - P_Z Z_1] + [P_2(Y_2) - P_L L_2 - P_Z Z_2] - T_e\,(e) \tag{16a}$$

By substituting each production function [Equations (1a), (2a), and (4a) into the profit function (16a)], we have:

$$\max \Pi = [P_1(L_1^{.6}\, Z_1^{.2}) - P_L L_1 - P_Z Z_1] + [P_2(L_2^{.4}\, Z_2^{.3}) - P_L L_2 - P_Z Z_2] \tag{16a'}$$
$$L_1, Z_1, L_2, Z_2 \quad - T_e\,(Z_1^2/L_1).$$

Before deriving the first-order conditions for this problem, it is instructive to examine the last term in (16a'). Since e is written in terms of its input equivalent, T_e, can now be viewed explicitly as affecting the costs of the purchased input and land used in producing good 1. Costs of these inputs are no longer constant per unit; they are non-linear in the input levels. This additional term reflects the social cost of each input's contribution to the environmental residual. As Z_1 increases, the added cost to the farmer grows exponentially. As production becomes more land intensive, the land's contribution to reducing pollution, *ceteris paribus*, is reflected in the fact that land costs rise only by the product of the marginal social cost of pollution times the reciprocal of land in good 1. These features of policies that tax or subsidise the externalities directly ensure their economic efficiency and set them apart from conventional taxes or subsidies on inputs or outputs (Thomas and Boisvert, 1995).

The same information is apparent from the first-order conditions for a maximum, but in a slightly different form. The conditions are:

$$\partial\Pi/\partial L_1 = .6\, P_1\, L_1^{-.4} Z_1^{.2} - P_L + T_e\,(Z_1^2/L_1^{-2}) = 0 \tag{17a}$$

$$\partial\Pi/\partial Z_1 = .2\, P_1\, L_1^{.6} Z_1^{-.8} - P_Z - 2T_e\,(Z_1/L_1) = 0 \tag{18a}$$

$$\partial\Pi/\partial L_2 = .4\, P_2\, L_2^{-.6} Z_2^{.3} - P_L = 0; \text{ and} \tag{19a}$$

$$\partial\Pi/\partial Z_2 = .3\, P_2\, L_2^{.4} Z_2^{-.7} - P_Z = 0 \tag{20a}$$

To understand how the explicit recognition of the environmental residual implies joint production and economic interdependence, we must compare these first-order conditions with those for Case 1. From (19a) and (20a), we can still solve for optimal levels of L_2^* and Z_2^* independently of the output of commodity 1 or the environmental residual. Inputs committed to commodity 2 are non-joint with those used to produce good 1 and the environmental residual. Commodity 2, when we assume the landscape amenities do not exist, is economically independent of the other two outputs.

If $T_e = 0$, conditions (17a) and (18a) reduce to conditions (6a) and (7a), respectively, from Case 1. In contrast if $T_e > 0$, we know that the production of commodity 1 is now more expensive, because of the implicit tax on the inputs that contribute to the environmental residual. Thus, as the tax increases, production of both commodity 1 and the environmental residual fall; the two outputs are economic complements.

What is fascinating about this case is the mechanism by which the outputs are reduced. This has to do with the extra terms in (17a) and (18a). These terms are equal to the tax on the residual multiplied by the marginal production of the residual associated with an additional unit of land or input Z allocated to the production of good 1. Since a *ceteris paribus* increase in land reduces pollution, the tax on pollution actually mimics a land payment. To restore the equality in (17a), land is thus applied to commodity 1 beyond where its marginal value product equals its price. Similarly, (18a), the marginal product of Z_1 must rise (less is used), while the marginal product of L_1 must fall (land use increases). Thus, Z_1^2/L_1, the production of the environmental residual, also falls. Further, while this tax reduces both the environmental residual and production of commodity 1, it does so by making production of good 1 more land intensive.[4]

From a policy perspective, we must be reminded that as the level of the environmental residual increases, the actual quality of the environment deteriorates. It follows, therefore, that commodity 1 and environmental quality

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are economically competitive, although the opposite is true for commodity 1 and the environmental residual itself. The policy significance of this economic interdependence is subtler than it appears when there are more than a single non-commodity output of interest.

Case 4. A *landscape amenity*

In an effort to determine the profit maximising levels of output when we reward the farmer for the social value of the amenities, we ignore the environmental residual. By again substituting the production function [Equations (1a), (2a), and now (3a)] into a profit function, we have:

$$\max \Pi = [P_1(L_1^{.6} Z_1^{.2}) - P_L L_1 - P_Z Z_1] + [P_2(L_2^{.4} Z_2^{.3}) - P_L L_2 - P_Z Z_2] \quad (21a)$$
$$L_1, Z_1, L_2, Z_2 + S_a (L_1 + L_2)^{.5}.$$

Here, the cost of land devoted to each crop is being subsidised by its contribution to the social value of amenities. The rate of reduction in costs per acre actually increases with the land committed to agricultural production, but it does so at a decreasing rate. Since this is the rate at which land contributes to the value of amenities, such a policy again would be more efficient in trying to achieve the socially desirable level of amenities than either direct input or output subsidies. To achieve the socially optimal level of amenities, we would have to set the payment at the marginal value of amenities. Making such a determination is challenging and is discussed elsewhere in the OECD reports. The literature cited is the text provides clear evidence that such values might well differ by region, and across countries.

The first-order conditions for a maximum for this problem are also instructive. They are:

$$\partial\Pi/\partial L_1 = .6\ P_1\ L_1^{-.4} Z_1^{.2} - P_L + .5\ S_a\ (L_1 + L_2)^{-.5} = 0 \quad (22a)$$
$$\partial\Pi/\partial Z_1 = .2\ P_1\ L_1^{.6} Z_1^{-.8} - P_Z = 0 \quad (23a)$$
$$\partial\Pi/\partial L_2 = .4\ P_2\ L_2^{-.6} Z_2^{.3} - P_L + .5\ S_a\ (L_1 + L_2)^{-.5} = 0; \text{ and} \quad (24a)$$
$$\partial\Pi/\partial Z_2 = .3\ P_2\ L_2^{.4} Z_2^{-.7} - P_Z = 0 \quad (25a)$$

In this situation, there is an extra term in both conditions (22a) and (24a) reflecting the payment on amenities multiplied by the contribution to amenities of an additional acre of land in farming. Consequently, land allocated to both products increases beyond the point at which the marginal value product equals the price of land, and total amenities rise as well. Due to the production of amenities, this additional land commitment recognises the additional value of land to the farmer Because the two inputs are complements in production of both crops, the marginal value products of Z in the production of both crops rises as well. To restore equality in the other two first-order conditions, both Z_1 and Z_2 must increase – clearly leading to increased output of both commodities. The landscape amenities are economic complements with both commodity outputs because land is an allocable input from the perspective of the two commodities, but is non-allocable in terms of its contribution to amenities.

Case 5. B*oth a landscape and an environmental residual*

Finally, we consider both non-commodity outputs in an effort to determine the profit maximising levels of commodity outputs. We can again substitute each production function into a profit function. Then we:

$$\max \Pi = [P_1(L_1^{.6} Z_1^{.2}) - P_L L_1 - P_Z Z_1] + [P_2(L_2^{.4} Z_2^{.3}) - P_L L_2 - P_Z Z_2] \quad (26a)$$
$$L_1, Z_1, L_2, Z_2 \quad - T_e\ (Z_1^2/L_1) + S_a\ (L_1 + L_2)^{.5}.$$

The first-order conditions for a maximum are:

$$\partial\Pi/\partial L_1 = .6\ P_1\ L_1^{-.4} Z_1^{.2} - P_L + T_e\ (Z_1^2/L_1^{-2}) + .5\ S_a\ (L_1 + L_2)^{-.5} = 0 \quad (27a)$$
$$\partial\Pi/\partial Z_1 = .2\ P_1\ L_1^{.6} Z_1^{-.8} - P_Z - 2T_e\ (Z_1/L_1) = 0 \quad (28a)$$
$$\partial\Pi/\partial L_2 = .4\ P_2\ L_2^{-.6} Z_2^{.3} - P_L + .5\ S_a\ (L_1 + L_2)^{-.5} = 0; \text{ and} \quad (29a)$$
$$\partial\Pi/\partial Z_2 = .3\ P_2\ L_2^{.4} Z_2^{-.7} - P_Z = 0 \quad (30a)$$

From discussions surrounding Cases 3 and 4, we know that this production is joint in inputs. Thus, all four outputs are economically interdependent. Only by considering this "four-output" case are we able to appreciate the full policy significance of this model.

We can see from Equation (27a) that more land is allocated to producing commodity 1 than when neither externality is valued explicitly in the farmer's decision problem. Rather than equating the value of the marginal product of land in good 1 to the price of land, additional land is employed until the diminishing value of the marginal product falls sufficiently to account for land's contribution to the social value of the two non-commodity outputs. On the one hand, land contributes to the amenities in a direct way, and on the other, contributes to a reduction in the environmental residual as production of commodity 1 becomes more land intensive, *ceteris paribus*.

Similarly, by Equation (29a), there is more land allocated to producing commodity 2. Land in the production of commodity 2 also contributes to amenities, and this contribution is equal to that of land in commodity 1.

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In contrast, the value of the marginal product of the purchased input in producing good 1 is now higher than its price by the input's marginal contribution to the environmental residual, *ceteris paribus* [Equation (28a)]. Less of the purchased input is used, and the production of commodity 1 becomes more land intensive.

The purchased input in producing good 2 is still allocated to the point where its price equals the value of its marginal product [Equation (30a)]; in that use, the purchased input has no effect on the environment. However, land and the purchased input are complementary inputs in the production of good 2, and, thus, the total amount of the purchased input will increase along with land. Now that we explicitly recognise the value to society of the landscape amenities, more of both the second good and amenities are produced.

The conclusions are less clear in the case of commodity 1. Here, the two externalities tug in opposite directions. We know that for each unit of good 1 produced, there is more amenity production, because production is more land intensive. Less of the environmental residual is produced as well per unit of output, and in total. We would, however, have to know more about actual prices, taxes, and subsidies to know what happens to the actual output of good 1 relative to the level when social values and costs are ignored.

A *final case of particular interest*

Before leaving this discussion, it is useful to study a slightly different case–one in which only land in good 2 contributes to amenities. This modification highlights the critical nature of technical relationships between inputs and both non-commodity and commodity outputs in affecting joint production and the particular economic interdependencies that obtains. If land in good 1 were assumed to no longer contribute to landscape amenities, there is still joint production, but the jointness is altered in an important way. Good 1 and the environmental residual would remain joint products, as would good 2 and the landscape amenities. In this modified case, L_1 would no longer appear in the last terms of conditions (27a) and (29a). This situation would mean that production across the two groups of commodities would remain non-joint.

NOTES

1. Several of the components of this model are similar to those in Peterson *et al.* (1999).
2. We also need to recall that inputs in a Cobb-Douglas production function are technical complements. As stated in the text, this means that an increase in the level of one input leads to an increase in the marginal product of the second.
3. One would arrive at a similar conclusion by assuming an initial increase in the price of commodity 2, or for initial decreases in either price.
4. We could begin with a fixed Te, assume a change in P1 and arrive at the same conclusion.

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Annex 3

MULTIFUNCTIONALITY IN OTHER PARTS OF THE ECONOMY

This annex provides a brief discussion of how issues that are similar to those addressed under the heading of multifunctionality in agriculture, are treated in other parts of the economy. The discussion is based on a review of the economic literature.

The term "multifunctionality" is practically not used outside of agriculture, but there are a number of related issues that are discussed in other economic sectors in connection with joint production and the management of resources for multiple uses. Most of the studies addressing these issues are concentrated in a few economic areas, primarily forestry, fishing, household production and banking. The majority of the studies deal with situations where all of the multiple outputs are marketable. There are also examples, however, where the provision of public goods is involved, notably in the forestry sector.

Most of the results of the studies are not directly applicable to agriculture, but there are numerous parallels to the multifunctionality discussion, concerning the issues raised and the conceptual and analytical problems encountered in dealing with them.

The literature review was guided by the following questions: in which other sectors of the economy have issues related to multiple outputs and joint production become the subject of widespread debate? Which associated economic and policy issues have been identified as being important? Which conceptual and analytical approaches have been used to address these issues? Which qualitative and quantitative result have been obtained? Finally, which are the main factors that have influenced these results?

Given the substantial body of literature on joint production and multiple-use management, and the limited time available for review, this annex can only provide an introduction to the relevant research in this area. A more complete coverage of the literature and a more in-depth discussion of the research results and their relevance to multifunctionality in agriculture would require an additional work effort.

Forestry

Forestry is an industry that has many similarities with agriculture: forest production is land-based, depends on biological processes and site-specific environmental factors, and is influenced by climatic conditions. Forestry has an important impact on the environment and can provide various types of amenities. Unlike agriculture, where the production cycles seldom exceed one or two years, trees are harvested only after long growing periods. As a result, the stock of trees and its management, and the timing of harvesting decisions, play an important role in forestry.

Forestry economists have given considerable attention to the concept of joint production in their work. In fact, joint production is seen as one of the issues that distinguish forestry economics from other economic fields (Hyde and Newman, 1991). The way joint production is approached in forestry is frequently in the context of "multiple-use" management. This approach has spread so widely that textbooks of forestry economics and other comprehensive texts in this area routinely include a chapter on multiple-use management of forests (*e.g.* Klemperer, 1996; Loomis, 1993; van Kooten, 1993; Hyde and Newman, 1991; Bowes and Krutilla, 1989; Gregory, 1987).

The central question, which is directly relevant to the debate on multifunctionality in agriculture, concerns the synergies and conflicts that arise when timber and non-timber goods are produced on the same piece of land. The forestry economics literature has a long history of addressing this question (*e.g.* Clawson; 1974; Bentley and Strand, 1972).

At the heart of the discussion are economies of scope (see also Annex 1). Economies of scope exist if the costs of jointly producing several outputs are lower than the sum of the costs of each individual production. Diseconomies of scope imply the reverse. The existence of economies or diseconomies of scope is a crucial factor in determining whether multiple outputs are better produced jointly or separately. In forestry, separate production of timber and non-timber products usually implies a spatial division of the total forest area into areas with intensively managed commercial forests and areas that are managed for environmental and amenity values.

The fact that there is a longstanding debate among forestry economists as to whether the production of timber and non-timber goods affords economies of scope, indicates that there is no easy and unique answer. Indeed, the literature review suggests that there are situations in which joint production (multiple-use management) leads to considerable cost savings, whereas in other cases it is better to separate the various functions. There are also situations where cost complementarities are limited to certain outputs, or dependent on specific conditions.

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Bowes and Krutilla (1989), in a study of US public forestland, provide examples of cases in which forest management for timber production alone is uneconomic, but management for multiple purposes including increased water supply, the creation of hunting grounds and improvements in wildlife habitat, is economically sound (provided, of course, that a value for the non-timber outputs is imputed). According to the authors, a move to multiple-use management is justified on economics grounds if the benefits from including an additional output in the production plan exceed the incremental costs.

Management of forests for multiple uses requires careful planning of the timber harvest cycle. Dole (1999) examines the optimal harvesting time when the value of the non-timber services is not known. He provides a harvesting rule that permits the implicit calculation of the stream of values from the non-timber services that would make a given rotation length optimal. Snyder and Bhattacharyya (1990) also try to determine optimal rotation lengths for forests that provide non-timber services.

Many non-timber services, including those linked to landscapes, ecosystems and water supply, extend beyond a single forest stand, thus creating interdependencies among different parts of a forest. The marginal value of a service generated on a given stand may rise or fall as a result of harvest decisions on surrounding stands depending on whether the services under consideration are complements or substitutes.

Swallow and Wear (1993) analyse such interactions. Their work suggests that the optimal management decision for a forest stand, including the relative emphasis on timber versus non-timber outputs, depends on the conditions and the expected management of the adjacent stands. The results are derived for non-timber goods that directly benefit the forest owners (*e.g.* game for hunting), but the reasoning underlying the analysis can be extended to other services, including landscape and biodiversity.

Interdependencies between forest stands require management plans at the forest level that are different from the ones that would be optimal if each stand were managed in isolation. For example, since older stands generally have higher biodiversity and amenity values, part of the forest area may be set aside for the development of an old growth forest, while shorter timber rotation cycles are instituted on the remaining sites (Bowes and Crutilla, 1989). A similar specialisation of land use may be necessary to achieve an optimal supply of wildlife or water services.[1]

Hyde and Newman (1991) draw from the empirical research carried out by Bowes and Krutilla the conclusion that implementing multiple-use management is much simpler in practice than suggested by the economic theory behind it. Theoretically there are a large number of joint forest products, but seldom do more than two products compete economically for the same forested land area or, alternatively, show important economic complementarities. Careful accounting of the costs and benefits of including non-timber outputs in the production plan, will generally result in only a small number of viable outputs.

Vincent and Binkley (1993) demonstrate that even in a forest with identical stands specialised production may be optimal, if the timber and non-timber outputs react differently to management efforts and the overall management effort can be allocated across stands.[2] While multiple outputs are supplied at the forest level, management of individual stands will tend towards "dominant uses". Invoking the concept of comparative advantage, the authors argue that if foresters attempt to satisfy multiple demands by managing the entire forestland for all outputs, both commodity and amenity values of the forests may be inappropriately supplied and resources may be inefficiently employed.

Several applied studies support the arguments in favour of spatial differentiation. Sahajananthan *et al.* (1998) provide an example from Canada where the separation of commercial timber production from non-timber activities leads to gains both in terms of increased land productivity in timber production and an enhanced flow of benefits from amenity values and habitat protection. Yin (1998) recommends a forestry division strategy for China to meet the increasing demand for wood and environmental services. His plan, which is based on efficiency criteria, consists of a commercial forestry sector with intensive tree plantations, an extensive multiple-use sector, and an "environmental" forestry sector.

In addition to spatial differentiation, an optimal forest management plan may require changes in the management of forest stands over time. Swallow, Talukdar and Wear (1997), who analyse ecosystem management in forests, find efficiency gains from temporal specialisation in management activities.

While much of the multiple-use literature is prescriptive, some has attempted to explain actual management decisions based on the utility forest owners gain from non-timber goods. Max and Lehman (1988) look at management decisions of nonindustrial private forest owners in the United States who, based on the timber functions of their forests, were thought to under invest in their land. However, the management decisions are rational if the utility obtained from both the timber and non-timber outputs is taken into consideration. Newman and Wear (1993) compare industrial and nonindustrial forest owners' behaviour with respect to changes in input and output prices. They find that nonindustrial owners gain significantly more non-market benefits from their standing timber than do industrial owners.

Price (1990) analyses the evolution of demand for multiple forest products, including wood, recreational opportunities and protection from natural hazards, and its implications for forest management and legislation. Using case studies from the Swiss Alps and the Rocky Mountains, he illustrates how the bundle of goods and

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services provided by forestry has evolved in response to changing demands from local and national communities, and how forestry policy has adapted.

Hyde and Newman (1991) argue that market failures in forestry due to joint production and missing incentives for non-timber outputs, are generally overstated. In their literature review, they cite case studies to back up their claim that while market failures may exist, policy failure is more likely to occur. There are few documented cases in both developed and developing countries where public policy intervention in support of multiple-use management has created economic improvements. The authors also state that attempts to encourage specific management practices through subsidies have had little impact on the behaviour of forest owners. They conclude that prices have a greater influence on long-term production decisions than subsidies aimed at medium-term management choices.

Given the similarities between agriculture and forestry regarding the joint provision of private and public goods, the importance of land as an input, the role of biological processes in production and the close link with the natural environment, there are a number of insights to be gained from the forestry economics literature. Among these are that there is usually a variety of ways to produce a given bundle of timber and non-timber products; that these differ mainly in the spatial and temporal allocation of production and the use of different management practices; and that the existence of economies of scope depends on the production relationships underlying timber and non-timber provision, regional and local environmental conditions, and the structure of demand for the non-timber services.

The forestry examples demonstrate the importance of management decisions in pursuing a combination of timber and non-timber goals. Drawing parallels to agriculture, this would correspond to the impact of different land use and farming practices on the cost of achieving a set of food and non-food objectives. Additional insights could perhaps be gained by examining the forestry literature in more detail, especially concerning the factors that make it economic in some cases to produce timber and non-timber goods jointly, while favouring a separation of the various functions in other cases.

Fisheries

Like agriculture and forestry, fisheries concerns the management of natural resources, but it has certain important aspects that distinguish it from the other two sectors. For one, while plants and trees can be replanted and breeding decisions have a major influence on the stock of farm animals, fishermen usually only affect the size and development of fish stocks through adjustments in the harvest quantity (except for aquaculture), and indirectly through the impacts of their harvesting methods on the aquatic ecosystem. Second, while each plot of land in farming and forestry is generally tied to a single enterprise, fisheries are often managed as a common-property resource with access for a certain number of users.

Fishing vessels often harvest several types of fish simultaneously. Commercial fishing can thus be analysed as a multiproduct activity, with the different types of harvested fish being the multiple outputs. Some fisheries research has focused on this type of jointness, including the economics of harvesting multiple fish species, and on the difficulties this poses for regulation, including the implementation and effectiveness of catch limits for individual species within multi-species fisheries.

Eggert (1998) reviews recent developments in fisheries management and finds that economic gains could be made by better identifying interdependencies between the various fish species. Thunberg *et al.* (1995) examine whether jointness can be used to simplify the regulation of fishing activities. They estimate the degree of jointness of different pairs of fish species in the Florida near-shore fishery and find that jointness in production exists for all pairs of species, but that the complementarities are stronger for some pairs than for others. Building on this result, they suggest that several fish species could be managed by regulating the catch of the species that has the strongest interdependencies with the others.

Turner (1997) examines various types of individual fishing quotas in situations of multi-species fisheries. The results suggest that while most individual fishing quota arrangements induce discarding of fish, value-based quotas do not suffer from this problem. Since discarded fish have a high mortality rate, the author concludes that value-based quotas waste fewer fish.

The effect of individual harvesting decisions on the development of the fish stock is in the nature of an externality (Cornes and Sandler, 1984). An externality can also be created through the impact of harvesting on the aquatic ecosystem. Certain harvesting techniques can damage the seabed and affect biodiversity by incidentally catching endangered fish and non-fish species (FAO, 1999).

Another externality, which evokes parallels to multifunctionality in agriculture, is the economic and employment impact of fishing activities on coastal communities, including their social fabric and traditional lifestyles. The EU's Common Fisheries Policy attempts to respond to the fact that a considerable number of European coastal regions are economically dependent on the commercial fisheries sector and that there are few economic alternatives to fishing.

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Haynes *et al.* (1986) identify a range of beneficiaries of a well-managed fish stock. In addition to commercial fishers, recreational fishers, consumers, society and cultural minorities obtain benefits from a stock that is well managed. The authors stress that non-commercial users are "incidental" beneficiaries of the services that are produced. Eggert (1998) demurs from this "incidental" beneficiary perspective and recommends the development of a multiple-use management approach to marine resources, including ecological and recreational services provided by aquatic ecosystems.

Other examples involving natural resource management

Joint production theory has also been applied in the context of wildlife and wetland preservation. Montgomery *et al.* (1994), for instance, examine the preservation of woodland as a means of protecting spotted owl habitat. They suggest that joint production may be a factor to be considered, but that it might not be important enough to influence management decisions.

The intangible benefits of preserving wetlands have, among others, been addressed by Gupta and Foster (1974), who discuss questions of benefit valuation. Gren (1995) shows, for the Gotland area of Sweden, that wetland preservation of as a means of nitrogen purification is preferable to other methods, such as sewage treatment, due to the other environmental outputs provided jointly by wetlands.

Concerning natural resource management in the context of sustainable development, negative externalities have in general been given greater attention in the literature than positive externalities (for example, Tisdell, 1993 and Bartelmus, 1997).

Household production

The goods and services produced in private households contribute to the functioning and development of society, but are usually not rewarded in the market place. Issues addressed by the literature on household production include the difficulties inherent in valuing household work (including the question of deciding what is work and what is leisure), the absence of household production from national accounts, and the implications of the "economic invisibility" of household work for public policy choices. The more feminist oriented part of the literature addresses, in addition, issues of justice concerning the recognition of women's work. Attempts have also been made to consider household production and ecological issues within a common framework based on their public goods aspects.

Household production is generally neither recognised nor recorded as part of productive economic activity. This can lead to inaccurate representations of the economy as well as to inappropriate policy choices. Certain authors (for example, Ferber and Birnbaum, 1980) recommend the incorporation of household production into standard economic analysis, while other authors feel that a new approach to economic analysis may be needed altogether.

The debate on the non-inclusion of household production in national accounts goes back a long time. Already in the 19th century Marshall noted the productive and valuable nature of home production. A variety of writers commented on the absence of household production from national accounts, including Pigou in the 1920s and Margaret Reid in the 1930s, but household production did not enter mainstream academic research until much later (Ferber and Nelson, 1993). It was generally held that conceptional and measurement difficulties would make it impossible to include household production in national accounts.

With the development of the "new home economics" in the 1960s, the household was posited as a site not just of consumption, but also of production. Although the new home economics initially met with considerable criticism, economists and sociologists soon began to develop time use data, which formed the basis for putting an economic value to housework. Since then, part of the household literature has been devoted to the valuation issues. While the debate over valuation methods continues, numerous empirical studies have been carried out. For example, the value of household production in the United States has been estimated at between 24 and 60% of GDP (Silbaugh, 1996). Quah (1993) values household production, including home education and family supervision, based on data from Singapore.

An indirect way of assessing the value attributed to household production by society is by looking at welfare policies. Shaver and Bradshaw (1995) compare taxation and welfare regimes across European countries to examine how the level of state support for different kinds of families varies.

Household models have also been used to investigate the allocation of time to various household activities, and the trade-offs between monetary and non-monetary benefits obtained from these activities. Kolodinsky (1990), for instance, examines the time allocated to search activities for grocery prices by a dual earner household, under the assumption that the search time also produces enjoyment.

Joint production in households exists at both the micro and the macro level, though much of the literature focuses on the macro level. Some authors see household production as providing the underpinning for the rest of the economy. O'Hara (1997) suggests a theory of "sustaining production" in which "social sustaining services" are considered to be part of the production process. Many of these services are produced within the household, including those that allow labour to reproduce itself.

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In a similar vein, Jochimson and Knobloch (1997) insist on the importance of incorporating "caring activities" into economic analysis. They argue that caring activities and ecological processes make up the "maintenance economy", without which the "industrial" economy could not exist. Because the maintenance economy is largely absent from standard economic considerations, the authors conclude that current economic practices are unsustainable.

Pietilä (1997) suggests that many public policies and institutional arrangements are rational only if the invisible costs they impose on households are ignored. For example, the institutional fragmentation of the services provided by hospitals, schools and the workplace, ends up to be time-consuming and difficult to manage for households. She argues that a more efficient functioning of the economy could be obtained if these invisible costs were taken into account in policy making.

Staudt (1996) concludes from an analysis of the taxation system in the United States that the public/private division that prevents housework from being taxed also prevents women from having access to taxation-linked social security benefits. She advocates that both market and non-market labour be valued and housework be taxed. As a consequence, women that work in the household and have no market income, would gain economic security and better access to social programmes.

Banking

There are numerous studies in the banking sector that address joint production of multiple goods. Almost all of these revolve around one question: are there economies of scope in the joint provision of multiple bank services? The services under consideration are, with few exceptions, private goods.

The context for the studies is often provided by government plans to reform the banking sector and broaden the range of activities banks can engage in. The results suggest that there may or may not be economies of scope depending on the type, number and combination of services provided, the type and size of the banks, the way the banks are organised and operate, and the structure of demand.

Among the researchers that find evidence of cost complementarities in banking is Rogers (1998), who suggests that US commercial banks might benefit from an expansion of the traditional banking business into off-balance-sheet activities and other financial services, if these new products have supply-side and demand-side characteristics similar to those of existing bank products. Porrini (1994) detects economies of scope in the Italian banking sector for different combinations of services provided. Van der Vennet (1994) finds that expansion of off-balance sheet activities may provide European credit institutions with cost economies, although these seem to be more important for certain types of services than for others. Lang and Welzel (1994), in a study of Bavarian co-operative banks, find evidence for the existence of economies of scope regarding the joint supply of loans and non-traditional services.

Lawrence (1989), who focuses more on methodological issues, also obtains results that point in the direction of cost complementarities. Testing various functional forms for the estimation of production relationships in the US banking sector, he concludes that only functional forms that allow for economies of scope provide an adequate description of the industry.

However, not all studies support the idea of cost savings through the joint provision of bank services. Jagtiani *et al.* (1995), who analyse off-balance-sheet activities of US banks, conclude that in the majority of cases there is no evidence of cost complementarities. Rather, the rapid growth of off-balance-sheet activities may be explained by the small pecuniary cost of these activities. Pulley and Humphrey (1993) analyse the cost implications of separating jointly provided services. They find that the separate provision of deposit and loan services would only marginally increase costs. Mester (1992), who analyses the implications of combining commercial bank functions with investment bank activities based on a sample of large US banks, even finds evidence of diseconomies of scope.

An analysis of the US banking industry by Clark and Speaker (1994) suggests that there are no global scope economies because economies from the joint production of selected product pairs are offset by diseconomies in the production of others. A similarly mixed result is obtained by Berger *et al.* (1993) who, in a comparison of banks, come to the conclusion that joint production may be optimal for some banks, while specialisation would be better for others. Hermann and Maurer (1991) find that only the larger ones of the Swiss universal banks may benefit from economies of scope.

Pulley *et al.* (1993) make an interesting attempt to distinguish between economies of scope due to joint production (yielding cost savings) and economies of scope due to joint consumption (leading to revenue increases). They find, for the US banking sector, that cost complementarities between the deposit and the loan businesses are small, and that revenue economies are virtually non-existent.

While the overwhelming majority of the studies in the banking sector involve only private goods and services, there are a few that also address public good aspects. Such aspects arise in connection with central banks or similar institutions that facilitate the smooth operation of private transactions and create confidence in the stability of the financial system. One example is provided by Broz (1997) who analyses the formation of central banks as a function of their ability to jointly provide private and collective goods.

The results from the banking sector reinforce the impression that joint production analysis is only meaningful if the multiple goods and services are clearly defined, the specific production characteristics are identified, and the economic environment in which the firms operate, is taken into consideration.

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Other applications

Studies of joint production in other parts of the economy include education; the telecommunications, oil and gas extracting, and water supplying industries; medical care; police services; and trade. In the following paragraphs, selected examples from these areas are presented to illustrate the context in which jointness arises, but no further discussion of the results is provided.

Empirical studies of the higher education system in the US and Japan suggest that the provision of multiple products (undergraduate teaching, graduate teaching, research) by universities can lead to economies of scope (Koshal and Koshal, 1999; Hashimoto and Cohn, 1997; Cohn *et al.*, 1989). A study by de Groot *et al.* (1991) of US research universities finds economies of scope related to the joint production of undergraduate and graduate teaching, but not with research.

While the explicit purpose of the higher education system is to create and spread knowledge, there are other, less formal ways, in which knowledge can be generated. One is through "learning on the job". Perroni (1997) provides an example of how joint production theory can be applied in the context of creating knowledge as a by-product of private production activities.

Hunt and Lynk (1995) examine cost complementarities in the UK water supplying industry due to the joint provision of private goods and environmental services by public water authorities. The same authors find that cost complementarities exist between some but not all of the services provided by the UK postal service (Hunt and Lynk, 1991) and that joint provision of inland and international services by the UK telecommunications industry may be cheaper than independent provision (Hunt and Lynk, 1990).

Other applications of multiproduct analysis include: the oil and gas extracting industry (joint production of oil and natural gas – Helmi-Oskoui *et al.*, 1992; Livernois and Ryan, 1989); medical care (hospitals as providers of multiple services; joint provision of goods and bads in cases were medical care has potentially negative side-effects – Chetty, 1998; Maceira, 1991); and the joint provision of multiple service by police departments (Gyapong and Gyimah-Brempong, 1988).

A special case of jointness arises if a good is produced by a number of people who share a common input or use a common technology and who split the benefits obtained from the good (team-work dependent tasks). Such a situation can give rise to problems of moral hazard and free-riding, inducing individuals to minimise their contribution to the overall work effort. Problems of this type have been explored in studies by Arya *et al.* (1997), Jeon (1996) and Nandeibam (1995). Parallels to agriculture might include landscape provision by a group of farmers who in turn benefit from farm tourism.

Trade economists have mainly focused on the question whether or under which conditions joint production might impede equalisation of factor returns in a free-trade situation (Blackorby *et al.*, 1993; Samuelson, 1992; Jones, 1992).

A problem related to joint production is the attribution of the total production cost to individual outputs. A firm that produces a bundle of outputs has the possibility to cross-subsidise in the production process. Furthermore, if a public good is produced jointly with a private good, the entire production costs have to be covered by the private good. In both cases, it may be interesting to estimate the "stand-alone" costs of the outputs: in the case of private goods to assess whether cross-subsidisation has occurred; in the case of public goods to carry out a cost-benefits analysis. However, cost allocation by product is difficult and estimation procedures, such as the one proposed by Palmer (1991), which gives upper bounds on the stand-alone costs of multiple outputs based on certain cost parameters, are often only approximate.

NOTES

1. According to Bowes and Krutilla (1989), the differential treatment of forest stands based on an overall forest-level plan is consistent with the multiple-use (joint production) approach to forest management and does not amount to a separation of land use functions (disjoint production). The question is how large the area on which multiple outputs are obtained, can be to still speak of multiple-use management. Originally, multiple-use management was a forest-level concept. Chapman (1950) employed the term with the meaning of attributing carefully considered priorities of use to different portions of a forest. Later the term became used in a more restricted sense, meaning that various uses take place on closely intermingled tracts of land (Clawson, 1974). At present, multiple-use management is generally understood to refer to the production of timber and non-timber benefits on the same plot of land or "stand".
2. See also Helfand and Whitney (1994) and Vincent and Binkley (1994).

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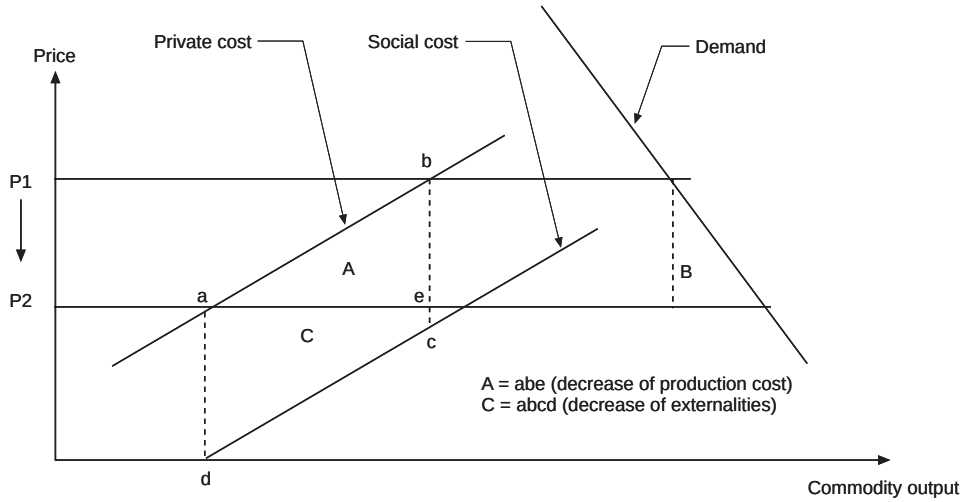
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Annex 4

ECONOMIC INEFFICIENCY CAUSED BY A DECREASE IN IMPORT PRICE

To keep the discussion simple, Type-II-a externalities (constant marginal values) are taken as an example. The welfare gains due to the decrease of the import price for a commodity output are equal to the production cost savings, represented by the area A in Figure A4.1, and the increase in the consumers' surplus, represented by the area B. The welfare loss associated with the decrease in the externality caused by lower agricultural production is area C. The net welfare gains (or losses) are equal to A + B – C, with the sign depending on the price elasticities of demand and the private cost, and on the demand for the externality. If A + B – C were negative, then the decrease in the import price leads to inefficiency.

Figure A4.1. **Economic inefficiency caused by price decreases**



Source: Revised from Sinabell, Franz (1998), "Are support measures and external effects of agriculture linked together? Conceptual notes and empirical evidence from the Austrian agricultural sector", Chapter 7 in J.M. Antle, J.N. Lekakis and G.P. Zanias (eds.), *Agriculture, Trade and the Environment*, Edward Elgar Publishing, United States.

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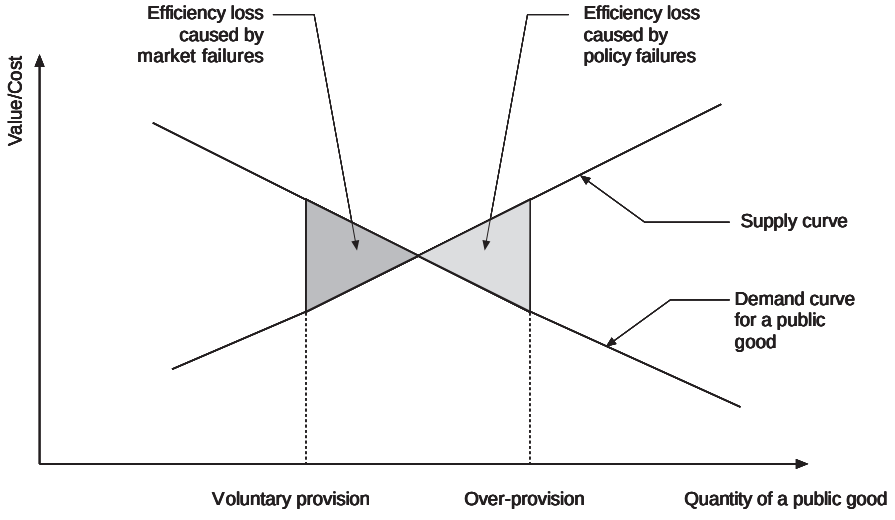
Annex 5

SUPPLEMENTAL NOTE ON CHARACTERISTICS AND OPTIMAL PROVISION OF PURE AND IMPURE PUBLIC GOODS

Market and policy failures in providing pure public goods

As discussed in the main text, the question of whether the inefficiency associated with market failure (*i.e.* the underprovision of pure public goods by voluntary provision) is greater than the inefficiency associated with policy failure (*i.e.* under or overprovision of pure public goods because of the government's failure to correctly estimate demand) is empirical, not theoretical. The degree of market failure depends on population size and relative preferences for various pure public goods. In general, the greater value people put on a pure public good, the closer its voluntary provision is to the Pareto optimum (*i.e.* the market failure would diminish). Annex 6 also gives some examples where the usual free-rider theory cannot be applied. These examples show that Pareto optimality may be achievable through voluntary provision.

Figure A5.1. **Market and policy failures**



Source: OECD.

There are factors other than the difficulties of estimating demand for pure public goods that can increase the degree of policy failure. First, rent-seeking behaviour by bureaucrats can bias policies in order to increase departmental budgets. As Niskanen (1975) describes, bureaucrats often try to maximise their budget allocations in order to maximise their utility. Secondly, rent-seeking behaviour can also be observed from interest groups that have an impact on policy decision-making.

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Non-inferiority in providing public goods

This concept is usually used in multiobjective programming and planning, where there are multiple objectives in decision-making that cannot be converted into a single objective. It can also be useful for understanding some of the features of multifunctionality that originate from the fact of multiple externalities. Noninferiority can be defined as follows (Cohon, 1978):

> A feasible solution to a multiobjective programming problem is non-inferior if there exists no other feasible solution that will yield an improvement in one objective without causing a degradation in at least one other objective.

The table below illustrates this using multifunctionality. The numbers are purely hypothetical. A, B, C, D, E, are different farming practices generating different quantities of externalities (environment, rural amenities, and land conservation in this example). The numbers in the cells indicate the relative quantity of an externality produced with each farming practice. While the numbers can be compared for the same externality, they cannot be compared with the numbers for different externality. In this example, only A is inferior. The others are noninferior, making the practices of B through E Pareto-optimal and A Pareto-inferior. Choosing between B, C, D, and E is a matter of political judgement, unless the figures are converted into some comparable unit such as a monetary value. If measuring the demand for all public goods under multifunctionality is found to be difficult, then multifunctionality could be discussed using the framework of multiobjective problems.

Multifunctionality farming practice	Environment	Rural amenities	Land conservation	
A	10	7	6	Inferior
B	13	17	8	Non-inferior
C	11	18	7	Non-inferior
D	15	10	15	Non-inferior
E	20	8	7	Non-inferior

Open access resources, common property resources and pure public goods

The use of the term "open access resources" can lead to confusion. As Bromley and Cernea (1989) criticise, many studies "[confuse] an open access regime (a free-for-all) with a common property regime (in which group size and behavioural rules are specified)" and "the metaphor denies the very possibility for resource users to act together" (Ostrom, 1990).

These goods are also often confused with pure public goods. These goods are open access resources because their uses are open (free) to all. Pure public goods also have open access, but are usually not called open access resources. This term conventionally refers to goods that may be overexploited. Because of non-rivalry, pure public goods do not face this problem.

Common property resources share many features with the club goods described below. In fact, they could be considered as a subgroup of club goods. The main reason for differentiating common property resources from club goods is that common property resources "[rely] very much on informally agreed custom and convention, within which such resources are exploited as, in some sense, common property" (Cornes and Sandler, 1996).

"Converting open access situations to common property systems is a complex process that cannot be done by administrative decree" (Bromley and Cernea, 1989). Supplying a new set of rules may be equivalent to providing a new public good, which would then also face the prisoner's dilemma. Monitoring the rules can be costly to society. Therefore, there should be various types of institutional rules that govern common property resources depending on the social, cultural, economic and natural conditions in each community. "An important lesson that one learns by carefully studying the growing number of systematic studies by scholars associated with the new institutionalism' is that these institutional details' are important" (Ostrom, 1990).

Another advantage of common property resources is that the value of the resources for future generations can be taken into account to a greater degree than for other types of resources. The current generation in a community may include in their calculations the value to future generations of the resource.

Optimality of club goods

Discussions of the optimality of clubs have two dimensions: the club members' perspective and the economy-wide perspective. "When the club decisions are represented as a co-operative action, the resulting outcome will be a Pareto optimum for the members. Members belong because they perceive a net benefit from membership. If the club decisions are centralised to account for the well-being of those within the club and those outside of the club, then the outcome will be a Pareto optimum for the economy as a whole" (Cornes and Sandler, 1996).

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From the perspective of members, club goods seem similar to common property regimes as discussed in the above. The difference lies in that voluntarism is perfectly guaranteed for club members while common property resources usually rely on informal arrangements to enforce decisions. At the economy-wide level, the key point is whether or not the provision of club goods is competitive. If there is a large number of clubs providing similar goods or services, and the entire population belongs to one of the clubs, efficiency is likely to be achieved. An exceptional case is a natural monopoly, which is an industry with decreasing average cost. In this case, the provider of the goods or services needs to charge the average cost to "club" members so that the operation can maintain financial stability. However, the marginal cost should be charged if achieving economic efficiency from an economy-wide perspective is the priority. This could force the provider to face a deficit (when the average cost decreases as the output increases, the marginal cost is always below the average cost).

Intergenerational club goods

Intergenerational clubs are clubs where multiple overlapping generations share a club good. These clubs are especially important when there is a depreciation of the good caused by current users. The depreciation of the club good by the current users would cause "congestion" for future users, while at the same time current users cause real congestion for one another. A typical example of these goods is highways. Crowding caused by current users can accelerate the depreciation of structures, which increases the maintenance burden for future generations. Some environmental goods such as biodiversity and rural amenities may have intergenerational club good characteristics.

Failure to account for the character of intergenerational clubs could cause economic inefficiency in the long run. However, estimating the demand of future generations for these goods is almost impossible.* It is, therefore, important for policies to encourage the establishment of institutional arrangements with "built-in" mechanisms to avoid myopic behaviour. For example, future generations could always be considered when members of a community make any decisions related to the resources they maintain. A more formal example is the system of equity stocks suggested by Cornes and Sandler (1996). The use of equity stocks issued at the formation of a member-owned intergenerational club might help the current generation not to pass on some burdens to future generations because short-sighted behaviour by the current generation would cause a decline in the equity stock price.

* Solow (1991) states in his speech that "we don't know what they (future generations) will do, what they will like, what they will want. And, to be honest, it is none of our business".

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Annex 6

SOME FACTORS SUPPORTING VOLUNTARY PROVISION OF PUBLIC GOODS

A standard approach to explain the free rider problem is to use game theory, especially the "Prisoners' Dilemma". The prisoners' dilemma has been used to argue against the efficiency of voluntary provision of public goods. In this two-person static game, each player has two choices, and cannot communicate with one another. The choices are "to contribute to the provision of a public good" or "not to contribute to it". Each player can benefit from both their own contribution and the other's contribution because the good in question is a public good.

The matrix for game 1 below shows a typical example of a prisoners' dilemma game, in which the first number of each cell represents the net benefit accruing to Player A and the second one the benefit to Player B. The contribution costs "8" for anyone who contributes and yields "6" as a non-excludable and non-rival benefit. In this example, the dominant strategy for the individual players is not to contribute, while the social optimum (the sum of the two players' net benefits) lies with the contribution of both players. The dominant strategy is, therefore, Pareto-inferior.

Whether prisoners have a dilemma or not, however, depends on the payoff matrix. For example, the second game below also meets the criteria of pure public goods (*i.e.* one individual's contribution to the provision of a good can be enjoyed by the others), where the dominant strategy is to contribute. The second game, called a "privileged game" "highlights the fact that public good problems need not result in a Pareto-inferior outcome when net benefits are supportive of individual contributions" (Cornes and Sandler, 1996).*

Game 1 (Prisoners' Dilemma)

B's Strategy A's Strategy	Do not contribute	Contribute
Do not contribute	0, 0 (Dominant Strategy)	6, –2
Contribute	–2, 6	4, 4

Source: OECD.

Game 2 (Privileged Game)

B's Strategy A's Strategy	Do not contribute	Contribute
Do not contribute	0, 0	8, 2
Contribute	2, 8	10, 10 (Dominant Strategy)

Source: OECD.

* Cornes, Richard and Todd Sandler (1996), *The theory of externalities, public goods and club goods*, Second Edition, Cambridge University Press.

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Annex 7

TRADE AND INTERNATIONAL INCOME DISTRIBUTION ISSUES IN THE PRESENCE OF EXTERNALITIES

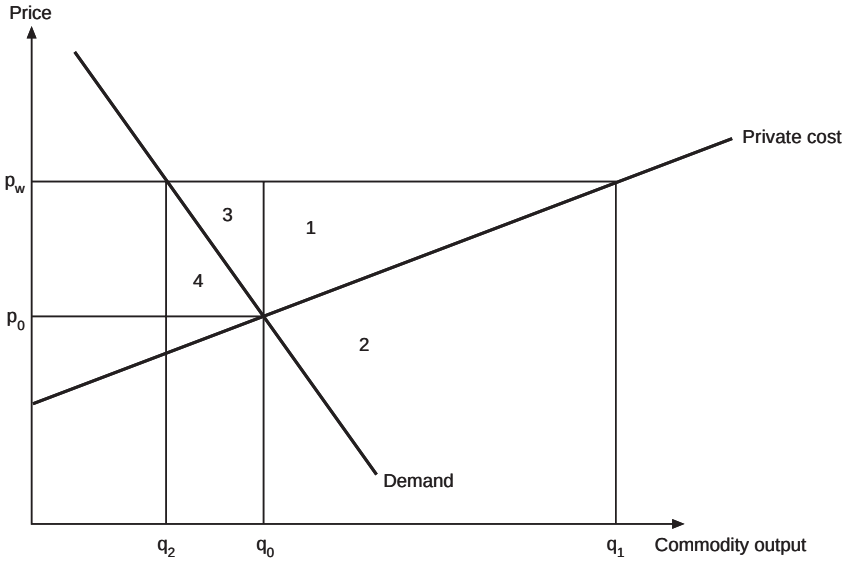
This annex gives a detailed description of how a country's welfare is affected from a move to free trade when there are externalities and when there are policies to internalise them. Illustrative analyses of various possible combinations of externalities are used to consider the overall gains and losses of different groups when a country moves to greater free trade. In Part III, these analyses are used to create a table showing the overall income distribution effects among countries. The analyses are based on a number of assumptions, including that full employment is satisfied in both countries, and that the exchange rate is correctly adjusted. The model here replicates and builds on the model used in Corden (1997),* Chapter 13.

Benchmark case: no externalities

In this typical text-book example, following the standard trade model, free trade would improve global and country welfare. Any equity issues would be on a domestic level. Within a given country, a move to greater freedom of trade implies a shift in production across sectors, as exporting sectors increase production, and import-competing sectors decrease production. This clearly has implications for the distribution of income domestically.

The equity trade-offs at the domestic level can be seen through the following partial equilibrium diagrams. Figure A7.1 shows the case of an exported good. Under autarky, the price of the good is p_0 and the quantity produced is q_0. With a shift to free trade, the producers accept the world price, p_w, which is higher than p_0. As can

Figure A7.1. **Exportable good with no externalities**



Source: OECD.

* Corden, W.M. (1997), *Trade policy and economic welfare*, Second Edition, Clarendon Press, Oxford.

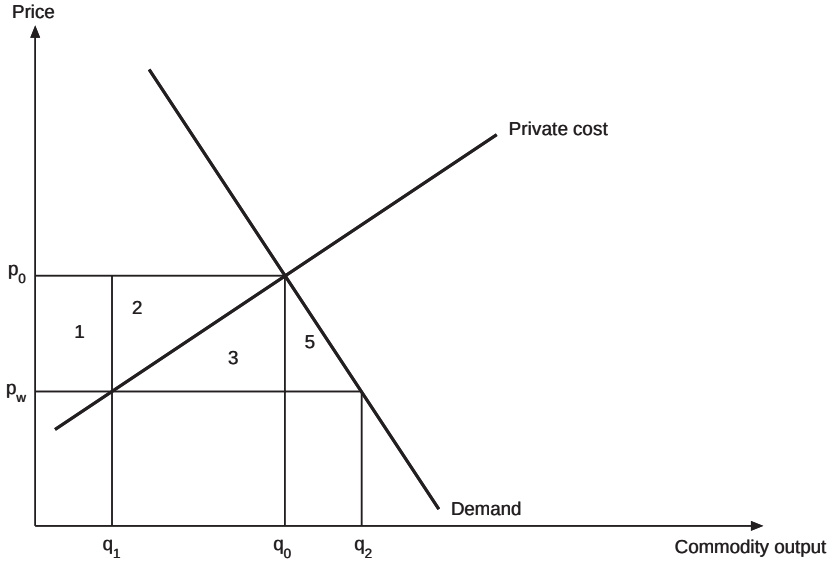
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be seen, production increases to q_1, although domestic consumption declines to q_2. The difference between q_1 and q_2 is exported.

The costs and benefits of this shift in production can be seen in Figure 1. On the production side, there is a gain of areas 1 and 2, corresponding to the value of the increased production, and there is a loss associated with the cost of the increased production (area 2). On the consumption side, there is a gain of the value of the additional exports due to decreased consumption, equal to areas 3 and 4. There is also a cost from the consumer surplus foregone, equivalent to area 4. Overall, there is a net gain equivalent to areas 1 and 3.

In the case of an import-competing good, the opposite scenario occurs (Figure A7.2). The price moves from p_0 to the lower world price, p_w. Quantity produced decreases from q_0 to q_1, but domestic consumption increases to q2 due to increased imports. In this case, on the production side there is a loss of areas 1 and 2, due to a decrease in production surplus. On the consumption side, there are gains from increased consumer surplus equivalent to areas 1, 2, 3, and 5. Overall, there is a gain of areas 3 and 5. From the economy-wide point of view, there is an overall gain. However, there is a shift in production from the import-competing sector to the export sector. This implies that there may be equity issues to resolve at the domestic level.

Figure A7.2. **Import-competing good with no externalities**



Source: OECD.

Externalities that are not internalised

With the addition of externalities to the question of the effects of trade on welfare, the issues can be less clear. The presence of externalities can mean that the social cost curve is different from the private cost curve.

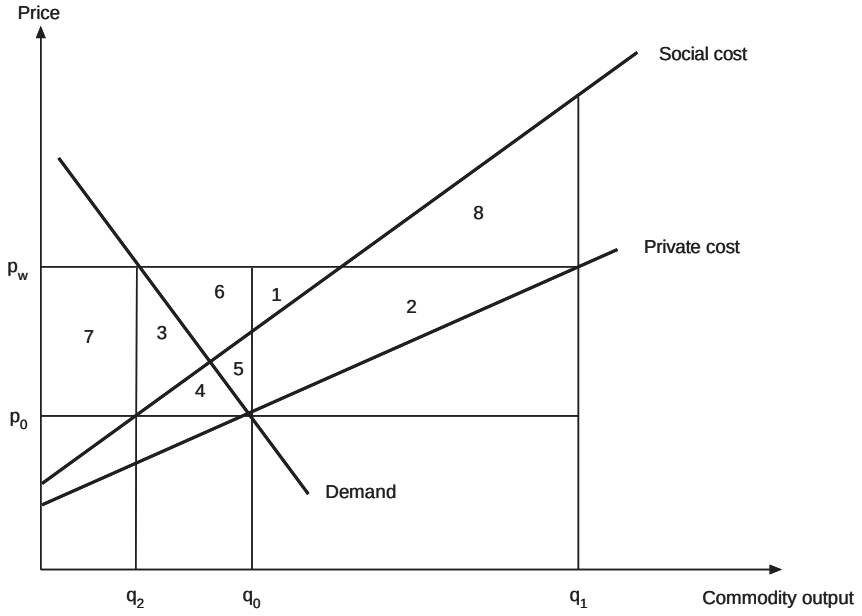
In the presence of externalities that are not internalised in some way, international trade can make a difference depending on whether or not the externality is positive or negative, and if it is associated with the production of an exportable or an import-competing good. The four possible combinations of these will be examined in turn.

Exportable good with a negative externality

With an exported good, a move towards free trade would lead to a higher price, increased production, and decreased domestic consumption. As in the case of a good without an externality, producer surplus would increase (areas 1, 2, 3, 4, 5, 6 and 7 in Figure A7.3), while consumer surplus would decrease (areas 3, 4 and 7), leaving a private net gain of areas 1, 2, and 6. However, in addition to the private costs, the increase in production is associated with increased social costs (areas 2 and 8). A net welfare gain or loss is therefore the difference between areas 1, 5 and 6, and an area 8. Whether or not the country as a whole gains from trade would depend on whether the increased social costs outweighed the gains from increased exports. This is an empirical issue, but it is theoretically possible for a country to lose from increased trade if the goods exported are associated with a negative externality that has not been internalised.

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Figure A7.3. **Exportable good with negative externality**

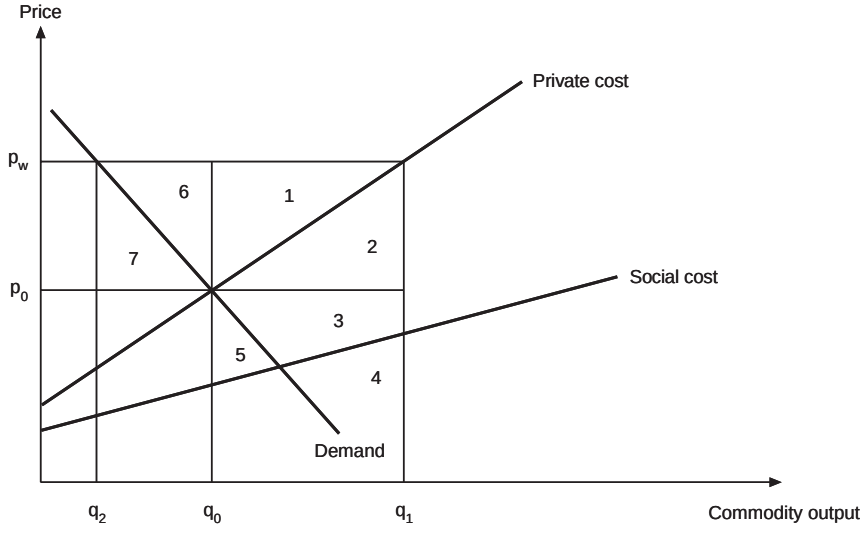


Source: OECD.

Exportable good with positive externality

In the case of a positive externality associated with an exportable good, a country will gain from trade more than in the case without a positive externality. The private gain from trade is similar to the case above, which is areas 1 and 6 in Figure A7.4. There are also social gains due to the increase in externalities (areas 2, 3, and 5). Overall, there are net gains from the increased externalities and the private gain from trade (areas 1, 2, 3, 5, and 6).

Figure A7.4. **Exportable good with positive externality**



Source: OECD.

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The size of these gains will depend on the precise shapes of the cost and demand curves. In general, however, the presence of positive externalities increases the gains from trade for an exported product, as compared to a situation where there are no externalities.

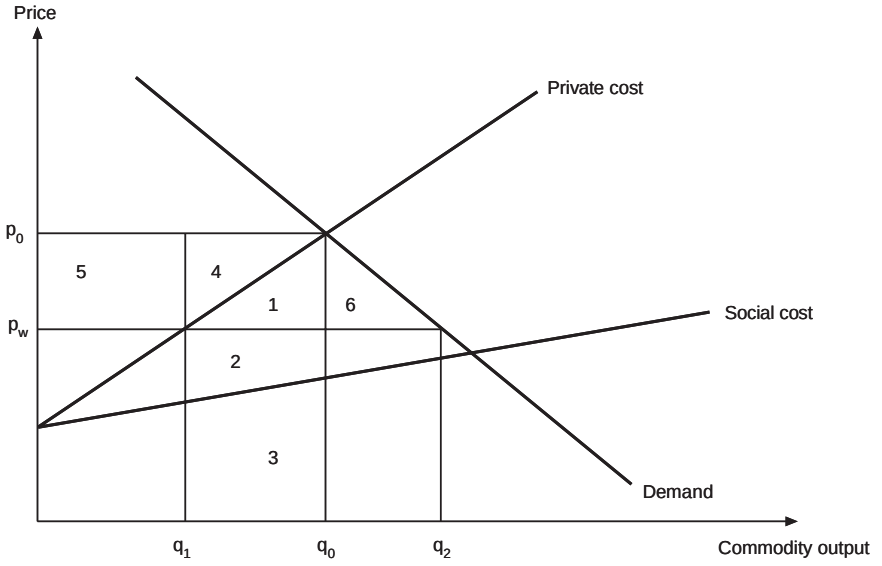
Import-competing good with a negative externality

The move to free trade in the case of an import-competing good leads to a fall in the price, a decline in the quantity produced, and an increase in the quantity consumed. The difference between the case where the production of the good is associated with a negative externality and the case where there is no externality is that the gains from trade are greater when there is an externality. This is similar to the case of an exportable good with a positive externality.

Import-competing good, positive externality

As usual, there is a private gain from trade (areas 1 and 6 in Figure A7.5). There is also a social cost equal to the amount of externality foregone (areas 1 and 2). Whether or not there are net gains from trade depends on the relative size of the areas lost and gained (areas 2 and 6).

Figure A7.5. **Import-competing good with positive externality**



Source: OECD.

Externalities that are internalised

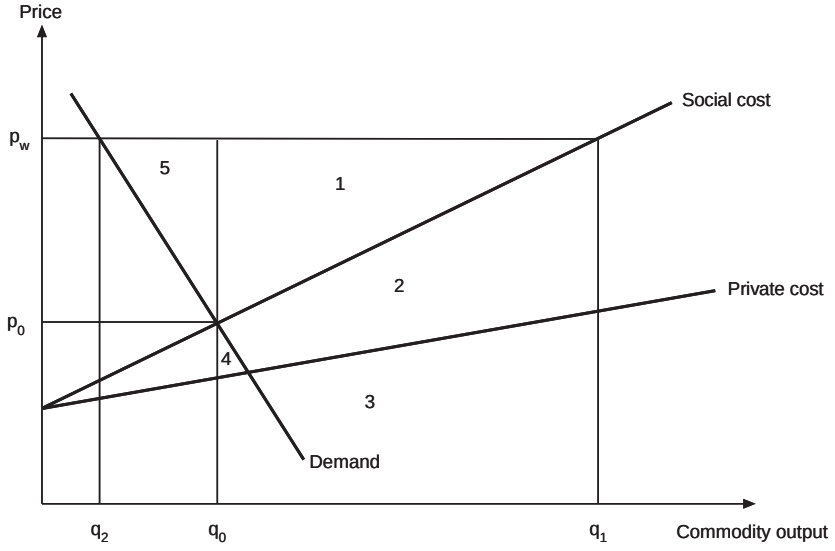
When externalities are internalised, the quantity produced is determined by the intersection of the social cost and demand schedules, in the case of no trade. When there is trade, the quantity is determined by the intersection of the social cost curve and the world price. Compared with the situation where the externality is not internalised, in general the quantity produced of the good is greater in the case of positive externalities, and less in the case of negative externalities. A small-country model in which policies to internalise externalities by a country would not affect international prices is first examined, followed by an analysis of a large-country case.

Negative externality, exportable good

In the case of a negative externality associated with an exportable good, there are gains and costs from the move from no trade to free trade. On the production side, the gains come from the increased production (areas 1, 2, 3 and 4 in Figure A7.6), while private costs are equivalent to area 3, and social costs are equal to areas 2 and 4. There is thus a net production gain equal to area 1, unlike the case when the externality is not internalised. On the consumption side, there is a net gain equivalent to area 5. Thus, in the case of an appropriately internalised negative externality for an exportable good, there are unambiguous gains from trade, although production (and

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Figure A7.6. **Internalised negative externality: exportable good**



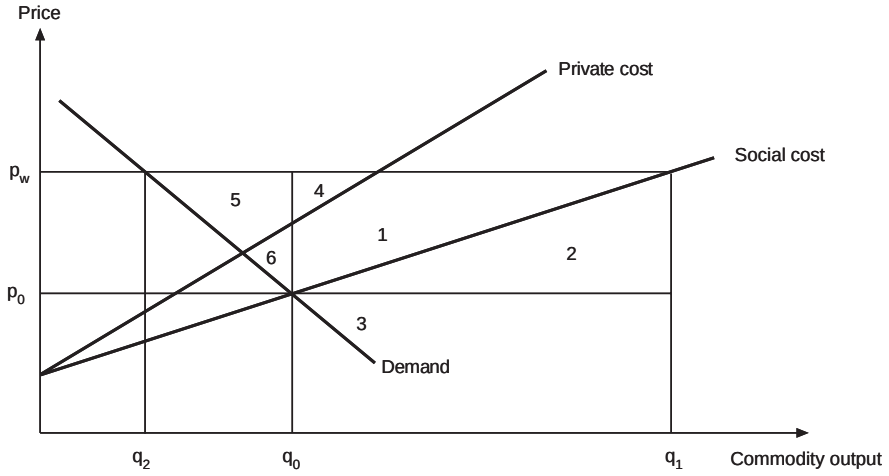
Source: OECD.

hence the levels of the externality) are greater than when there is no trade. It is likely that the country's welfare would be increased by a policy to internalise externalities under free trade, as compared to when there is no policy under free trade. This is absolutely true especially when there is a net loss due to free trade with no policy to internalise negative externalities.

Positive externality, exportable good

In the case of a positive externality that is appropriately internalised, there are production side gains equivalent to the value of the extra production (areas 1, 2, 3, and 4 in Figure A7.7). The production side costs are equivalent to areas 2 and 3, with area 1 being the social benefit received from the internalisation of the externality. The net consumption gains are equivalent to the areas 5 and 6. The net gain overall is equivalent to areas 1, 4, 5 and 6. This gain is greater than the gain due to free trade with no policy to internalise externalities.

Figure A7.7. **Internalised positive externality: exportable good**



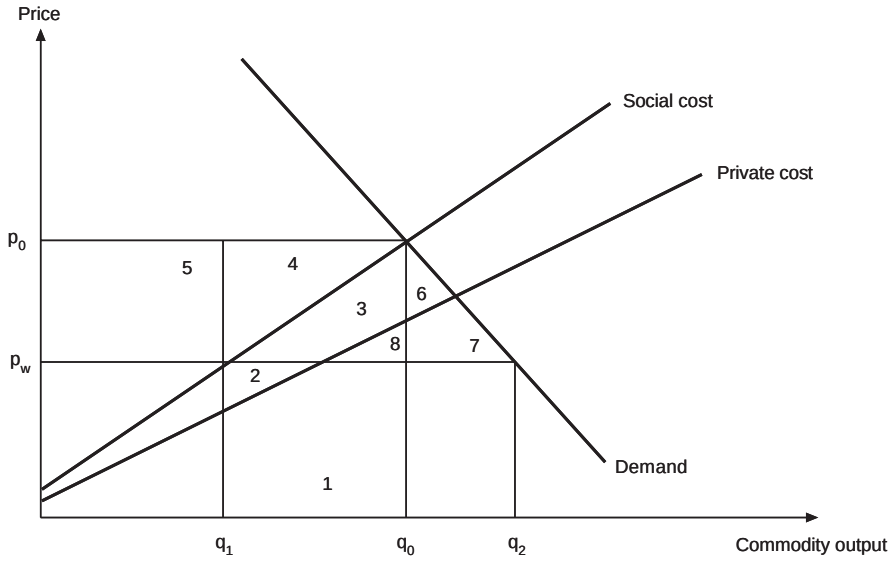
Source: OECD.

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Negative externality, import-competing good

In the case of a negative externality associated with the production of an import-competing good, a move from no trade to free trade causes production-side gains due to lower costs. The private production gains are equivalent to area 1 in Figure A7.8, while the social gains are equivalent to areas 2 and 3. Production-side costs are areas 1 and 8, leading to a net production-side gain of area 3. Consumption gains come from increased consumer surplus (areas 6 and 7). There is thus a net overall gain from trade, equivalent to areas 3, 6, 7 and 8. This gain is greater than the gain due to free trade when there is no policy to internalise externalities.

Figure A7.8. **Internalised negative externality: import-competing good**



Source: OECD.

Positive externality, import-competing good

Production-side gains from trade are equivalent to areas 1 and 2 in Figure A7.9, while losses are equal to area 2. In consumption, there is a gain of area 6 due to the increased consumption and decreased price. Overall, there is a net gain from trade of areas 1 and 6. It is likely that the country's welfare would be increased by a policy to internalise externalities under free trade as compared to the situation of free trade without any policies. This is absolutely true when there is a net loss due to free trade with no policy to internalise negative externalities.

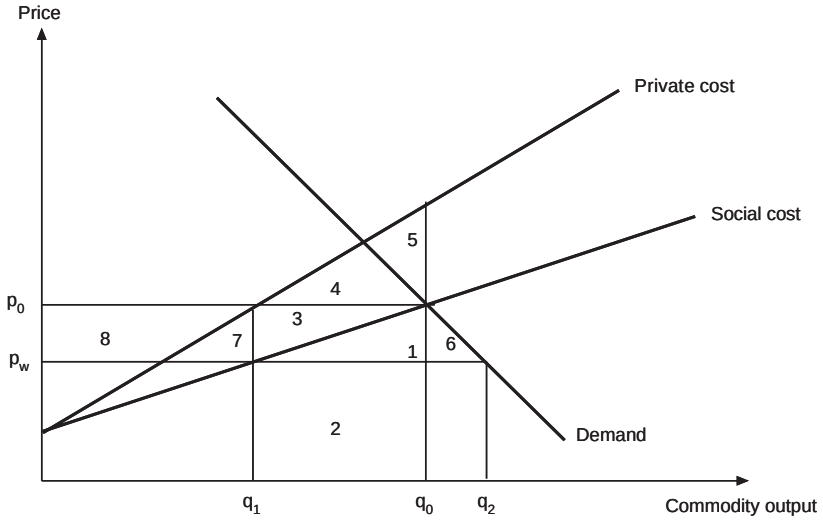
Large country-case: terms-of-trade effects

The above examples dealt only with cases where the main issue was welfare effects associated with externalities. This is the case when a country is small, and its policies to internalise externalities have no effect on world prices. However, when a country is large, there can be terms-of-trade effects, which should also be taken into consideration when evaluating overall welfare effects from externalities.

Figure A7.10, which again has been taken from Corden (1997), shows the situation for an importing country in a two-country model where the second, exporting country, which is assumed to be a large country, implements a policy (*e.g.* tax) to internalise a negative externality associated with the traded good. Suppose that the importing country has not implemented such a policy. The implementation of the policy by the exporting country causes an increase in the world price for the good, which shifts from pw to p_w'. This drop in price is due to a decrease in production in the exporting country from the internalisation of the negative externality, which then has an effect on the world price. As is shown below, the change in the terms of trade effect would increase the quantity produced in the importing country (from q_1 to q_1') and decrease the quantity consumed (from q_2 to q_2'). When considered from the benchmark of trade at price pw, then the welfare of the importing country unambiguously declines. The consumer surplus loss are areas 1 through 7, while the gain in producer surplus is areas 4, 5, 6, and 7. The loss caused by the terms-of-trade effects is therefore area 1, 2, and 3. The social cost associated with an increase in negative externalities is areas 4 and 8. Thus, there is a net loss of areas 1, 2, 3, 4, and 8. There should be a gain in the exporting country from the combination of the terms-of-trade effect and a decrease in negative externalities. Global welfare, where the terms-of-trade effects in both countries cancel one another out, could increase or decrease depending on whether the gain associated with the decrease in negative externalities in the exporting

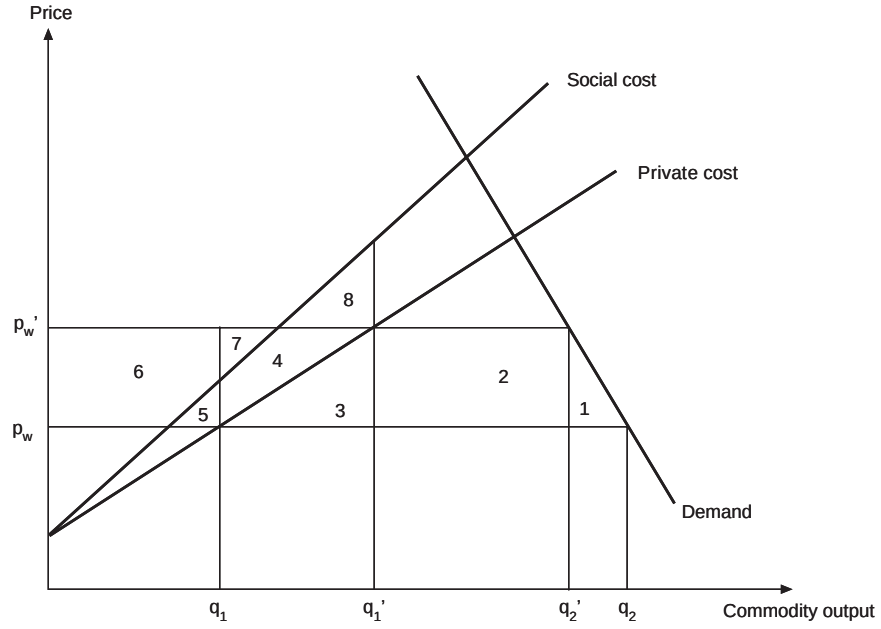
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Figure A7.9. **Internalised positive externality: import-competing good**



Source: OECD.

Figure A7.10. **Terms-of-trade effect – Importing country, increase in world price**



Source: OECD.

country is greater than the loss associated with the increase in negative externalities in the importing country. If the importing country implements a measure to internalise externalities, global welfare would increase although the importing country would continue to suffer from the costs caused by the policy of the exporting country. Similarly, policies that led to production increases in the large country and a related fall in world prices would lead to welfare gains for importing countries and losses in exporting ones.*

* If the effect on price is large enough to change a given country's direction of trade, these welfare gains and losses would be reversed. However, since this would be a very particular situation, in the following analysis it is disregarded.

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The effect of internalisation in only one of two countries

The table below provides a detailed explanation of the conclusions presented in the section on international equity in Part III. It illustrates the effects of the implementation of policies to internalise externalities when there are two large countries trading in the good jointly produced with the externality. Only one of the two countries implements a policy. As the countries are large, both terms-of-trade effects and the effects of changing levels of externalities have an impact on the changes to welfare of each country. These effects are evaluated individually for each country. The overall effects (*i.e.* the combination of the effects of changes in both terms-of-trade and externalities) on the welfare of each country and on global welfare are given in the final three columns.

The benchmark against which the changes in welfare are evaluated is when trade is already occurring, and the countries implement (or not) policies to internalise the externalities associated with the production of the traded good.

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Case	Externality in importing country	Policy in place	Externality in exporting country	Policy in place	Global welfare	Importing country welfare	Exporting country welfare
1	Negative	Yes	Negative	No	Increase or decrease	Increase or decrease	Increase or decrease
Welfare effects	Terms of trade cause welfare to: decrease Externalities cause welfare to: increase		Terms of trade cause welfare to: increase Externalities cause welfare to: decrease				
2	Negative	Yes	Positive	No	Increase or decrease	Increase or decrease	Increase
Welfare effects	Terms of trade cause welfare to: decrease Externalities cause welfare to: increase		Terms of trade cause welfare to: increase Externalities cause welfare to: increase				
3	Negative	No	Negative	Yes	Increase or decrease	Decrease	Increase
Welfare effects	Terms of trade cause welfare to: decrease Externalities cause welfare to: decrease		Terms of trade cause welfare to: increase Externalities cause welfare to: increase				
4	Negative	No	Positive	Yes	Increase or decrease	Increase	Increase or decrease
Welfare effects	Terms of trade cause welfare to: increase Externalities cause welfare to: increase		Terms of trade cause welfare to: decrease Externalities cause welfare to: increase				
5	Positive	Yes	Positive	No	Increase or decrease	Increase	Decrease
Welfare effects	Terms of trade cause welfare to: increase Externalities cause welfare to: increase		Terms of trade cause welfare to: decrease Externalities cause welfare to: decrease				
6	Positive	Yes	Negative	No	Increase or decrease	Increase	Increase or decrease
Welfare effects	Terms of trade cause welfare to: increase Externalities cause welfare to: increase		Terms of trade: decrease Externalities: increase				
7	Positive	No	Positive	Yes	Increase or decrease	Increase or decrease	Increase or decrease
Welfare effects	Terms of trade cause welfare to: increase Externalities cause welfare to: decrease		Terms of trade cause welfare to: decrease Externalities cause welfare to: increase				
8.	Positive	No	Negative	Yes	Increase or decrease	Increase or decrease	Increase
Welfare effects	Terms of trade cause welfare to: decrease Externalities cause welfare to: increase		Terms of trade cause welfare to: increase Externalities cause welfare to: increase				

Source: OECD.

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