Ambiguous jointness and multifunctionality

Eirik Romstad

Norwegian University of Life Sciences
Department of Economics & Resource Management, PO Box 5033, NO-1432 Ås, Norway
telephone: (+47) 6496 5708 fax: (+47) 6496 5701 mobile: (+47) 922 97 226
e-mail: *eirik.romstad@umb.no*, WEB: *http://www.umb.no/ior/*

Abstract

Many previous analyses of multifunctionality in agriculture claim there is positive jointness between the production commodities and nonmarket goods and services. Those analyses have not treated acreage as an endogenous variable. This leads to several errors in terms of the analysis of policy impacts, and hence also policy advice. The main contribution of this paper is the development of an analytical framework where acreage is endogenously determined.

This framework is then used to demonstrate that any policy that influences resource allocation also affects agricultural commodity production. Hence, there is no such thing as a decoupled support. The impacts on commodity markets from direct payments to environmental goods and services are, however, smaller than the distortions from policies that inflate commodity prices.

Key words: multi-product production, comparative statics, nonmarket goods.

JEL classification codes: Q180, Q200

1. Introduction

A common definition of multifunctionality is that agriculture may be defined as multi-functional when it has one or several roles or functions in addition to its primary role of producing food and fiber (Norwegian Ministry of Agriculture, 1999).

The objectives of this paper is to look more closely at the acclaimed jointness between agricultural commodity production and the provisioning of nonmarket goods from agriculture (for example Vatn, 2002). From a theory perspective I show that positive jointness generally does not exist per acreage unit. Positive jointness may, however, be observed when one looks as agriculture in a region, i.e., with more agricultural acreage, there will also be more nonmarket services supplied.

This observation does not justify the use of commodity price supports or other measures targeted at boosting commodity production. The reason for this is that when for example commodity price supports are used, more acreage goes into agriculture, thereby appearing as positive jointness when one looks at aggregate data over time.

Many landscape amenities are not traded in markets because of their public good nature.[1] It is difficult to design policies that induce farmers to produce the right quantities of these non-market goods in the least costly fashion. First, the value of many of these nonmarket goods is not known, although there is strong evidence to suggest that these goods have a positive and significant value under certain settings. Finding their value is not straight forward as noted by Randall (2002). It is therefore difficult to assess the optimality of the level of nonmarket goods provided by agriculture. An alternative approach is cost effectiveness, i.e., that any target shall be reached at the least social costs.[2]

Second, there are many nonmarket goods, and hence possible objectives, associated with agriculture. This alone makes it difficult to formulate consistent policies. Matters are made worse as each policy objective generally requires a policy instrument to secure the desired outcome (Tinbergen, 1950). This implies that the number of instruments could become large, thereby augmenting policy costs.

Third, the linkages between these nonmarket goods and agricultural production or land use, imply that changes in commodity production may affect the production of the nonmarket goods, or vice versa. This gives rise to the non-trade concerns (NTCs) of food imports: They influence domestic food prices and hence domestic production or land use. There is also a reverse issue: (Ill defined) public programs for securing production of nonmarket goods can easily be used to favor domestic products over imports, leading to welfare losses abroad and at home.

Designing policies for securing nonmarket goods under such settings is not straight forward. One difficulty with multifunctionality is that the target is vague, often consisting of multiple and conflicting objectives. Finding an orderly way or treating these objectives is therefore a first step in making a policy that works, and that meets the TTT criterion: *targeted, tractable and transparent* (Batie, 1996).

This goes to the core of the multifunctionality issue that is discussed in the next section. Section three sketches the notion of multi-product production. In section four I present a model to highlight some policy implications and rationalize how price supports may result in more

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[1] A more precise definition of *public goods* is that they are nonrival and nonexcluding in consumption (Randall, 1983).

[2] Note that the optimal level of nonmarket goods provided, i.e., where marginal willingness to pay may equal the marginal costs of production, belongs to the set of least cost solutions.

nonmarket goods and services being produced even when the per hectare relationship is negative. The final section concludes and presents some policy implications.

2. Multifunctionality revisited

Multifunctionality (MF) is a rather loose concept, with many different definitions. Romstad (2004) clarifies matters by distinguishing between primary and secondary MF attributes. Primary impacts include goods and services that are unique to agriculture, or at least stronger linked to agriculture than other sectors of the economy. Secondary impacts entails goods and services that could be supplied by other sectors of the economy. Such a distinction makes it easier to focus agricultural policies. Rural employment is an illustrative example on these matters.

In most industrialized countries, agriculture employs 2-4 percent of the overall population, or 6 to 15 percent of the rural population. Thirty years ago, those shares were about twice as high. Many regions have experienced a substantially larger decline in rural employment in the same period. The reduction in agricultural employment therefore only explains a fraction of the lost jobs. This does not imply that agriculture is unimportant in this regard. It is, however, logically flawed to claim that maintaining agricultural employment is a key to rural viability. Agriculture's importance as an employer is likely to continue to fall. Technological change is one driver in this process. Another important driver is relative wages between agriculture and other sectors. For agriculture to employ a larger share of the rural population than today, wages in agriculture need to grow faster than in other sectors of the economy.

To make the concept more operational the associated policies needs to focus on the primary impacts first. The primary reason for this is that a large number of objectives increases the likelihood that some of the objectives may be conflicting. In turn, that makes it more difficult to formulate policies that are work, cfr. Tinbergen's "one objective, one instrument" thesis (Tinbergen, 1950).

Another benefit from separating primary and secondary impacts is that it is highlights that multifunctionality is about site specific attributes. This has another profound impact - "one size fits all" policies are rarely going to be optimal. Specifically, the conditions for agricultural commodity production, and hence types of production, differ from one location to another. The same holds for the nonmarket attributes as they depend on topography, the presence of forests, etc. Romstad, Vatn, Søyland and Rørstad (1999) elaborate this reasoning in more detail.

Empirical modeling of tradeoffs between commodity production and public good attributes need sound empirical work. In recent years there has been a flux of empirical studies. Unfortunately, few of these separate observed effects at the farm and the acreage levels. A notable exception is Groot, Rossing, Jellema, Stobbelar, Renting and Van Ittersum (2007). Their results are at the per hectare level and suggests negative tradeoffs between gross margins and positive nonmarket attributes like plant species and landscape values, and a positive relationship with the negative impact of nitrogen losses. If the latter is framed as a reduction in nitrogen losses, a negative tradeoff emerges that is consistent with the arguments I bring forward in this paper. Lankoski (2003) and Lankoski and Ollikainen (2003) get similar results as Groot et al. (2007). Their application deals with the impacts of buffer strips on nutrient leaching and on wildlife. They find that unless the leaching reduction or wildlife components are positively priced or mandated by other regulations, farmers will not choose to plant buffer strips. Their results are consistent with the theoretical approach of this paper.

3. Multi-product production[3]

In the conventional definition of production possibility sets, physical input use is assumed constant at the production possibility frontier (Debertin, 1986). This also implies that production costs are kept constant for any allocation of *y* and *z* on frontier. In the case of multi-product – multi-input production, assuming that input use is kept constant is a restrictive assumption. Letting the production possibility frontier be defined by any combination of *y* and *z* that does not exceed a given cost is a more flexible approach (Chambers, 1988). This gives the following constrained joint revenue maximization problem:

$$\left\{\begin{matrix} Max \\ y,\, z \end{matrix}\right\} p_y y + p_z z \qquad s.t.\ C(y,\, z) = \overline{C} \tag{1}$$

when the cost constraint has to be met. This gives the following Lagrangian:

$$L = p_y y + p_z z + w\left[\overline{C} - C(y,\, z)\right] \tag{2}$$

with the following first order conditions:

$$\frac{\partial L}{\partial y} = p_y - w\,C_y = 0 \tag{3a}$$

$$\frac{\partial L}{\partial z} = p_z - w\,C_z = 0 \tag{3b}$$

$$\frac{\partial L}{\partial w} = \overline{C} - C(y,z) = 0 \tag{3c}$$

where C_y and C_z are the partial derivatives of the joint cost function, $C(y,z)$ with respect to *y* and *z* respectively. With standard assumptions on the second order conditions this gives the familiar expression for the (marginal) rate of product transformation between *y* and *z*:

$$RPT_{yz} = -\frac{p_y}{p_z} \tag{4}$$

i.e., that the optimal allocation of *y* and *z* is determined by their relative prices, p_y and p_z.

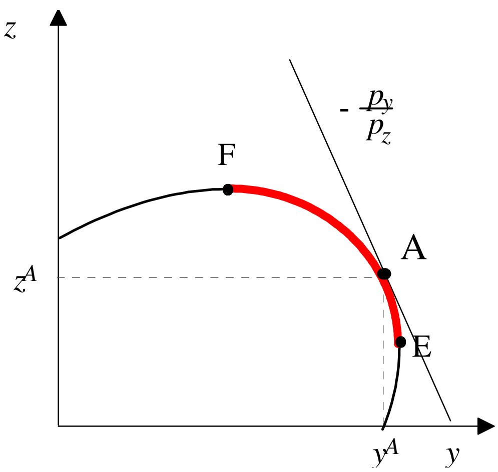

Figure 1: The production possibility frontier and the optimal allocation.

Note that all joint pairs (*y*, *z*) on the production possibility frontier (the product transformation curve) can be achieved with the same costs, $\overline{C}$. For positive prices on *y* and *z* the profit maximizing allocations must then be located on the thick portion of the production pos-

[3] Parts of this section is taken from another paper by the author - not referenced here to maintain anonymity.

sibility frontier. This implies that in an equilibrium with non-negative prices, one will should not observe allocations outside the segment between F and E. Also note that for a zero price on z, the nonmarket good, implies that production takes place at E.

Figure 2 illustrates the impacts of decreasing the price of one good, y. This is illustrated by multiplying p_y with the scalar a, that is less than one (like one half). This changes the slope of the price line, which using a strict cost constraint yields a shift in the optimal allocation from A to B. However, when costs are not constrained, the production possibility set may shrink, yielding two effects: (i) the substitution effect from A to B, and (ii) and a movement from B to D that resembles the income effect in consumer behavior.

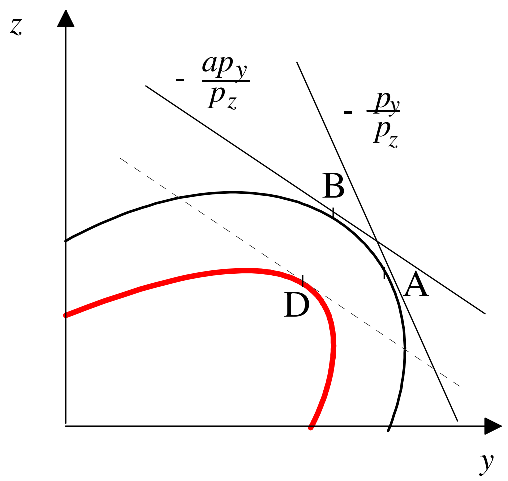

Figure 2: Substitution and income effects when costs are allowed to vary.[4]

Naive understandings of equation [4] may lead to serious misinterpretations of price changes. Suppose that the price on y, p_y, is dramatically reduced. This is often interpreted as a movement along the production possibility frontier. From [3a] it follows that the price drop changes the optimal use of y, and thereby also the optimal resource use (costs). In section 4 the same result will be derived using comparative statics.

4. An analysis with endogenous agricultural acreage

Agricultural production involves decisions regarding land use as well as field specific choices on fertilization, chemical treatment, etc. Such nested decisions easily become quite messy. It is therefore useful to explicitly model the decision problem. In this section I take particular care of incorporating key parameters to enable analyzing the linkages I deem important. Recent work along the same line includes Guyomard, Le Mouël and Gohin (2004), and Lankoski and Ollikainen (2003). The novel feature in my model formulation is the treatment of acreage.

4.1 Model formulation

A typical farm runs several productions. To make the analysis more tractable I model a stylized farm that produces one market commodity, y, and one nonmarket good, z. The farm has a total acreage of one. Let a denote acreage used for the joint production of y and z, and the

[4] The change in the size of the production possibility set in Figure 2 from the decrease in p_y to ap_y is made large for demonstrative purposes, but it illustrates that when costs are not constrained to a fixed amount, there could be both substitution and income effects.

rest of the acreage for some other activity *r*, with the per hectare profits π_r. Using area entails a cost, $c(a)$ that is assumed to be C_2. The only prices in this model is the commodity price, p_y, the payment for the nonmarket good, p_z, and the acreage payment, p_a, for land producing *y* and *z*. All prices are non-negative. Let $c(y,z)$ denote the joint costs of producing *y* and *z* with the desired standard properties. Farm profits are then given by:

$$\pi = \left[p_y y + p_z z - c(y,z)\right]a + p_a a - c(a) + \pi_r(1-a) \qquad [5]$$

From the previous section we know that with non-negative prices and a relationship different than Leontief production, multi-product production occurs on negative sloped segment (the thick line) of Figure 2. The relationship between the production of *z* can then be described by the function $z(y)$, where $\frac{\partial z(y)}{\partial y} = z_y \leq 0$. [5] can then be written the following way:

$$\pi = \left[p_y y + p_z z(y) - c(y, z(y))\right]a + p_a a - c(a) + \pi_r(1-a) \qquad [6]$$

Taking the first order conditions of [6] with respect to the choice variables *y* and *a*, letting c_y and c_z denote partial derivatives of the cost function with *y* and *z* respectively, letting c_a be the partial derivative of the cost of using land for agriculture, and rearranging yields:

$$\frac{\partial \pi}{\partial y} = \left[(p_y - c_y) + z_y(p_z - c_z)\right]a = 0 \qquad [7a]$$

$$\frac{\partial \pi}{\partial a} = \left[p_y y + p_z z(y) - c(y, z(y))\right] + p_a - c_a - \pi_r = 0 \qquad [7b]$$

Taking the second order derivatives of [7a] and [7b] results in the following Jacobian:

$$|J| = \begin{vmatrix} a\left[z_{yy}(p_z + c_z) + z_y c_{zy} - c_{yy}\right] & (p_y - c_y) + z_y(p_z - c_z) \\ (p_y - c_y) + z_y(p_z - c_z) & c_{aa} \end{vmatrix} > 0 \qquad [8]$$

[8] is positive as $\left[z_{yy}(p_z + c_z) + z_y c_{zy} - c_{yy}\right]$ and c_{aa} are negative, and $(p_y - c_y) + z_y(p_z - c_z)$ is zero at the optimum. The conditions for applying the implicit function theorem on [7a] and [7b] are therefore met. Taking the complete derivative of [7a] results in:

$$\begin{aligned} d\left(\frac{\partial \pi}{\partial y}\right) &= a\,dp_y + a\,z_y\,dp_z \\ &+ a\left[z_{yy}(p_z + c_z) + z_y c_{zy} - c_{yy}\right]dy \\ &+ \left[(p_y - c_y) + z_y(p_z - c_z)\right]da \end{aligned} \qquad [9a]$$

Similarly, for [7b] the result is:

$$\begin{aligned} d\left(\frac{\partial \pi}{\partial a}\right) &= y\,dp_y + z(y)\,dp_z + dp_a \\ &+ \left[(p_y - c_y) + z_y(p_z - c_z)\right]dy \\ &- c_{aa}\,da + dp_a - d\pi_r \end{aligned} \qquad [9b]$$

We are now in the position to start analyzing the comparative statics of [6].

4.2 Some selected comparative statics

Policy impacts on commodity production levels are of primary interest in the non-trade concern (NTC) debate. The effects of a change in the commodity prices p_y on commodity production and acreage are:

$$\frac{dy}{dp_y} = -\frac{-a\,c_{aa}}{|J|} > 0 \qquad [10a]$$

$$\frac{da}{dp_y} = -\frac{a\left[z_{yy}(p_z + c_z) + z_y c_{zy} - c_{yy}\right](-y)}{|J|} > 0 \qquad [10b]$$

These results are as expected. An increase in commodity prices implies more production per hectare [10a], and that a larger area is used for commodity production [10b].

Now, suppose that the price of the nonmarket good, p_z, is increased. This yields the following expressions:

$$\frac{dy}{dp_z} = -\frac{-a\, z_y\, c_{aa}}{|J|} < 0 \qquad [11a]$$

$$\frac{da}{dp_z} = -\frac{a\left[z_{yy}(p_z + c_z) + z_y c_{zy} - c_{yy}\right](-z(y))}{|J|} > 0 \qquad [11b]$$

[11a] is consistent with the discussion in section 3 on the effects of making the price line $\frac{p_z}{p_y}$ in [4] less steep: an increase in the environmental payment, p_z, reduces the per hectare production level of *y*. However, the total impact on commodity production levels from an environmental payment is therefore undetermined in the general setting. It must therefore be checked in each single case.

[11b] shows that the acreage may grow as a result of an increased environmental payment. Consequently, one cannot rule out that a higher environmental payment, p_z, leads to an increase in the market commodity produced, *y*. A joint analysis of [11a] and [11b] shows that the total impact of an environmental payment on commodity production levels is undetermined in the general case. It must therefore be analyzed with the parameters of the functions describing these interactions. Please note that the problem of signing the total impact of an environmental payment is similar to determining what is the largest of the substitution and income effects discussed in connection with figure 3.

However, the substitution effect in [11a] that for standard relationships between the market commodity and the nonmarket good is negative. Given the similarity between [10b] and [11b], the total impact on commodity production is likely to be larger from a price support than from a direct payment for nonmarket goods

4.3 Discussion of model insights

The model in the previous subsection is highly stylized. Still, it provides some important general insights. First, the number of truly decoupled payment schemes appears to be far less than previously believed. Second, any policy that works (in terms of changing agent behavior) will impact commodity production levels.

These findings may at first appear to be bad news for dealing with NTCs. That is a severe misinterpretation. The fact that more policy regimes than previously believed have adverse (or at least not as negligible) impacts on commodity production does not imply that one should discard NTCs. That would be inconsistent with all we have learnt in welfare economics.

What are the implications of this result for the choice of policy instruments for improved environmental quality from agriculture? Stronger policy focus on the unique features will in may cases lower unintended impacts, and hence improve the net benefits. Non-unique attributes may still be important. Hence, they need to be accounted for. A guiding principle is that the non-unique should take place in the sector(s) where the net gains are the largest.

The model produces results that are consistent with those of the multi-product production models of Runge (1999) and Romstad (1999a, 2004). This is due to the model's treatment of land use.

The model clearly illustrates the adverse effects of price supports. First, there is the direct effect on per hectare production levels [10a]. Second, there is the indirect effect on commodity production through the land use [11a]. Third, it opens for a more insightful interpretation of the empirical various agri-environmental policies. Most notably, by providing an explanation for how price supports may lead to an increase in the production of public goods from agriculture that is consistent with negative relationship between commodity production and public goods in a production possibility framework.

5. Concluding remarks

In an equilibrium with non-negative prices and rational agents, one will never observe allocations outside the segment of the per acreage production possibility frontier where one must offset an increase in the production of one commodity with a decrease in the some other production or attribute.

With acreage as an endogenous variable one may observe equilibria that appear to entail some (positive) jointness. The linkage in such cases is through agricultural acreage being non-fixed. For example, an increase in price supports may lead to an increase in the production of public goods from agriculture. At first sight, this appears inconsistent with the production possibility framework. However, this apparent "jointness" is due to an increase in acreage as agricultural production becomes more profitable relative to other uses of the land.

This leads to the following policy conclusions:

(1) Price supports generally lead to larger distortions of commodity markets than payments for environmental goods and services as price supports lead to substitution and income effects that work in the same direction on commodity production levels.

(2) Direct environmental payments, or acreage payments in the case of high transaction costs, may also increase commodity production, but to a far lesser degree than price supports as the substitution and income effects work in opposite directions.

In practical terms we should note the following. Devising policy schemes for multifunctionality is not straight forward. There are two primary reasons for this. First, there is a large number of attributes, and all are internally in conflict if they are optimally allocated for a set of given prices and regulations. Second, as this paper has shown, targeted environmental policies that work will also impact commodity production. That implies that many domestic policies will have undesired welfare impacts abroad.

Unless policies for managing the nonmarket goods associated with agriculture become more targeted, transparent and tractable (cfr. Batie's (1996) 3Ts principle), potentially valuable attributes may be lost or decay. That could lead to severe domestic welfare losses. In turn, that may jeopardize further developments in international trade of agricultural commodities.

There exists a tradeoff between transaction costs and how precise a regulation can be. Transaction costs are usually much less than the costs agents encounter in complying. The main focus should therefore be on achieving policy objectives at the least social costs. Multifunctionality can be a helpful concept in this process. However, the policy instruments for capturing multifunctionality need to be focused, and must meet the resource allocation mechanism criteria. Finally, when designing these instruments and the general agri-environmental policies, one must acknowledge that there is a tradeoff between the impacts on commodity markets and trade on side, and the welfare impacts of improved management of public goods on the other side.

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