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# Identification and Valuation of Public Goods within the Vertical of Cattle Breeding

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## Abstract

The paper identifies and discusses the production of public goods in the vertical of cattle breeding. The cattle breeding vertical was divided into four basic levels – producer, processor, retailer, and consumer and main public goods were determined and discussed. Moreover, it provides the methods for the valuation of public goods. The method is applied in the estimation of manure shadow price. Using the fitted multiple output distance function with two market and one non-market output and applying the Lagrange method and the Shephard's dual lemma the shadow price of manure was calculated. The results show that the shadow prices differ significantly among the groups of farmers. This especially holds for the classification of groups according to the size and technology of production.

## Keywords

Public goods, externality, cattle breeding, production, shadow price.

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## Introduction

Production of agricultural commodities is associated with a considerable number of externalities or goods that match the definition of public goods. Literature very often cites examples of externalities, e.g., in the form of grazing biomass by cattle for landscape maintenance, pollination of fruit trees to produce honey, etc., are closely linked to agricultural activities. Discussions of the role of agriculture in the production of public good began to evolve especially towards the end of the 20th century, as the professional and general public became aware of the externalities in agricultural production and began to pay more attention to the expanding spectrum of agrarian policy instruments. Specifically, it is about externalities associated with and inseparable from the production of agricultural commodities. The source of information about the associated aspects is according to Shumwaye et al. (1984) in Lankoski and Ollikainen (2003) where mutual technical dependence on inputs is enhanced by fixed or quasi-fixed inputs, such as the soil. The very link of the agricultural sector onto the soil may be viewed as one of the causes for the origin of externalities, both positive and negative, so often associated with agricultural activities.

The situation is similar even in other fields of the agricultural and food processing sectors, where activities are differentiated into crop and livestock production that are characteristically associated with different types of externalities with specific causes and consequences each. The next part of the study focuses on livestock production, primarily cattle breeding both for meat and dairy production, whereby the main objective was to identify individual examples of externalities related to this field, while distinguishing their characteristics, in order to achieve a theoretical overview of the origin and classification of public asset using real examples of agricultural production. Moreover, another aim of the paper is to provide the method and the example of the valuation of chosen public good in the cattle breeding. Choosing the commodity vertical of cattle breeding is entirely intentional here, as cattle being a typical representative of the meat vertical constitutes the majority and irreplaceable segment of the livestock production in agricultural production practically in all European countries, including the Czech Republic. Moreover, the chosen vertical is relatively broad, so that it is possible to identify – as part of the processes of a segmental market (both pricing and production – see, e.g., Malý (2013)) – a broad scale of public goods from various production and processing processes. Finally, the chosen public good for valuation serves entirely as an example that can be used for valuation of any public good which is directly produced by particular agricultural activity.

## Materials and methods

Generally, an externality may be defined as an event that is considerably beneficial (or wasteful) to the person or persons who are not fully entitled to take part in the decision-making that leads, directly or indirectly, to the given event (see Maede, 1973). Pillet et al. (2000) add that externalities are from the broader perspective defined as "spillovers", i.e., effects outside commercially measurable parts of economic activities. During the transformation of the above view of agriculture, it is possible to define as situations where the activities of agricultural enterprises impact on the condition of the environment, social and spatial structure of the region or country and on the welfare of the people who do not participate in the decision-making about the given event. According to Anderson (2000), it becomes a non-commercial net benefit that agricultural producers give to the rest of the society. In the Czech environment, externalities were defined, e.g., by Kršková (2007), as by-effects of production which do not pass through the pricing system of the enterprises' primary activity, i.e., they are not included in the price of the good that the originators of the externalities produce.

From the perspective of possible consequences, production and consumption externalities may be divided into negative externalities, were the activities of one participant cause decline of another participant's benefit (i.e., cause external expenses), and positive externalities, where the activities of individuals of the society increase the benefits of another entity (i.e., lead to external profit or saving). The examples of above-mentioned externalities associated with agricultural activities have been selected as random models which however have something in common in the sense of positive externality. According to Burrell (2011), there exist very few positive externalities whose assurance is linked to the production of agricultural commodities, as the production of agricultural commodities is far more often associated with negative externalities.

Public goods were defined the first time by Samuelson (1954) as goods having the property of non-exclusivity and non-rivalry. Non-rivalry goods are, according to Špalek (2011) indivisible in consumption, meaning that an increase in the number of consumers will not increase the variable costs of the given goods' production, hence the benchmark costs. Moreover, non-rivalry goods are consumed by all consumers in equal quantities, so that the volume of consumption is forced in a way upon the consumers by the provider. Non-exclusivity of consumption means that the consumer cannot be barred from consuming the goods. The impossibility of excluding certain goods from consumption is often due to technical infeasibility, yet there exist economic reasons for exclusion – namely, high costs. The above definition of public goods based on non-rivalry and non-exclusivity was fundamental for a number of studies dealing with these issues (e.g., Miceli, 2005; Cooper et al, 2009; Jongeneel et al., 2010; Slee and Thomson, 2011; Burrell, 2011; Harvey and Jambor, 2011). On the basis of the above aspects, Burrell (2011) in the end suggests to define agricultural public goods as separable (independent) outputs of such agricultural activities as may be increased independently of the augmentation of the production of a certain agricultural commodity.

Based on the above definitions of both concepts – externality and public goods – it is evident that that they overlap to some extent. OECD (2001) solves this terminological overlap by differentiating the outputs of agricultural activities into market and non-market ones, which subsequently include both externalities as well as public goods. OECD (2001) furthermore presents examples of production relations for selected non-market outputs, see Table 1.

Many other authors, e.g. Madureira and Santos (2012) and Kaley et al. (2011) count non-market outputs specified in Table 1 among basic agricultural public goods and complement them with climate stability, resistance to floods and fires, see Table 2, which contains an account of basic agricultural public goods, as well as their definitions.

The extent of assurance of the above goods varies by type of agricultural activity. For instance, extensive cattle breeding, combination of animal and crop production, and ecological agriculture ensure a greater scope of public assets than intensive agricultural production. Maciejczak and Zakharov (2011) define the scope of public goods ensured by individual agricultural practices, see Table 3.

| Non-market outputs | Market production | | | | Other commercial activities | Direct assurance of public goods |
|---|---|---|---|---|---|---|
| | Fixed inputs | Variable inputs | Farm technology and practice | Market outputs | | |
| Landscape | Use of arable land, agricultural buildings | | Silos, greenhouse, stables, irrigation | Crops | Buildings and equipment for agrotourism | Upkeep of agricultural buildings, meadows |
| Biodiversity | Use of arable land | Use of agro-chemicals | Intensity of breeding, soil cultivation, harvesting technology | Crops | Charging for access to specific ecosystems | Wetlands and other specific environment, corridors for wild animals |
| Soil quality | Soil cultivation | | Rotation of crops, breeding intensity, irrigation | Crops, field coverage | | Permanent field coverage |
| Water quality | Cultivation of eroded soil | Use of pesticides and fertilizers | Storage and application of fertilizers, concentration of animals | Crops, field coverage | Charging for access to clean water in rivers and lakes | Permanent field coverage, protective zones |
| Air quality | Cultivation of eroded soil | Use of pesticides | Storage and application of fertilizers | Crops and animals, field coverage | | |
| Vitality of rural areas | Demand for laborers | | | | Adequate income | |
| Food safety | Sustainability of production capacity (soil, basic herd) | Sustainability of production capacity (seed production) | Technology diminishing health risks | Food supply | Sales and marketing | Sustainability of soil fertility, genobank |
| Animals welfare | Stables | Fodder | Technology of transport and slaughter, access to free range | | | |

Source: Author's elaboration as per OECD (2001)

Table 1: Examples of relations in production.

| Public asset | Definition |
|---|---|
| Climate stability | Degree of ecoregion‘s capability to retain suitability (climatic conditions prevailing current parameters) for biological varieties and ecosystems contained today. (Watson et al., 2013) |
| Biodiversity | Variability of living organisms, including dryland, sea, and other aquatic ecosystems and ecological complexes (Bartkowski et al., 2015).<br>Degree of biodiversity (McNeely, 1988 in Cairns and Lackey, 1992). |
| Water quality and accessibility | Stable supply of non-contaminated water (Kaley & Assoc., 2011). |
| Soil fertility | Capability of the soil to meet required natural requirements or soil behavior in natural condition. (Volchko et al., 2013)<br>Result of pedologic processes arising from the complexity of interactions between living (biological) and non-living (physical and chemical) soil components using universal forces impacting on substance and energy (de Groot et al., 2002). |
| Air quality | Clean, clear, non-contaminated air meeting given criteria (British Columbia, 2015) |
| Resistance to floods and fires | System's capability to absorb disorders and to reorganize itself in response to being exposed to changes, as well as ability to retain basic functions, structure, identity, and feedback. (Walker et al., 2004) |
| Cultural agricultural landscape | Visual phenomenon comprised of tangible attributes, including geomorphology, earth surface, and cultural development (Moran, 2005).<br>Unique geographical region (Swanwick and Assoc., 2007).<br>Ecological infrastructure that supports ecological processes and functions, with a cultural dimension arising from long-term influence of man and technology (Madureira and Santos, 2012). |

Source: Author's elaboration

Table 2: Main agricultural public goods (staples) and definitions thereof.

| Public asset | Definition |
|---|---|
| Vitality of rural areas | Availability of a certain level of economic opportunities, minimum level of services and infrastructure, human capital and functional social networks to guarantee long-term sustainability livability and attractiveness of rural areas as good places for living, work, and leisure (Kaley et al., 2011).<br>Attractiveness of life in the country for rural and urban population (OECD, 2001). |
| Animals‘ welfare | Elimination of suffering of animals and preservation of their good physical and mental condition (Webster, 1994).<br>Combination of physical and mental health of animals ensured by harmonious existence of animals in a certain environment (Hughes, 1976, in Carenzi and Verga, 2009). |
| Food safety | Availability of food any time any place (Kaley and Assoc., 2011). Status quo where all people always have physical and economic access to healthy food of adequate nutritional quality and quantity to satisfy their dietologic needs for quality and healthy life (OECD, 2001).<br>Reduction of diseases and pathogens, measured by decline of the probability of health risks, for which customers are willing to pay more money (Stenger, 2000). |

Source: Author’s elaboration

Table 2: Main agricultural public goods (staples) and definitions thereof (continuation).

| | Landscape | Biodiversity | Water quality | Water availability | Soil fertility | Climatic stability | Air quality | Resistance to floods | Resistance to fire |
|---|---|---|---|---|---|---|---|---|---|
| Production of crops with low nutritional requirements | x | x | x | x | x | x | | x | |
| Use of own fertilizers | | x | x | | x | x | | x | |
| Animal grazing | x | x | x | | x | | x | | x |
| Limitation of herbicides | x | x | x | x | x | | x | | |
| Manual weeding | x | x | x | | x | x | x | | |
| Lower percentage of arable land | x | x | x | | x | | | x | |
| Limitation of pesticides | | x | x | x | x | | x | | |
| Mixed production with rotation | x | x | x | | x | | | | x |
| No-cultivation economy | | | x | x | x | x | | | |
| Breeding of local breeds | x | x | | | x | | | | |
| Minimization of mechanical technology | | x | | | x | | | | |
| Genetic selection for higher productivity | | x | | | | x | | | |
| Intensive breeding of dairy cows | | x | | | | x | | | |
| Production of biogas from animal waste | | | x | | | x | | | |

Source: Author’s elaboration as per Madureira and Santos (2012) and et al. (2011)

Table 3. Scope of public goods by individual agricultural practice.

However, agricultural production does not lead to assurance of the above goods in the positive sense. As there also exist situations where the impact of agricultural activities on biodiversity, water and air quality, etc., is negative, therefore Madureira and Santos (2012) differentiate the impact of agriculture on public goods into positive and negative, see Table 4. This is corroborated by Burrell (2011).

The presented tables (especially 2 and 4) indicate that the contents of some public assets overlap or act as links in the assurance of other public assets, such as quality and availability of water and biodiversity, biodiversity and cultural landscape, soil fertility and cultural landscape, etc. Many of them have a very complex character, such as biodiversity which is the result of the sustainability of agricultural landscape, activities related to the soil and agricultural practices. Simultaneously, however, landscape may be harmed by agricultural practices, e.g., concretely, intensive agricultural production, breeding of very concentrated livestock etc.

| Effect | Public asset | Cause |
|---|---|---|
| Negative | Biodiversity | Intensification of agricultural production, change in the use of land |
| | Water quality | Intensive use of fertilizers and pesticides |
| | Availability of water | Depletion of water sources for irrigation |
| | Soil quality | Intensive use of pesticides, herbicides and fertilizers |
| | Air quality | Intensive livestock production, emission gases |
| | Climatic stability | Emission of greenhouse gases |
| | Cultural landscape | Intensive agricultural production reducing biodiversity |
| Positive | Cultural landscape | Increase of biodiversity due to use of land, composition of commodities, agricultural practice |
| | Soil and water quality | Extensive agriculture |
| | Climatic stability | Depositing of carbon in soil Substitute of fossil fuels |
| | Resistance to fire | Soil management, extensive grazing meadows |
| | Resistance to floods | Soil management |
| | Vitality of rural areas | Creation of work conditions and subsequent income |
| | Food safety | Growing offer of food |

Source: Author's elaboration as per Madureira and Santos (2012)

Table 4: Dominant impact of agriculture on selected public assets.

Apart from defining public goods related to agricultural activities as such, it is important to quantify their values (prices), which can be used for determining the amount of subsidies to the production of the given commodity. In this paper, we introduce the application of theory of production and a parametric approach – Stochastic Frontier Analysis (SFA) – to quantify the value of a particular public good. The chosen public good for valuation serves in this paper entirely as an example or demonstration, respectively, which can be used for a valuation of any public good which is directly produced by particular agricultural activity. The manure was chosen for the reason of data availability. The application of theory of production and SFA provides the advantage over the methods as e.g. cost calculations that it takes into consideration the farm technology.

We assume that the production process can be well approximated by a translog multiple output distance function. Thus, considering a joint-production process in which a farm employs the input vector $x \in \Re_+^I$ to produce the output vector $y \in \Re_+^J$ (milk, other animal products and plant products) and vector of public goods $g \in \Re_+^K$, the production technology can be expressed by the output possibility set $P(x) = \{(y,g): x \text{ can produce } (y, g)\}$. The output possibility set is assumed to be closed, convex and bounded by isoquant defined as $IsoqP(x)=\{(y,g):(y,g)\in P(x),\lambda(y,g)\notin P(x),\lambda>1\}$. The output vector *(y, g)* must belong to the output possibility set *P(x)*, but it need not to be located on its outer frontier. A radial measure of the distance from output vector *(y, g)* to *IsoqP(x)* is Shephard's output distance function (1):

$$D_O(x, y, g) = inf\{\theta > 0: (y/\theta, g/\theta) \in P(x)\}, \quad (1)$$

where $\theta$ is the value of the output distance function that measures the maximum degree by which *(y, g)* can be proportionally increased given *x* (see Zhou et al., 2014). This function is estimated using Stochastic Frontier Analysis (SFA) in translog functional form which incorporates the weak disposability assumption:

$$lnD_O(x, y, g, t) = \alpha_0 + \sum_i \alpha_i \, lnx_i + \sum_j \alpha_j lny_j + \alpha_g lng + \alpha_t t + \tfrac{1}{2}\sum_i \sum_{i'} \gamma_{ii'} lnx_i lnx_{i'} + \tfrac{1}{2}\sum_j \sum_{j'} \gamma_{jj'} lny_j lny_{j'} + \tfrac{1}{2}\gamma_{gg}(lng)^2 + \tfrac{1}{2}\gamma_{tt} t^2 + \sum_i \sum_j \beta_{ij} lnx_i lny_j + \sum_i \beta_{ig} lng lnx_i + \tfrac{1}{2}\sum_j \delta_{jg} lng lny_j + \sum_i \beta_{it} t lnx_i + \sum_j \beta_{jt} t lny_j + \beta_{gt} t lng, \quad (2)$$

where *t* denotes time vector.

Defining $-lnD_0(x,y,g,t)=u$ and allowing for a stochastic noise, together with the imposition of the linear homogeneity in outputs (similarly to Hadley (1998) by normalizing the outputs by one of output, the output distance function leads to the following form:

$$-lny_1 = \alpha_0 + \sum_i \alpha_i \, lnx_i + \sum_{j-1} \alpha_j ln\frac{y_j}{y_1} + \alpha_g ln\frac{g}{y_1} + \alpha_t t + \frac{1}{2}\sum_i \sum_{i'} \gamma_{ii'} lnx_i lnx_{i'} + \frac{1}{2}\sum_{j-1} \sum_{j'-1} \gamma_{jj'} ln\frac{y_j}{y_1} ln\frac{y_{j'}}{y_1} + \frac{1}{2}\gamma_{gg}(ln\frac{g}{y_1})^2 + \frac{1}{2}\gamma_{tt}t^2 + \sum_i \sum_{j-1} \beta_{ij} lnx_i ln\frac{y_j}{y_1} + \sum_i \beta_{ig} ln\frac{g}{y_1} lnx_i + \frac{1}{2}\sum_{j-1} \delta_{jg} ln\frac{g}{y_1} ln\frac{y_j}{y_1} + \sum_i \beta_{it} tlnx_i \sum_{j-1} \beta_{jt} tln\frac{y_j}{y_1} + \beta_{gt} tln\frac{g}{y_1} + u + v, \quad (3)$$

where $u \sim i.i.d.N^+(0, \sigma_u^2)$, $v \sim i.i.d.N(0, \sigma_v^2)$ and are independently distributed to each other.

According to Shephard (1970) there exists a duality between the output distance function (ODF) and revenue function. Färe and Grosskopf (1998) show that "the revenue function can be derived from the output distance function by maximization with respect to outputs":

$$R(x,p) = \max_{(y,g)}\{py + rg: D_O(x,y,g) \leq 1\}, \quad (4)$$

where $p \in \Re_+^M$ is the price vector of desirable outputs and $g \in \Re_+^K$ is the shadow prices vector of public goods.

Appling the Lagrange method and the Shephard's dual lemma, and following Färe and Grosskopf (1998) the shadow price of public goods can be calculated from (4) as follows:

$$r = r_y \frac{\partial D_O(x,y,g)/\partial g}{\partial D_O(x,y,g)/\partial y}, \quad (5)$$

where $r_y$ is the shadow price of output that is assumed to be the same as market price $p$.

The analysis uses an unbalanced panel data set drawn from the FADN database provided by the European Commission. The data covers the period from 2004 to 2011. Information on cattle breeding in the Czech Republic (4020 cases) are used.

In the empirical part of the paper we estimate Shephard's ODF with two traditional outputs (milk ($y_2$) and other market products from plant and animal production ($y_1$)) and one public good (manure ($y_3$)). To solve the collinearity problem between milk and manure, we used milk in monetary value deflated by price index and we involved price index into the equation (5). The inputs were represented by labour ($x_1$), land ($x_2$), capital ($x_3$) and material and energy ($x_4$). Labour is represented by the total labour measured in AWU. Land is the total utilised land. Capital is the sum of contract work and depreciation. Outputs as well as inputs (except for labour and land) are deflated by price indices on each individual output and input (2005 = 100). The price indices are taken from the EUROSTAT database. The ODF was estimated in form of Random Parameter Model by maximum likelihood method in software Limdep 9.0.

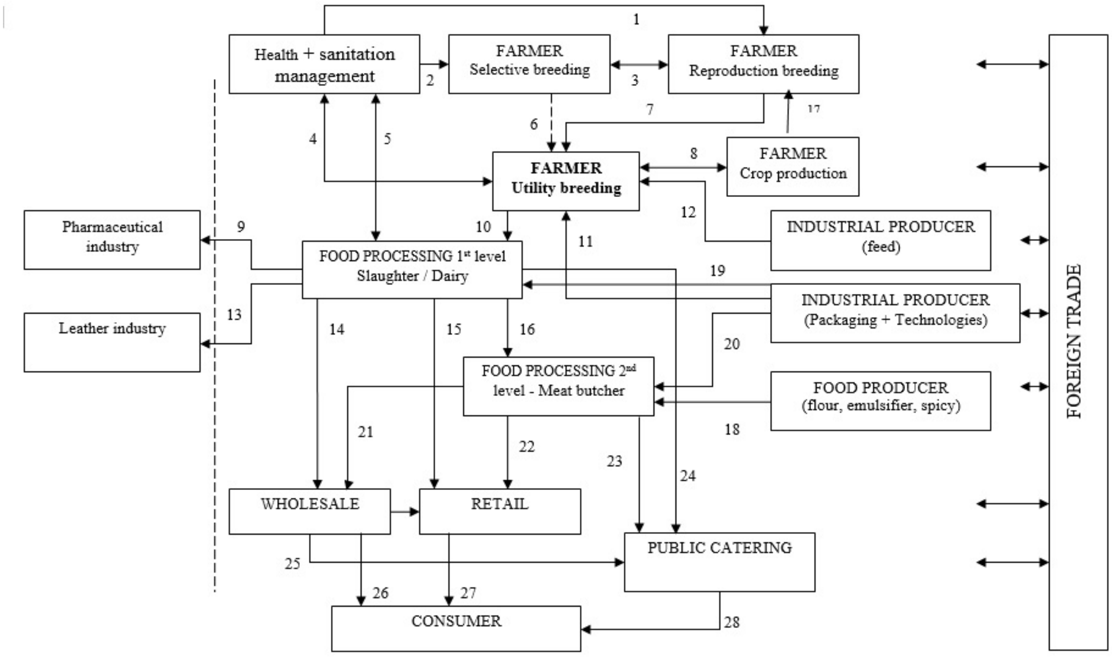
## Results and discussion

In order to reach the main objective, i.e., identification of public goods involved in the given agricultural activity, it is advisable to analyze the vertical first and then declare the adequate models of public goods on the level of the defined segments. For these purposes, Scheme No. 1 was derived, which characterizes in a simplified form the commodity vertical of beef meat and the structure of the vertical under study, so that individual production processes could be allotted to individual segments.

For the sake of simplicity, the whole vertical was divided into four basic levels – production, processor, retailer, and consumer (thus forming so-called "baseline" elements), whereby further segments of the vertical were detected on each level, which had the character of input/ output agents necessary for proper functioning of the basic elements. Parts of the segments were natural and financial flows could generate effective public assets in the course of their realization. However, such effects could also be the consequence of natural (own) activities of the given element of the vertical during production as the very purpose of its existence, and in the form of a secondary (associated) effect to its main activity.

On the basis of the above notion, it was subsequently possible to identify individual types of public assets as per Table 2 and allocate to them Table 3 and Scheme 1 concrete processes of the analyzed vertical with an adequate example of the public good in the area of cattle breeding. Finally, it is possible to use Table 4 for dividing identified public goods into positive or negative categories.

The first generally defined public good is climatic stability, i.e., the ecoregion's capability to remain permanently suitable for the current varieties or complex ecosystems. This production good involves activities comprising all basic elements of the vertical, but is primarily the result of activities in the area of production input segments. Positive effect may be observed during careful crop production of fodder base realized through appropriate seeding methods, so that the soil properties are regularly restored




Source: Author's elaboration (Number of individual processes can uniquely identify the individual streams for eventual quantification of their volume.

Scheme 1: Cattle Breeding Vertical.

and the soil is not depleted. Simultaneously, appropriate agrotechnical interventions prevent excessive occurrence of weeds, which may have a positive effect on the creation of further public goods, such as soil fertility, landscape maintenance, resistance to floods, availability of water, and water quality. Negative effects of cattle breeding on climatic stability can be defined by negation of the foregoing methods, or can be found, e.g., in breeding stations that in today's consumer-oriented society concentrate primarily on augmentation of productivity (both meat and dairy) of farm animals. This may lead to a loss of the original breeds, both on the level of breeding and utility breeds, in the sense of intensification of production that generates greater requirements on the production and quality of fodder, which in turn leads to a greater burden on the soil as well as fodder production, mostly in the form of a high production of nitrogen or other elements and gases, as well as animal waste that affects the ecoregion's natural capability of restoration.

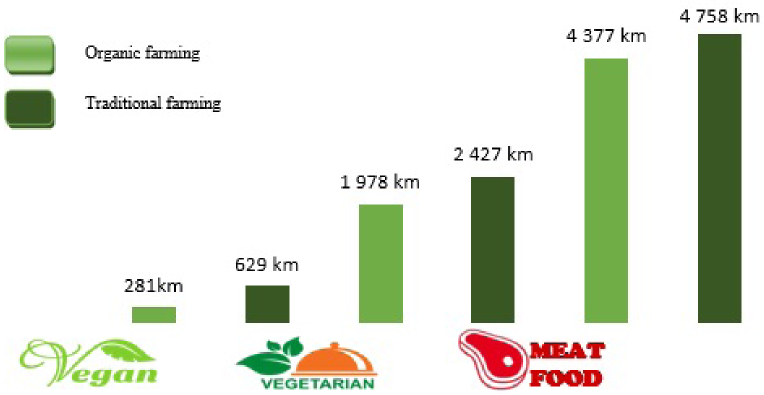
Biodiversity (variability of ecosystems), as another example of a public goods, comprises probably the most numerous groups of determinants, which take part in the creation of the studies vertical's segments, in the form of both positive and negative effect. On the production level, a positive externality that has a positive effect on biodiversity is, e.g., breeding of animals from the genetic reserve or grazing of the animals at the breeding stations, thereby regularly restoring the environment for numerous plants and animals. The same function can be achieved by certain land cultivation processes, soil preservation processes, appropriate application of fertilizers, minimization of the use of mechanical technology and other intervention measures taken by the producers of fodder crops. Moreover, food processors may also help improve biodiversity, e.g., by demanding products from specific types of farm animals (meat from certain breeds, milk with high fat content, milk with low content of allergens, products from specific breeds of other farm animals – sheep, goats, etc.), retailers or even end customers, too, may transpose their positive influence, as sufficiently strong impulse can force primary producers and processors to meet their requirements. On the other hand, too specialized production or demand may have a negative effect of biodiversity, e.g., in the form of genetic selection in highly cultivated species (breeding and commercial reeds), intensification of dairy cow breeding (utility breeds), augmentation of required qualitative parameters of meat breeds (meat processors), extension of the shelf life of products (based on the requirements of meat and delicatessen processors), or transposed or assorted demand (consumers).

The quality and availability of water is a common public good that has the ability to generate (in both forms, again) especially the production part of the vertical. Cattle breeding in itself helps maintain natural water streams, improves the retention capability of grazing meadows, absorb adequate quantities of water/precipitation and last but not the least solves the problem of processing farm fertilizers, thus impacting on the quality of water as well. On the contrary, inadequate management of farm fertilizers and other auxiliary products in livestock production may affect water quality considerably. Similarly, on the level of the suppliers of inputs (especially fodder) inappropriate (i.e. high) use of herbicides and pesticides may impact directly on the quality both of surface and underground water. Increase in the percentage of arable land cultivation or expansion of the production of wide-furrow crops may affect the production of the analyzed asset, especially in terms of water supply. Yet another way in which cattle breeding significantly impacts on the production of the studied public asset is high consumption of water for the cattle. Certain sources (e.g. Vegan 2010) claim that the production of one kilogram of beef consumes about 15,000 liters of water, compared to the production of one kilogram of grain that requires mere 450 liters of water (Holm and Jokkala 2009). This much higher consumption of water puts a great burden on the availability of water sources, as they are exploited too intensively.

Moreover, cattle breeding impacts significantly on yet another public asset in the area of soil fertility, due to crop fertilizers that subsequently penetrate into the soil in the form of animal fertilizers, thus enriching the soil with nutrients and enhancing its fertility. However, there are other aspects related to animal breeding that have a negative effect. The very production of farm fertilizers may – in high concentration that is typical for current farms – have a negative effect, because it leads to high concentration of certain elements in the soil, which therefore gradually loses fertility, especially in the case of plants that are sensitive to animal fertilizers. Moreover, their application in the soil is usually accompanied by the use of heavy machinery that packs the soil and causes deterioration of its properties from the perspective of fertility. Regular fertilizing with manure is necessary for retaining soil fertility (the usual cycle is approx. one application every 3-4 years, whereby grain crops require about 20 t, root crops 30-35 t, annual forage and oil seed 25-30 t, and vegetables about 40 t per ha-1, etc.). However, late fertilizing, inappropriate application of manure/dung, or other errors in agricultural primary production deprive the soil of moisture and cause nitrogenous depression which in turn reduces fertility. Cattle grazing, too, requires grass meadows, which may appear to be counterproductive, if inappropriately maintained, especially in the CR where absence of active care is quite typical. Last but not the least, let us mention the production of fodder crops, both as volume forage and grains grown in uninterrupted sequences, which again causes soil degradation and decline of its fertility. Involved in the foregoing aspects may also be the processing part of the vertical that – if highly concentrated regionally (as the case happens to be in the CR, e.g. in milk) – where regional demand leads to concentrated livestock production with all the consequences for the soil fertility possible.

Air quality is probably the most frequently discussed public asset at this time, because cattle breeding accounts for a major share of greenhouse emissions due to industrial and commercial uses of livestock. It is estimated that 9 % of the total emission rate of carbon dioxide is caused by human activities related to livestock breeding (Holm and Jokkala 2009). Of course, $CO_2$ is not the only greenhouse gas generated by cattle breeding. The atmosphere is also burdened by methane that contributes to global warming 23-times more than $CO_2$, whereby one cow produces about 600 liters of methane per day. Here again, according to Holm and Jokkala (2009), the share of the meat industry in the global emissions of methane is generally 35 – 40 %! Even more burden for the environment, in terms of the quality of the atmosphere, is accountable to by nitrous oxide which is generated when oxygen comes into contact with nitrogen. The share of livestock breeding in the overall emissions of nitrous oxide, due to human activities, is 2/3. According to FAO, the animal (meat) industry is responsible for about 18 % of all greenhouse gases generated by human activities (Holm and Jokkala, 2009).

Resistance to floods and fire can be another example of public assets indirectly affected by cattle breeding. The resistance is a natural capability of the system to absorb disorders in water circulation or natural defense of the landscape against the outbreak of fire. The effect of raising cattle is noted indirectly, primarily in the form of a negative effect on the availability of water in the country. Although cattle grazing may have a certain positive effect, it may under certain circumstances be one of the factors contributing to extensive natural or man-caused fires.




Note: BMW CO2 equivalent emissions (119g CO2 / km)

Source: The foodwatch report on the greenhouse effect of conventional and organic farming in Germany, 2008

Scheme 2: The greenhouse effect of different sorts of food (inh./y.) – in kilometres by car.

Cultural agricultural landscape is multifaceted and very complex phenomenon that is viewed as a widely-known and frequently cited example of a public asset, which professional often associate with elements of biodiversity. It is mainly a visual phenomenon comprised of landscape elements, containing the dimension of biodiversity, as well as the cultural dimension created by long-term human activities. Of course, cattle breeding has a major share in its production. The negative consequences can be seen above all in the consumption of meat that has gone up considerably over the last 50 years, thus leading to more intensive cattle breeding in both categories of use. This in turn led to a substantial expansion of the use of grazing meadows at the expense of other landscape elements that in the end form a constantly diminishing portion of agricultural land. Simultaneously, cattle breeding is very often referred to as the main factor in the upkeep of the countryside (biomass), whereby land cultivators (farmers) participate secondarily in other landscape-forming processes in the form of other auxiliary activities, e.g., grass mowing, maintenance of local roads, orchards, wooded areas, etc. As a side benefit, this practice helps reduce the emissions of gases by sparing the use of technology that would have to be used otherwise, as well as reduction in the use of chemicals (pesticides) that would have to applied, if the grazing meadows were used for intensive crop cultivation, along with a number of other effects.

The vitality of rural areas is characterized primarily by minimal availability of services, infrastructure of human capital, and functionality of social networks – these are additional public assets where the effects of cattle raising are double-sided. Negative consequences are accountable to aging technology that is still based on ancient prejudices or outdated know-how that does not provide for implementing modern elements of infrastructure in transport or information. The result is that the existing infrastructure is used excessively – unfortunately, without timely renovation from local sources. A possible side-effect of this approach might be the aesthetic effects of livestock breeding that may be accountable for the decline of population in rural areas or may be considered an obstacle to population expansion, especially of the younger generation. On the other hand, however, cattle breeding is in many regions (especially in those with harsher natural conditions) one of the few sectors that are capable of adapting to the given conditions and facilitate social integration of the population. In connection with the impact of agricultural producers or product processors, this sector can create favorable conditions for employment opportunities, thus at least help preserve the occupancy of rural regions.

Cattle breeding is closely associated with yet another example of a public asset – animal welfare that is based on the combination of physical and mental health of animals. In this context, we can mention a number of externalities, most of which are highly dependent on human activities and capabilities or at least on willingness to preserve the given conditions. Violation of these principles diminishes the commented asset´s production, whereas support of these principles or increase of standards quite logically ring about positive effects. As the aforesaid indicates, the welfare of animals is determined by the human factor. Therefore, identification of the relevant processes is based on conditional phenomena. Generally, it may be said that animal slaughter is perceived as certain form of suffering, which clearly denies the principle of animal welfare. On the other hand, however, modern (meaning humane) methods of slaughtering animals have greatly improved the situation in this area, as the requirements on breeders continue to become stricter, along with ever higher hygienic and spatial standards of livestock raising – all of which constitute positive factors in the production of the studied public asset.

Food safety is the last defined public asset whose relation to cattle breeding is indisputable. Meat is considered an irreplaceable (or very briefly expendable) food component. Hence, meat production is an inseparable part of human activities and, as such, it is accompanied by certain processes an all levels of the vertical. Qualitative as well as sensory parameters of meat are basic factors that form part of the food palette and assurance of an adequate quantity of nutrients, by extension food safety. Cattle breeding is a vertical that produces red meat that is rich in elements which are essential for the human organism. Moreover, it is desirable or even irreplaceable, so that the very act of cattle breeding is viewed as a positive element in the assurance of food safety. The following comparison of the ratio of land taken up by meat production with the possible effect of food production counters the above statement. For instance, Véda (2001) says that land where one ton of beef is produced would over the same time interval produce 10 to 20 tons of crops for direct human consumption. This may be a good example of negative exploitation of land that could under different circumstances generate a greater volume of food. A certain form of a negative impact may also be seen in the pricing aspects, because achieving the commented asset is related not only to a physical, but also economic availability/accessibility of food products, whereby it is questionable, whether the current production of beef is acceptable price-wise for the whole population spectrum. Last but not the least, let us mention the existence of problems with the assurance of food safety in terms of risks to human health. In particular, due to several fairly recent cases of infected beef, it is evident that cattle breeding might be viewed as a sector that has the potential to impact significantly on the safety of food, if supervision fails, and consequently be regarded as a source of problems leading to depletion of the public assets under study.

In order to attain the other objective, i.e., to quantify the shadow price of the public good produced by dairy cattle breeding, we used the parametric approach to estimate the multiple output distance function (MODF). The results of fitted translogarithmic MODF are provided in Table 5.

First, we start with the discussion on the quality of fitted model. As far as theoretical consistency is concerned, the estimated model should inherit the properties of an output distance function. According to Coelli et al. (2005) the output distance function should be non-decreasing, positively linearly homogenous and convex in outputs, as well as decreasing and quasi convex in inputs. That is, the monotonicity requirements for outputs imply: $\alpha_{y2} > 0$, $\alpha_{y3} > 0$ and $\alpha_{y2} + \alpha_{y3} < 1$; and for inputs: $\alpha q < 0$ for q = x1, x2, x3, x4. Table 5 shows that these conditions are met. Moreover, convexity in inputs requires $\gamma_{qq} + \gamma_q^{\ 2} - \gamma_q > 0$ for q = x1, x2, x3, x4. This condition holds for all inputs evaluated on the sample mean. Furthermore, the majority of estimated parameters are significant even with 1 % significance level.

Since all variables are normalised in logarithm by their sample mean, the first order parameters of outputs represent the share of outputs y2 and y3 in the total output and the first order parameters of inputs the production elasticities. Thus, the results show that the share of plant and other animal production in total output is around 12 % pointing to the high specialization of farms. The share of y3 shows the importance of manure in the dairy production as a by-product.

As far as the elasticities of inputs are concerned the production elasticity for materials inputs (material and energy) has the highest values and the elasticity for capital is the lowest. Labour and land has approximately the same impact on the production. As far as economies of scale are concerned, no indication of economies of scale (the sum of the elasticities is about one) was estimated for the average dairy farm in the Czech Republic. Thus the farms produce in optimal scale evaluated on the sample mean.

Technological change is not pronounced. However, the estimates of parameter $\beta_{it}$ and $\beta_{jt}$ are statistically significant even with 1 % significance level. The parameter sigma provides information about the joint variation of uit and vit. Lambda is the relation between the variance of $u_{it}$ and $v_{it}$.

| | Means for random parameters | | | | Non-random parameters | | |
|---|---|---|---|---|---|---|---|
| | Coefficient | Standard Error | p-value | | Coefficient | Standard Error | p-value |
| Constant | -0.16167*** | 0.00500 | 0.0000 | TT | -0.00020 | 0.00100 | 0.8454 |
| T | 0.00088 | 0.00092 | 0.3411 | Y2 | 0.12344*** | 0.00722 | 0.0000 |
| X1 | -0.21516*** | 0.00512 | 0.0000 | Y3 | 0.35966*** | 0.00749 | 0.0000 |
| X2 | -0.21716*** | 0.00664 | 0.0000 | Y2T | -0.01198*** | 0.00274 | 0.0000 |
| X3 | -0.04450*** | 0.00413 | 0.0000 | Y3T | 0.01553*** | 0.00302 | 0.0000 |
| X4 | -0.51867*** | 0.00741 | 0.0000 | Y22 | 0.13807*** | 0.01587 | 0.0000 |
| | Scale parameters for distr. of random parameters | | | Y33 | 0.18704*** | 0.02293 | 0.0000 |
| Constant | 0.16221*** | 0.00208 | 0.0000 | Y23 | -0.08429 | 0.01898 | 0.0000 |
| T | 0.00518*** | 0.00080 | 0.0000 | X1T | 0.00840*** | 0.00235 | 0.0004 |
| X1 | 0.02519*** | 0.00442 | 0.0000 | X2T | -0.00250 | 0.00286 | 0.3819 |
| X2 | 0.07935*** | 0.00406 | 0.0000 | X3T | -0.00663*** | 0.00146 | 0.0000 |
| X3 | 0.01123*** | 0.00292 | 0.0001 | X4T | 0.00076 | 0.00332 | 0.8189 |
| X4 | 0.07462*** | 0.00574 | 0.0000 | X11 | -0.01272 | 0.01410 | 0.3671 |
| | Variance parameter for v +/- u | | | X22 | -0.16227*** | 0.00773 | 0.0000 |
| Sigma | 0.016909 | 0.00255 | 0.0000 | X33 | -0.00599 | 0.00535 | 0.2629 |
| | Asymmetry parameter, lambda | | | X44 | -0.10232*** | 0.02704 | 0.0002 |
| Lambda | 2.01024 | 0.10980 | 0.0000 | X12 | 0.08488*** | 0.01219 | 0.0000 |
| | | | | X13 | -0.02024*** | 0.00681 | 0.0029 |
| | | | | X14 | -0.05019*** | 0.01721 | 0.0035 |
| | | | | X23 | -0.04103*** | 0.00627 | 0.0000 |
| | | | | X24 | 0.11161*** | 0.01429 | 0.0000 |
| | | | | X34 | 0.05877*** | 0.00844 | 0.0000 |
| | | | | Y2X1 | 0.00383 | 0.01240 | 0.7572 |
| | | | | Y2X2 | 0.05763*** | 0.01165 | 0.0000 |
| | | | | Y2X3 | -0.02379*** | 0.00711 | 0.0008 |
| | | | | Y2X4 | -0.01452 | 0.01635 | 0.3745 |
| | | | | Y3X1 | 0.04859*** | 0.01404 | 0.0005 |
| | | | | Y3X2 | -0.08265*** | 0.01424 | 0.0000 |
| | | | | Y3X3 | 0.02624*** | 0.00819 | 0.0013 |
| | | | | Y3X4 | 0.02855 | 0.01853 | 0.1233 |

Source: Authors‘ calculations

Table 5: MODF - Parameter estimates.

| Variable | Mean | Std. Dev. | Minimum | Maximum | Cases | Missing |
|---|---|---|---|---|---|---|
| TE | 0.893168 | 0.054111 | 0.455595 | 0.980349 | 3818 | 0 |
| PMAN | 1.246721 | 1.677119 | 0.000627 | 19.67848 | 3818 | 0 |

Source: Authors‘ calculations

Table 6: Descriptive statistics of technical efficiency and shadow price of manure.

Thus, the parameter indicates the significance of TE in the residual variation. Since lambda is highly significant and higher than one, the estimates indicate that efficiency differences among dairy producers are important reasons for variation in production (see Table 6).

Appling the Lagrange method and the Shephard's dual lemma we calculated the shadow price of manure. The average value of manure is 1.24 EUR per tonne. However, the variation in the sample is large, with standard deviation of 1.68. Moreover, the distribution is skewed to larger values. The shadow prices differ significantly among the groups of farmers. This especially holds for the classification of groups according to the size and technology of production. Thus, the shadow price is significantly determine by the farm characteristics and technological heterogeneity.

## Conclusion

The paper identifies and discusses the production of public goods in the vertical of cattle breeding. Moreover, it provides the methods for the valuation of public goods. The method is applied in the estimation of manure shadow price.

The cattle breeding vertical was divided into four basic levels – production, processor, retailer, and consumer (thus forming so-called "baseline" elements), whereby further segments of the vertical were detected on each level, which had the character of input/output agents necessary for proper functioning of the basic elements. Among main public goods, which production consequences were revealed and discussed, belong: the ecoregion's capability to remain permanently suitable for the current varieties or complex ecosystems; biodiversity (variability of ecosystems); the quality and availability of water; public goods in the area of soil fertility; air quality as a probably the most frequently discussed public asset at this time, because of cattle breeding accounting for a major share of greenhouse emissions due to industrial and commercial uses of livestock; resistance to floods and fire; cultural agricultural landscape; the vitality of rural areas characterized primarily by minimal availability of services, infrastructure of human capital, and functionality of social networks; animal welfare based on the combination of physical and mental health of animals; and food safety.

Furthermore, the paper presents the application of theory of production and parametric method SFA to calculate the value of public goods. This approach has the advantage over other methods as e.g. cost calculations that it takes into consideration the farm technology that is crucial with respect to the nonlinearity of production process and significant farm heterogeneity. We provided the valuation of public on the example of the manure. However, this way we can calculate the value of each public good which is directly produced by agricultural production.

Specifically, the fitted multiple output distance function with two market outputs and one non-market output – manure as a representation of public good, in our case, shows that the shadow price differs significantly among the producers depending on several factors (e.g. size, production technology). That is, the policy makers should take into the consideration different production characteristics, technology and production environment in the discussion of the price which should be paid for public goods in general.

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