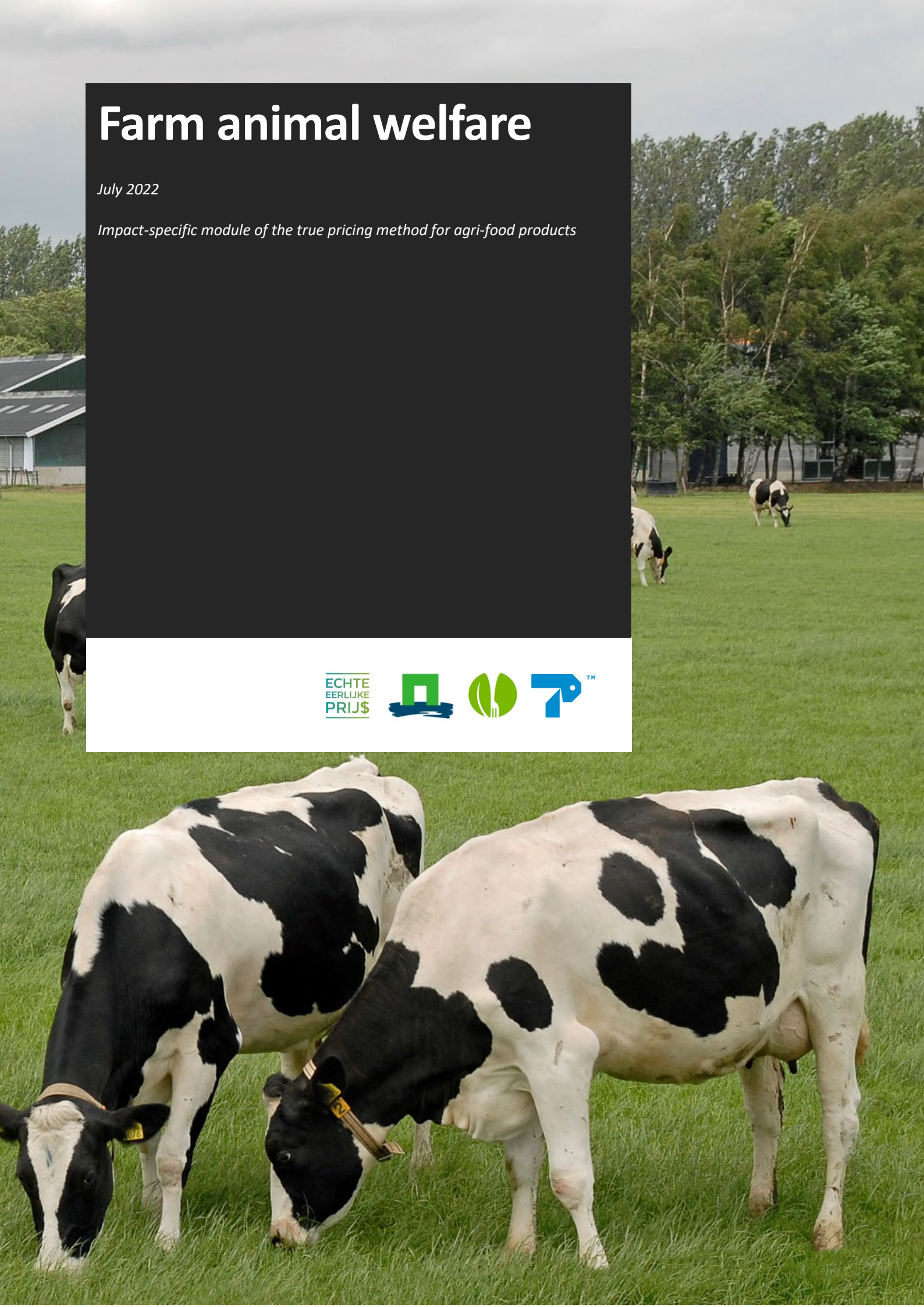
Farm animal welfare

July 2022

Impact-specific module of the true pricing method for agri-food products



Farm animal welfare

Impact-specific module for true price assessment

True pricing method for agri-food products

July 2022

This document provides the animal welfare module for the assessment of the true price of an agricultural product, within the PPS 'Echte en Eerlijke prijs' developed by True Price and Wageningen Economic Research. It provides information on quantification and monetisation of these impacts and it is meant to be used in combination with the **True Pricing Assessment Method for Agri-food Products** (Galgani et al., 2021a). The **Valuation Framework for True Price Assessment of Agri-food Products** explains the underlying framework (Galgani et al., 2021b). Both these documents are developed within the same project.

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1. Introduction

This document provides a method module for the assessment of the true price of food products, within the public-private partnership 'Echte en Eerlijke Prijs' by Wageningen Economic Research, True Price and Bionext.[3] It contains the key methodological aspects to measure and value animal welfare costs. As such, this study makes an important contribution to the field of true pricing. True pricing is a way of accounting for negative social and environmental consequences of production and consumption at the product level. In the **True Pricing Assessment Method for Agri-food Products**, animal welfare is considered as one of social impacts relevant for true pricing (Galgani et al., 2021a). In this document, Section 2 provides the definition of animal welfare. Section 3 discusses the rationale for including animal welfare in a true price assessment. Section 4 discusses the modelling approach. Section 5 applies the approach to Dutch livestock production systems. Finally, Section 6 provides an overview of the limitations and key items for further research.

2. Definition

The term animal welfare is widely used by consumers, veterinarians, politicians and others. However, the term can mean different things to people. According to the World Organization for Animal Health (OIE), animal welfare means "the physical and mental state of an animal in relation to the conditions in which it lives and dies" (OIE, 2021). The OIE states that an animal experiences good welfare if the animal is healthy, comfortable, well nourished, safe, is not suffering from unpleasant states such as pain, fear and distress, and is able to express behaviours that are important for its physical and mental state. Good animal welfare requires disease prevention and appropriate veterinary care, shelter, management and nutrition, a stimulating and safe environment, humane handling and humane slaughter or killing (OIE, 2021). While animal welfare refers to the state of the animal, the treatment that an animal receives is covered by other terms such as animal care, animal husbandry, and humane treatment. The OIE outlines five aspects of animal welfare under human control, defined as the "Five Freedoms". These five freedoms are globally recognised as the gold standard in animal welfare, encompassing both the mental and physical well-being of animals. The five freedoms include freedom from hunger, thirst and malnutrition; freedom from fear and distress; freedom from physical and thermal discomfort; freedom from pain, injury and disease; and freedom to express normal patterns of behaviour (OIE, 2021).

In the Triple-P Framework, sustainability consists of three dimensions: the social (people), environmental (planet), and economic (profit) dimension (Elkington & Rowlands, 1999). Although animal welfare is generally considered as a social issue, it is not a stand-alone issue seen from a sustainability perspective. There are cross-links between different types of sustainability impacts. For example, global warming (environmental dimension) may have a profound effect on the welfare of wild animals (social dimension). Also infrastructure and biodiversity loss due to land use (change) may have negative effects on welfare of wild animals (Duncan, 2019). Animal welfare is relevant to all kinds of animals, such as animal pets, animals used in experiments and farm animals. In this assessment module, only farm animal welfare is considered. Welfare aspects of other types of animals will not be further discussed.

[3] See https://www.wur.nl/nl/project/Echte-en-eerlijke-prijs-voor-duurzame-producten.htm for more information on the public-private partnership

3. Background and rationale for including animal welfare as part of the true price

3.1. Introduction

The relationship of people with animals has changed significantly over time. From using animals for food, clothing, and labour toward the animal as companions. Dogs were the first species to be domesticated and proved useful as guards and as hunters for the hunting-gatherers (Driscoll et al., 2009). Domestication of today's barnyard animals proceeded as a result of pressure by early hunter-gatherers as they intuitively sought to stabilise their food resources (Driscoll et al., 2009). There are different philosophical approaches to the interaction between humans and animals, such as contractarianism, utilitarianism, and the animal rights view (Rogers, 2017). These approaches and their advantages and disadvantages will be further discussed in this section. As such, this section provides the required background for the assessment of animal welfare as specified in Section 4.

3.2. Contractarian view

In the contractarian view, there is a difference between the moral status of humans and animals (Rogers, 2017). Humans have to be approached with respect, while animals do not. It is assumed that only the wellbeing of human beings counts and that animal welfare is a subset of human welfare. Based on this approach, one could argue that animal welfare should be included in the true price as animal suffering is a potential source of disutility for people. As utility cannot be observed directly, willingness-to-pay is often used as a proxy to estimate utility (Bar-Gill, 2021). People might be willing to pay for improvements in animal welfare to the extent that their own utility directly increases by such improvements or indirectly out of altruistic concern for other people's behaviour. A considerable body of research focused on consumer willingness-to-pay for improved animal welfare (Lagerkvist & Hess, 2011; Clark et al., 2017). Advantages of the willingness-to-pay approach are that it is grounded in economic theory and that it can be ascertained through a simple survey. However, the willingness-to-pay approach has some limitations for the assessment of the true price of animal welfare. First, as the bulk of 'the public' have little awareness of on-farm livestock production processes, their appreciation of technical production conditions and how they relate to welfare standards is almost inevitably weak (McInerney, 2004). Second, studies found a high variation in the willingness-to-pay, which can be explained by differences in socio-economic characteristics (Clark et al., 2017). According to Bar-Gill (2021), the willingness-to-pay is largely affected by the respondent's wealth. Therefore, an average willingness-to-pay may be a poor estimate of a society's willingness-to-pay for improved animal welfare. Third, a willingness-to-pay approach is measured via a questionnaire. Questionnaires on animal welfare may have problems with framing bias, scaling bias and lack of relative measures (Harvey & Hubbard, 2013). Because of these limitations, we consider willingness-to-pay not as an appropriate approach to assess the true price of animal welfare.

3.3. Utilitarianism

Utilitarianism assumes that all sentient beings, including animals, have interests that count morally. Therefore, it seems logical to include animal welfare in the true price as animal suffering affects the utility of both humans and animals. Animals cannot be asked what their welfare is, and cannot pay for it, so it is impossible to quantify the impact of impaired animal welfare on the utility of animals. The impact of impaired animal welfare on the utility of humans can be assessed based on human altruism and judgements. Because utility cannot be observed directly, willingness-to-pay can be used as a proxy for utility. But, as mentioned in Section 3.2, the willingness-to-pay approach has several shortcomings, and therefore we consider it not as a suitable approach for the assessment of true price of animal welfare.

3.4. Animal rights-based view

The animal rights view was a reaction to the commercialisation and use of animals for food and medical purposes. People who believe in animal rights are often identified as those who oppose the use of animals in research, industry, agriculture, and entertainment (Rogers, 2017). Based on the animal rights view, humans should enable animals to fulfil their behavioural needs and protect them from suffering. However, it is difficult to know exactly what the needs of animals are. Therefore, animal welfare science claims to look at the needs of animals in a more objective way and checks if their needs are being met. Animal welfare can be measured by the use of three parameters: health, physiology and behaviour (Rogers, 2017).

In many mainly Western countries, animal welfare standards (legislation and private sector initiatives) have been imposed in the past two decades (European Commission, 2007; USDA, 2015). As a first reference, one may use the international standards for animal health and welfare and slaughter of farm animals drawn up by the OIE. These standards provide requirements on the production system and transport and slaughter of terrestrial animals and farmed fish (World Organization for Animal Health, 2021). These standards were adopted by consensus by all 180 OIE member countries. As a second reference, one may use legislation on animal welfare, laid down by many countries such as the United States and the European Union (European Commission, 2007; USDA, 2015). The existing European Union regulation on animal welfare is described in article 13 of Title II of the Lisbon Treaty of 2009 and states that:

> *"In formulating and implementing the Union's agriculture, fisheries, transport, internal market, research and technological development and space policies, the Union and the Member States shall, since animals are sentient beings, pay full regard to the welfare requirements of animals, while respecting the legislative or administrative provisions and customs of the EU countries relating in particular to religious rites, cultural traditions and regional heritage."*

As is stated in the treaty, national governments may adopt more stringent rules provided they are compatible with the provisions of the Treaty. In the Netherlands, for example, rules and regulations on animal welfare are set out in the Animals Act, the Decree containing rules for keepers of animals and the Decree concerning permitted veterinary procedures (Dutch Ministry of Economic Affairs Agriculture and Innovation, 2021).

As discussed in the previous paragraph, legislation on farm animal welfare has been imposed in many mainly Western countries (European Council Directive, 2008; USDA, 2013). Furthermore, surveys show that animal welfare is deemed important by many citizens in Western countries (Eurobarometer, 2016; Weathers et al., 2020). Therefore, it seems logical to include the societal costs associated with the violation of animal rights in the true price. Including these costs in the true price also fits in the rights-based approach of the True Price concept as described in Galgani et al. (2021b). In the rights-based approach, the true price of animal welfare can be assessed by calculating the costs of improving animal welfare to a level that satisfies animal rights. An advantage of this approach is that animal rights cover multiple dimensions of animal welfare, which is in line with international standards on animal welfare (see e.g. OIE (2021)). Another advantage of this approach is that animal rights can be based on international standards on animal welfare. Therefore, the assessment of the true price of animal welfare is less or not affected by socio-economic or cultural differences between countries compared to willingness-to-pay estimates. If the true price of animal welfare is based on national standards, it is affected by the societal norms of the country. A disadvantage of the rights-based approach is that the minimum level of animal rights that should be satisfied depends on the philosophical approach that is taken and is therefore debatable. Despite this disadvantage, we consider the rights-based approach more appropriate for the assessment of the true price of animal welfare than the willingness-to-pay approach.

4. Approach

4.1. Introduction

The true pricing assessment method describes three main steps to calculate the true price of an impact (Galgani et al., 2021a). First, the impact of the product under scope should be measured (e.g. kg CO_2 eq./kg milk). Second, the impact should be valued (e.g. euro/kg CO_2 eq.). Third, magnitude and value of the impact should be integrated to obtain the true price gap (euro/kg milk). To operationalise this approach for animal welfare, the approach was slightly adjusted. First, a semi-quantitative indicator (animal welfare score) was generated to measure the level of animal welfare of farms. Second, a cost function was generated that establishes the relationship between the animal welfare score and the production costs. Third, a monetisation factor was derived from this cost function (euro/animal welfare point/kg product). Fourth, the level of animal welfare and the monetisation factor were integrated to calculate the costs required to improve animal welfare to the level that satisfies animal rights. In the remainder of this section, this approach is further discussed.

4.2. Measuring animal welfare

In the past years, various methods have been developed to measure farm animal welfare. The conventional methods are based on measuring the provision of resources to ensure good welfare, for instance by specifying the maximum stocking density. However, the link between specific resource measures and an animal's welfare status is not always clearly understood (Blokhuis, 2008). Therefore, animal welfare scientists moved away from resource-based methods and have instead focused on the use of animal-based measures. This approach is based on measuring the actual welfare state of the animals in terms of their behaviour, health and physiology (Hubbard & Scott, 2011). An example of the animal-based approach is the Welfare Quality® Assessment Protocol[4] (Welfare Quality Consortium, 2009), which has been used by many scientists to evaluate farm animal welfare (see e.g. De Jong et al. (2015) and Gocsik et al. (2016)). Other examples are Wagner et al. (2021) and Temple et al. (2011). The Welfare Quality® Protocol is a standardised way of assessing animal welfare and applies to pigs, poultry and cattle. It includes welfare at the farm, welfare in transport and welfare in slaughter. Although there is no protocol available that can serve as a 'gold standard', the Welfare Quality® Protocol is considered as the most extensive one to assess animal welfare (Van Eerdenburg et al., 2021). Therefore, the Welfare Quality® Protocol is chosen as a measuring standard for true price. In the Welfare Quality® Protocol, four welfare principles are included in all evaluations: good feeding, good housing, good health, and appropriate behaviour. These four principles are subdivided in twelve welfare criteria (see Table 1). Each criterion consists of one or more assessment measures.

[4] The Welfare Quality® project is a partnership of 40 institutions in Europe and four in Latin America.

Table 1. The principles and criteria that are the basis for the Welfare Quality® Assessment protocol

Welfare principles	Welfare criteria	
Good feeding	1	Absence of prolonged hunger
	2	Absence of prolonged thirst
Good housing	3	Comfort around resting
	4	Thermal comfort
	5	Ease of movement
Good health	6	Absence of injuries
	7	Absence of disease
	8	Absence of pain induced by management procedures
Appropriate behaviour	9	Expression of social behaviours
	10	Expression of other behaviours
	11	Good human-animal relationship
	12	Positive emotional state

The Welfare Quality® Protocol describes four steps that should be followed to calculate the overall welfare state of the animals (see Figure 1). First, data should be collected for the assessment measures (i.e. values obtained for the different assessment measures on the animal). Second, these assessment measures are combined to calculate criterion scores for each welfare criterion using the formulas described in the Welfare Quality® Protocol. The criterion scores reflect the compliance of the animal unit to the welfare criterion. The criterion score is expressed in a 0 to 100 value scale, in which 0 reflects the worst welfare situation and 100 reflects the best welfare situation of an animal. It should be realised that 0 is likely not achieved in practice, as it means extremely low levels of welfare that fall outside the range of what is actually measured. Third, the criterion scores are aggregated to principle scores for each welfare principle (good feeding, good housing, good health and appropriate behaviour) in a non-linear manner. Fourth, the animal unit is assigned to a welfare category according to the principle scores it obtained. Four welfare categories are distinguished:

- Not classified: the welfare of animals is low and considered unacceptable.
- Acceptable: the welfare of animals is above or meets minimal requirements.
- Enhanced: the welfare of animals is good.
- Excellent: the welfare of the animals is of the highest level.

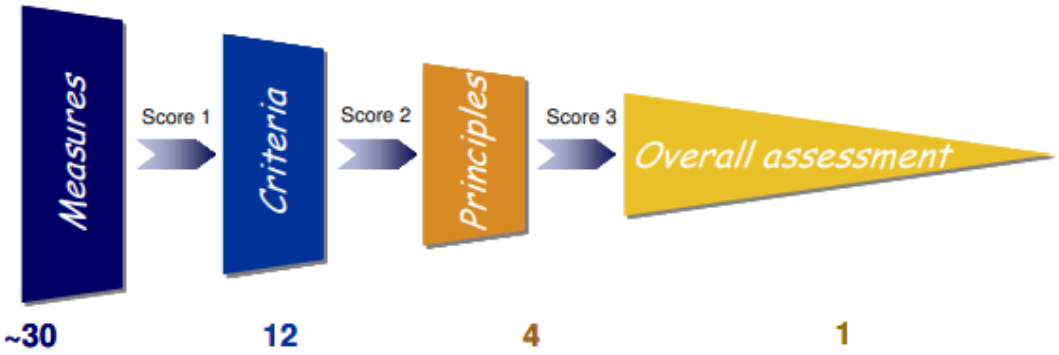

Figure 1. Bottom-up approach for integrating the data on the different measures to an overall assessment of the animal unit

For each welfare category, 'aspiration' values are defined. These values represent the minimum score a farm should achieve for each principle to be assigned to a welfare category. In this module, it was assumed

that a farm satisfies animal rights when it achieves the highest welfare category, i.e. excellent. This category is achieved when a farm scores at least 80 on two principles and at least 55 on the other two principles (Welfare Quality Consortium, 2009). These values were aggregated to obtain an 'excellent threshold' (score of 270).

Figure 2 displays the excellence threshold and the welfare score of six hypothetical farms. The welfare score of these farms is obtained by aggregating the four principle scores. According to the Welfare Quality® Protocol, no compensation between principle scores is possible if these scores are below a threshold. For example, a score of 56 (e.g. for good health) cannot compensate a score of 54 (e.g. for good housing) to achieve the welfare category 'excellent'; both scores need to be 55 for the welfare category 'excellent' if the other two scores are 80 (Welfare Quality Consortium, 2009). If the scores are above this threshold, compensation is possible as the scores are added. In a similar way, we assumed that compensation is possible if welfare complied with minimum requirements, i.e. if all principles achieved the welfare category 'acceptable' (score of 20 or higher). If one or more principles did not achieve this welfare category, the lowest principle score was used for all four principles when calculating the welfare score (equation 1 and 2). Hence, no compensation between principle scores is possible. We assumed that some compensation between the principles is allowed if the welfare category 'acceptable' was achieved, i.e. if each principle score meets minimum requirements of 20 welfare points. To operationalise this, we assumed that the difference between the lowest principle score and the other principle scores may not be larger than 35 welfare points. This value is based on the difference between the threshold of the welfare categories 'acceptable' (20 welfare points) and 'enhanced' (55 welfare points). If the difference between a principle score and the lowest principle score is larger than 35, the score of the corresponding principle is equal to the lowest principle score plus 35 welfare points (equation 3). If the difference between a principle score and the lowest principle score is smaller than 35, the original principle score applies (equation 4). The welfare score is calculated by aggregating the (corrected) principle scores (equation 5).

$$P_n = \min\left(P_{1n}, P_{2n}, P_{3n}, P_{4n}\right) \quad (1)$$

$$If\ P_n < 20 \quad \text{then } S_n = 4 * P_n \quad (2)$$

$$If\ P_n \geq 20 \text{ and } P_{jn} - P_n > 35 \quad \text{then } CP_{jn} = P_n + 35 \quad (3)$$

$$\text{Else } CP_{jn} = P_{jn} \quad (4)$$

$$S_n = CP_{1n} + CP_{2n} + CP_{3n} + CP_{4n} \quad (5)$$

Where: P_n minimum principle score of farm n; P_{jn} principle score j of farm n, $j = 1 \ldots 4$; S_n = welfare score of farm n; CP_{jn} = corrected principle score j of farm n

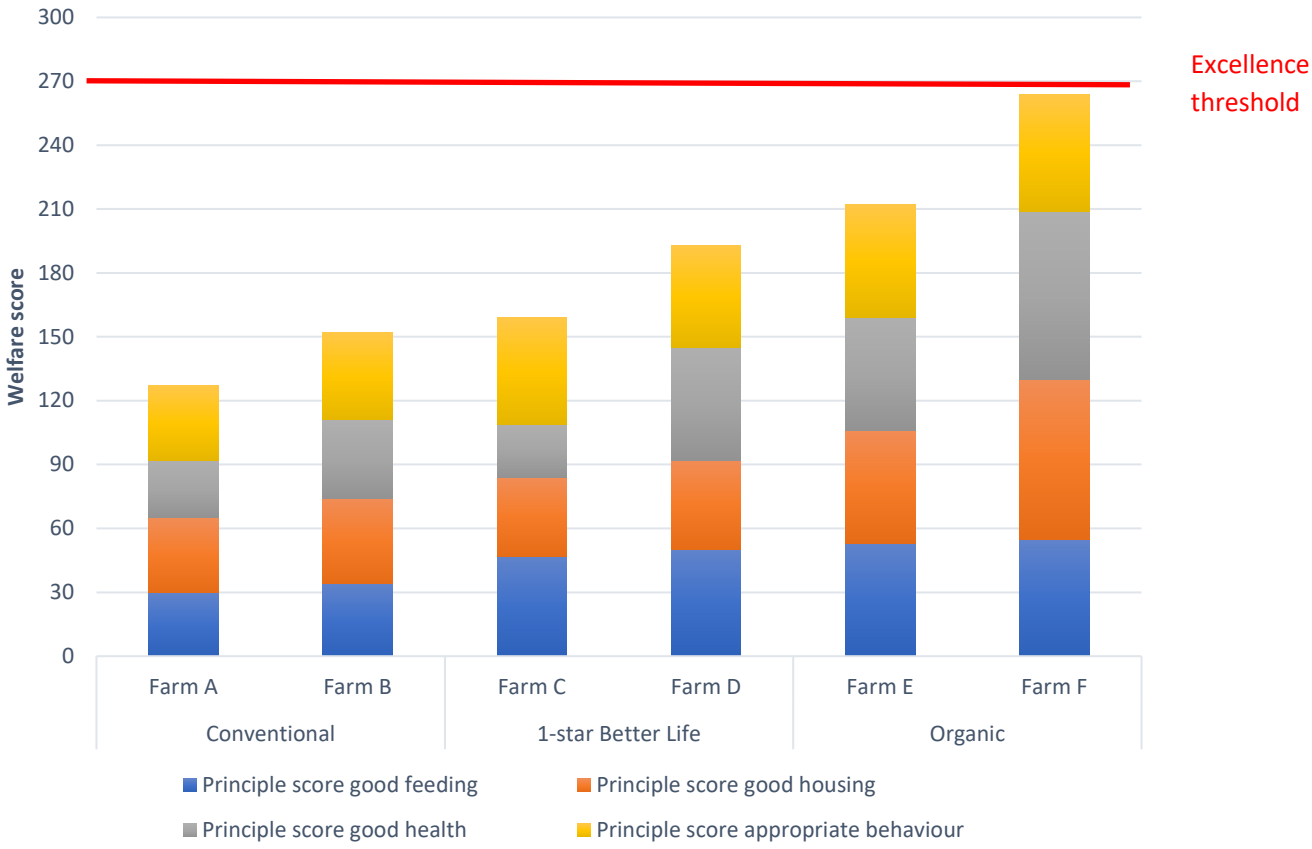

Figure 2. The excellence threshold and principle scores of six hypothetical farms

Some studies do not consider all the principles of the Welfare Quality® Protocol. For instance, Hoogstra (2019) and Gocsik et al. (2016) do not consider the principle 'good feeding' as all Dutch broiler and pig farmers are required to give access to feed and water constantly due to regulation, irrespective of the system type (European Council Directive, 2007). Therefore, they did not expect large differences between the production systems for this criterion. The authors argue that if there are differences, it has to do with farmer management instead of housing design. If data is lacking for one or more principles, expert estimation should be used to estimate the welfare measures underlying these principles. These estimates can, for example, be based on the attributes (e.g. stocking density or breed type) of the farm and the welfare measures of systems comparable to the system for which the welfare measures are estimated. All principle scores are required for the analysis. Hence, the monetisation factor cannot be calculated if data is lacking for one of the principles.

The Welfare Quality® assessment protocol has been applied by various studies. For instance, Gocsik et al. (2016) used the Welfare Quality® protocol to score different Dutch broiler production systems and found that the more expensive organic and extensive outdoor systems reach a lower level of animal welfare than the less expensive Volwaard/Puur en Eerlijk system. In the master thesis of Hoogstra (2019), this approach was used to evaluate the level of welfare in Dutch pig production systems. The results show that the organic pig farming system does not score better on all welfare aspects, and is only marginally better than the 1-Star Better Life system (Hoogstra, 2019). Vermeer and Hopster (2018) suggest that the tool may underestimate some welfare effects. For example, outdoor access has a negative effect on animal welfare in the study of Hoogstra (2019) and Gocsik et al. (2016), but pigs may prefer to be outside when they have the opportunity. The same is true for straw bedding. Therefore, Hoogstra (2019) concludes that it may be

that for highly intelligent animals, higher level needs of the Maslow pyramid are not included in the Welfare Quality® assessment protocol, and if it would be included, the evaluations would be different.

4.3. Monetisation approach

The valuation framework for true price assessment of agri-food products was taken as a guidance for monetising animal welfare (Galgani et al., 2021b). According to the remediation philosophy of true price, harm to people or communities should always be restored if technically feasible. If the damage cannot be restored, it should be compensated. Furthermore, severe and irreversible damage to people or communities should be prevented from re-occurring. In case of animal welfare, compensation is not possible because animals are the harmed party and you cannot compensate them. Restoration is not possible as most animals that have experienced negative welfare are dead already. Prevention of re-occurrence is possible by improving farm management or the environment of the animals to a level that satisfies animal rights. The prevention costs reflect the increase in costs at farm level needed to satisfy these rights**.**

To calculate the prevention costs of animal welfare, a cost function should be established. The cost function is derived from the welfare scores and the cost of production of the farms (see equation 6). The cost function shows the relationship between the animal welfare score and the production costs (see Figure 3) and can be obtained by performing a regression analysis. The cost function was assumed to be concave with a positive slope as earlier studies found a positive relationship between animal welfare improvements and production costs (Lusk & Norwood, 2011). Furthermore, studies found that the shift from conventional towards middle-segment systems is found to be relatively cost efficient, whereas the shift from middle-segment systems towards top-market systems is relatively cost inefficient (Gocsik et al., 2016; Hoogstra, 2019). The slope of the cost function reflects the change in production costs associated with an extra unit of animal welfare and is obtained from the first-order derivative of the cost function (see equation 7). This slope is defined as the monetisation factor and is expressed in euro/extra unit of animal welfare/kg eggs or milk (animals not reared for meat) or in euro/extra unit of animal welfare/kg live weight (animals reared for meat). Note that the monetisation factor is country-specific, as it is derived from the production costs of farms in a specific country.

$$C_n = f\,(S_n) \tag{6}$$

$$M_n = f'(\,S_n) \tag{7}$$

C_n = production costs in euro/kg (live weight, milk or eggs) for farm *n*, M_n is monetisation factor in euro/unit of animal welfare/kg (live weight, milk or eggs) for farm *n*, S_n = welfare score of farm n

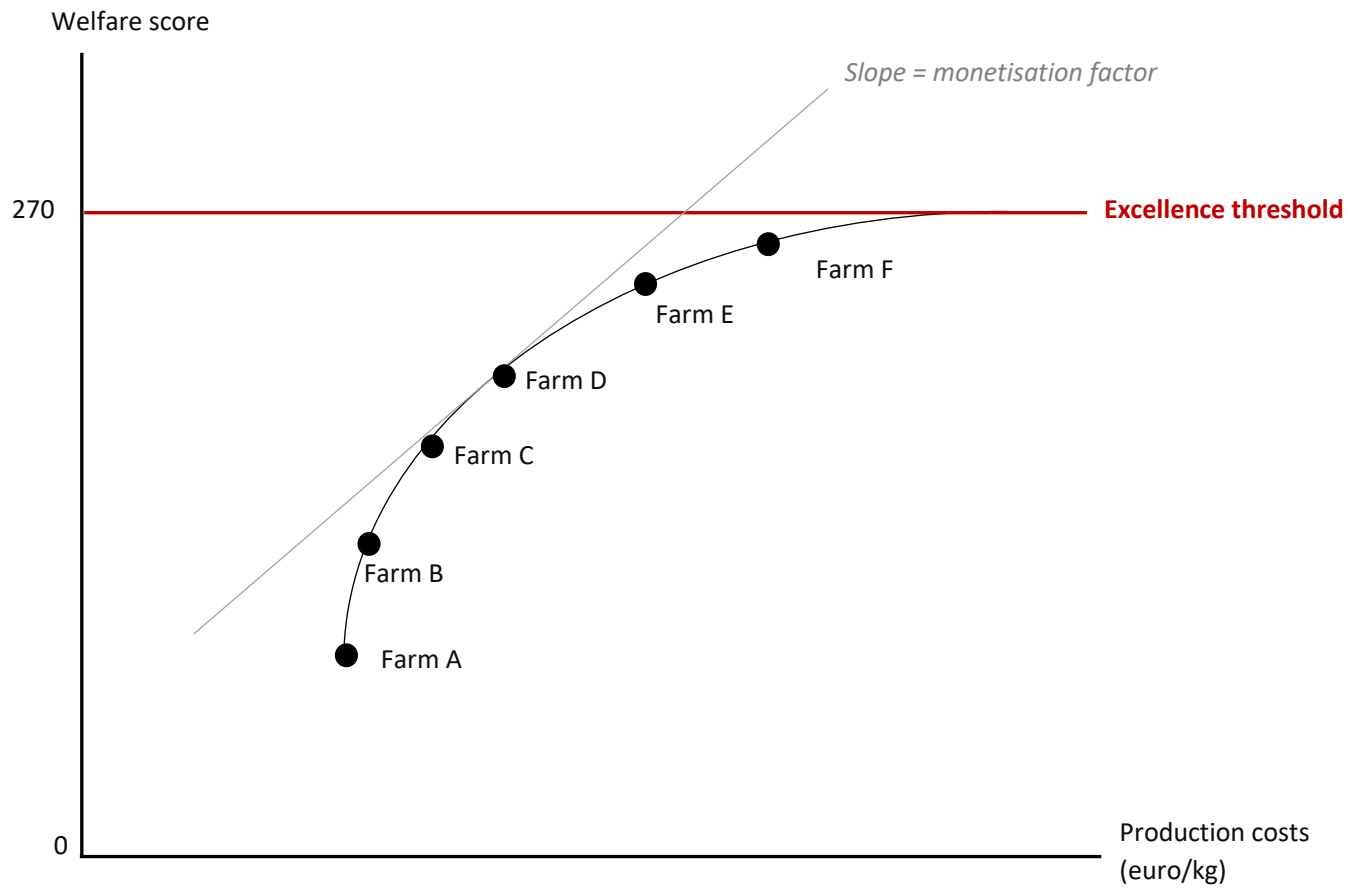

Figure 3. Illustration of the cost function and the monetisation factor for animal welfare

The production costs and welfare scores of a production system (e.g. conventional) were calculated as the mean of the production costs and welfare scores of the farms in a given production system (denoted as x) (equation 8 and 9).

$$S_x = \frac{\sum S_n}{k} \quad (8)$$

$$C_x = \frac{\sum C_n}{k} \quad (9)$$

$$M_x = C'_x \quad (10)$$

Where: S_x = average welfare score of production system x, S_n = welfare score of farm n with production system x in a sample of size k, k = number of farms with production system x in the sample, C_x = average production costs of system x, C_n = production costs of farm n, M_x = monetisation factor for production system x.

The monetisation factor is used to calculate the prevention costs (see equation 11). Figure 4 illustrates the prevention costs for the conventional, 1-star Better Life and organic system. The prevention costs are the true price gap of animal welfare in the True Pricing Assessment Method for Agri-food Products (see Galgani et al. (2021a)). The prevention costs are zero when a production system has an animal welfare score equal to or higher than the excellence threshold (equation 12):

$$If\ S_x < 270,\ \ then\ P_x = M_x * (270 - S_x) \quad (11)$$

$$Else\ P_x = 0 \quad (12)$$

Where: P_x = prevention costs of system x (in euro/kg live weight, milk or eggs)

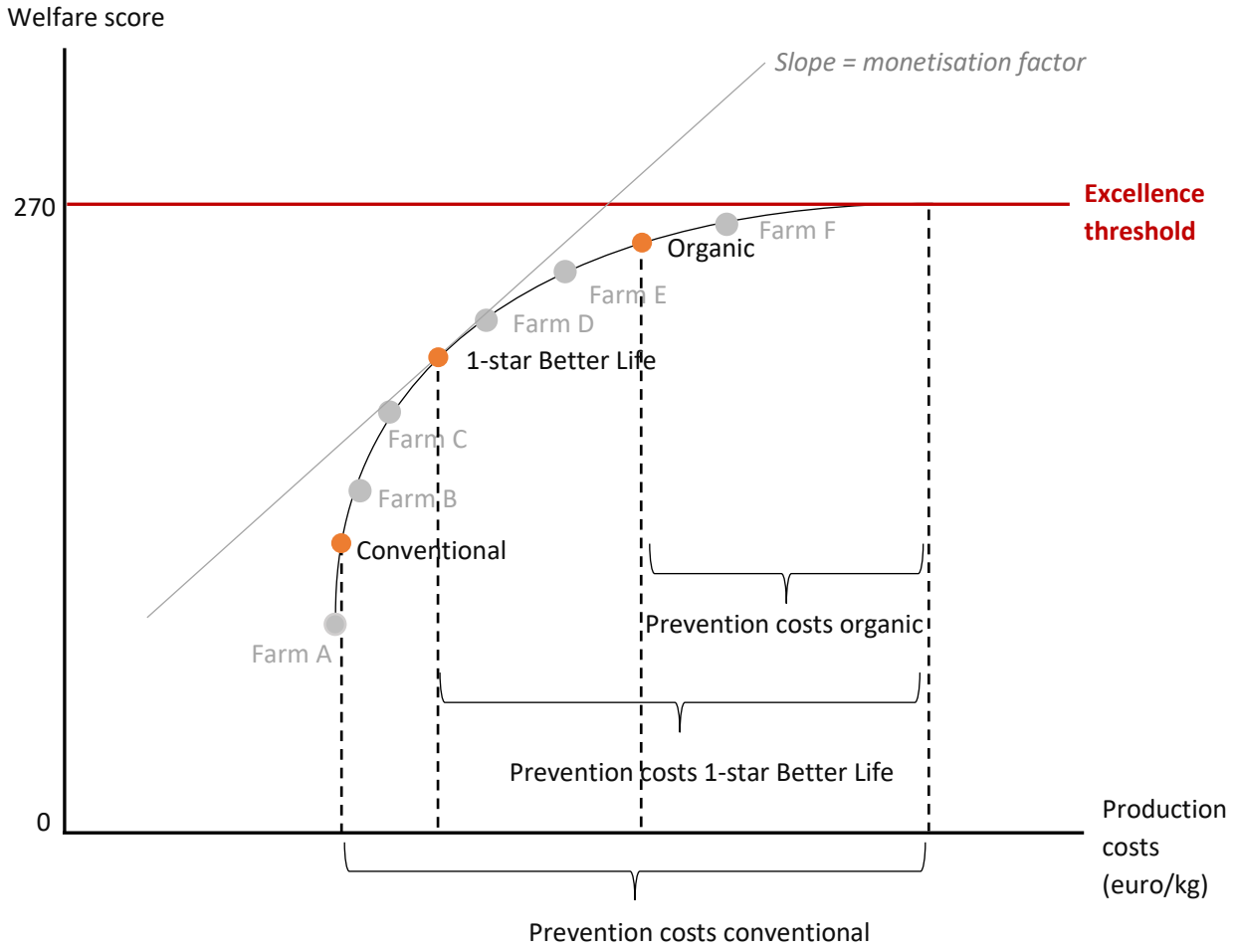

Figure 4. Illustration of the prevention costs for the conventional, 1-star Better Life and organic production system

5. Empirical application

5.1. Application of approach

In this section, the approach developed in Section 4 is applied to the production systems of three livestock species, namely dairy cattle, pigs and broilers. A literature study was conducted to obtain the welfare score and production costs of these systems in the Netherlands. Only average production costs and average welfare scores of livestock production systems were found (see Appendix). Hence, data about the production costs and welfare scores of individual farms were lacking. Because of this data limitation, it was not possible to estimate the (non-linear) cost function with a regression analysis. Therefore, as illustrated in Figure 5, this (non-linear) cost function was approximated by two linear cost functions. The first cost function shows the relationship between the animal welfare score and the production costs of the system

under consideration (defined as system x) and the reference system (defined as system r, i.e., the organic system). In Figure 5, the system under consideration is the conventional system. The system with the highest welfare score should be taken as the reference system (organic system in Figure 5). The monetisation factor of this cost function (M_{1x}) is derived from the welfare score and production costs of the system under consideration, i.e. the conventional system, and the reference system, i.e., the organic system (see equation 12). As shown in Figure 5, it is possible that the reference system does not satisfy the excellence threshold. Therefore, a second cost function was established that reflects the relationship between the animal welfare score and the production costs of the reference system, i.e., the organic system, and the excellence threshold. As shown in equation 13, the monetisation factor of this cost function (M_2) is derived from the welfare score and production costs of the reference system, i.e., the organic system, and the system with the second highest welfare score indicated as the middle system, i.e., the 1-star Better Life system.

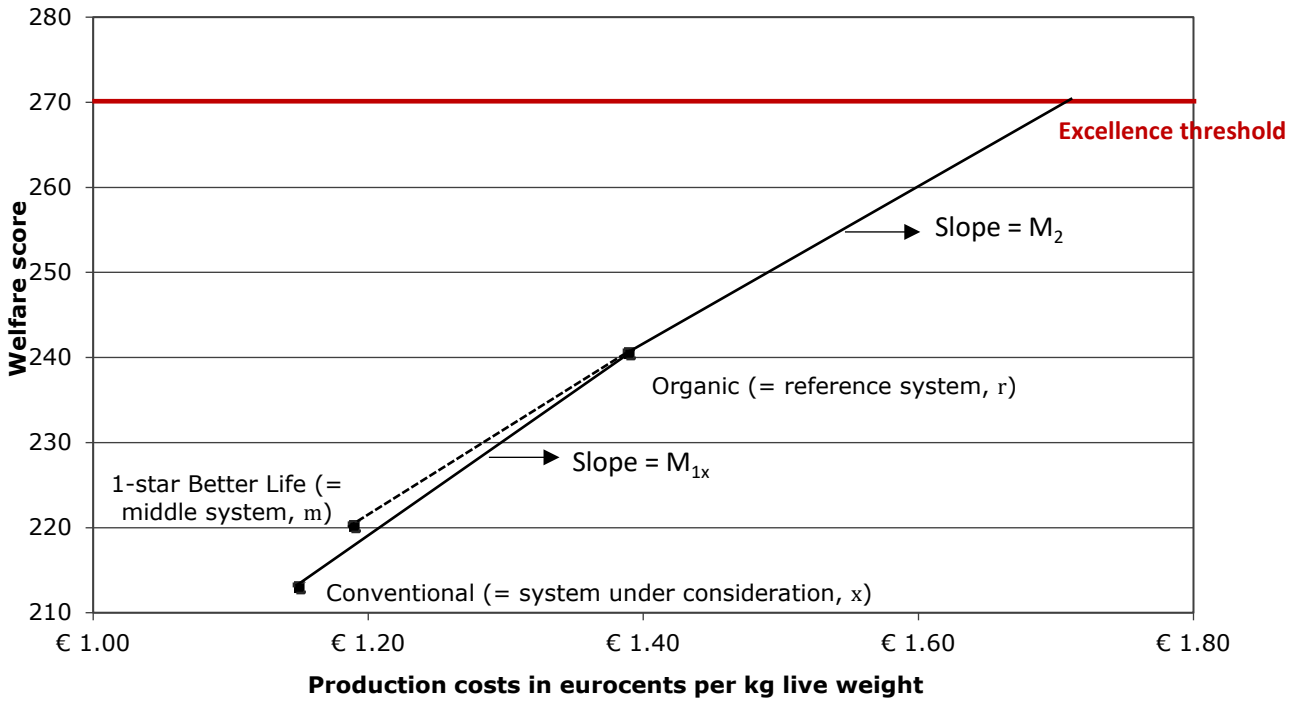

Figure 5. Production costs and the welfare scores of Dutch pig production systems

In line with the approach presented in Section 4, the monetisation factors are based on the slope of the cost functions and are provided in equation 13 and 14:

$$M_{1x} = \frac{(C_r - C_x)}{(S_r - S_x)} \quad (13)$$

$$M_2 = \frac{(C_r - C_m)}{(S_r - S_m)} \quad (14)$$

Where: M_{1x} is monetisation factor 1 of system x in euro/unit of animal welfare/kg (live weight); M_2 is monetisation factor 2 in euro/unit of animal welfare/kg (live weight); C_r is the production costs of the reference system in euro/kg (live weight, milk or eggs); C_x is the production costs of system x in euro/kg

(live weight, milk or eggs); C_m is the production costs of the middle system; S_r is the animal welfare score of the reference system; S_x is the animal welfare of score x; S_m welfare score of the middle system (if available) or conventional production system.

The monetisation factors are used to calculate the prevention costs of each production system (see equation 15 and 16). The prevention costs (P_x) reflect the costs (in euro/kg) that production system x has to incur to achieve the excellence threshold. The prevention costs are zero when the system has an animal welfare score equal to or higher than the excellence threshold:

$$If\ S_x < 270\ then \quad (15)$$
$$P_x = M_{1x} * (S_R - S_x) + M_2 * (270 - S_R)$$

$$\text{Else } P_x = 0 \quad (16)$$

Where P_x are the prevention costs of system x in euro/kg; 270 reflects the excellence threshold

The prevention costs of organic systems are considered in the examples. Organic certification does not only impose more stringent requirements on animal welfare, but also on the origin of the feed (organic) and the use of antibiotics. Therefore, the increase in production costs associated with organic production should not only be attributed to animal welfare. Hence, the costs associated with improved animal welfare in organic systems are most likely overestimated when considering the total production costs of this system. To solve this issue, the feed costs associated with organic production systems were corrected by using the feed price of non-organic feed (see Appendix). These costs were corrected because organic certification requirements on livestock production mainly affect feed costs (Gocsik et al., 2016; Van Horne, 2020).

5.2. Examples

In this subsection, it is demonstrated how the equations should be applied to calculate the prevention costs of animal welfare for Dutch livestock production systems. The calculations were based on the data shown in the Appendix, in which the principle scores and production costs of various livestock production systems are provided. Examples are shown for three livestock species, i.e., pigs, dairy cattle and broilers.

5.2.1. Pigs

Table 2 shows the data used for calculating the prevention costs of Dutch pig production systems.

Table 2 Overview of principle scores and production costs of Dutch pig production systems

System	Principle score				Production costs (euro/kg live weight)[3]
	Good feeding[1]	Good housing[2]	Good health[2]	Appropriate behaviour[2]	
Conventional	55.0	60.1	74.9	31.4	1.15
1-star Better Life	55.0	70.6	75.4	31.7	1.19
Organic	55.0	84.9	69.1	40.6	1.39

[1] Hoogstra (2019) did not consider the principle good feeding. A score was assigned to this principle based on the expert knowledge of H.M. Vermeer (see step 1).
[2] own calculations based on data of Hoogstra (2019).
[3] Hoogstra (2019).

Step 1: calculate animal welfare score

As indicated in Table 2, Hoogstra (2019) did not consider the welfare principle 'good feeding'. Expert elicitation is needed to estimate the welfare score of this principle. According to Dutch legislation, farm

animals need to be provided permanent access to feed and water (Dutch Ministry of Agriculture Nature and Food Quality, 2022). Furthermore, pigs usually have non-stop access to feed in the finishing pig industry (Hoogstra, 2019). Therefore, H.M. Vermeer (expert in pig welfare) estimated that prolonged hunger or thirst does not occur in pig husbandry, unless there is a technical malfunction in the system (personal communication, 13 June 2022). Therefore, it was assumed that the welfare category 'enhanced' was achieved, i.e. a score of 55 was assigned to this principle.

Table 2 shows that the lowest principle score is higher than 20 for each system. However, the difference between the lowest principle score and some other principle scores is more than 35 welfare points. As described in Section 4.2, these scores should be corrected (see equation 3). For instance, the principle score good health in the conventional and 1-star Better Life system was corrected as follows:

Conventional: $P_3 = 31.4 + 35 = 66.4$

1-star Better Life: $P_3 = 31.7 + 35 = 66.7$

The (corrected) principle scores in Table 3 were used to calculate the welfare scores of the conventional ($\boldsymbol{S_c}$), 1-star Better Life ($\boldsymbol{S_m}$) and organic pig production system ($\boldsymbol{S_o}$):

S_c = 55.0 + 60.1 + 66.4 + 31.4 = 212.9

S_m = 55.0 + 66.7 +66.7 +31.7 =220.1

S_o = 55.0 + 75.6 + 69.1 + 40.6 = 240.4

Table 3 Overview of corrected principle scores of Dutch pig production systems.

System	Principle score			
	Good feeding	**Good housing**	**Good health**	**Appropriate behaviour**
Conventional	55.0	60.1	66.4	31.4
1-star Better Life	55.0	66.7	66.7	31.7
Organic	55.0	75.6	69.1	40.6

Step 2: calculate first monetisation factor

In Step 1 it is shown that the organic system has the highest overall level of animal welfare. Therefore, this system was used as the reference system for calculating the first monetisation factor. The 1-star Better Life system was selected as the middle system as it is the system with the second highest welfare score.

Conventional: $M_{1c} = \frac{1.39-1.15}{240.4-212.9}$ = 0.0086 euro/unit of animal welfare/kg live weight

1-star Better Life: $M_{1m} = \frac{1.39-1.19}{240.4-220.1}$ = 0.0099 euro/unit of animal welfare/kg live weight

Organic: first monetisation factor was not calculated for the organic system as it is the reference system

Step 3: calculate second monetisation factor

$M_2 = \frac{1.39-1.19}{240.4-220.1}$ = 0.0099 euro/unit of animal welfare/kg live weight

Step 4: calculate prevention costs

The prevention costs of the conventional (P_c), 1-star Better Life system (P_m) and organic system (P_O) are:

$P_c = 0.0086 * (240.4 - 212.9) + 0.0099 * (270.0 - 240.4) = 0.53$ euro/kg live weight

$P_m = 0.0099 * (240.4 - 220.1) + 0.0099 * (270.0 - 240.4) = 0.49$ euro/kg live weight

$P_o = 0.0099 * (270.0 - 240.4) = 0.29$ euro/kg live weight

5.2.2. Dairy cattle

Table 4 presents the data used for the calculation of the prevention costs of conventional and organic dairy farming systems.

Table 4 Overview of principle scores and production costs of Dutch conventional and organic dairy farming systems

System	Principle score				Production costs (euro/kg milk)[2]
	Good feeding[1]	Good housing[1]	Good health[1]	Appropriate behaviour[1]	
Conventional	42.0	64.7	44.8	50.4	0.39
Organic	59.5	69.9	56.2	68.8	0.48

[1] Wagner et al. (2021)

[2] Van der Meulen (2021). The feed costs of the organic system were corrected by using the feed costs of the conventional system (see appendix for calculation).

Step 1: calculate animal welfare score

Table 3 shows that all principles-scores are higher than 20. Furthermore, the difference between the lowest principle score and the other principles was less than 35. Therefore, the principle scores should not be corrected. The welfare score of the conventional and organic system is obtained by aggregating the principle scores:

S_c = 42.0 + 64.7 + 44.8 + 50.4 = 201.9

S_o = 59.5 + 69.9 + 56.2 + 68.8 = 254.4

Step 2: calculate first monetisation factor

In step 1 it is shown that the organic system has the highest overall level of animal welfare. Therefore, this system was used as the reference system for calculating the first monetisation factor.

The first monetisation factor is calculated as follows:

Conventional: $M_{1c} = \frac{(0.48-0.39)}{(254.4-201.9)} = 0.0017$ euro/unit of animal welfare/kg milk

Organic: first monetisation factor was not calculated for the organic system as it is the reference system

Step 3: calculate second monetisation factor

The second monetisation factor is derived from the production costs and welfare score of the conventional and organic system:

$M_2 = \frac{(0.48-0.39)}{(254.4-201.9)} = 0.0017$ euro/unit of animal welfare/kg milk

Step 4: calculate prevention costs

The prevention costs of the conventional (P_c) and organic dairy farming system (P_O) are:

$P_c = 0.0017 * (254.4 - 201.9) + 0.0017 * (270.0 - 254.4) = 0.12$ euro/kg milk

$P_o = 0.0017 * (270.0 - 254.4) = 0.03$ euro/kg milk

5.2.3. Broilers

Table 5 shows the data that is used for calculating the prevention costs of the conventional, 1-star Better Life and organic broiler production system.

Table 5 Overview of principle scores and production costs of Dutch broiler production systems

	Principle score				Production costs (euro/kg live weight)[3]
	Good feeding[1]	**Good housing[2]**	**Good health[2]**	**Appropriate behaviour[2]**	
Conventional	55.0	31.4	41.1	15.9	0.84
1-star Better Life	55.0	56.1	58.9	16.3	1.19
Organic	55.0	54.4	38.6	51. 3	1.48

[1] Gocsik et al. (2016) did not consider this principle. A score of 55 was assigned to this principle based on the information provided by I.C. De Jong (expert in poultry welfare).
[2] own calculations based on data of Gocsik et al. (2016)
[3] The production costs of the conventional, 1-star Better Life and organic system were obtained from Van Horne (2020). The feed costs of the organic system were corrected by using the feed price of the 1-star Better Life system (see appendix for calculation).

Step 1: calculate animal welfare score

As indicated in Table 5, Gocsik et al. (2016) did not consider the welfare principle 'good feeding'. Broilers usually have permanent access to feed and water in the Netherlands (personal communication I.C. De Jong, 16 June 2022). Therefore, it was estimated that prolonged hunger and thirst do not occur in broiler farming. Based on this information, it was assumed that the welfare category 'enhanced' was achieved, i.e. a score of 55 was assigned to this principle.

Table 5 shows that the principle score appropriate behaviour is lower than 20 in the conventional and 1-star Better Life system. Therefore, this principle score was used to calculate the welfare scores of these systems (see Table 6). All principle scores in the organic system are more than 20 and the difference between the lowest principle score and the other principle scores is less than 35. Therefore, the principle scores of the organic system should not be corrected. Table 5 shows the principle scores that were used for calculating the overall welfare scores:

S_c = 15.9*4 = 63.6

S_m = 16.3*4 = 65.2

S_o = 55.0 + 54.4 + 38.6 + 51.3 = 199.3

Table 6 Overview of corrected principle scores of Dutch broiler production systems.

System	Principle score			
	Good feeding	Good housing	Good health	Appropriate behaviour
Conventional	15.9	15.9	15.9	15.9
1-star Better Life	16.3	16.3	16.3	16.3
Organic	55.0	54.4	38.6	51.3

Step 2: calculate first monetisation factor

In step 1 it is shown that the organic system has the highest overall level of animal welfare. Therefore, this system was used as the reference system when calculating the first monetisation factor. The 1-star Better Life system was selected as the middle system as this system has the second highest welfare score.

Conventional: $M_{1c} = \frac{1.48-0.84}{199.3-63.7} = 0.0047$ euro/unit of animal welfare/kg live weight

1-star better life: $M_{1m} = \frac{1.48-1.19}{199.3-65.3} = 0.0022$ euro/unit of animal welfare/kg live weight

Organic: first monetisation factor was not calculated for the organic system as it is the reference system

Step 3: calculate second monetisation factor

$M_2 = \frac{1.48-1.19}{199.3-65.3} = 0.0022$ euro/unit of animal welfare/kg live weight

Step 4: calculate prevention costs

The prevention costs of the conventional (P_c), 1-star Better Life (P_m) and organic system (P_O) are:

$P_c = 0.0047 * (199.3 - 63.7) + 0.0022 * (270.0 - 199.3) = 0.79$ euro/kg live weight

$P_m = 0.0022 * (199.3 - 65.3) + 0.0022 * (270.0 - 199.3) = 0.45$ euro/kg live weight

$P_o = 0.0022 * (270.0 - 199.3) = 0.16$ euro/kg live weight

6. Limitations and items for further development

6.1. Limitations

- According to The Welfare Quality® protocol, no compensation between principle scores is possible if welfare is below a threshold, while some compensation is possible if welfare is above this threshold (see Section 4.2). We followed this approach by assuming that no compensation is allowed if welfare did not meet minimum requirements, i.e. if welfare was at a level that was considered unacceptable by the Welfare Quality® protocol. Limited compensation between principle scores was allowed if welfare met minimum requirements. One could argue that no compensation between principle scores is allowed, regardless of the level of animal welfare. It is debatable which assumption should be used (no compensation or limited compensation).

Furthermore, it is debatable to which degree principle scores can compensate each other when limited compensation is assumed. The costs needed to achieve the excellent threshold depends on the selected assumption. This issue should be taken into account when interpreting the results.

- The Welfare Quality® Protocol has been developed only for cattle (without veal), poultry (layers and broilers) and pigs. Hence, there is no protocol for other species (e.g. sheep, cattle for beef production, turkeys). Therefore, it is currently not possible to apply the method developed in this module to these species. Another limitation of the Welfare Quality® protocol is that transportation and the slaughtering process are not considered. Despite these shortcomings, the Welfare Quality® Protocol can be seen as the state of the art to assess animal welfare. Therefore, this method was used to measure animal welfare.
- To calculate the monetisation factor, a reference point was required that reflects no violation of animal rights. The question is what should be used as a reference. This reference is debatable and depends on the philosophical approach of animal rights. In this module, the highest welfare category in the Welfare Quality® Protocol, i.e. excellent, was used as a reference. It is important to note that this level reflects not only the theoretical acknowledgement of what can be considered excellent but also what can realistically be achieved in practice when rearing animals for food production.
- In the empirical application, the welfare scores of some systems were relatively low compared to the 'excellence threshold'. As a result, the prevention costs of the systems were quite high in absolute terms. This finding can be explained by our assumption that no compensation between principle scores is allowed. Furthermore, it can be explained by the level selected for the 'excellence threshold' (score of 270). As mentioned in the previous bullet point, the reference situation ('excellence threshold') is debatable. As this issue affects all systems similarly, it does not affect the differences between the systems in terms of prevention costs. Because of this issue, the costs associated with animal welfare are less comparable to the costs associated with other externalities such as climate change and air pollution.
- The feed costs of organic systems were corrected to estimate the costs associated with animal welfare improvements in these systems. In some sectors, such as the dairy farming sector, most farmers cultivate (part of) their own feed (mostly roughage). Therefore, organic certification requirements do not only affect feed costs but also other cost components such as labour costs. The costs associated with these requirements should be taken into account when correcting the costs of organic livestock production systems. Insight in the effect of organic certification requirements on these costs is however lacking. Correcting only the feed costs of organic systems in these sectors implies an overestimation of the costs associated with animal welfare improvements. The preventions costs of animal welfare in these systems should therefore be interpreted with caution.
- Only average production costs and welfare scores of livestock production systems were found for the empirical application. Hence, data of individual farms were lacking. Because of this limitation, it was not possible to establish a non-linear cost function. Instead, a linear cost function was derived from the costs and welfare scores of existing production systems. As a result, the costs needed to achieve the excellence threshold are most likely underestimated. This limitation should be taken into account when interpreting the results.

6.2. Items for further development

- Currently, insight is lacking into the costs associated with animal welfare improvements in organic production systems. To estimate the marginal costs of animal welfare, the production costs of organic systems were corrected by using the feed price of non-organic feed. Future research could

analyse which share of the production costs of organic livestock production can be attributed to animal welfare. This insight provides a more accurate estimate of the monetisation factor.

- The number of studies that applied the Welfare Quality® Protocol is limited. This could be explained by the fact that the collection of data for the Welfare Quality protocol tends to be time consuming and is therefore costly. Furthermore, appropriate and recognized training in the use and practical application of the protocol is essential to ensure uniform scoring. Various studies developed simplified methods of the Welfare Quality® Protocol, thereby making animal-based welfare assessment more practicable. Future research could apply these methods to alternative systems (e.g., the 2-star Better Life system) to obtain animal welfare scores for these systems. With this insight, more accurate estimates of the prevention costs for animal welfare can be generated for these systems.
- The application of the approach requires data on the production costs and welfare scores of livestock production systems in a specific country. In the empirical application, Dutch livestock production systems were considered. The number of studies that applied the Welfare Quality® Protocol to livestock production systems in other countries is relatively small. More data is required on the welfare scores and production costs of livestock production systems in other countries. This data can be used to calculate the prevention costs of animal welfare in these systems.

Appendix

Data used for calculation of the prevention costs

Data that can be used for calculation of the prevention costs. The welfare scores are measured with the Welfare Quality Protocol. The production costs are calculated for Dutch livestock production systems.

Livestock specie	**System**	**Welfare score**				**Feed price (euro/kg)**	**Feed conversion ratio (g/g)**	**Production costs in euro/kg (milk, eggs or live weight)**
		Good feeding	**Good housing**	**Good health**	**Appropriate behaviour**			
Broiler	Conventional	-	31.4[1]	41.1[1]	15.9[1]	31.0[2]	1.60[2]	0.84[2]
	1-star Better Life	-	56.1[1]	58.9[1]	16.3[1]	29.60[2]	2.10[2]	1.19[2]
	Organic	-	54.4[1]	38.6[1]	51.3[1]	65.0[2]	2.65[2]	1.48[2]
Pig	Conventional	-	60.1[3]	74.9[3]	31.4[3]	24.80[4]	2.55[4]	1.15[4]
	1-star Better Life	-	70.6[3]	75.4[3]	31.7[3]	24.80[4]	2.67[4]	1.19[4]
	Organic	-	84.9[3]	69.1[3]	40.6[3]	39.68[4]	3.05[4]	1.39[4]
Dairy cattle	Conventional	42.0[5]	64.7[5]	44.8[5]	50.4[5]	[6]	-	0.39[6]
	Organic	59.5[5]	69.9[5]	56.2[5]	68.8[5]	[6]	-	0.51[6]

[1] own calculations based on data of Gocsik et al. (2016)
[2] Van Horne (2020)
[3] own calculations based on data of Hoogstra (2019);
[4] Hoogstra (2019)
[5] Wagner et al. (2021)

[6] The production costs of the dairy organic system were corrected using the milk yield and feed costs per cow. According to Van der Meulen (2021), feed costs were on average 1,051 euro/cow in conventional dairy farms and 1,063 euro/cow in organic dairy farms in 2017-2019. The average milk yield was 8,564 kg/cow in conventional dairy farms and 6,708 kg/cow in organic dairy farms.

Calculation of the production costs of organic systems corrected with the price of conventional feed:

Organic broiler production system: $2.42 - \left(\frac{65-29.6}{100}\right)\ x\ 2.65 = 1.48$ euro/kg live weight

Organic dairy farm: $0.51 - (\frac{1,063}{8,564} - \frac{1,051}{6,708}) = 0.48$ euro/kg milk

Note: the production costs of the organic pig production system were already corrected for the feed price of conventional feed in the study of Hoogstra (2019)

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