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Article

Hidden Costs Associated with Smallholder Family-Based Broiler Production: Accounting for the Intangibles

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Abstract: The contractual relationship between the processing firm and the broiler smallholder presents incessant conflicts of interest and inequality due to technical and economic discrepancies, leading to an undervaluation of the producers' remuneration. This study aims to deepen the discussions in searching for a more balanced monetary exchange between processing firms and broiler smallholder based on scientific aspects. For this, the Emergy theory and its concepts were used considering a representative broiler production system at Concórdia, Santa Catarina, Brazil. This study suggests the inclusion of cultural information in the Emergy-based model calculation. For the broiler smallholder, cultural information showed the highest Emergy contribution (62.95%; transformity = 1.73×10^8). However, only considering cultural information was not sufficient to increase the sustainability of the broiler production system. The results highlight an imbalance of the monetary exchange between agroindustry and broiler smallholder payment for both the economic and Emergy-based payment. Both estimated payments were higher than the practiced payment value (0.24 USD/broiler as well as 0.32 USD/broiler and 1.62 EmUSD/broiler, respectively). Thus, evaluating the "(eco)cost" in Emergy-based accounting recognises that production depends not only on tangible physical resources but also on knowledge, skills and information ("iceberg of value" thinking). Policy and decision makers must therefore consider the promotion of public policies that subside initiatives, including social and environmental welfare programmes.

Highlights:

- There is an imbalance exchange between the agroindustry and broiler smallholders;
- Emergy-based approach could suggest a holistic view-based payment for broiler smallholders;
- Emergy theory can help in a deeper understanding of economic systems and their foundations.

Keywords: Broiler production systems; Broiler producer; Emergy; Environmental assessment

1. Introduction

Poultry farming is an activity that generates important economic dividends all over the world. It ensures food security in several developing countries, besides of generating jobs, income and foreign exchange [1]. Brazil is one of the countries with the lowest production costs [2], which provides competitive advantages and places the country among the largest world producers. National production jumped from 375 thousand tonnes in 1975 to 14.25 million tonnes in 2022, a growth of approximately 38 times [3], which is unusual among the main agribusiness activities in the country.

The origin of commercial poultry farming in Brazil dates back to the first half of the last century. During that time, the production was located mainly in the southeastern region of the country. However, from the 1970s onward, poultry farming became professionalised and advanced towards the south of Brazil, with the incorporation of new productive and organisational techniques [4]. The supply of grains (corn and soybeans), subsidised credit and the imported genetic and health

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technologies stood out among the driving factors. Another additional factor for the development of poultry farming in the south of the country was the adoption of a production model based on the integration between slaughterhouses and small family farmers [5,6]. This strategy was inspired by the integrated model of chicken production already implemented in the United States, known as the Southern Model [7]. In this model, the processing firm (slaughterhouse) did not need to produce everything internally or, on the contrary, buy everything from independent external suppliers but organised the creation through a set of partners (rural producers).

The smallholder families (called "integrated") became responsible for raising the chickens, receiving the main inputs from the industry, such as feed, medicines, chicks, in addition to technical assistance. In this model, the chickens were passed on to the processing firm (slaughterhouse) in exchange for remuneration for the work and goods made available in the creation. This integrated production model is now considered as the basis for the Brazilian poultry competitiveness as it provides transactional efficiency (low production costs) to the system [4].

However, until now, the relationship between the processing firm and the smallholder family has not been without challenges. The contractual relationship is notably unequal due to the technical and economic discrepancies between industrial conglomerates (oligopsony) and small farmers [8,9]. Thus, the structure of this market tends to undervalue the remuneration of producers [10,11]. In general, contracts place the broiler smallholders in direct dependence on the power of processing firms, removing them from the free competitive market and making them co-adjuvants in the formation of the price of the product offered to the processing firms [4,12]. It was in this context and after a lot of pressure from the integrated producers that, in 2016, the integration law was created in Brazil (Federal Law n.º 13,288), which came to standardise the processing firm - broiler smallholder relationship. However, the law does not state how the remuneration of the integrated member should be. It only imposes new mechanisms to alleviate the asymmetries in the relationship through the creation of a bipartite commission of representatives of the integrated members and integrating companies [9].

Broiler smallholder remuneration methods are generally based on productive efficiency indices [13] and economic cost indicators [14]. As the processing firms have more power than the integrated farmers, it is highly likely that the prices received by the farmer (weaker party) are depressed. The economic theory [15] shows that an agent should only remain in a given activity when what he/she receives covers all expenses with that activity. Therefore, for an integrated poultry farm, its remuneration should cover all costs with the operation (such as labour, energy, materials), known as explicit costs. However, the mainstream economic costs neither consider the expenses with the so-called free factors (such as energy of sun, water) nor the contribution of the cultural information brought by an indigenous population to an agricultural production system. As shown by Abel [16,17], cultural knowledge plays an import role in sustaining the progresses of society and agricultural systems.

In the case of the integrated poultry production system in southern Brazil, the cultural contribution of family farmers to the success of the business model is notorious. Family farmers are descendants of European settlers who exalt the value of work, the cult of discipline, the importance of community and family life [18]. These values shaped family farming and were fundamental for the successful integration of family farming with agroindustries over time [4,18]. Therefore, cultural information provides support to the agricultural production systems [19–21] and is part of the total contribution of the poultry farmers to the integrated production system.

Thus, for measuring the total contribution of farmers to the poultry system, it is inadequate to use the classical economic approach. This discussion needs to be purposed using a holistic point of view, based on the total effort of smallholders and the nature of the production system. For this purpose, the "iceberg (or pyramid) of value" thinking could help to deepen the discussion regarding the smallholder payment and considering a holistic point-of-view and system thinking. In the "iceberg (or pyramid) of value" perspective, the market and cost values are observed from the mainstream economic system, whereas there are hidden resources of the "visible peak", supporting the production system, but they are not measured from the mainstream economic metrics. To

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measure the hidden costs from a holistic point of view, it is appropriate to use a holistic tool such as Emergy.

Emergy is a theory and method that quantifies all energy inputs (embodied energy) needed to generate some product or service [22–24]. Emergy Synthesis can put together all environmental, economic, and sociocultural efforts provided by the smallholder families to the broiler production chain in a unique common base (solar-equivalent energy). Converting this total flow into a monetary-equivalent payment is a way to quantitatively bring the intangibles (cultural information and other hidden costs) into economic indicators. According to Abel [17], Emergy Synthesis is a tool for characterising system structure, whether or not it is self-organised with information control. Where information does exist, Emergy is a method to judge the relative impact of its control. It is a means to 'locate' its production within the hierarchy of energy transformation processes [17]. Thus, measuring all energy-matter inputs used in broiler production in a common base (solar-equivalent energy) and then converting the flow in a monetary-equivalent payment could be a way to quantitatively bring the intangibles into economic indicators and search for a holistic view-based payment for the smallholder broiler family by their services.

Thus, this article aims to deepen the discussions in searching for a more balanced monetary exchange between processing firms and broiler smallholders based on scientific aspects from a holistic perspective using the Emergy theory. Besides providing discussions based on quantitative data regarding the broiler production case in Brazil, this work contributes to the discussions about the usage of Emergy synthesis as an alternative in measuring value for intangibles resources, an important and current debate towards the Agenda 2030 goals.

2. Contextualising about the importance of intangibles in sustaining smallholder family-based broiler production

Most of the South Brazilian land occupation took place from the second decade of the 19th century onwards by descendants of European immigrants [25]. From the beginning, raising animals (mainly pigs) was one of the ways to pay for land and of paramount importance for the development of the region. Therefore, the knowledge and ability to deal with small animals has been one of the characteristics of these farmers since the beginning of the occupation of the territory [4,18]. From small factories (mostly salami and lard), the enterprises diversified into poultry production from the 1970s. Since its origin, poultry farming in the region has been developing from the smallholder family - agroindustry relationship via integration contracts. Integration provided efficient control mechanisms over the production process, with family farming as the social basis for its support.

As the settler strongly envisaged social ascension, the arrival of poultry farming was seen as an opportunity, including to take advantage of the workforce of women and children in the daily operations. Farmers saw this as another opportunity to increase their family income. Poultry farming is a confined production which requires specialised labour and total dedication to the care of the animals. It is necessary to be permanently present in the aviaries, whether at night or on weekends, which requires obedience to the rules established in the contract [9].

On the one hand, it is through the relationship with family farmers that the integrating company guarantees the existence of raw material in sufficient quantity and quality for production, without the need to incur huge production costs if it adopts the verticalization strategy. On the other hand, the integration contract reduces transaction costs, both *ex-ante* (to find farmers, to negotiate prices, to draft contractual instruments) and *ex-post* (to enforce obligations assumed). Therefore, the role played by the farmer through contracting with the agroindustry has been fundamental for the performance of the Brazilian poultry industry, which has grown more than 38 times the volume produced from the mid-1970s until today. However, despite its unquestionable contributions, the knowledge and cultural information from agricultural smallholders are not fully evaluated in this market [17].

Cultural information is turned into techniques that support agricultural production [19–21], improving the production and food security. However, since the information is always "carried" on a material or energetic carrier of some kind, to maintain the "information carrier", the human-controller is primordial [17]. When it comes to humans, this maintenance requires satisfactory levels

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of social welfare and good quality of life to support it. According to Odum [23], higher welfare levels for humans are obtained when there is a good match of the small-, medium- and large-scale inputs. In this sense, environmental influence, exergy-level support (i.e., fuel, electricity and transport) and information exchange are inputs that may be required for human individual benefits (Figure 1). In addition, Brandt-Williams [26] suggests that wage and food input flows are needed to produce work. Also, we believe that the information generated for this human feeds back into the knowledge network.

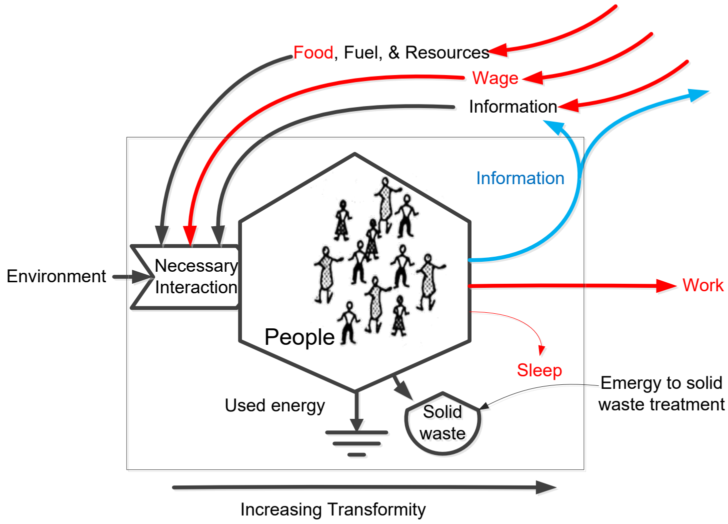

Figure 1. Aggregated Emergy diagram of a citizen: Emergy requirements for the welfare of human individuals, including fuels, resources (e.g., minerals and services), environment and information [23] (in black); Emergy flows of worker, including food and wage [26] (in red); work, sleep as output; information feedback can be generated in leisure time (in blue).

3. Material and Methods

3.1. Mainstream economic cost model

The economic cost model was developed according to the Economic theory, considering the total cost as the result of the summatory of the variable cost and the fixed cost (total cost = variable cost + fixed cost) and following the model proposed by Nacimento et al. [27] (Figure 1). The calculation memory is provided in the Supplementary Material 1.

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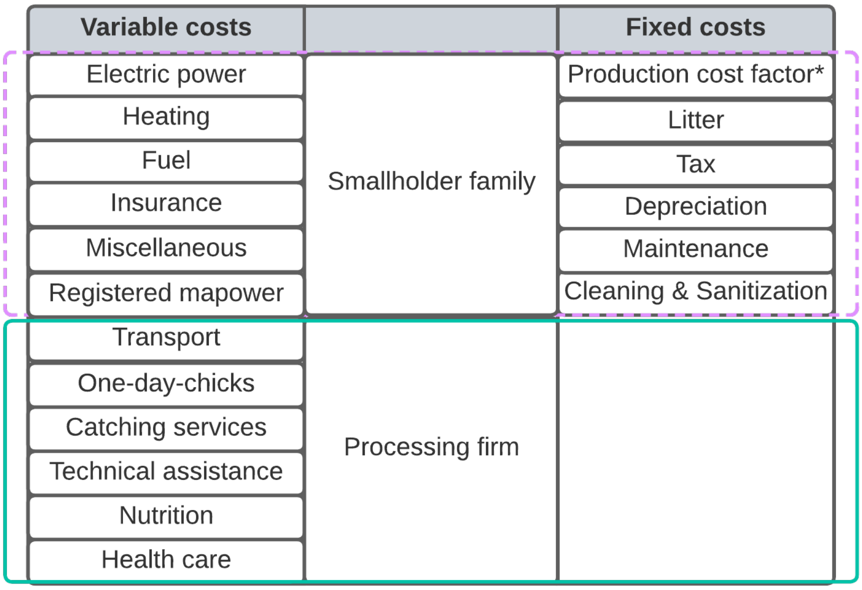

Figure 1. Scheme representing the division of inputs to the cost assessment in a conventional broiler production system. The inputs are divided according to their respective partners in variable and fixed costs. Note: dashed line square shows the inputs under smallholder responsibility; continuous line square shows the inputs under processing firm responsibility. Despite some particularities among broiler processing firms, this is the most common division of responsibilities. * Production cost factor: opportunity cost of working capital, land, facilities and equipment use

3.2. Alternative economic cost model: Emergy synthesis as a way to include the intangibles

The study followed three steps established by Odum [23] and the suggestions by Brown and Ulgiati [28] as follows: (i) construction of a diagram of the energy flow of the system, defining the energy sources, the system boundaries and the internal components (producers, consumers, stocks, interactions, etc.); (ii) organisation of data in an Emergy table, listing all resources and later classifying them as natural (I) or economic (F). The sum of these inputs (Y = I + F) demonstrates the value in Emergy; and (iii) calculations of Emergy indicators and discussion of the results for practical purposes. The transformities (Tr) of the items listed in the calculation table were obtained from the scientific literature and, when necessary, corrected to the biogeosphere Emergy baseline proposed by Brown et al. [29] (12.0×10^{24} seJ/J). For further detailed information on the Emergy methodology, please see Odum [23].

As a way to include the important variables (intangibles) of smallholder family-based broiler production into economic data, the following three approaches were considered: (i) estimative of cultural information transformity based on the Emergy theory; (ii) transformity assessment for the Smallholder broiler family labour force with and no cultural information; (iii) estimative of a more balanced payment for the smallholder broiler family. All these three approaches are detailed and separately presented in the following sections.

3.2.1. Estimative of cultural information transformity based on the Emergy theory

For Odum, information consists of the unit, connections and configurations of systems. Also, information is responsible for carrying the material-energy of some kind [17]. Information carriers are subject to the second law of thermodynamics (entropy) and must be maintained with "information cycles" that comprehend selection, extraction, copying and dispersal [17]. The information has as functional activity (i) to maintain time-tested energy pathways and processes and (ii) to provide control in system designs that (self-)organise for maximum empower [17,24].

According to Abel [17], any information transformities could only be calculated in area and populational analyses. Thus, the method could provide an 'areal' and 'populational' calculation of

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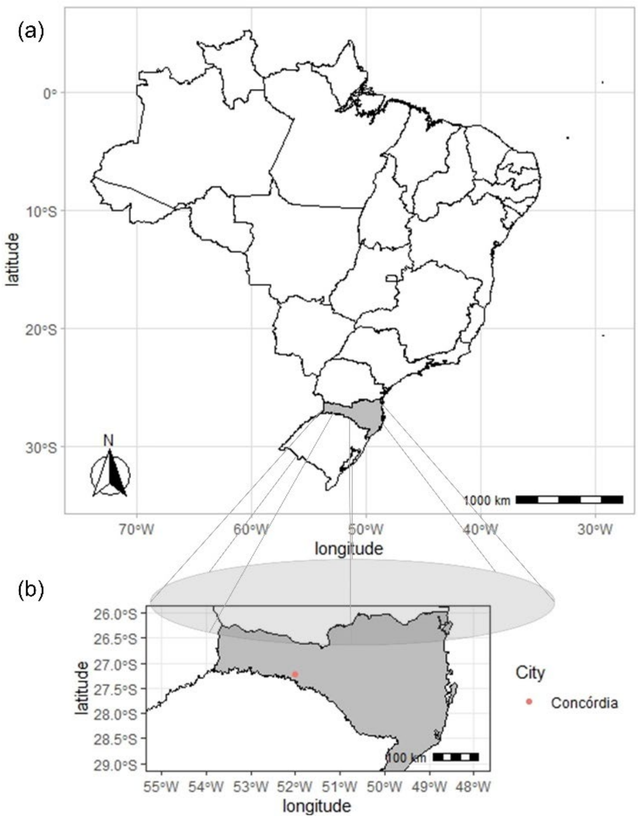
information transformities, specifically considering the human body, information and DNA creation and maintenance concerning energy storage and flow. In this sense, the evaluation of storage is intended to represent the original production of information, whereas the evaluation of flow is intended to represent the maintenance of information.

In this study, the method used to estimate the cultural information of Santa Catarina State citizens followed an Emergy-based model proposed by Odum and Doherty [30] and Odum [23], using populational information from Santa Catarina State, Brazil, for 2018, according to the Brazilian Institute of Geography and Statistics [31]. For the authors, there is the comprehension that the social interactions among indigenous people suffered over the past ~100 years; the earliest and newest European immigrant people were responsible to promote the needed knowledge exchange to push and strengthen the broiler industry on the West of Santa Catarina State (Supplementary Material 2, sheet "Cultural information"), making cultural information an important control flow for the broiler industry (Table 1).

3.2.2. Transformity assessment for the broiler smallholder service with and without cultural information

To determine the Tr of the work from the broiler smallholder, "areal" and "populational" data were recorded from governmental agencies reports for the City of Concórdia, Brazil, following the steps according to Su et al. [32]. The City of Concórdia was selected due to its current and historical importance in Brazilian broiler production, being the cradle of modern Brazilian broiler production. The reports compiled the data of forests and water bodies, agricultural lands, and uncovered areas; import and export trade data were collected to analyse the Emergy flows of urban ecosystems (Figure 2).



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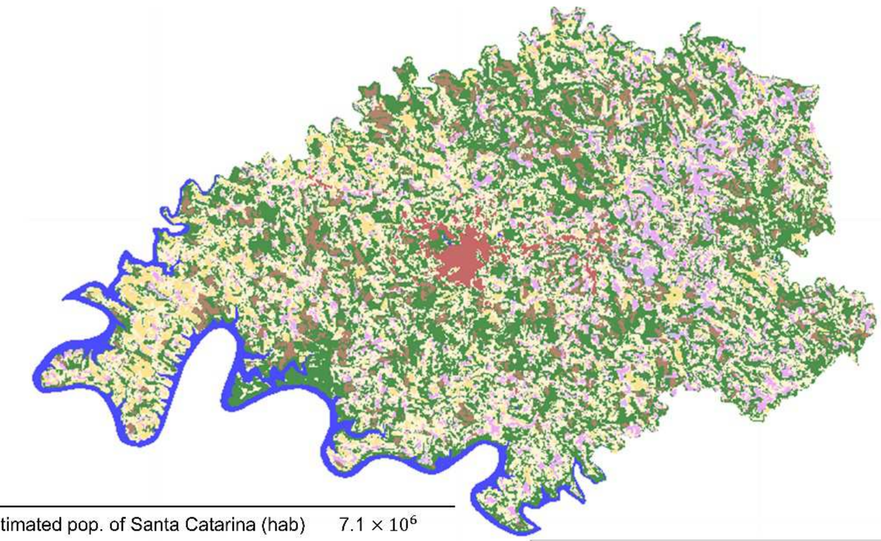
(c)



(d)

	Estimated pop. of Santa Catarina (hab)	7.1×10^6
	Estimated pop. of Concórdia's city (hab)	71,401
	Total area (1000 ha)	79.9
☐	Agriculture* (1000 ha)	45.2
☐	*Grazing land (1000 ha)*	*5.8*
☐	*Temporary crops (1000 ha)*	*6.9*
☐	*Silviculture (1000 ha)*	*6.1*
☐	Forest (1000 ha)	29.6
☐	Body of water (1000 ha)	3.5
☐	Uncovered area (1000 ha)	1.6

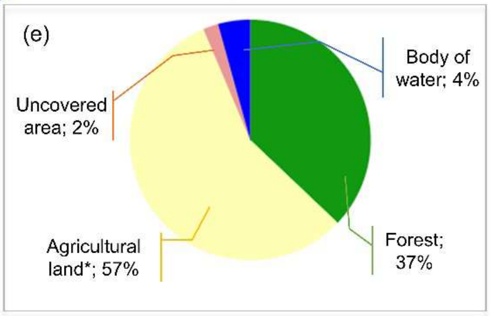


Figure 2. Location of Concórdia City (Santa Catarina, Brazil), area and population information for 2018. (a) Brazilian map and location of Santa Catarina State; (b) Location of Concórdia City (pink point); (c) Land cover and landscape distribution of Concórdia; (d) Numerical information regarding land cover and landscape distribution of Concórdia; (e) percentage of the Concórdia landscape distribution. Source: a and b: available in https://www.gps-coordinates.net/; accessed in July 18, 2023 (for latitude and longitude data); c, d, and e available in https://mapbiomas.org/; accessed in July 18, 2023. * Considering agricultural land as the summatory of grazing land, temporary crops and silviculture.

The renewable resources flowing into the urban ecosystem included sunlight, rain (geopotential energy and chemical potential energy), wind and earth cycle (for further details, see Supplementary Material 2, sheet "Manpower"). The non-renewable resources were associated with the support of citizens to assure social welfare. According to Odum [23], the three kinds of inputs of different transformities that may be required for human individual benefit (humane welfare) are as follows: (i) environmental influence; (ii) exergy-level support (available energy of medium transformity sources such as fuels and electricity) and (iii) informational exchange. Also, the waste may perform as a negative influence. On the other hand, in modern society, humans provide their workforce as the main output and receive monetary payment [26]. Thus, the non-renewable resources included food, hydroelectric power, fuel (ethanol, gasoline and lubricants), natural gas, information, wages and solid waste treatment (Figure 3).

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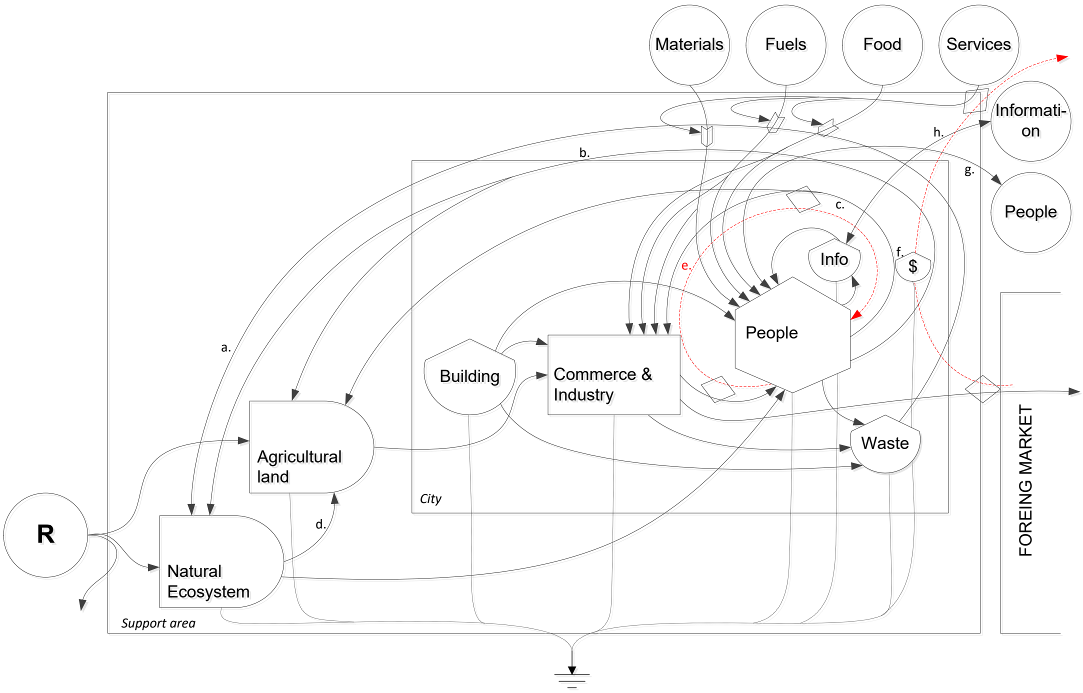

Figure 3. Emergy diagram of an urban ecosystem for Concórdia City (Santa Catarina, Brazil). Source: adapted from Su et al. [32]. Note: [a] Vegetable biomass providing ecosystem services for the negative externalities dissolution; [b] Landscape aesthetic contemplation; [c] agricultural workforce; [d] ecosystem services supporting agricultural production; [e] monetary flow used to pay goods & services in the support area; [f] economic assets used to pay services from outside of the support area; [g] people exchange; [h] information exchange (i.e., social media, specialised literature, social interaction, etc.).

3.2.3. Estimative of a holistic view-based payment for the broiler smallholder by their services

The model used to estimate a holistic view-based payment for the smallholder broiler family by their services was based on the Emergy exchange ratio (EER) proposed by Odum [23]. For Odum, this indicator can help to develop equity in trade, employing shared information among the agents and increasing the benefits for them. This indicator considers the Emergy exchanged in a trade or purchase (the given Emergy in product form and the received Emergy in money form) and is generally expressed concerning one trading partner or the other trading partners. Is a measure of the relative trade advantage of one partner over the other [28]. Thus, the best result for EER is 1.0, indicating a balanced trade under Emergy units among the trading partners. In this sense, in a holistic view, the EER can indicate an imbalanced Emergy trade between the buyer (processing firm) and the smallholder broiler family using the buying power of money paid for this end.

First, the Emergy accounting model is used to evaluate the Emergy flows according to Nacimento et al. [33] (Figure 4). The model was filled using data previously recorded from the Embrapa Suínos e Aves reports [34,35]. This report provides information regarding broiler production system features, buildings and management for representative broiler systems at Santa Catarina State. For the monetary data collection, interviews with producers, technical staff and experts in broiler production were conducted. The Emergy flows were divided into agroindustry (processing firm) and producer (smallholder broiler family) according to each input under their responsibilities, as previously shown in the Economic cost calculation. The detailed calculation memory is available in Supplementary Material 3.

Second, the EER was used considering only the Emergy flows of the broiler smallholder. Thus, the EER was the ratio between (i) the economic and socioenvironmental costs under the responsibility of the broiler smallholder in Emergy terms and (ii) the wealth provided in monetary terms and received by the smallholder broiler family for its services (broiler rising), as follows:

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$$EER_p = \frac{Y_p}{Price \times EMR} \quad (1)$$

If $EER_p = 1$,

$$1 = \frac{Y_p}{a \times EMR} \quad (2)$$

in which EER_p is the Emergy exchange ratio for the producer (adimensional), and Y_p is the Emergy of the inputs under the responsibility of the producer (sej/yr). To this end, as inputs were considered those inputs under smallholder broiler responsability inputs used to calculate the economic costs. The $Price$ is the price received as payment for the smallholder broiler family services in 2018 (USD/yr); EMR is the Emergy/money ratio for the Santa Catarina State previously assessed by Demétrio [36]. An average EMR (sej/$) can be calculated by dividing the total Emergy use of a state or nation by its gross economic product. The EMR can be defined as the Emergy supporting the generation of one unit of economic product (expressed as currency) and is used as the economic equivalent of Emergy. The contribution to a process represented by monetary payments is the Emergy that people purchase with the money since money is not paid to the environment. Also, the amount of resources that money buys depends on the amount of Emergy supporting the economy and the amount of money circulating [37,38]. For Brown and Ulgiati [38], the EMR is useful for evaluating service inputs given in money units, where an average wage rate is appropriate. The a is the searched value as the more balanced payment in monetary equivalent under the balanced condition $EER_p = 1$.

Thus, Emergy with and without cultural information was used to suggest a holistic view-based payment for the smallholder broiler family. For the model implementation and test, the Solver tool (MS-Excel) by means of the non-linear GRG solution method was used. For further details, see Supplementary Material 3.

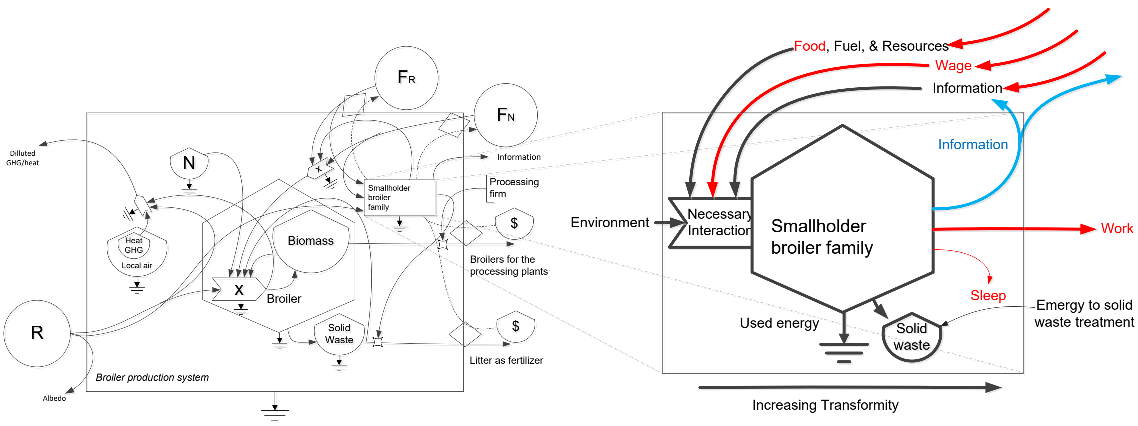

Figure 4. Emergy diagram for a representative broiler production system in Santa Catarina State.

4. Results and Discussion

4.1. Valuing cultural information

The Tr for the culture information storage of citizens of Santa Catarina was 2.77×10^{10} sej/J (Table 1). As expected, this result is near the native culture storage demonstrated in Odum [23] and depicted in graphical form by Abel [16]. It is also close to the value of traditional farming culture storage for the Oak Openings region found by Higgins [39].

Table 1. Emergy evaluation of culture information of Santa Catarina citizen, Brazil.

Item	Unit	Energy (units/yr)	Transformity (sej/unit)	Solar EMERGY ($\times 10^{13}$sej/yr)	Em$Value (emdollar/yr) in millions

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		Annual Flow			
[1] Renewable resource	J			5.60×10^{9}	23,769.10
[2] Human metabolism	J	2.71×10^{16}	2.06×10^{6}	5.60×10^{9}	23,769.10
[3] Information flow	J	2.71×10^{15}	2.06×10^{7}	5.60×10^{9}	23,769.10
		Steady-state Storage			
		(sej)	(sej/J)	($\times 10^{13}$ sej)	(emdollar) in millions
[4] Population	J	2.02×10^{15}	9.13×10^{8}	1.85×10^{11}	784,380.31
[5] Culture information	J	2.02×10^{14}	2.77×10^{10}	5.60×10^{11}	2,376,910.02

Note: Number of citizens of Santa Catarina state: 7,1 millions of people; Emergy/money ratio from Santa Catarina state: 2.36×10^{12} sej/USD [36]; the method proposed to estimate the Culture information follow the equations suggested by Odum [23] and Odum and Doherty [30]; for further detail see Supplementary material 2, sheet "Cultural information".

[1] The Emergy of renewable resources for Santa Catarina State was obtained from data previously published by Demétrio [36].

[2] Human metabolism.

Used Energy (J) = (7.1E06 people)(2500kcal/day)(4186 J/kcal)(365day/yr) .

Used Energy (J) = 2.71E+16 J/yr.

Transformity = (Emergy of Renewable resource) / (Human metabolism).

[3] Information flow:

Used Energy (J) = (Used Energy)(10%) .

Used Energy (J) = 2.71E+15 J/yr.

Transformity = (Emergy of Renewable resource) / (Information flow).

[4] Population:.

Used Energy (J) = (0.2 dry)(454 g/lb)(7.4E4 people)(150 lb ea)(5 kcal/g)(4186 J/kcal) .

Used Energy (J) = 2.02E+15 J/yr.

EMERGY = (Aver. age)(Renewable resources) .

EMERGY = (33yr)(Renewable resources) .

EMERGY = 1.85E+24 sej.

Transformity = (Emergy of Population) / (Used Energy).

[5] Culture information:.

Used Energy (J) = (Energy used)(10%) .

Used Energy (J) = 2.02E+14 J/yr.

EMERGY = (Renewable resources)(100yr) .

EMERGY = 5.60E+24 sej.

Transformity = (Emergy of Culture information) / (Used Energy).

An Emergy-based culture evaluation can be made using the energy-matter inputs and time required for cultural development [23]. For this, this study adopted a time window of 100 years. For the authors, the events and interactions as well as the information and knowledge exchange that occurred in this period between the earliest and the newest people (i.e., immigrants and indigenous people) allowed the broiler production chain in South Brazil to become stronger. For Abel [17], using

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the 'areal' and 'populational' calculation facilitates an estimation of the quality of the information by means of Tr for an original production of information. Thus, the Tr represents the quality of generational information about broiler production over the 100 years to which the smallholder family had access. In addition, the Tr of cultural information is similar to the spectrum of legacy and public status. Since the Tr represents the quality information, the information is the legacy built from the successes and failures of the first Brazilian broiler producers.

4.2. Emergy synthesis of broiler smallholders

According to the results, cultural information showed the highest contribution for the Emergy of the smallholder (62.95%), followed by wage (20.62%) and educational information (13.43%; Table 2).

Table 2. Emergy for broiler smallholder in Concórdia, Santa Catarina, Brazil.

Item	Unit	Data (units/yr)	Transformity (sej/unit)		Solar EMERGY (10^{13} sej/yr)	Em$ Value (sej/$.yr) 2018	%
ENVIRONMENT RESOURCES (considering kinetic wind and Earth cycle Emergy contrib.; Emergy per person)				**	0.37	1.55	0.00
RESOURCES CONSUMPTION					19,828.42	84,161.36	78.20
Food	J	3.06×10^9	1.52×10^5	a	46.45	197.15	0.18
Electric power	J	1.12×10^7	6.45×10^4	b	0.07	0.31	0.00
Fuel	J	2.92×10^{10}	1.41×10^5	c	411.73	1,747.58	1.62
Natural gas	J	9.66×10^7	2.90×10^4	b	0.28	1.19	0.00
Ethanol	J	2.12×10^8	1.41×10^5	c	2.99	12.70	0.01
Information							
Cultural information	J	5.77×10^6	2.77×10^{10}	Table 1	15,961.45	67,748.08	62.95
Educational information	J	9.84×10^7	3.46×10^8	b	3,405.45	14,454.36	13.43
MONETARY FLOW							
Wage	USD	2.22×10^4	2.36×10^{12}	e	5,228.87	22,193.86	20.62
PRODUCED WASTE							
Solid waste treatment	J	1.30×10^9	2.29×10^6	f	298.31	1266.19	1.18
OUTPUTS*							
Product							
Work	J	1.47×10^9	1.73×10^8		25,355.97	107,622.96	100.00

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Coproducts				
Sleep	J	5.50×10^8	4.61×10^8	25,355.97
Leisure	J	3.82×10^8	6.64×10^8	25,355.97

Note: Number of citizens of Concórdia, Brazil: 74.106 of people; Emergy/money ratio from Santa Catarina state: 2.36×10^{12} sej/USD [36]; BRL to USD exchange ratio: 3.65 :1.00;. * Ci is Cultural information; for further detailed see Supplementary material A, sheet "Manpower". ** To avoid double-accounting, the environment resources were considered as the sommatory of wind, kinetic energy [40] and Earth cycle [41]; [a] Brandt-Williams [26]; [b] Giannetti et al. [40]; [c] Odum [23]; [e] Demétrio [36]; [f] Huang et al. [42].

In other words, information comprised 76.38% of smallholder Emergy as a whole. The Tr for the work of broiler smallholders with cultural information was 1.73×10^8 sej/J. According to Giannetti et al. [43], this Tr is similar to the spectrum of people education. Also, considering cultural information, the quality of the human service was similar to that of the post-college educated students [44,45]. This leads to the following question: is the human service provided by smallholders in broiler production similar to that of a technician or a college graduate in quality terms? Although the broiler smallholder could not have a formal education at any post-graduate education level, it is possible that the longer period used to learn about production techniques with parents or technical assistants could closer the quality information between professional and broiler smallholder. For Odum [23], the knowledge is the collection of information transmitted and the Emergy flows that support the person. Thus, the raised supposition could be understood better when considering the broiler smallholder´s age and his/her service years. In this sense, quality information (or knowledge) will be related to the interaction based on the age and service time.

There was a higher Emergy value for labour (2.5×10^{17}) when compared to the focus on agricultural system perspectives [26,46,47]. According to Odum [23], human service is evaluated (i) by multiplying the energy expended by a human being by the Tr of that person's education and experience or (ii) by dividing the total national Emergy flow by the number of people and the metabolism. The higher Emergy observed in this study was expected since it included the Emergy for cultural and educational information, which is generally not considered in other studies. In addition, leisure and sleep were included in this study [26], proposing a holistic view regarding the costs for human services, considering the "real" wealth. In this sense, it is important to include inputs that support the social welfare and quality of life. Also, this holistic perspective may contribute to further studies in agricultural systems that aim at a deeper comprehension of the impact of human services on system sustainability.

4.3. The impact of culture information on the broiler production Emergy indicators

The Emergy indicators were not impacted when the cultural information from the broiler smallholder was considered (Table 3). In other words, including the cultural information was not sufficient to promote the better use of local renewable resources (EYR = 1.22), to minimise the environmental load (ELR = 4.52) or even to increase sustainability (ESI = 0.27) in the broiler production system.

Table 3. Comparison of Emergy indicators considering the cultural information (Ci) of family producer in a broiler production system.

			w/ Ci			w/o Ci		
Name of Index	Expression	Unit	Total	Agroindustry	Producer	Total	Agroindustry	Producer
Emergy	R+N+F	sej/yr	1.29×10^{18}	9.22×10^{17}	3.66×10^{17}	1.13×10^{18}	9.22×10^{17}	2.07×10^{17}

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Broiler UEV	Y / Ep	J	4.72×10^5	3.38×10^5	1.34×10^5	4.14×10^5	3.38×10^5	7.58×10^4
Litter (as fertilizer) UEV	Y / Ep	J	3.68×10^6	2.64×10^6	1.05×10^6	3.23×10^6	2.64×10^6	5.91×10^5
Renewable resource from nature	(R) / (R+N+F)	%	18%	22%	6%	20%	22%	11%
Non-renewable resource from nature	N/(R+N+F)	%	0%	0%	0%	0	0%	0%
Non-renewable purchase resources	(F)/(R+N+F)	%	82%	78%	94%	80%	78%	89%
Environmental Loading Ratio	$(N+F_N)/(R+F_R)$	sej/sej	4.65	3.49	15.01	3.95	3.49	8.04
Emergy Investment Ratio	(F) / (N + R)	sej/sej	5,496.66	-	1,562.05	4,815.69	-	881.08
Emergy Yield Ratio	$Y / (F_N)$	sej/sej	1.22	1.29	1.07	1.25	1.29	1.12
Emergy Sustainability Index	EYR / ELR	sej/sej	0.26	0.37	0.07	0.32	0.37	0.14
Emergy Exchange Ratio	Y / ($) (sej/$)	sej/sej	2.08	1.49	0.59	1.82	1.49	0.33
Emergy Exchange Ratio (producer)	Yproducer / ($/bird) (sej/$)				1.00			1.00
	if EER = 1.0	USD/bird			1.61			0.91

In which Y is Emergy; R is renewable local resouce; N is non-renewable local resource; F is purchased input; F_R is renewable fraction from purchased inputs; F_N is non-renewable fraction from purchased inputs; UEV is unit Emergy values; Ep is produced energy.

Services (38%), feed (36%) and labour (20%) contributed most significantly to the Emergy of the broiler production system. In this sense, including services, feed and labour renewability could be a way to a more complete assessment of the Emergy indicators. For this study, the renewabilities of services (in currency) and feed ingredients were considered. Although the renewability of labour was included, it was near zero. This can be explained by the fact that the renewability of the F inputs that composed its Emergy-based assessment was not considered. Thus, hypothetically and empirically, if the Emergy contribution of the information (culture and educational information; 76%) is considered as a renewable resource, the Emergy sustainability index can increase by 2.7 times (ESI = 0.72 vs. 0.26). However, it is still not clear to which extent generational information is renewable. According to Abel [16], 'culture' is a 'kind' of information that requires a population to maintain it within continuous information cycles of selection and renewal. These cycles could increase the knowledge durability, creating a cultural model in a population of individuals over time. Thus, the original information is not lost but supplanted by the most efficient information. The first one is needed to give rise to the last one, which solves the problem more efficiently. This could explain the importance of generational information as a "useful information" for broiler production optimisation over time. For Abel [16], useful information is a product of the self-organisation of systems, wherein its function is to remember successful configurations. Agriculture, manufacturing, education and every other cultural 'industries' could not exist without humans. Thus, the pathway to the (re)construction of a more

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sustainable and socially fair agriculture is through a greater indigenous knowledge system attention [19].

In summary, human services are central to the functioning of any human-influenced process. Without human control, there is no application of information, and there is no organisation of material and energy inputs [48]. Also, system studies that do not include human service inputs do not properly depict the system under study. In addition, there is a risk that omission of labour inputs in environmental assessment promotes a leakage of environmental effects linked to the human labour needed [48] and impairs the sustainability assessment. Thus, the inclusion of labour contribution in Emergy-based assessments for agricultural systems in a more accurate perspective must be estimated. "Areal" and "populational" aspects as well as culture and microeconomics must be considered in these models.

4.4. The imbalance between the estimated economic-based and environmental-based payments

The results highlight an imbalance in the monetary exchange between agroindustry and broiler smallholder payment for both the economic- and Emergy-suggested form of the payment of the broiler smallholder. Both estimated economic-based and environmental-based payments per broiler were higher than the practiced payment value (Figure 5).

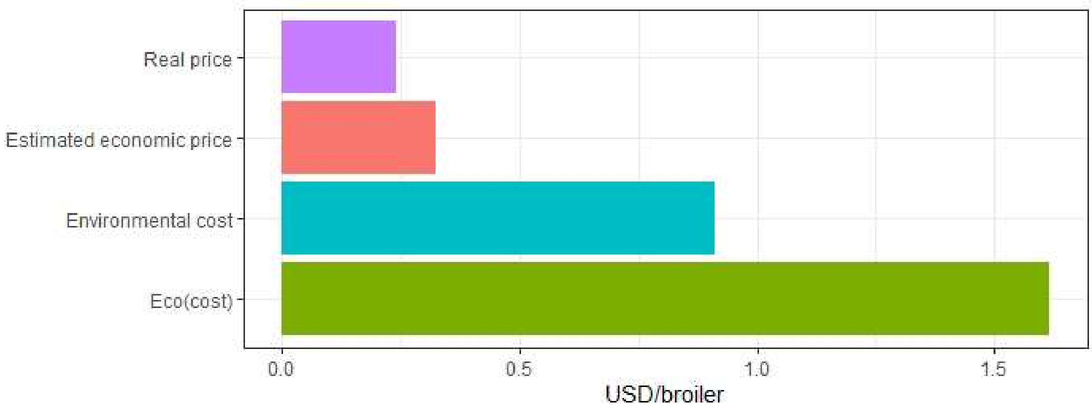

Figure 5. Comparison between the payments received by the broiler smallholders for their services (real price) and the estimated payment considering the economic cost (plus 10% of profit; estimated economic price), the estimated payment considering the Emprice without cultural information ("environmental cost") and the estimated payment considering the Emprice with cultural information ("eco(cost)"). *For the emprice, considered the emdollar was considered; the dollar value was used for the real price and the estimated economic price. The Emprice is a measure of the money that circulates in an economy as the result of some processes [28]. The emprice is given with and without cultural information inclusion (Ci); BRL to USD exchange rate: 3.65:1.00.

The values shown in Figure 5 present a picture that can be interpreted in three stages. The first concerns the difference between the real and the estimated price (including infrastructure depreciation). The estimated payments per broiler surpass the current payment value in practice. The amount paid to the producer does not cover some tangible costs; the producer only receives payment for handling the product, having to bear the costs of maintaining the infrastructure and payments for the services necessary to serve the industry. In this context, the decapitalisation of the broiler smallholder is in serious danger. Given this situation, it is advisable to recommend a revised agreement between the parties involved.

In a second step, the broiler price is estimated by the Emergy synthesis. The emprice (without cultural information) includes natural resources (sunlight, rain, wind) and is calculated considering not only the quantity of resources employed but also their quality. This estimate, with a monetary equivalent of 0.5 EmUSD/broiler, measures the Emergy that supports the poultry production process in the given economy. The difference between the estimated price and the Emprice (0.25 USD/broiler)

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could provide a measure for an eco-compensation of the industrial activity [49] and/or be reserved and eventually employed as a reinforcement of the productive basis (natural and man-made) and subside the negative externality reduction provided by the inputs.

The discussion becomes more complex when cultural information is included in the third interpretation stage. Culture is perceived as socially spread, differently internalised and actively debated or bargained among various groups and subgroups within a community [16]. It is a constructed outcome of interactions with others and the cultural knowledge generated on different levels and over time. The fact that the region is culturally dedicated to poultry production carries with it the idea that the workers in this region are culturally indoctrinated to believe that this is their vocation and that the activity is a family business. This cultural indoctrination, passed down through generations, naturally creates specialised producers dedicated to this activity and who understand and accept the working conditions, which would be difficult to implement in other regions without effort. As an example, the Brazilian Mid-West region has several competitive advantages that could promote broiler production (i.e., low feed costs, available area for production and governmental tax benefits). However, although some micro-regions have been able to take advantage of those benefits for promoting production, broiler production is concentrated in the southern region [50,51]. Thus, ignoring the cultural aspects of the population and its contribution as one of the most important variables for broiler production strengthening could be unfair. In addition, the intangible value of this effort can be estimated when including the value of cultural information in the Emprice of the final product. This estimate is a monetary equivalent to the process enabling humans not only to build innovation upon 'cumulative cultural evolution' or 'social learning' [16] but also a guarantee for the industry to receive culturally moulded and trained partners for this specific activity.

The discrepancy (Em0.70 USD/broiler) could serve multiple purposes not only for educational programmes, training and health initiatives but also as a reserve, fund and/or reinforcement that could be used to strengthen the productive foundation, encompassing both natural and man-made aspects.

In summary, a methodological approach based on the Emergy theory could demonstrate the imbalance in monetary exchange between the agroindustry and the broiler producer family. The current business model places the responsibility for tangible costs (such as infrastructure maintenance and services) on poultry-producing families, whereas the industry benefits from accumulated cultural knowledge without recognising or compensating it. Introducing a new business/contract model based on the procedure outlined in this paper could establish a more equitable balance between the integrator and the integrated parties. Thus, this model would contemplate more appropriately the importance of the generational acknowledge of broiler production success and then accurately remunerate the contributions of all stakeholders involved.

4.5. General insights into quantifying the value

There are several objective forms of evaluation that aim to assign a quantifiable and measurable value to a given product, service or asset, eliminating or minimising the subjectivity involved, including the following. Some of these objective forms of valuation include:

1. Market valuation: This form of valuation involves the analysis of prices and recent transactions of similar products or assets on the market. The idea is to use concrete data from real transactions to establish a value based on market conditions.
2. Valuation by cost: This method aims to determine value based on production costs, including materials, labour, depreciation, operating expenses and other expenses. In the industry, the cost of production is a good indicator of the value of the product.
3. The valuation of environmental costs based on Emergy (without services or information) uses only a physical inventory of the resources used in its accounting. This type of valuation takes into account the energy embodied in natural resources and considers their quantity and quality; Emergy makes it possible to assess the environmental costs associated with production. The Emergy valuation approach (without services and information) can be useful especially when

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the focus is on analysing the physical resources, production technologies and geographical aspects (such as rainfall and land use) involved in a given production system.

4. The valuation of the environmental cost in Emergy with services (including the money paid in environmental accounting) offers a more comprehensive view and may be more appropriate when it is desired to understand the social, economic and environmental impacts of the organisation in a more complete and integrated way.
5. Evaluating the "(eco)cost" in Emergy by including information can take into account scientific knowledge, technology, intellectual capital and culture, which are essential to the operation and functioning of production systems. Including information in the estimation of Emergy aims to reflect the contribution of these elements and allows for a more comprehensive assessment of the efficiency and sustainability of the production system. This approach is highly relevant in Emergy-based environmental accounting as it recognises that production depends not only on tangible physical resources but also on the knowledge, skills and information available. Therefore, Emergy-based environmental accounting that includes information seeks to understand and quantify both the physical and intangible aspects involved in the production and functioning of economic and ecological systems.

The "iceberg of value (or pyramid)" thinking becomes interesting and useful for understanding the functioning of production systems and their underlying bases. This approach recognises that there are different layers of value and resources involved in any economic system and that not all of these resources are easily observable or quantifiable on the surface. The "iceberg of value" thinking suggests that there are hidden costs in invisible layers of resources and contributions that support the production system, beyond the market and cost values. These layers can include intellectual capital, scientific knowledge, innovation, technology, human skills and the natural resources used. By recognising the importance of underlying resources that are not directly visible, the value pyramid concept highlights the relevance of sustainability and the efficient management of these resources for the long-term success of an economic system. Ignoring or underestimating these invisible layers can lead to problems of overexploitation of resources or a lack of innovation and competitiveness. In turn, the "iceberg of value" thinking encourages a more holistic and integrated analysis of production systems, considering not only the direct economic aspects but also the social and environmental impacts associated with these invisible layers of value. This can lead to a better understanding of the challenges and opportunities of a production system in relation to its sustainability and resilience.

Thus, the "iceberg of value" thinking offers an interesting way of visualising the different levels of value and resources involved in production systems. Recognising the importance of invisible resources can lead to a more balanced and sustainable approach to economic development and resource management. As with any conceptual model, its practical application may vary depending on the specific context and the objectives of the analysis, but it can be a valuable tool for a deeper understanding of economic systems and their foundations.

5. Conclusions

Human beings use information to allocate the available resources in the best way to make the human-influenced process as efficient as possible. Therefore, even in the more technological perspectives, broiler production will not give up the human factor for its continuity. However, the contribution of knowledge and cultural information from people is not fully evaluated. It would be unfair to disregard the cultural aspects of the producers and their contribution as some of the most important resources for agricultural production chain strengthening. Methodological approaches that consider intangible and hidden costs (natural resources and sociocultural aspects), such as Emergy-based assessment, could help to demonstrate an unequitable monetary exchange between the agroindustry and the broiler smallholder.

This study highlights that cultural information contributes most significantly to the Emergy of broiler smallholders (62.95%). In turn, its contribution raised the quality of the smallholder service to a spectrum of people education (1.73×10^8) similar to that of post-college-educated students. The large amount of time applied to learn about production techniques with parents or technical

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assistants could result is a more similar quality information between professionals and broiler smallholders.

In addition, there was an imbalance in the monetary exchange between agroindustry and broiler smallholder payment for both economic and Emergy-based payments. Both estimated payments were higher than the practiced payment value (0.24 USD/broiler, 0.32 USD/broiler and 1.62 EmUSD/broiler, respectively). Considering these results, it can be suggested that the sustainability of the broiler production chain could be impaired in the long term. Not only the decapitalisation of the broiler smallholder and also the supports of the poultry production process regarding environmental (i.e., ecosystem services) and sociocultural aspects (i.e., smallholder retention) could be some of the main consequences.

Thus, policy and decision makers must consider the promotion of public policies that subside initiatives, including social welfare programmes (i.e., educational programmes, training, health initiatives, funds that strengthen the productive foundation, encompassing both natural and man-made aspects) and environmental welfare (i.e., landscape protection and rural tourism promotion).

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