HUNGARIAN UNIVERSITY of AGRICULTURE and LIFE SCIENCES

THESES OF DOCTORAL (PhD) DISSERTATION

ANALYSIS OF THE COST AND INCOME SITUATION OF PIG FARMING IN HUNGARY AND POSSIBILITES FOR THE PRODUCTION OPTIMISATION

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1. BACKGROUND AND OBJECTIVES

With the growth of the world's population and increasing consumption, the importance of the agricultural sector has been increasingly highlighted. Hungary's excellent quality arable land is among its most valuable assets. From the perspective of the nation's economic interests, it is desirable to sell our products derived from nutrient-rich soils with high added value in both domestic and international markets. This can also enhance our trade balance, resulting in additional resources flowing into the national economy for the benefit of all Hungarian citizens. To achieve higher added value, a revival of animal husbandry is necessary. Hungary has favourable conditions for cultivating fodder crops, which is a significant strength for feed-consuming livestock farmers. This includes sectors such as sow rearing and pig fattening.

The Hungarian pig industry has been facing numerous challenges for decades. For many pig farmers, production is not profitable, while they must meet increasingly complex environmental and animal health requirements. Market conditions have been highly volatile in recent years, exacerbated by the emergence of African swine fever. The crisis initially caused by the outbreak in Hungary resulted in significant losses of our export markets. Subsequently, the unpredictable situation and price volatility caused by the outbreak in China created extreme market conditions. Given the uncertain future, it is not surprising that the pig population is not increasing. Nevertheless, there are still highly efficient farms in the country.

In my doctoral dissertation, I examine the cost and income situation of pig farming and present, without claiming completeness, a selection of production optimization procedures that, by facilitating sound managerial decisions, can improve the profitability of production. I consider this research timely because the efforts of the National Pig Strategy to increase the stock can only be achieved by enhancing the competitiveness of domestic enterprises, with profitability improvement as one of the basic pillars. I believe that in the current situation, achieving higher profitability does not solely rely on costly investments but also requires process optimization and appropriate economic decision-making, for which the competence of farmers is essential. If pig farmers engage in self-evaluation more frequently based on the analysis of their current situation and future possibilities and utilize decision-making mechanisms more extensively, it could provide a significant boost to the growth of the pig population to the extent that Hungary could once again meet its pork demand from domestic sources, thereby eliminating a national security risk.

I selected a 15-year period following Hungary's EU accession as the time interval for analysis, covering the years 2005 to 2019. During the conduct of the research, the latest cost-income database available was for the year 2019. I did not intend to update my calculations for two main reasons: 1. Recent extreme market conditions would distort my general findings concerning the sector. 2. The aim was not specifically to showcase a particular time period but rather to establish a general methodology for economic analysis applicable to any time period, any geographical unit, and any agricultural sector.

The justification for choosing this topic lies in my involvement as an employee of the Agricultural Economics Research Institute (AKI) since 2014, where I have been participating in the processing, cleansing, and publication of data from the Farm Accountancy Data Network (primary). Additionally, within the international network called InterPIG, I am personally responsible for the appropriate conversion and provision of Hungarian data from a professional perspective. Therefore, I am well aware of the strengths, weaknesses, reliability, and usability of the aforementioned databases and their components.

The main objectives of my research were as follows:

- Evaluation of pig farming in Hungary through the cost-income situation and its positioning in an international context.
- Model calculations considering all relevant factors influencing the unit cost, and quantifying the impact of these factors.
- Quantification of the impact of optimization procedures that significantly affect the profitability of the operation.
    - Determination of the economically optimal slaughter weight.
    - Determination of the economically optimal culling time for breeding sows.
    - Quantification of the impact of capacity utilization.

In addition to achieving my main objectives, I aimed for the thesis to shed light on the research potential of the Farm Accountancy Data Network's sectoral data collection and to present an economic analysis framework that can be transferred to the analysis of any other agricultural sector.

Prior to my research, I formulated the following hypotheses closely related to my main objectives:

Hypothesis 1 (H1): The natural efficiency of pig fattening shows an improving trend between 2005 and 2019.

Hypothesis 2 (H2): Pig farming is in a less favourable economic position compared to other major livestock sectors (dairy cattle farming, beef cattle fattening, broiler production, table egg production).

Hypothesis 3 (H3): The high unit cost of pork in international comparison is primarily attributed to poor natural efficiency.

Hypothesis 4 (H4): The average slaughter weight of fattening pigs is not optimal from the perspective of income maximization.

2. MATERIAL AND METHODS

The calculations presented in the dissertation are primarily based on the results of the Farm Accountancy Data Network's sectoral data collection. In Hungary, the Agricultural Economics Research Institute (AKI) is responsible for operating the Farm Accountancy Data Network. It can be considered as a primary source, as I have been involved in the development of questionnaires and data processing, and not only examined sample averages but also analyzed farm-level data. In addition to the sectoral test farm data, the following databases have been utilized:

- Farm Accountancy Data Network regular database (AKI)
- Market Price Information System (AKI)
- Agricultural Statistical System (AKI)
- Data collection by the Central Statistical Office
- International databases (e.g., FAO, EUROSTAT, USDA data collections)
- InterPIG

The data collection on the cost-income situation of agricultural sectors has a significant history in Hungary. The continuously evolving sectoral data collection systems had two fundamental objectives: 1. To provide a realistic picture of the production costs of major agricultural products and assess their income situation by comparing them with typical selling prices. 2. To comprehensively address issues related to sectoral economics, thereby assisting decision-makers in their work. Starting from the early 2000s, the collection of cost-income data joined the data collection of the Farm Accountancy Data Network, and publishable data were available for the year 2003. From then on, the sectoral sample almost overlapped with the test farm sample. Participating accounting offices in the data reporting process are expected to fill out the sectoral data collection form for at least 80 percent of the farms in each county. Exceeding the minimal requirement, data collectors process sectoral data from 1700-1900 farms annually.

In my research, I focused on two sectors of the Farm Accountancy Data Network, utilizing both national average data and farm-level analysis. The time-series analysis was based on data from the *Pig Fattening* sector, but the results of data collection in the *Sow Breeding* sector were also utilized in certain chapters.

2.1. The methodology of the Slaughter Pig Scissors and Constant Input Price test

The Slaughter Pig Scissors and Constant Input Price test were based on the same calculation. The essence of this approach was to assign a chain index (for the Slaughter Pig Scissors) or a base index (for the Constant Input Price) to each element of the cost structure in the pig fattening sector. For cost components where quantity data was available, I used data from the Farm Accountancy Data Network to calculate the price indices. For other cost components, I relied on values from the agricultural price index published by the Central Statistical Office (KSH). The price indices associated with different cost elements were weighted based on their proportionate representation in the cost structure for a given year, resulting in the overall cost index. I then multiplied the reference year data with the indices to obtain the adjusted cost-income tables. In the case of the Constant Input Price test, the base year was considered as 2019, and from there, I determined the base indices for various cost categories going back to 2005. Therefore, the costs between 2005 and 2018 were recalculated based on the prices of 2019.

2.2. The InterPIG

The basis for international comparisons is provided by the InterPIG database.

Measuring the natural and economic performance of pig farming is justified at the international level. Therefore, representatives from six countries established the InterPIG network in 2001 with the primary goal of creating a methodologically consistent database for comparing the profitability and production costs of pig farming. Currently, data is collected from 17 countries by the organization. In some cases, the analysis goes beyond national averages and includes the examination of specific segments (e.g., average of the top 33%, extensive producers' average). The Agricultural Economics Research Institute joined the InterPIG network as the representative of Hungary in 2016, but prior to that, the Institute also provided pilot data for preceding years. The membership requirement is the regular submission of data to the organization in the expected format on an annual basis. The Agricultural Economics Research Institute carries out data conversion based on the Farm Accountancy Data Network's sectoral data collection (AKI), the Market Price Information System (AKI), the Central Statistical Office, and the Hungarian National Bank databases.

The majority of cost data comes from the AKI's sectoral data collection sample; however, there may be significant differences between the results of InterPIG and AKI cost calculations. Firstly, the deadline for data submission to InterPIG is earlier than the closure of sectoral data collection in Hungary. Secondly, methodological differences exist between the two. The calculation principle also differs, as in the case of domestic data collection, we generate performance indicators based on actual accounting records and inventory, while InterPIG uses projected figures, natural indicators, and specific economic values (e.g., prices) as inputs, and the InterPIG calculator calculates the main economic indicators.

The most significant methodological difference is that in accordance with the Hungarian Accounting Act, in domestic data collection, self-produced inventories are valued at direct unit costs, while purchased inventories are valued at acquisition cost. In contrast, the InterPIG system values almost all input materials at price. The InterPIG calculator builds the national sectoral cost-income structures based on the logic of a closed-system farm.

2.3. Formation of Composite Performance Indicators

One of the objectives of my research was to develop an indicator that integrates the information content of relevant efficiency measures and predominantly represents the impact of natural efficiency on costs. Evaluating performance requires considering whether the pig producer supplies the fattening material from their own resources or purchases it. In the former case, it is necessary to gather indicators influencing the cost of piglet production, while in the latter case, it suffices to focus on factors affecting the fattening phase. I initially collected the following natural efficiency indicators that exhibited the closest relationship with the cost of slaughter pigs:

- Average daily gain (ADG) - kg/day
- Feed conversion ratio (FCR) - feed kg/gain kg
- Labor efficiency in fattening (LabH F) - hours/place
- Weaned piglet number (Piglet Q) - piglet/sow/year
    - Pig born alive per litter
    - Litter/sow/year
    - Piglet mortality - %
- Feed consumption in sow breeding (Feed K) - kg/sow/day
- Labor efficiency in sow breeding (Labor K) - hours/sow

In the next step, the direction of the relationship between the selected indicators and efficiency, as well as the composite indicator value indicating the target efficiency, needed to be analyzed. For average daily gain and weaned piglet number, there was a positive relationship, indicating that efficiency increases with higher values of these indicators. However, in the case of feed and labor efficiency, the direction was opposite, with higher values of these indicators indicating lower efficiency. To address this issue, I took the reciprocal of the indicator values for indicators with opposite directions and left the values unchanged for indicators with the same direction. As a result, I created six sub-indices from the selected six indicators.

The obtained results are influenced by the units in which the sub-indices are expressed. Therefore, in the third step, I transformed the sub-indices into dimensionless values. I achieved this by assigning values to the sub-indices based on the Agribenchmark and InterPIG databases, dividing them by a constant value of 100. I selected the values of the best farms and group averages from the Agribenchmark and InterPIG databases.

To establish a closer relationship between the composite indicator and the unit cost, it was necessary to assign weights to the individual sub-indices. This principle is similar to some bankruptcy models, where different weights are assigned to input variables based on their impact on potential liquidity problems or their predictive power. However, this principle is not applied in the Dutch Broiler Index (EPEF) and the European Broiler Index (EBI). In these indicators, all elements required for calculations are given equal weight, as if they contribute equally to the economic performance of the farm. This is clearly not the case, yet these indicators are widely popular and frequently used in the industry.

In the fourth step, I quantified the impact of the six selected natural efficiency indicators on the unit costs. My goal was to create a deterministic simulation model that includes the selected indicators as input parameters and the unit cost as an output parameter. With this model, it was possible to determine the unit cost without detailed accounting and inventory records and obtain important information for this study: the exact change in the unit cost resulting from a unit change in the values of the natural efficiency indicators. This could be achieved by keeping all other factors influencing costs unchanged, thus eliminating their distorting effects (ceteris paribus). This way, the impact of a specific natural efficiency indicator on the unit costs could be numerically quantified. I established the model equations based on my own experiences, the characteristics of industry data collection, and the average values of the industry data collected between 2017 and 2019. The functioning of the model is illustrated in Figure 1.

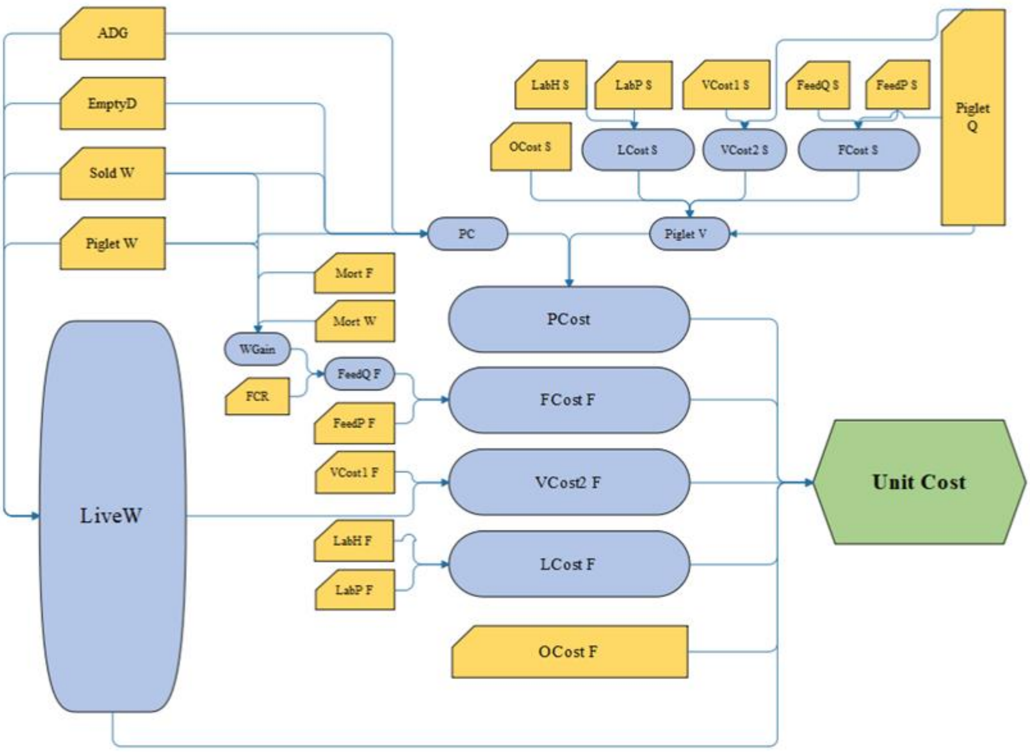


Figure 1: Model of the Cost Calculation for Slaughter Pigs
Source: own editing

Table 1: Weighting of the used Sub-Indices

Indicator	Sub-indices	Cost impact*	Cost multiplier	Dimension multiplier	Overall multiplier	Simplified multiplier
ADG	ADG	-0,07	2,05	90,91	185,93	19
FCR	1/FCR	0,44	13,58	230,00	3122,45	312
LabH F	1/LabH F	0,03	1,00	35,00	35,00	3,5
Piglet Q	Piglet Q	-0,36	11,11	2,70	30,03	3
FeedQ S	1/FeedQ S	0,19	5,77	335,00	1932,95	193
LabH S	1/LabH S	0,09	2,85	1100,00	3136,62	314

** The impact of a 1% change in the indicator on the cost (%)*
Source: own calculations

Using my deterministic simulation model, I was able to determine the exact impact of the selected six natural indicators on the unit cost of pork production. As shown in Table 1, a 1% increase in feed conversion ratio, work hours per fattening place, feed consumption per sow, and work hours per sow leads to a 0.44%, 0.03%, 0.19%, and 0.09% increase in unit cost, respectively. On the other hand, a 1% increase in daily weight gain and weaned piglet numbers per sow results in a 0.07% and 0.36% decrease in unit cost, respectively. Since only the magnitude of the impact on cost was important to me, regardless of its direction, I compared the absolute values of the percentage changes. Firstly, I identified the indicator with the smallest impact (work hours in fattening), and assigned it a cost multiplier of 1. Then, I calculated how many times larger the impact of the other indicators was compared to the smallest one, and these results became the cost multipliers. Next, I multiplied the dimension multipliers calculated in the previous step by the cost multipliers calculated in this step, resulting in an overall multiplier assigned to each individual sub-index, quantifying the weight of each sub-index in the composite indicator. For the sake of simplicity and ease of use of the indicator, I divided the values of the overall multipliers by 10 and rounded them (to one decimal place for single-digit numbers and to whole numbers for numbers greater than one). This simplified the representation of sub-index weights while having minimal distorting effects on the calculation of the composite index for a given analysis unit (e.g., farm).

As the weighted sum of sub-indices using the simplified multipliers, the composite indicator should reflect a strong correlation with cost per liveweight. However, liveweight also includes the weight of dead pigs, which does not generate economic profit. Therefore, in a separate step, I supplemented the composite indicator by multiplying the weighted sum of sub-indices by the survival rate. The survival rate was calculated as follows:

$$1 - Mortality\ rate$$

Where:

Mortality rate = Weight of dead animals / Liveweight

As a result of all steps, the ***Complex Pig Performance Indicator (CPPI)*** is calculated as follows:

$$CPPI = (1 - X_1) * \left(19 * X_2 + \frac{312}{X_3} + \frac{3{,}5}{X_4} + 3 * X_5 + \frac{193}{X_6} + \frac{314}{X_7}\right)$$

Where:

X_1 *= Mortality rate (kg deadweight / kg liveweight)*
X_2 *= Daily Weight Gain (kg/day)*
X_3 *= Feed Conversion Ratio (kg feed/kg weight gain)*
X_4 *= Labor efficiency in fattening (hours/place)*
X_5 *= Weaned piglet number (piglet/sow/year)*
X_6 *= Feed consumption in sow breeding (kg/sow/day)*
X_7 *= Labor efficiency in sow breeding (hours/sow)*

Of course, this formula cannot be applied in cases where the supply of fattening animals is sourced from purchased sources, as the three natural indicators related to breeding cannot be measured on the farm. In such cases, the performance of the farm can only be evaluated using natural indicators related to swine fattening. Following the previous steps, I have also developed an indicator applicable to farms solely engaged in fattening, which I named the **Complex Pig Fattening Performance Indicator (CPFPI)**, with the following formula:

$$CPFPI = (1 - X_1) * \left(19 * X_2 + \frac{312}{X_3} + \frac{3{,}5}{X_4}\right)$$

Ahol:

X_1 *= Mortality rate (kg deadweight / kg liveweight)*
X_2 *= Daily Weight Gain (kg/day)*
X_3 *= Feed Conversion Ratio (kg feed/kg weight gain)*
X_4 *= Labor efficiency in fattening (hours/place)*

2.4. The methodology for determining the optimal slaughter weight

The methodology for determining the optimal slaughter weight considers the point at which pig fattening activity can achieve maximum average income. When referring to average income, it is essential to define the projection basis. Given that in this activity, the scarcity of space typically influences the production process - with space being the bottleneck - duration optimization must be performed by projecting income per unit of time and maximizing it *(Szakál, 2000).* The determination of the optimal slaughter weight involved several steps:

The fundamental factor influencing the cost development is the change in natural efficiency throughout the life of the fattening pig. Therefore, in the initial phase of the work, it was necessary to establish the relationship between key efficiency indicators and body weight. Two relevant indicators affecting costs were selected: feed conversion ratio (FCR) and average daily gain (ADG).

To develop the required FCR curve, I started with the standardization formula of the InterPIG organization. To ensure a more accurate comparison among countries participating in InterPIG, the organization uses a standardization formula for feed conversion ratio and average daily gain. The formulas standardize three different intervals: 8 to 30 kilograms, 30 to 120 kilograms, and 8 to 120 kilograms. This means that regardless of the initial and slaughter weights reported by a country for the efficiency indicators, the formulas convert the values, allowing us to see the values for the two efficiency indicators assuming weights between 8-30, 30-120, and 8-120 kilograms. Since the InterPIG formulas are not publicly available, I provide the functions I created based on these formulas in the methodology chapter of my dissertation.

By extrapolating the standardized FCR formula, I obtained the development of cumulative feed intake as a function of live weight. This relationship can be described by two quadratic functions after extrapolation. The two functions can easily be transformed into live weight-FCR functions by subtracting the feed intake at the previous point from the feed intake at point x. This results in the amount of feed required for a 1 kilogram increase in live weight, which is essentially the FCR indicator. However, there were still some issues to address. Firstly, I wanted to obtain a single function for both the FCR curve and the unit cost curve. Secondly, there was a large discontinuity when the two functions intersected. To address this, I treated the values of the two FCR functions as a sample data set and searched for the best-fitting regression function. I performed function fitting using six different methods in Microsoft Excel: linear, exponential, logarithmic, power, second-degree polynomial, and fourth-degree polynomial fitting. The best-fitting function was the one with the smallest relative error variance.

The relative error variance was as follows for the selected fittings:

- Linear: 5.7%
- Exponential: 10.7%
- Logarithmic: 8.6%
- Power: 3.8%
- Second-degree polynomial: 3.2%
- Fourth-degree polynomial: 2.6%

Based on the results, I chose the fourth-degree polynomial fitting.

Upon examining the function values, it became clear to me that the creators of the original standardization formulas (InterPIG) developed their formulas based on data from a pig population with significantly better natural efficiency than the Hungarian average. My goal was to create curves specific to the Hungarian average. Therefore, I compared the feed conversion ratio curve I developed using the fourth-degree polynomial with the average values for the Farm Accountancy

Data Network's feed conversion ratio between 22 and 116 kilograms. The average feed conversion ratio of the test farm system was 23% higher, so I increased the values of the fourth-degree polynomial curve by 23% at each examined point on the x-axis (live weight). The result was the Hungarian feed conversion ratio curve.

The methodology for creating the Hungarian average daily gain curve was similar to that of the feed conversion ratio curve, with the difference being that it was based on a single InterPIG formula instead of two. I reverse-engineered the InterPIG standardization formula for average daily gain into a function based on cumulative fattening days as a function of live weight, which became a logarithmic function. By subtracting the value corresponding to x-1 live weight from the value corresponding to x live weight, I obtained the duration required for a 1 kilogram gain at a given x point. Taking the reciprocal of the obtained results, we can assign daily weight gain values to the x points. Through a multi-step function transformation, I arrived at the ADG curve. After examining the values, I faced the same problem as with the FCR curve, namely that the creators of the original standardization formulas (InterPIG) developed their formulas based on data from a pig population with significantly better natural efficiency than the Hungarian average. Similar to the FCR curve procedure, I compared the average values of the Hungarian ADG curve between 22 and 116 kilograms with the difference between the average value of the test farm system and the values obtained from the fourth-degree polynomial function. Since the average value of the test farm system in 2019 was 20% lower, I decreased the values of the function by 20% at each examined point on the x-axis (live weight). The result was the Hungarian average daily gain curve.

The next stage of the work involved establishing the unit cost function. The estimated cost as a function of live weight was prepared for the phase between 23 and 131 kilograms. The cost categories in pig fattening were divided into three main groups based on the 2019 test farm system - which represents the national average - data: raw material cost, feed cost, and other costs.

Raw material cost refers to the value of the piglet set as fattening material. The individual value is completely independent of the animal's weight since it only arises once, at the beginning of fattening. Therefore, the individual raw material cost takes on the same value at each point on the x-axis.

In determining feed costs, two factors must be considered: the previously calculated Hungarian feed conversion ratio curve and the feed prices. By multiplying the value of the FCR curve by the feed price, we obtain the feed cost for a given point. Different prices were used for the evaluation of the fed feed quantity in the intervals between 23 and 66 kilograms and between 66 and 131 kilograms. In determining the precise prices, the goal was for the average feed price in the examined interval to match the average feed price of the test farm system while maintaining the proportion between the average feed price of the first interval (23-66 kg) and the average feed price of the second interval (66-131 kg) as the same as the price ratio between *Feed I* and *Feed II*. The Market Price Information System's quantity and price data for pig feed were used for these adjustments.

Of course, it would have been justified to perform a detailed analysis for other cost categories to examine how the sum of these costs changes throughout the animal's life. However, due to a lack of data that comprehensively analyzes the dynamics of costs representing the national average, it was impossible to do so. Therefore, simplifications had to be applied. The majority of other costs, apart from raw material and feed costs, consist of energy and labor costs. My assumption was that these costs should be taken into account in proportion to the number of days spent in a given live weight range. This can be obtained by taking the reciprocal of the values of the Hungarian average daily gain curve. The duration assigned to each live weight range can then be multiplied by the daily other costs, resulting in the total other costs associated with that live weight range.

By adding the values of the raw material cost, feed cost, and other cost functions, we obtain the unit cost function.

By multiplying the points of the unit cost function with the live weight, we can plot the production cost function. Multiplying the average selling price of slaughter pigs in 2019 (based on the Market Price Information System) with the live weight gives us the production value function. The difference between the two represents the sectoral income, which I divided by the number of days required to produce the given live weight, resulting in the average income function.

2.5. The methodology for determining the optimal culling time for breeding sows

In my calculations, I started from Dobos's (1980) calculations and further developed and adjusted the methods he used, adapting them to the data collection structure of the Farm Accountancy Data Network. In Dobos's calculations, he considered the initial value of the gilts, the variable cost from weaning to weaning (including the cost of the sow and progeny), the value at culling, and the quantity and value of weaned animals. Based on these factors, he determined the per-litter and cumulative average variable costs and contribution to cover fixed costs.

I modified Dobos's method with the following elements:

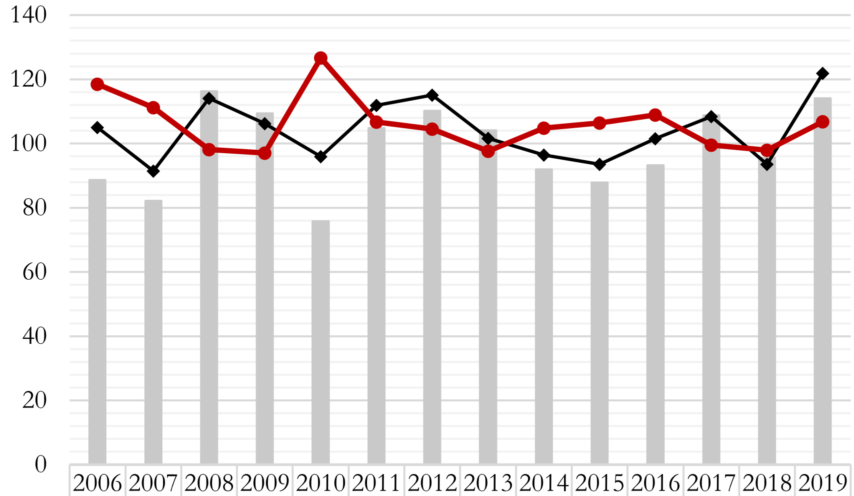
- I used actual data instead of empirical model numbers. Using the cost data from the Farm Accountancy Data Network's sectoral data collection for the years 2017-2019 and the average production cycle (sow turnover), I determined the cost per litter. I estimated the variation in the number of piglets per litter and the change in sow weight per litter based on the sample average, indexed according to literature sources *(Dijkhuizen et al., 1986; Rajnai et al., 2001; Jalvingh et al., 1992; Koketsu and Dial, 1997).* Based on the culling rate in the sample database (38.61%), the average culling time in the sample was assumed to be after the 5th farrowing. Since culling can be done after the 5th farrowing, I assumed that the average age of the sow herd is around the 3rd farrowing. Therefore, the cost and income calculations for the 3rd farrowing (except for the initial value) considered the average costs and returns from the sample for the years 2017-2019 and indexed these values to calculate the costs and returns for the other farrowings.
- I did not only consider variable costs. Although Dobos did not specify which cost categories he considered as variable and which ones as fixed, it is likely that the set of elements used in the two methods differs.
- The calculations were performed using both market price and cost-based initial value (I do not have information on which one Dobos used).
- I separated the feed and other variable costs for the sow herd (sow + progeny), unlike Dobos. Based on my previous experience and calculations, I estimated the proportion allocated to the breeding animals and the progeny. I allocated 12% of the feed cost to the piglets, which I indexed based on the specific changes in progeny (according to literature sources) between farrowings. I indexed the feed cost for the sows based on the estimated change in sow weight (also according to literature sources). For the other variable costs, I allocated them equally between the breeding sows and the piglets (50-50%). The indexing for piglets was again based on the specific changes in progeny, while no indexing was performed for breeding sows, assuming that the sow's age has no effect on the development of other variable costs per individual.
- I estimated the value at culling based on the sample average and the estimated change in sow weight between farrowings.

- I discounted the specific income per piglet (Sales price - Cumulative variable cost at the given number of farrowings). The discounting frequency was not annual but per farrowing, contrary to what Dobos did.

3. RESULTS AND DISCUSSION

3.1. The Slaughter Pig Scissors and the Constant Input Price test

The Agricultural Scissors commonly used in agricultural analyses combines the agricultural producer price indices with the cost price indices into a single indicator. Following this principle, I have developed the Slaughter Pig Scissors for the period between 2006 and 2019, which quantifies the evolution of external factors affecting pork fattening (Figure 2).



	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Slaughter Pig Scissors	89	82	116	109	76	105	110	104	92	88	93	109	96	114
Producer price index	105	91	114	106	96	112	115	102	96	94	102	108	94	122
Input price index	118	111	98	97	127	107	104	98	105	106	109	100	98	107

Figure 2: The producer price index and input price index of pig fattening, along with the Slaughter Pig Scissors, between 2006 and 2019 (Base year = 100%).

Source: Own calculations based on data from the AKI FADN and the Hungarian Central Statistical Office (KSH)

Based on the evolution of the Slaughter Pig Scissors, it can be determined that the market environment for pork fattening deteriorated in 2006, 2007, 2010, 2014, 2015, 2016, and 2018. In parallel, except for 2006, the sector's performance worsened in all of the listed years. In the remaining years, the Slaughter Pig Scissors opened up, indicating improvements in external conditions for producers, except for 2013 when the sector's performance declined by 14%. Overall, it is evident that the changes in the Slaughter Pig Scissors Slaughter Pig Scissors mostly indicate the direction of profitability fluctuations, highlighting the significant exposure to external factors in this sector. Therefore, proper risk management plays a prominent role in this industry. However, the two exceptional years (2006 and 2013) also demonstrate that unfavorable market changes can be offset by improvements in farm management, and conversely, an improving market environment does not necessarily guarantee improved profitability. There is a close correlation between the Slaughter Pig Scissors and the pig cycle, as the decision to initiate, continue, suspend, or cease production is heavily influenced by the producers' income situation, which is closely related to the output/input price ratio.

In most sector analyses, cost-related data are typically presented in current prices, as this best demonstrates the current economic situation of a given industry. However, when conducting time series analyses, it is advisable to examine how cost relationships change with constant input prices.

In time series comparisons, the development of the cost structure in current prices, adjusted for distortions caused by market price fluctuations and other external factors, is considered one of the best indicators for monitoring economic efficiency. By purifying this indicator from the effects of market price changes and other external factors, we essentially obtain a new indicator related to the ratio of output and input quantities, combining all essential efficiency parameters into a single value. Therefore, the evolution of the cost structure in constant input prices can be considered a nearly perfect indicator for monitoring natural efficiency. Its drawback is that it does not provide detailed insights into the factors influencing the changes, but its advantage lies in evaluating the performance of farmers comprehensively through a single number.

In studies using constant input prices, values are often adjusted only for inflation. However, in my calculations for the Slaughter Pig Scissors, I used a set of input price indices and weighted them based on the cost structure. I considered 2019 as the base year and calculated the base indices for various cost categories for each year going back to 2005. Therefore, the cost calculations between 2005 and 2018 were recalculated using the input prices of 2019 (Figure 3).

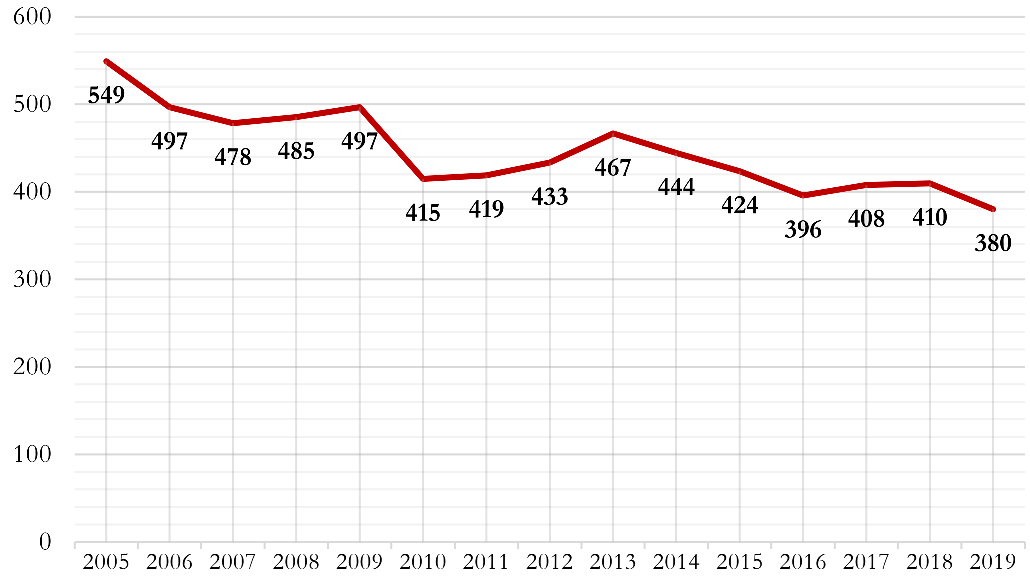


Figure 3: The cost of pig fattening, calculated at constant (2019) input prices, between 2005 and 2019
Source: Own calculations based on data from the AKI FADN and the Hungarian Central Statistical Office (KSH)

The evolution of the cost structure in constant input prices exhibited a decreasing trend during the examined period. The average rate of decrease was 2.59% per year. Until 2017, the direction of change aligned with the trend in the Slaughter Pig Scissors, indicating that the natural efficiency declined precisely in those years when the market situation improved. The most efficient year for pork producers was 2019 when an excellent market environment was coupled with previously unseen natural efficiency. The record-high sector performance of nearly 70 HUF per live weight kilogram in 2019 can be attributed not only to favourable external conditions but also to the continuous improvement of internal factors by pig farmers. This positive development provides a solid foundation for the industry and holds promising prospects for the future. Although there is still ample potential for enhancing economic and natural efficiency in production, an overview of the national averages between 2005 and 2019 suggests that the Hungarian pork industry is on a positive trajectory.

3.2. Assessing the cost-income situation of Hungarian pig farming in international comparison, 2019

The cost of pig production ranged between 0.74 and 1.51 euros per kilogram of live weight in 2019 for the selected countries. Based on the cost level, we can distinguish six distinct groups:

The first group includes Brazil and the United States, which are globally the most cost-effective producers (ranging from 0.74 to 0.79 Euros per liveweight kilogram). The success of these two countries can be attributed to overlapping and distinct factors. Both countries' pig producers have access to locally sourced soybeans and grains at lower prices. The level of feed costs in these two countries is the lowest, at 0.50 and 0.53 Euros per liveweight kilogram, respectively. Additionally, the proportion of feed costs in the cost structure is the highest in these two countries (68% and 67%). This implies that they spend less on other variable expenses compared to their competitors, and their relatively low constant costs may be due to larger operation sizes. They also gain a competitive advantage in terms of labor costs, with Brazil benefiting from extremely low wages and the United States from outstanding labor efficiency. However, it should be noted that the United States has different meat quality standards. Despite having a similar carcass weight to the European average, the percentage of lean meat is only 55%. This difference may be influenced by varying consumer preferences. In terms of meat quality, it is worth mentioning that both countries allow the use of ractopamine, a growth-promoting substance for pigs. Ractopamine is known as a doping agent and is included in the World Anti-Doping Agency's prohibited list. While its use as a feed additive is not permitted in most countries, these two overseas countries are exceptions. The United States has a high percentage of pigs raised with ractopamine, while Brazil has a minimal usage. This is because the Brazilian pork industry is highly export-oriented, and their target markets do not demand such high-quality pork. Following this group are the "European tops" Spain and Denmark, with a cost of 1.07 and 1.08 Euros per live weight kilogram of pork production in 2019. Denmark has long been considered one of the world's most significant pork-producing nations, with a pig population more than twice the size of its human population. Denmark is known for having perhaps the best genetic base in the world and outstanding breeding organization. They establish success by producing high-quality breeding animals at low cost, locally. The other European example is the development of the Spanish pork industry. While Spain had 24.9 million pigs in 2005, by 2019, this number had increased to 31.2 million. During this period, Spain surpassed Germany, and it can now be said that Spain has the largest pig population in the European Union. The rapid development is driven by the spread of vertical integrations. They owe their low costs, continuous development, and population growth to the advantages derived from vertical integration. In the third group, Belgium, France, and Finland produced pig at a cost of 1.15 to 1.17 Euros per live weight kilogram, followed by the fourth group consisting of the United Kingdom, the Netherlands, and Germany, which lag behind by approximately 8 Eurocents. It can be said about all three members of the fourth group that they attach great importance to animal welfare and animal health issues. In the Netherlands and Germany, traditional large pork-producing nations, the increasing social pressure to meet animal welfare and animal health requirements has a negative impact on cost development. Moreover, in the Netherlands, the current agricultural policy aims to reduce the population, while Dutch pig hybrids can achieve similar performance to Danish hybrids. Great Britain stands out among the surveyed countries with a uniquely high proportion of extensive outdoor pig farming. In terms of animal welfare, British pigs are inherently better off, and they do not require as significant a paradigm shift as in other Western European countries. The fifth group consists of countries that produce pig at the highest cost, including Hungary, Austria, and Ireland (ranging from 1.30 to 1.31 Euros per live weight kilogram for traditional carcass weights of 110-120 kilograms). Hungary, therefore, lags behind in international comparison and still has a significant disadvantage compared to its European competitors. Among the surveyed 15 countries, Italy has the highest cost (1.51 Euros per live weight kilogram). However, it should be noted that fattening is carried out up to 170 kilograms, indicating a completely different type of pork industry.

After reviewing the feed prices and wages, it can be determined that we have advantages compared to some countries and disadvantages compared to others based on these factors. I attempted to quantify these differences in Euros. I modified the data submitted by the selected countries using the calculation sheets provided by InterPIG, specifically by calculating their cost-income situation using Hungarian feed prices and wages for each country. The differences between these adjusted costs and the original costs demonstrate the extent of our competitive advantage or disadvantage solely due to varying feed prices and wages compared to the selected countries (Figure 4).

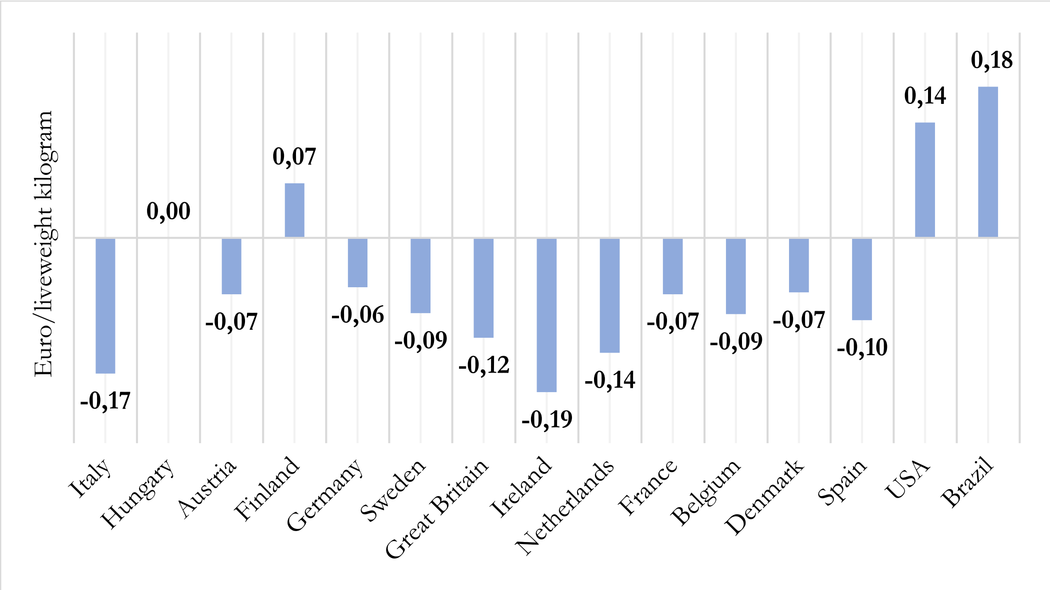


Figure 4: The impact of adjusting for Hungarian feed prices and wages on the cost of pig production
Source: Own calculations based on InterPIG database (2019)

Based on the diagram, it is evident that the correction of input prices had the greatest impact in the cases of Ireland and Brazil. With Hungarian feed prices and wages, the cost of producing one kilogram of slaughter pig could be reduced by 19 Eurocents in Ireland, while it would increase by 18 Eurocents in Brazil. This essentially means that we have a competitive advantage of 19 Eurocents compared to Ireland due to these factors, but a competitive disadvantage of 18 Eurocents compared to Brazil. Domestic pig farmers also face a competitive disadvantage of 14 and 7 Eurocents against their North American and Finnish counterparts, respectively. The European competitors, which have not been mentioned before, exhibit disadvantages ranging from 6 to 17 Eurocents compared to us.

3.3. The Complex Pig Performance Indicator (CPPI) and the Complex Pig Fattening Performance Indicator (CPFPI)

In light of the formulas, another aspect of evaluating the efficiency of domestic pig farming can be considered. The value of CPPI increased by 44 points between 2005 and 2019, indicating a 22% improvement in efficiency (Figure 5). Similar proportional improvement of 21% can be observed for CPFPI. When examining the changes in key natural efficiency indicators individually, we can observe varying degrees of change. The mortality rate decreased by 66%, the daily weight gain increased by 11%, the feed conversion ratio improved by 16%, the labor efficiency in fattening increased by 62%, the number of weaned piglets increased by 34%, the feed consumption in sow management decreased by 4%, and the labor efficiency in sow management improved by 10% in 2019 compared to 2005. Examining individual important natural indicators does not provide an accurate picture of the overall improvement in pig farming efficiency over the analyzed period. In the previous chapters the constant input price method, which was referred to as an almost perfect natural efficiency indicator by me, showed a 31% lower value in 2019 than in 2005. The 9 percentage point difference between CPPI and constant input price method efficiency is considered significant, and it arises from the different methodology. The advantage of the constant input price calculation is that it attempts to measure the efficiency of other cost factors by assigning an index to all types of costs. The advantages of CPPI and CPFPI lie in their ability to be used not only for generating dynamic relative ratios and conducting time series analysis but also for excellent comparative analyses in any context. They can be used for benchmarking between farms, as well as for comparing regions or different groups of farms.

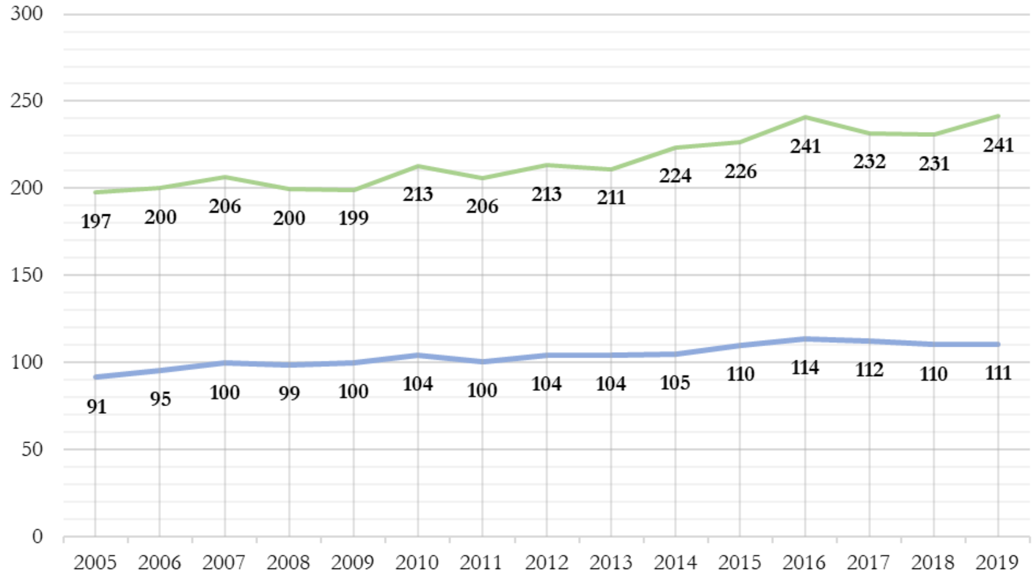


Figure 5: The values of CPPI (green) and CPFPI (blue) in Hungary between 2005 and 2019
Source: Own calculations based on AKI FADN database

The 22% and 21% growth of the two composite indices corresponds to an average annual growth rate of 1.44% and 1.37%, respectively. However, the values did not change to the same extent over the years.

In order to achieve a more accurate self-evaluation, a classification system has been developed that categorizes the units of analysis into 5 classes based on their performance (Table 2). To calculate the lower threshold of the "A" category, values were substituted for the independent variables that approximate parameters of modern farms at the international level and should serve as target goals for farm managers. The "B" category includes farms that can achieve a cost-effective profitability of at least 21% under the average input and output prices of 2017-2019, which is considered favorable in animal husbandry. The "C" category represents a minimum level of performance that ensures profitable production even without subsidies, while the "D" category represents a level that, together with subsidies, provides positive contribution to covering costs for the farm (under the average input and output prices of 2017-2019). This means that farms unable to consistently reach the "D" category under the market conditions of 2017-2019 may face the possibility of sectoral elimination. Since market conditions play a significant role in three out of the four dividing points, periodic reconsideration and updating of the classification will be necessary.

Table 2: The recommended classification of The Complex Pig Performance Indicator (CPPI) and the Complex Pig Fattening Performance Indicator (CPFPI)

Category	CPPI	CPFPI
A	310 -	140 -
B	255 - 310	120 - 140
C	220 - 255	105 - 120
D	205 - 220	95 - 105
E	- 205	- 95

Note: The intervals assigned to the categories are open at the lower end and closed at the upper end.
Source: Own editing

3.4. The variation of slaughter pig unit cost and average income of production as a function of slaughter pig weight

Based on the standardization formulas of InterPIG and the data from the Test Farm System in 2019, I have developed the cost functions for raw materials, feed costs, and other costs, which, when combined, lead to the cost curve of pig fattening in Hungary. With the help of the cost function, the average income and the optimal slaughter pig weight can be determined.

The raw material cost occurs only once during production (at the beginning of the fattening phase), so its sum remains a fixed amount throughout the pig's life, at 15,923 HUF per animal. Therefore, it behaves as a constant cost from this aspect. The cumulative feed cost shows a continuous, steep upward trend. This is because the animals' feed utilization capacity deteriorates continuously, requiring more feed for weight gain. Although feed changes occur due to the animals' constantly changing needs, resulting in a decrease in the value of leftover feed, it only causes breaks in the cumulative feed cost function and does not alter the trend. The cumulative feed cost ranges from 157 to 27,543 HUF per animal within the observed range. The function of cumulative other costs also shows an increasing trend, but its slope is much smaller than that of the cumulative feed cost function. Its variation is primarily linked to changes in daily weight gain, and as it decreases from a certain point, the number of days spent at a specific weight increases, leading to an increase in the slope of the other cost function. The cumulative other costs range around 84 to 6,202 HUF per animal within the observed range.

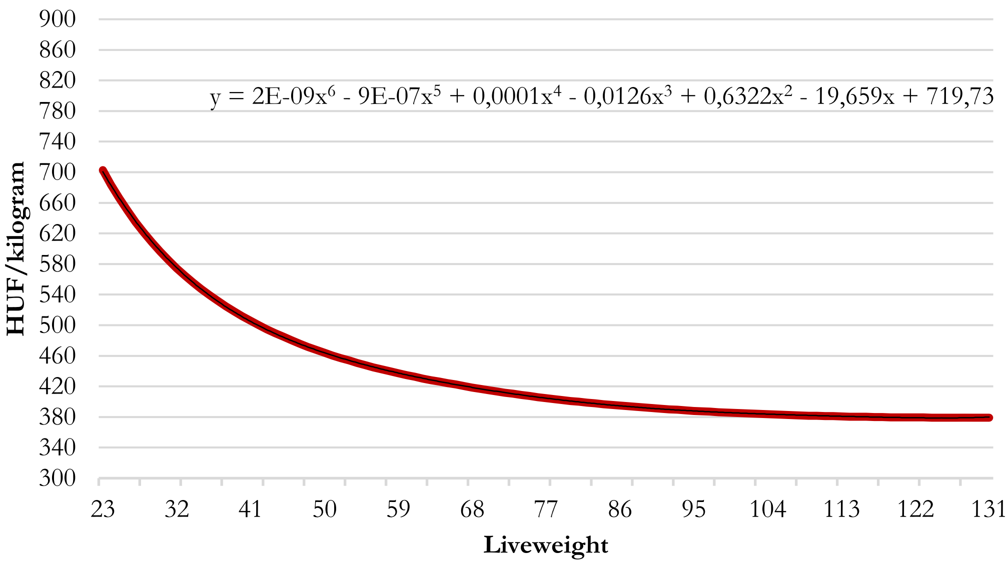


Figure 6: The unit cost curve of slaughter pigs in Hungary exhibits a range between 23 and 131 kiograms in 2019
Source: Own calculations

By summing up the cumulative values of the raw material cost, feed cost, and other costs functions and dividing it by the live weight, we arrive at the desired outcome, the unit cost curve shown in Figure 6. If we examine the changes in the three partial costs divided by live weight, we would observe two increasing trends (feed cost, other costs) and one decreasing trend (raw material cost). The unit cost curve combines these three effects in a single shape, which represents the average for Hungary in 2019. The curve has a U-shape, as expected for an average cost curve, although it may not be explicitly visible in the figure. The increasing segment starts from the end of the illustrated range and would become noticeable by extending the observed range. The function's values range from 702.78 to 379.14 HUF per live weight kilogram within the observed range of 23 to 131.99 kilograms. The function reaches a minimum value at 127 (379.11 HUF per live weight kilogram), indicating that for cost minimization purposes, the fattening pigs should be sent for slaughter between 127 and 128 kilograms.

Based on the unit cost curve, I was able to create the production cost function (per animal), and with the help of the average market price in 2019, I also developed the production-value function. The difference between the values of the production-value and production-cost functions represents the industry income per animal as a function of live weight. To calculate the average income, I projected this onto a time unit (day), leading to the average income function. With this function, I was able to determine the optimal slaughter weight. According to my calculations, profit maximization can be achieved when the fattening pigs are slaughtered at a live weight between 128 and 129 kilograms, making this point the optimum slaughter weight.

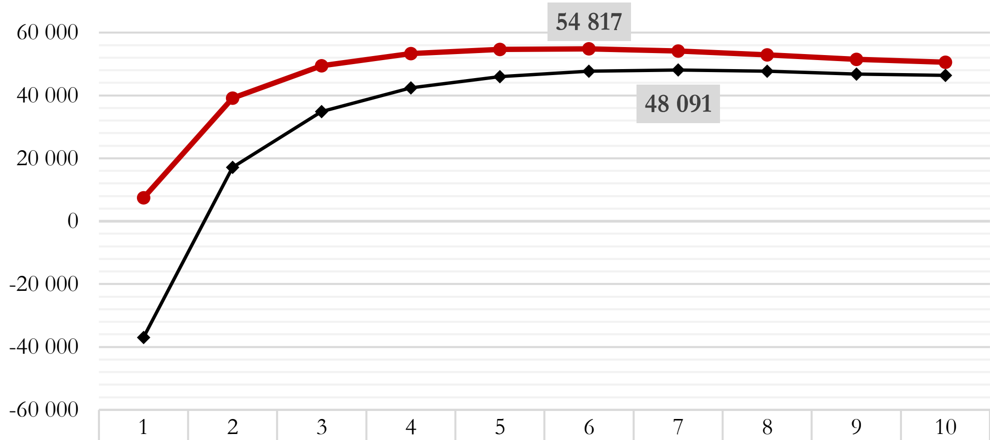
3.5. The optimal culling time for breeding sows

The value assigned to the breeding sow significantly affects the cost dynamics, thus yielding different results when the breeding sow is not purchased but raised within the operation from the existing herd. Therefore, I performed the calculations considering the cost of breeding sow establishment, modifying the initial value of 140,067 HUF per sow to 95,680 HUF per sow. When using own breeding sows, the cost minimum occurs at the sixth farrowing. At this point, the weaned piglet's cost is 11,055 HUF per piglet, which is 5% lower than the cost calculated for the eighth farrowing with purchased breeding sows. The difference between the two calculations decreases continuously as the impact of establishment value on costs diminishes over time. The difference is 4,449 HUF at the first farrowing and reduces to 389 HUF at the tenth farrowing.

The source of the breeding sow also affects the discounted specific income as it considers the difference between the selling price and the cost, taking into account the time value of money. In the case of own sows, the maximum discounted specific income is 5,076 HUF per sow, achievable after the sixth farrowing. This value is 14% higher than the maximum point calculated for purchased breeding sows.

To determine the optimum, I also prepared the average income functions projected onto the production cycle (Figure 7).

Based on the average data from 2017-2019, the investment in breeding sow establishment becomes profitable after the second farrowing. However, initiating a new investment at this point is not justified, as it is more beneficial to keep the breeding sows for further breeding to maximize their economic potential. The optimal culling time for boars is around the 6th to 7th farrowing, depending on whether the breeding sow originates from own production or is a purchased animal. According to the model calculations, it is advisable to cull boars well beyond their reproductive performance peak. However, this conclusion is based on the market conditions and natural efficiency of the 2017-2019 period, indicating the need for continuous updates of calculations and analysis of results. At the micro-level, it is practical to apply the calculation method on a per-sow basis and make individual decisions on culling based on specific considerations. In such cases, the decline in reproductive performance may coincide with the optimal culling point.



	1	2	3	4	5	6	7	8	9	10
Purchased sow	-36 956	17 160	34 896	42 446	46 037	47 709	48 091	47 720	46 846	46 403
Own sow	7 431	39 177	49 457	53 279	54 635	54 817	54 135	52 966	51 473	50 534

Figure 7: The average income per sow (HUF/production cycle) in the case of purchased and own sow
Source: Own calculations

4. CONCLUSIONS AND RECOMMENDATIONS

4.1. Conclusions

Between 2005 and 2019, the profitability of pig fattening varied greatly. The fluctuating profitability can be attributed to the volatility of pig prices, which is partly due to the natural process of the pig cycle and also to market disruptions arising from economic, political, and natural events. Another source of variable income is the development on the cost side. Pig farmers have more flexibility in managing their costs, and by effectively managing their expenses, they can contribute to achieving higher income and ensuring the long-term sustainability of their farms. The cost of pig production has gradually increased during the analyzed period, with larger jumps often attributed to market forces. The relationship between market prices and income changes is well demonstrated by comparing the Slaughter Pig Scissors and the income of the Farm Accountancy Data Network in the time series.

However, the negative effects of market processes can be significantly mitigated by improving natural efficiency, and during periods of stable input prices, cost reduction can also be achieved. Natural efficiency can be characterized by various indicators, but even the most commonly used indicators evaluate efficiency from a specific perspective, and there is no single indicator that takes into account all the key factors in assessing production efficiency. To address this, I calculated the annual costs based on constant input prices for the period between 2005 and 2019. The calculated unit cost based on unchanged input prices effectively illustrates the magnitude of cost variation solely due to changes in natural efficiency, which provides insights into the extent of natural efficiency changes. This method provides information specifically on the temporal changes in natural efficiency, but the calculated values alone do not provide much information. Therefore, I developed the Complex Pig Performance Indicator (CPPI) and the Complex Pig Fattening Performance Indicator (CPFPI), whose values indicate natural efficiency regardless of time and space. Based on these three indicators (constant input price cost, CPPI, CPFPI), an improving trend in natural efficiency can be observed between 2005 and 2019. However, the improvement is not continuous, as there are years of stagnation or minor declines. Significant improvements are particularly evident in 2010, 2016, and 2019. These trends are supported by the findings of *Novozánszky (2015, 2019),* indicating significant improvements in the domestic genetic base since 2015. The improvement in natural efficiency is also explained by the observations of *Ózsvári and Búza (2015)*, who noted improvements in animal husbandry conditions between 2005 and 2015 due to investments. By focusing solely on changes in natural efficiency indicators, a positive outlook emerges as the values continue to improve and show visible effects of technological advancements reported in the literature. However, to avoid drawing misleading conclusions, it is important to compare the data with changes in the pig population. The pig population is declining, and it is evident that producers who are economically unviable are exiting the industry, likely with low levels of natural efficiency. Therefore, the improvement in natural efficiency is not solely attributed to modernization.

It was justified to compare the profitability of pig farming with other sectors that compete for almost the same resources. The comparison with major livestock sectors was conducted based on the average data from 2017 to 2019. This three-year period is considered favourable within the examined 15-year timeframe, as 2019 can be regarded as the most successful year in terms of profitability in recent decades. However, the sector comparison paints a bleak picture. According to several key economic indicators, pig farming is in a worse position compared to major livestock sectors, yet the sector receives relatively low financial support. This contradiction is certainly worrisome, and with such financial support levels, it can only facilitate the survival and maintenance of the sector, rather than its development. However, the presence and increase of community and national resources allocated to the sector alone do not provide a solution to all problems. It is important to use these resources wisely and address other systemic problems.

Although *Ózsvári and Búza (2015)* report improvements in pig farming conditions, the analysis by *AKI (2020)* reveals that Hungarian pig farmers mostly operate in outdated facilities. Therefore, overall, the situation is not good, but at least it is improving. I arrived at the same conclusion based on the analysis of the time series data from the Farm Accountancy Data Network and the 2019 database from InterPIG. Examining a longer time series, 2019 can be considered excellent, but our production costs are high in an international context, and the income situation in the sector can be considered average. We are unable to capitalize on the advantages arising from low feed and labor costs, and our significant lag in natural efficiency translates into an economic efficiency lag.

The results of the time series, sectoral, and international comparisons draw attention to several problems. In my opinion, a significant portion of these problems could be addressed with additional financial resources allocated to the sector and improvement in management standards. Despite the current poor situation, there are extraordinary opportunities in pig farming that could be harnessed through the convergence of know-how and capital. Based on the three comparative analyses from different perspectives, I concluded that having high-quality databases is essential for a comprehensive situation analysis. This applies to both central planning and micro-level analyses. Benchmarking is a particularly valuable tool for company executives.

During my research, after conducting a situation analysis, I focused on procedures that are relatively simple and can be performed even without sophisticated farm management software. These procedures can assist pig farmers in improving production efficiency and navigating the currently unfavourable situation. There are several such methods, of which I highlighted only a few in my dissertation. One of them was determining the slaughter weight that facilitates cost minimization and defining the slaughter weight that promotes profit maximization. The goal was not only to find the optimal slaughter weight but also to develop a usable benchmarking method. *Chantziaras et al. (2020)* also recognized the problem that different parameters of pig farms cannot be compared if the slaughter weight varies, thus requiring standardization formulas. During the literature review, I did not find any study that aimed to establish a representative live weight-cost formula for the national average. Most of the studies I encountered relied on their own smaller-scale observations. According to my calculations, in Hungary, pigs are slaughtered much earlier than what would be justified from the perspective of cost minimization and profit maximization. The practical relevance of the cost-minimization principle I presented can be seen in the following cases: 1. It can be useful for determining the appropriate transfer point in vertical integrations. 2. It can be used to calculate the value of government compensation following any outbreak-related losses, as the animals die at different weights, and determining their value at the time of death is not straightforward in the absence of a market. In other cases, classic optimization is required, meaning that the point where average income is maximized needs to be sought.

Several researchers have already dealt with determining the optimal culling time for sows *(Márai-Székely, 1974; Kristensen, 1991; Rajnai et al., 2001; Balogh et al., 2007)*. Some aimed to develop the methodology, while others determined the actual culling time using some database or empirical data. Building upon a previous cost-minimization model, I developed a methodologically simple and practically usable approach to determine the maximum average income. Based on my own calculations, if the breeding sow is sourced from one's own herd, it is advisable to cull it after the 6th farrowing under current market conditions. However, if it is purchased, then culling should take place after the 7th farrowing. Therefore, according to my own model, the optimal culling of breeding sows occurs after the 6th or 7th farrowing from an economic perspective, which aligns with the 6th-7th farrowing optimum identified by *Rajnai et al. (2001)* but is later than the 5th farrowing point determined by *Balogh et al. (2007).*

Finally, my capacity utilization analyses aimed to investigate a current issue mentioned by several sector experts in terms of production organization, namely that the previously established space ratios within the farm are no longer suitable due to changes in natural efficiency. The results of my calculations indicate that pig farmers achieve the best results in terms of area-specific profitability when they try to gain a market for the surplus of weaned piglets, thereby diversifying the product structure. From the perspective of farm-level profitability, along with the improvement in natural efficiency, initiating additional investments is also justified.

4.2. Recommendations

Based on the results of my research, Hungarian pig farming is not in a favourable position, but it holds great potential. Professional debates related to the sector often position themselves along the small-scale/large-scale farm divide, and the question of whether small or large farms should receive greater support frequently arises during the allocation of central resources. In my opinion, it is not correct to prioritize either pole, but rather, different agricultural policy tools need to be developed taking into account the characteristics of small-scale and large-scale farms.

The central element of the dissertation is the examination of natural efficiency. Natural efficiency improvement could primarily be achieved through technological advancements and improvements in management quality. Increasing investment subsidies and interest rate subsidies for investments have contributed to significant development in Russia. However, such subsidies should be subject to strict conditions. Investment support should only be provided to farms where the incoming capital will be utilized effectively. These are typically larger enterprises with appropriate management and expertise. It is important that expertise becomes a prerequisite for accessing capital. When providing investment support, measures should be taken to ensure that the resources allocated to the sector do not migrate to contractors through increased input prices.

The improvement of genetic background is essential for enhancing natural efficiency. Currently, it would be justified to support the acquisition of high-quality foreign breeding hybrids. However, thinking in the long term, there is a need to develop Hungarian breeding stock and establish a Hungarian hybrid program, potentially by acquiring foreign experts and involving them in the process. The Dutch and Danish pig industries are exemplary in this regard.

Smaller producers should be encouraged to produce higher value-added premium products, and assistance should be provided in finding markets for them. The Italian pig farming industry provides a suitable example of how the sector can remain viable by producing high-quality products despite lower natural efficiency.

Support for the development and continuous monitoring of biological security would also be particularly relevant for small farms, especially considering the current focus on combating the spread of African swine fever.

During land auctions and land tenders, livestock farmers should receive significant advantages to ensure that the produced feed is not exported in its raw form but rather value-added.

Given the current market crisis and the overall price volatility characteristic of the sector, it is crucial for farmers to make extensive use of risk management tools. The Crisis Insurance System launched in 2021 provides a good opportunity to mitigate risks arising from market events. However, despite the low entry fees, only a few have taken advantage of this opportunity so far. The lack of contractual discipline, emphasized by major market players, is also related to market problems. Non-compliance with certain points of signed contracts reduces trust among market participants and makes it difficult to reach future long-term agreements. Several pig farmers do not even attempt to enter into longer-term agreements guaranteeing fixed prices with slaughterhouses. Instead, they engage in speculation, hoping that market prices will turn in their favour.

There is a need for openness to alternative protein sources both from producers and central management. According to the new guidelines implemented by the European Commission in 2021, the use of insect-based proteins will be permitted in the feed of poultry and pigs. It would be beneficial to support research in the insect industry, as it would be advantageous for Hungary to be among the pioneers in this regard instead of becoming importers in both products and technology in another potentially more significant sector in the future.

The widespread adoption of vertical integrations played a fundamental role in the rise of the Spanish pig industry. Supporting vertical integrations and improving the managerial attitude towards them would be extremely important for the sector. Instead of focusing on the issue of specialization and examining the future prospects of closed-system farms engaged in their own fattening material production versus specialized fattening and piglet-producing farms, we should promote entry into vertical integrations spanning from feed production to processing. Proper resource allocation, coordination of processes, and reduction of transaction costs within these vertical integrations together predispose the members to great success.

For those who do not wish to join vertical integrations, it is important to connect to horizontal organizations. The bargaining position of horizontal integrations is stronger both with buyers and suppliers.

The proposed measures require changes in the behaviour of pig farmers as well as state involvement. However, the actions of the Ministry of Agriculture are often constrained by European Union regulations. In my opinion, agriculture is precisely an area where the Community should take into account national interests to a much greater extent. Moreover, the area-based basic support system, which constitutes a major part of the first pillar of the Common Agricultural Policy, is highly unjust. Besides completely excluding livestock farmers from these resources, the allocated support amounts are not at all in line with value creation, the level of assumed risks, and the income situation of the sectors, even though the first pillar theoretically serves to stabilize income, produce public goods, and balance markets. It would be much fairer and more reasonable to distribute basic support based on production value, but considering production costs should not be overlooked in the allocation of resources.

Finally, I find it crucial to develop data collection systems and support them with financial resources since without a sufficient quantity and quality of data, we may formulate completely misguided strategies. Based on my experience, there is still room for improvement in this area.

4.3. The results of the hypothesis testing

H1: The natural efficiency of pig fattening shows an improving trend between 2005 and 2019.

After the political transition, the entire agricultural sector in Hungary faced a serious crisis. Newly established businesses predominantly focused on crop production, while a significant portion of those still engaged in animal husbandry lacked the necessary expertise *(Bartha, 2012).* The sector, compelled to comply with the European Union requirements that were considered new in 2005, was likely in a critical condition. *Ózsvári and Búza (2015)* found that the conditions of animal husbandry had improved significantly in the five to ten years prior to 2015 due to European Union investment support. Temperature, ventilation, feed quality, and water quality had improved. Observations by *Novozányszky (2019)* also hinted at the development of efficiency, as he perceived a significant improvement in the domestic genetic base. Based on these findings, I hypothesized that there was an improving trend in the natural efficiency of pig farming.

Natural efficiency can be evaluated using various indicators. Among the most important are daily weight gain, feed conversion ratio, and weaned number of piglets per sow. However, these indicators assess efficiency from only one perspective, and although these aspects are crucial, I wanted to validate my hypothesis with a comprehensive indicator that combines multiple efficiency elements. One potential indicator is the constant input price cost, and the other is the Complex Pig Performance Indicator (CPPI) developed during my doctoral work. The former provides an excellent value for time series efficiency comparison since the magnitude of change in constant input price cost reflects purely the change in natural efficiency, as the ratio of input to output quantity is the only variable considered in the analysis. The latter (CPPI) is a composite index that incorporates multiple efficiency indicators and is suitable for both time series analysis and intercomparison of facilities or regions.

The constant input price cost exhibited a decreasing trend between 2005 and 2019, while the Complex Pig Performance Indicator showed an increasing trend, indicating the improvement of natural efficiency for both indicators. However, the changes were not continuous in either indicator, and in some years, a decline in efficiency was observed compared to the previous year. The constant input price cost was 31% lower in 2019 than in 2005, and the CPPI was 22% higher in the last examined year compared to the first year. Therefore, I **accepted my hypothesis.**

H2: Pig farming is in a less favourable economic position compared to other major livestock sectors (dairy cattle farming, beef cattle fattening, broiler production, table egg production).

In my second hypothesis, I essentially started from the trends in livestock population. The poultry population did not decrease to the extent that the pig population did, and the number of cattle even increased between 2005 and 2019. I assumed that maintaining a consistently excellent income situation in the sector was essential for livestock growth. Another supporting factor for my second hypothesis is the fact that cattle farming belongs to the sectors strongly supported by the Common Agricultural Policy, and I believe that the economic situation of poultry farming is fundamentally aided by its regulation and a higher proportion of vertical integrations.

To test the hypothesis, I first needed to identify indicators suitable for inter-sector comparisons. Indicators commonly used in the analysis of sectoral income situation, such as cost per unit, unit income, and sectoral profitability, are almost meaningless for inter-sector comparisons. In contrast, benefit-cost ratio and contribution margin ratio are the two best indicators for sectoral comparisons. By utilizing the average values of these two indicators for the years 2017-2019 from the Farm Accountancy Data Network's sectoral database, I calculated that dairy cattle farming, table egg production, and broiler fattening were clearly in a more favourable position compared to pig fattening. The comparison results with beef fattening are not conclusive. Benefit-cost ratio is lower in beef fattening, while contribution margin ratio is lower in pig fattening. It should be noted that I primarily compared values related to the fattening phase. If we were to include the amount of direct state subsidies for the production of fattening animals (beef cattle farming), benefit-cost ratio would improve by 10 percentage points, while the same procedure would only improve the benefit-cost ratio of pig fattening by 1 percentage point. With this correction, beef fattening would be in an even more favourable position compared to broiler fattening. Considering this, the continuous increase in the number of beef cattle is not surprising. Overall, **I consider my second hypothesis to be accepted.**

H3: The high unit cost of pork in international comparison is primarily attributed to poor natural efficiency.

I was only able to conduct the international comparison among countries that are members of the InterPIG organization, so I also examined the investigation of my third hypothesis within this framework based on data from 2019. The relatively high cost can arise from two main sources: weak natural efficiency and high input prices. Considering the domestic problems identified during the literature review (genetics, management) and the existence of a diverse domestic feed base, prior to analyzing the database, I evaluated our lag in terms of natural efficiency as a greater problem.

Based on the analysis, **my hypothesis can only be partially accepted**. Compared to our major European competitors, our lag in terms of efficiency is indeed exceptional, and in some cases, we have a competitive advantage derived from low input prices (feed cost, labor wages). However, our natural parameters are weaker compared to Brazil, the United States, and Finland as well, but these three countries also feed their pigs with significantly lower-cost feed, and in Brazil, average wages are lower as well. Therefore, our lag behind these three competitors is not solely due to our weak natural efficiency.

H4: The average slaughter weight of fattening pigs is not optimal from the perspective of income maximization.

My assumption is that the pricing policy determined by slaughterhouses generally influences the slaughter weight, which is mainly based on the demand-supply conditions of the pork market, consumer trends, and income optimization in the processing phase. These factors can be overridden by extreme market conditions. For example, at the end of 2020 and the beginning of 2021, there was a significant backlog in domestic slaughter pig supply, and processors simply couldn't absorb the majority of market-ready pigs. As a result, the finishing period had to be extended, leading to an increase in the average slaughter weight. Although producers typically have limited bargaining power and must adapt to the pricing set by slaughterhouses, they still have some degree of flexibility. However, my hypothesis was that the development of average income during the finishing phase is irrelevant to the pricing of slaughter pigs, and therefore, the average slaughter weight will not coincide with the weight at which the average income in pig fattening is maximized. To confirm my hypothesis, I needed to create an income curve representative of the Hungarian average based on the most recent available data (2019). According to my calculations, the optimal slaughter weight is around 128-129 kilograms in Hungary, which is much higher than the average slaughter weight of 116 kilograms based on the Farm Accountancy Data Network's sectoral database. Therefore, **I consider my hypothesis to be accepted.**

5. NEW SCIENTIFIC RESULTS

During my research, the economic analysis of Hungarian pig farming was the focus, resulting in the following new scientific achievements:

1. I developed my own method to create **Slaughter Pig Scissors**, which provides a comprehensive view of the economic environment of pig farmers. Monitoring this value allows for predicting expected results well before the financial reports are published.

2. While **the examination of constant input price costs** alone may not be considered a new scientific achievement, the procedure I developed for calculations is. This method enables the analysis of changes in natural efficiency through time series analysis.

3. I developed a **cost calculation model for slaughter pigs** that allows for precise cost estimation without relying on detailed accounting or inventory records. The model utilizes natural indicators and input prices to quantify the impact of major parameters on unit cost.

4. I created the the **Complex Pig Performance Indicator (CPPI) and the Complex Pig Fattening Performance Indicator (CPFPI),** which facilitate easy evaluation and comparison of natural efficiency among pig farmers. When designing these comprehensive indicators, a key consideration was to accurately quantify the impact of sub-indices on cost, thus establishing complex measures closely related to economic efficiency.

5. Based on data from 2019, I constructed **growth curves for average daily weight gain and feed conversion ratio specific to the Hungarian average**. These curves illustrate the trends of these two important natural indicators as a function of live weight.

6. I developed a methodology for determining **the unit cost curve of pig fattening** in the absence of detailed inventory records. This curve shows the development of unit cost as a function of slaughter weight. I applied this methodology to calculate the curve for the national average in 2019.

7. By enhancing a previous cost minimization model and using current data for the national average, **I investigated the economically optimal time for culling breeding sows from a novel perspective**.

6. APPENDIX

6.1. The author's publications related to the topic of the dissertation

Scientific Journal articles in Hungarian

Udovecz, G - **Szili, V.** - Potori, N. (2017): Spanyol lecke a sertéságazat felemelkedéséről. GAZDÁLKODÁS 61: 2, pp. 93-102., 10 p.

Szili, V. (2015): A magyar sertéstartás költség- és jövedelemhelyzete = The cost- and income situation of the Hungarian pig breeding ANIMAL WELFARE ETOLÓGIA ÉS TARTÁSTECHNOLÓGIA / ANIMAL WELFARE ETHOLOGY AND HOUSING SYSTEMS 11: 2, pp. 175-184., 10 p.

Scientific Journal articles in English

Egri E. - Potori N. - Szabó Zs. - Szenderák J. - **Szili V.** (2023): Embeddedness of Hungarian pork prices in the European market: a volatility spillovers and partial wavelet coherence study - STUDIES IN AGRICULTURAL ECONOMICS 125:1, pp. 13-23, 11 p.

Szili, V. - Dunay, A. (2023): Pork production from global and European perspective - SELYE E-STUDIES 14: 1, p.14. ahead-of-print (2023)

Scientific other journal articles in Hungarian

Egri, E. - **Szili, V.** (2022): Sertésválság nemzetközi szinten – Magyarországon vitatták meg az aktualitásokat. AGRO NAPLÓ: 8 p.

Egri, E. - **Szili, V.** (2022): Nemzetközi összehasonlítás: Magyarországon vitatták meg nemzetközi szakértők a sertéspiaci aktualitásokat. MAGYAR ÁLLATTENYÉSZTŐK LAPJA 27: 8 pp. 22-25., 4 p.

Egri, E. - Molnár, Zs. - **Szili, V.** (2021): Fokozódó válság: Sertéspiaci helyzetkép. MAGYAR ÁLLATTENYÉSZTŐK LAPJA 26: 10 pp. 34-37., 4 p.

Garay, R. - **Szili, V.** (2019): A hazai sertéságazat hatékonysága. MAGYAR MEZŐGAZDASÁG 74: 9 pp. 24-26., 3 p.

Mándi-Nagy, D. - **Szili, V.** (2017): A tejelő tehéntartás költség- és jövedelemhelyzetének vizsgálta és néhány tejtermék vertikális elemzése. HOLSTEIN MAGAZIN 25: 6 pp. 50-51., 2 p.

Béládi, K. - **Szili, V.** (2015): A borszőlőtermelés költség- és jövedelemhelyzete. AGROFÓRUM EXTRA 26: 61 pp. 5-7., 3 p.

Kertész, R. - **Szili, V.** (2015): A kalászosok gabonák költség- és jövedelemhelyzete. AGROFÓRUM EXTRA 26: 60 pp. 40-43., 4 p.

Kertész, R. - **Szili, V.** (2015): A tejelőtehén-tartás helyzete. MAGYAR MEZŐGAZDASÁG 70: 38 pp. 44-46., 3 p.

Szili, V. - Béládi, K. (2015): A napraforgó, a repce és a szója költség- és jövedelemhelyzete. AGROFÓRUM EXTRA 26: 59 pp. 5-9., 5 p.

Béládi, K. - **Szili, V.** (2014): Az árpa költség- és jövedelemhelyzete. AGROFÓRUM - A NÖVÉNYTERMESZTŐK ÉS NÖVÉNYVÉDŐK HAVILAPJA 25: 12 pp. 100-103., 4 p.

Books and book chapters

Alvincz, J. - Porkoláb, E. - **Szili, V.** - Szlovák, S. (2019): A főbb mezőgazdasági ágazatok helyzete 2010 és 2017 között- In: Kurucz, Mihály; Jójárt, László; Fazekas, Sándor; Alvincz, József Mindent a magyar vidék jövőjéért: Mezőgazdaságunk 2010-2018. Budapest, Magyarország: Gondolat Kiadó (2019) 408 p. pp. 211-303., 93 p.

Szili, V. - Szlovák, S. (2018): A főbb mezőgazdasági ágazatok költség- és jövedelemhelyzete 2016. Budapest, Magyarország: Agrárgazdasági Kutató Intézet.

Béládi, K. - Kertész, R. - **Szili, V.** (2017): A főbb mezőgazdasági ágazatok költség- és jövedelemhelyzete 2013–2015. Budapest, Magyarország: Agrárgazdasági Kutató és Informatikai Intézet, 232 p. AKI Repozitórium.

Béládi, K. (szerk.) - Dancs, Gy. - **Szili, V.** (2017): A fontosabb élelmiszeripari termékek költség és jövedelemadatai 2014–2015. Budapest, Magyarország: Agrárgazdasági Kutató Intézet.

Béládi, K. (szerk.) - Kertész, R. - **Szili, V.** (2017): A főbb mezőgazdasági ágazatok költség- és jövedelemhelyzete 2013–2015. Budapest, Magyarország: Agrárgazdasági Kutató Intézet.

Szili, V. - Dancs, Gy. (2017): A fontosabb élelmiszeripari termékek költség és jövedelemadatai 2014–2015. Budapest, Magyarország: Agrárgazdasági Kutató és Informatikai Intézet. 48 p. AKI Repozitórium.

Publications in conference proceedings in English

Potori, N. – **Szili, V.** (2022): An assessment of the farm-level impacts of the transition from conventional farrowing crates in the Hungarian pig sector (a bolgár Agrárgazdasági Kutató Intézet IAE - Institute of Agricultural Economics) 9. nemzetközi konferenciája. The 9th International Scientific Conference „Agrarian Economy - in Support of Agriculture” Sofia, 2022. 10. 25-27.)

Szili, V. - Dunay, A. (2019): Economics impacts of African swine fever on pig farming. In: Dunay, Anna (szerk.) Proceedings of the 9th International Conference on Management: "People, Planet and Profit: Sustainable business and society": Volume II. Gödöllő, Magyarország: Szent István Egyetemi Kiadó Nonprofit Kft. 407 p. pp. 390-397., 8 p.

Szili, V. - Dunay, A. (2019): Formulation of the optimum crop structure for pig producers in Hungary. Megjelent: Fodor Zita. Book of Abstracts of the 9th International Conference on Management: "People, Planet and Profit: Sustainable business and society": 9th ICoM 2019. ISBN:9789632698366 pp. 65-65

Lencsés, E. - Kovács, A. - **Szili, V.** - Mészáros, K. (2017): Efficiency of the automatic milking robot and the manager skills. In: Košičiarová, I.; Kádeková, Z. (szerk.) Managerial trends in the development of enterprises in globalization era. Nitra, Szlovákia: Slovak University of Agriculture in Nitra 949 p. pp. 813-818., 6 p.

6.2. MTMT report

MTMT publication and citation summary table				
Szili Viktor's data (2023.07.13)				
Publication types	**Count**		**Citations**	
Scientific publications	All	Detailed	Independent	All
I. Scientific journal article	4	---	---	---
in international journal in foreign language	---	1	0	0
in international journal in Hungarian	---	0	0	0
in hungarian journal in foreign language	---	1	0	0
in hungarian journal in hungarian	---	2	0	0
II. Books	7	---	---	---
a) Book as author	7	---	---	---
in foreign language	---	0	0	0
in hungarian	---	7	1	1
b) Book as editor	0	---	---	---
in foreign language	---	0	---	---
in hungarian	---	0	---	---
III. Book chapter	1	---	---	---
in foreign language	---	0	0	0
in hungarian	---	1	0	0
IV. Conference in journal or conference paper	2	---	---	---
in foreign language	---	2	0	0
in hungarian	---	0	0	0
Publications (I.-IV.)	14	---	1	1
Abstract	1	---	0	0
Research data	0		0	0
Other scientific works	5	---	0	0
All scientific publications	20	---	1	1
Hirsch index	1	---	---	---
Educational works	0	---	---	---
Higher educational books	0	---	---	---
Higher educational book in foreign language	---	0	0	0
Higher educational book in Hungarian	---	0	0	0
Higher educational book chapter in foreign language	---	0	0	0
Higher educational book chapter in hungarian	---	0	0	0
Educational material	0	---	0	0
Titles of protection	0	---	0	0
Achievement	0	---	0	0
Popular science works	6	---	---	---
Journal article		6	0	0
Books	---	0	0	0
Other popular science works	---	0	0	0
Of public interest or unclassified publications6	0	---	0	0
More publications	0		0	0
Other authorships	0	---	0	0
Citations of edited publications	---	---	0	0
Citations in dissertations and other types	---	---	0	0
All publications and citations	26	---	1	1