

**THESIS FOR THE DEGREE OF DOCTOR OF PHILOSOPHY
(PHD)**

**ECONOMIC EVALUATION OF THE COMPETITIVENESS
AND EFFICIENCY OF THE DOMESTIC FRESH MARKET
(GREENHOUSE) TOMATO PRODUCTION**

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1. BACKGROUND, OBJECTIVES AND HYPOTHESES OF RESEARCH

According to the preliminary data of the Agricultural Accounts System, the output of agriculture in 2021 was 13.1% higher than in 2020 (AKI, 2021). The output of Hungarian agriculture in 2021 amounted to HUF 3,378 billion, of which crop and horticultural products contributed 61% (HUF 2,070 billion) (KSH, 2021).

In Hungary, the horticultural sector generates significant added value and employs a large number of workers per unit area, although horticulture occupies only 4% of the agricultural area (CZERVÁN, 2014). The area under vegetable production is about 80,000 hectares, of which the most important part of the fresh market produce for food is supplied to the market from covered production and greenhouses, which cover about 3,500 hectares. In terms of capital and labour usage, the most intensive horticultural crops are greenhouse vegetables, where there are many opportunities and reserves for improvement in order to produce a better-quality product and more efficient management. The majority of the fruit and vegetable sectors are characterised by high capital and labour requirements, and it is therefore very important for the efficiency of production that these production resources do not represent a bottleneck to achieving high quality farming. Labour shortages have now become the main obstacle to the development of the sector.

The issue and problem of capital and labour efficiency affects the entire agricultural sector, including not only the horticultural sector, which has a high labour demand, but also other crop and livestock sectors. "The Hungarian agricultural society is divided today. One part emphasises efficiency orientation and competitiveness, while the other part treats the challenges of economic efficiency as a secondary issue with a focus on rural employment (KAPRONCZAI, 2011)."

For those economies that fail to develop and produce competitive goods, their "survival" becomes questionable (TÉGLA, 2009).

A new impetus for development can be given by the fact that thanks to the VP tenders (Vidékfejlesztési Program - Rural Development Programme), in 2020 there were 145 winning applications for the establishment of glass and plastic houses in the horticulture sector. In terms of cultivated area, this means that approximately 80 hectares of new greenhouses have been built, 17 hectares of large air-space block greenhouses have been

awarded, of which 7 hectares have already been built, and 4.7 hectares of large air-space single-bay plastic houses have been built (FELDMAN, 2020)

Research that measures the capital and labour efficiency of different production methods is essential to move domestic horticulture in a positive direction. Although in the current economic climate, and in the long-term, which is expected to remain capital and labour scarce, these scientific results can form the basis for the development of the sector and for entrepreneurial decision-making.

Main objectives of the research

Quantifying the advantages and disadvantages associated with each type of production equipment will clearly help to make the right investment decisions to enable the sector to exploit its potential for development. In addition, the results of the analyses carried out will facilitate the key decisions to be taken by operators in the sector.

Taking into account the sectoral and professional opinions and perceptions presented above, as well as the sectoral problems related to the competitiveness and efficiency of the sector, the **main objective** of my thesis is to assess the competitiveness of the domestic production of greenhouse (fresh market) tomatoes and to evaluate its efficiency, with particular reference to capital and labour efficiency.

For this main objective, I have formulated the following specific objectives:

- To assess the competitiveness of domestic tomato production at the macroeconomic level, based on external trade performance.
- To assess the capital efficiency of the different technical and technological variants currently available and considered as the most advanced in the domestic context, for truss (round) and snack tomato varieties.
- Assessment of the labour efficiency of the different technical and technological variants currently available and considered state-of-the-art in the domestic context, for truss (round) and snack tomato varieties.

Taking into account and closely aligned with the main and related specific objectives, the following hypotheses were formulated:

H₁: Hungary does not have a comparative competitive advantage over the EU-27 countries for fresh market tomatoes.

H₂: Among the variants studied, snack tomatoes (under normal glass) have the most favourable capital efficiency, followed by truss (round) tomatoes under diffused glass and finally truss (round) tomatoes under normal glass.

H₃: Among the variants tested, the one with the best labour efficiency is the truss (round) tomato under diffused glass, followed by the truss (round) tomato under normal glass and finally the snack tomato under normal glass.

2. DATABASE AND METHODS APPLIED

The thesis was accompanied by a literature review, which helped to assess the situation of the international and domestic vegetable and tomato sector. Areas closely related to the subject of the thesis, such as the fruit and vegetable sector, the vegetable sector, the production of greenhouse vegetables and finally, the most narrowly defined area, the tomato sector, were examined. An analysis of databases related to production, trade and consumption was carried out. Data were processed at world, EU and national level for the period 2004-2020.

Information on international data was provided by the FAO (Food and Agricultural Organization of the United Nations) databases and reports, and the EU situation assessment and results related to the greenhouse sector were processed on the basis of EUROSTAT (Statistical Office of the European Communities). Market trends were based on the USDA (U.S. Department of Agriculture) database. The production statistics of the Hungarian vegetable and sprouted vegetable sector were analysed using the databases of FruitVeB (Hungarian Fruit and Vegetable Interprofessional Organisation) and KSH (Hungarian Central Statistical Office). In addition, detailed price data were available from the NAIK AKI (National Agricultural Research and Innovation Centre for Agricultural Economics) and Délkertész (Délalföldi Kertészek Szövetkezete - Southern Plain Gardeners' Cooperative).

An important principle in the methodology of the calculations for this thesis was to compare the results of different crops (*in this case, truss tomatoes and snack tomatoes*) and different growing systems within a crop; and therefore, the results must have been comparable with each other. With this principle in mind, I have consistently applied the same methodology, while eliminating random differences, such as biases due to the different farm sizes, production structures and set-ups of the reporting enterprises, but which have no relation to the variety or the growing equipment. The basic objective was not to analyse the reporting enterprises but the varieties and growing systems under consideration. To carry out the classic cost-benefit analyses, sensitivity analyses and investment-economy studies, it is necessary to collect information on natural inputs, input prices, yields and sales prices.

To make the calculations, I analysed the work processes involved in cultivation in terms of elementary work operations, and the data were collected in this dimension. In order to obtain costs from the naturals, values from a reliable source were used in the model using the mosaic principle (APÁTI, 2007), which for input prices are prices from major horticultural input distributors. To compile the sales price database, I used the sales prices of the dynamically growing fruit and vegetable producer marketing organisation with the highest sales revenue in the country. Furthermore, it was also essential to establish the C_0 , i.e., the capital cost of the investment, for the purpose of the investment economic analysis. I considered the same type of growing equipment with the same investment cost in all cases. For each type of growing equipment (*normal glass-diffuse glass*), I have calculated a realistic useful life of 20 years (*5% depreciation rate*), taking into account a 1% repair and maintenance rate.

As regards data collection, it is important to underline that in all cases we are talking about soil-less tomatoes, i.e., truss and snack tomatoes grown in a growing medium. The focus of the thesis is on two cultivation technologies that are currently considered state-of-the-art, namely the modern Dutch system of glass-covered and diffuse glass covered greenhouses. The data collection was followed by continuous professional consultation.

Personnel costs are a major cost item in the sector. Data collection was carried out in workhours. The currently accepted non-qualified hourly wage used in the calculations was 2080 HUF/hour gross (*including public charges*). General costs (overheads) have not been taken into account, in all cases reflecting sectoral costs and results.

An important boundary condition for the calculations is that the product 'outgoing' from the plant is bulk product (not packaged in any ways). Hence, the annual production costs do not include the costs of postharvest operations (storage, sorting, packaging), the labour operations cover only the operations of the 'production phase', and the physical journey of the product 'ends' with the costs of delivery to the postharvest plant site after or at the same time as the harvest, after simple mechanical sorting. The selling prices are therefore based on the bulk product (net producer price).

Using the data collection method described above, models and calculations could be constructed in which both the output side factors and the input side factors represent a realistic level of the average of the last 3 years. The other, variety-specific boundary

conditions are detailed for each version, but the interpretative framework is consistent as described above.

The data collected were processed using an Excel-based simulation deterministic model, similar to the work of APÁTI (2009) and SZÖLLŐSI (2008). The central element of the model is a technological operations sheet which details, in chronological order, the operations specific to a given production mode and aggregates the total direct production costs. A cost summary table by operation and a cost summary table by cost type are available to group the costs. A further table is then used to evaluate the results and efficiency of production management. The cost-benefit analysis is complemented by an investment profitability calculation. The sensitivity analyses can be run with additional variable parameters thanks to the dynamic model setup, which were defined using the @Risk 7.6 software package.

The analysis methods used are: cost-benefit analysis, investment-profitability analysis and sensitivity analysis (elasticity analysis, @Risk 7.6 standardised regression coefficient, sensitivity analysis, scenario analysis). The model developed is suitable for the treatment of yields and variations in input and output prices, and thus for complex cost-benefit analysis and investment-profitability analysis and sensitivity analysis.

Production costs and production values were used to calculate cost, value and income categories and efficiency indicators at different sectoral levels. These were evaluated and interpreted to determine the effectiveness, efficiency and profitability of the given production mode.

No direct production subsidies are associated with shoot production and therefore no such subsidies have been included in the calculation. A number of indicators are available for assessing the economic efficiency of investments, but for making economically sound decisions, several authors (HORVÁTH 1997; PFAU 1998; TÉTÉNYI 2001;) emphasise dynamic investment-economic indicators, which, unlike static indicators, take into account the time value of money.

According to CASTLE - BECKER - NELSON (1992) and BREALEY - MYERS (2005), one of the most widely used and applied methods for analysing investment is the net present value method. Following the cost-benefit analysis and the investment-economic analysis, sensitivity analyses have also been carried out for the complex economic evaluation. In the elasticity analysis, the factors that have the most significant impact on the selected profitability indicator are ranked. The elasticity test shows the extent to which a 1% positive change in a given factor leads to a

change in output. For the calculations, the 10 most influential input factors were identified and used as the input variables in the @Risk 7.6 software package.

The critical value test seeks to answer the question of what yield, quality and price conditions are required to meet the minimum level of long-term profitability in a given business environment and production technology (APÁTI 2015). The impact factors for the critical value test were determined based on the results of running the applied simulation model (@Risk 7.6) in the analysis.

Scenario analyses can be used to develop different plan versions (optimistic, average, pessimistic) to examine the impact on profitability if some elements of the economic environment are more or less likely to evolve favourably or unfavourably than expected.

An important principle for the data processing was that the unit of measurement, i.e., the projection dimension of the results, was 1 hectare, a unit technology in which it is useful to express the economic conditions of the farm. For the purpose of interpreting the calculations and the results, it should be pointed out that the unit prices of the collected inputs are always net sales prices, i.e., VAT is not included.

As general costs (overheads) are not included in the calculations as a matter of principle in the sectoral analysis, the investment-economy analyses and sensitivity analyses are also of sectoral level and therefore do not include overheads.

For the calculations of investment profitability, the imputed interest rate was determined as an average of the reference yields of long-term government bonds observed in recent years, and was set at 5%. By determining the imputed interest rate, the reference rates of the following government bonds were considered: Premium Hungarian Government Bond with 5-year maturity (6.6%), Bonus Hungarian Government Bond with 5 and 10-year maturity (4.13%-3.54%) and 2 types of government bonds with 10 and 15-year maturity (3.2%-3.49%; 5.96%-5.91%). The average yield of the government bonds under consideration was 4.9%, so the imputed rate was included in the analysis at 5%. The useful lifespan of the investments for the production mode under consideration is 20 years. The calculation of the efficiency indicators also complements the analysis, which relate to profitability in general, but more detailed indicators cover the capital and labour efficiency of the production equipment.

The most widely used methodology for measuring comparative advantage in relation to competitiveness is the Balassa index, which, although it has been the subject of much

criticism, is still the most commonly used indicator (FERTÓ, 2006). The methodology used in this research is the Revealed Comparative Advantage (RCA) index group. The index was first published by BALASSA (1965), with the following formula:

$$B_{ij} \text{ or } RCA_{ij} = \left(\frac{X_{ij}}{X_{it}} \right) / \left(\frac{X_{nj}}{X_{nt}} \right)$$

where X denotes export,

i, denotes a given country,

j, denotes a given product,

t, denotes a given product group,

n, denotes a given group of countries.

The value of the indicator may vary from 1 to infinity, but if the value of the indicator is between 0 and 1, the country under study has no comparative advantage. According to BOWEN (1983), the classical B-index is not in itself a suitable measure of comparative advantage, as it does not take into account trade distortions and economic policies. The Balassa index was complemented by VOLLRATH (1991) with the creation of three new indices for the import side. These indices are as follows

Relative trade advantage index (RTA)

$$RTA_{ij} = RXA_{ij} - RMA_{ij}$$

where $RMA_{ij} = RCA_{ij}$ or B_{ij} , where

$$RMA_{ij} = \left(\frac{m_{ij}}{m_{it}} \right) / \left(\frac{m_{nj}}{m_{nt}} \right) \text{ where } m = \text{import value}$$

This is the import side pair of the Balassa index. If the value is above 0, it represents a commercial advantage; the higher the value, the more competitive the area under investigation.

- Logarithm of the relative export advantage index (lnRXA)
- Relative Competitiveness Index (RC):

$$RC_{ij} = \ln RXA_{ij} - \ln RMA_{ij}$$

The findings of FERTÓ (2006) are summarised as follows. The combination of the four indicators completes the measurement of comparative competitive advantage. The indicators can take the following values. A country has a competitive advantage relative to a given country or group of countries if the conditions B (or RCA) > 1 , or $RTA > 0$ and/or

$\ln R_{XA} > 0$, and/or $RC > 0$ is/are fulfilled. Otherwise, it has a comparative disadvantage. Otherwise, it has a comparative disadvantage.

Economic decisions require information that is well collected and properly organised. In many cases, farmers do not have sufficient information to make a decision related to a possible improvement or change in production technology. The factors that influence the outcome of the farm and the outcome of economic decisions for farmers are not always known, whether they are external or internal (HARDAKER et al., 1997; DRIMBA, 1998a). Decisions about the future should be made with only information that is relevant to the past (BUZÁS, 2000). Simulation methods that allow a more accurate understanding and characterisation of reality are becoming increasingly common in agriculture. Simulation is an experiment that aims to create conditions that correspond to the conditions of reality, in order to explore the probability and the expected evolution of the phenomenon under study. Simulation procedures allow us to quantify the degree of error and risk. (SZÓKE et al., 2009) The main objective was to simulate the annual performance and expected outcomes of the model farm and to identify the factors that have the greatest impact on the evolution of sectoral income.

A simulation model is a mathematical implementation of a real, existing system that is designed to illustrate changes in various conditions and circumstances. The simulation procedure involves running the model over time, providing a representative sample of performance indicators that describe the system. (WINSTON, 1997) Stochastic and deterministic models are available to perform the analysis. Deterministic models do not account for randomness. Risks are usually analysed using the Monte Carlo¹ method, the most widely used technique. Basically, the method consists of randomly selecting values based on a probability distribution assigned to uncertain factors, which are used in the simulation (RUSSEL – TAYLOR, 1998).

The study was performed using the @Risk 7.6 simulation software. Input and output factors were determined to run the simulation model. The inputs were the following based on the

¹ Monte Carlo method: the Monte Carlo method is a special simulation method that uses elements of probability and statistics and then numerically evaluates the results. The method is essentially based on random sampling, which can be used to estimate definite integrals for a large enough sample, can be used to estimate certain risk factors in economics, and can be used for a variety of simulation estimations (SIPOS, 2016)

results of the elasticity test: yield, average selling price, depreciation cost, personnel cost, liquid carbon-dioxide cost, seedling cost, nutrient (fertilizer) management (input) cost, thermal water cost, biological pest control cost and finally growing medium cost. The output data were: specific gross margin (HUF/kg), revenue (HUF/ha), gross margin (HUF/ha), total direct production costs (HUF/ha).

The input data can be considered as probability variables with a triangular distribution. In this case, we know the minimum, maximum and most typical values (EVANS et al., 2000). For prices, the minimum value was a decrease of 10.4% from the original price and the maximum was an increase of 10.5%. For yields, it was the average of the worst and best results of the period under study. Personnel costs, plant protection products and other materials were as follows compared with the values used in the calculation. For the minimum value I have assumed a decrease of 5%, but for the maximum value I have assumed an increase of 40%, as recent events suggest that a decrease in input materials and personnel costs is less likely than a continuation of the price increases that have already started. I also applied a triangular distribution for fertilizer management. In this case, the most probable value was the value of the calculation, the minimum value was 95% of the value used in the model, and the maximum price was 150% of the average price. For all input variables, the greater bias towards the maximum price is due to the greater likelihood of an increase in the prices of fertiliser and machinery services, given past practice, i.e., in 2021. The chances for a decrease are relatively small. The simulation experiments were carried out with 10 000 repetitions.

Similar to the analysis of SZŐKE et. al. (2009b), a sensitivity analysis was performed for the main output data. Sensitivity testing was performed using standardized regression coefficients. The standardised regression coefficient (β) is a statistical indicator of the effect of the explanatory (input) variable obtained when both dependent and explanatory variables are used in a standardised form rather than in their original units of measurement (MOKSONY, 2006), the significance of which is that it reflects the ranking of importance of the explanatory variables regardless of the unit of measurement (HAJDU, 2003). Thus, the standardised regression coefficient could be used to rank the input factors affecting a given output variable.

3. MAIN FINDINGS OF THE THESIS

In my thesis, I present my conclusions and recommendations on the main and specific objectives set out in the topic and objective chapters, in the order of the relevant section of the chapter. I will also present the test of my hypotheses, their confirmation or rejection.

1. Assessing the competitiveness and comparative advantage of domestic tomato production at the macroeconomic level, based on external trade performance.

Focusing specifically on vegetable trade, the most important vegetable exporters in the EU-28 are Spain and the Netherlands. Hungary is 10th in this ranking. The top importers are Germany, the United Kingdom and France. Hungary is 18th in this ranking.

Table 1. Balassa index of examined countries (2004-2020)

RCA	2004-2020 average	2015-2020 average	2010-2014 average	2004-2009 average
Hungary	0.07	0.09	0.07	0.03
Spain	1.18	1.02	1.19	1.32
Netherlands	1.80	1.84	1.77	1.79
France	1.09	1.43	1.13	0.71
Greece	0.09	0.14	0.12	0.02
Belgium	0.75	0.81	0.67	0.76
Italy	0.43	0.33	0.46	0.49
Germany	0.26	0.21	0.24	0.32
United Kingdom	0.16	0.14	0.16	0.19
Poland	0.45	0.40	0.49	0.47

Source: based on FAO data, own compilation (2022)

Most important tomato producing countries: Italy (6.2 million tonnes), Spain (4.3 million tonnes), Portugal (1.4 million tonnes), the Netherlands (~1 million tonnes). These four countries account for almost 80% of total production. In 2020, 2.6 million tonnes of tomatoes will be imported into the EU, representing an import value of USD 4.3 billion. When looking at the export side, it can be seen that in 2004, 2.2 million tonnes of tomatoes were exported from the EU, a volume that has been steadily increasing over the period under review (2004-2020), reaching 4.2 million tonnes in 2020.

The external trade data and results show that Hungary does not have a comparative advantage in relation to the EU-27. The results of the period under review clearly show that in the short and medium term (3-5 years), we will not have a comparative advantage over the countries under review in terms of tomatoes as a fresh market product. Nevertheless, in

my opinion, in order to increase competitiveness and achieve an improved market position, it is essential to promote technical and technological improvements, which would improve the sector's current position through higher yields and would provide an opportunity for greater penetration of foreign markets in addition to the domestic market.

In line with this specific objective, based on the competitiveness analysis, I consider my hypothesis **H1** that Hungary does not have a comparative competitive advantage over the EU-27 countries in terms of fresh market tomatoes to be accepted, i.e., **confirmed**.

2. Assessment of the capital efficiency of the different technical and technological varieties currently available and considered state-of-the-art in the domestic context, for truss (round) and snack tomato varieties.

In order to answer the specific objective, it is necessary to distinguish between the type and the technical and technological variation of the cultivation equipment under consideration. Furthermore, the variety grown under a particular production equipment, as there can be significant differences depending on whether a traditional truss tomato (round) or a snack tomato variety is grown in a particular greenhouse.

In the case of a normal glass covered greenhouse, under which fresh-market truss (round) tomatoes are grown according to the first variant, favourable results in terms of plant efficiency can be observed. The production cost per hectare of greenhouse was 126,475 thHUF/ha. In this variant, the yield that could be obtained was 60.3 kg/m². Material costs represent 50.4% (63,742 thHUF/ha) of the total direct costs, while personnel costs represent 25.0% (31,635 thHUF/ha). The largest items in the labour operation costs are those related to depreciation (23,750 thHUF/ha) and planting (21,099 thHUF/ha).

Table 2. Results and efficiency of production
Truss (round) tomato in normal glass covered greenhouse

Name	Unit	Value/ha	Value/m ²	Value/kg
Specific yield	kg/m ²	60.30		
Mean selling price	HUF/kg	262.67		
TOTAL REVENUE	HUF	158,391,113	15,839.11	262.67
TOTAL DIRECT COST	HUF	126,475,273	12,647.53	209.74
GROSS MARGIN	HUF	31,915,841	3,191.58	52.93
Sectoral level cash-flow	HUF	55,665,841	5,566.58	92.31
Capital efficiency indicators (CCIs)				
Direct production cost	HUF/kg	209.74		
Direct cost proportional profitability	%	25.23		
Revenue proportional profitability	%	20.15		
Cost level	%	79.85		

Source: Based on own data collection, own compilation (2022)

Selling prices range from 160 to 480 HUF/kg depending on the season, with a seasonal average of 262.6 HUF/kg. The attainable revenue is 158,391 thHUF/ha. At sector level, the attainable income is 31,915 thHUF/ha and the cash flow at sector level is 55,665 thHUF/ha. For the indicators related to capital efficiency, the direct production cost is 209.74 HUF/kg and the direct cost proportional profitability is 25.23%. It should be noted that my previous research results (*with input prices in 2017-2018 and approximately 10% lower sales prices and also 10% lower yields*) showed significantly higher sector-level profitability, exceeding 35% in block plastic and greenhouse. The increasing input prices and investment costs have not yet been "caught up" by sales prices, and in my opinion, there is still biological potential in yields in relation to variety selection. As part of the doctoral thesis, a re-run of the earlier analyses was carried out: at the input prices and investment costs used in the present calculations, taking into account yield and selling price increases, block plastic has now become uneconomic, i.e. it has lost its competitiveness in tomato production.

The investment profitability studies showed that at an investment cost of HUF 47,500/m² and assuming a useful life span of 20 years, the investment is worthwhile to realize, as all the relevant dynamic indicators support this (*NPV: 218 719 thHUF/ha; IRR: 10%; PI: 1.46; DPP: year 12*). The investment should also be carried out with 50% subsidy, as in this case the above-mentioned indicators are even more favourable (*NPV: 456 000 thHUF/ha; IRR: 23.1%; PI: 2.9; DPP: 5. year*).

The most critical points of the activity were the evolution of yields and sales prices, since these factors had the greatest influence on the profitability of production (*standardised*

regression coefficient: price: 0.74; yield: 0.54). By far the greatest influence on the cost of production was due to changes in personnel costs and seedling costs (*standardised regression coefficient: personnel costs: 0.71; seedling cost: 0.41*). In the scenario analysis, the average and positive cases produced positive results, but in the pessimistic case the profitability of the activity would disappear, i.e. it would no longer be worthwhile to continue growing (Gross margin: - 6,389 thHUF/ha). The results of the critical value test suggest that a deterioration of only 20% in both sales prices and yields would be sufficient to make the activity unprofitable. The economic viability of investments is also affected by changes in the impact factors. The results for the average and optimistic versions are clearly positive. However, the values for the pessimistic scenario already suggest that it would not be worthwhile to carry out the investment under less favourable conditions (yield, price, personnel costs) than the current ones, with a NPV of -258,655 thHUF/ha and a payback period longer than the assumed useful lifespan. Looking at the critical values, we see that a yield and price decrease of 11.1% would already make the investment uneconomic, but the critical value of the investment cost would still - *ceteris paribus* - be able to withstand a deterioration of 369.5%.

The second technical and technological variation for fresh market (round) truss tomatoes was to test a diffuse glass covered greenhouse. The direct production costs were approximately 12% higher (143,557 thHUF/ha) than in the case of a normal glass covered greenhouse. The cost structure was similar for the different types of costs, with material (50.5%) and personnel costs (24.8%) being the most important. When looking at the work operations, I found that the largest item was the depreciation cost resulting from the high investment cost (19%; 27,250 thHUF/ha) as well as the cost of planting (14.7%; 21,109 thHUF/ha) and other operations (16.8%; 24,108 thHUF/ha). The cost of other operations also includes the cost of CO₂ fertilizer solution, which represents the largest share of the cost item. Thanks to the diffuse glass, the average yields are higher, with an average specific yield of 65.43 kg/m² over 3 years. This represents a yield increase of almost 10%.

Table 3. Results and efficiency of production
Truss (round) tomato in diffuse glass covered greenhouse

Name	Unit	Value/ha	Value/m ²	Value/kg
Specific yield	kg/m ²	65.43		
Mean selling price	HUF/kg	262.67		
TOTAL REVENUE	HUF	171,866,178	17,186.62	262.67
TOTAL DIRECT COST	HUF	143,557,070	14,355.71	219.41
GROSS MARGIN	HUF	28,309,108	2,830.91	43.27
Sectoral level cash-flow	HUF	55,559,108	5,555.91	84.91
Capital efficiency indicators (CCIs)				
Direct production cost	HUF/kg	219.41		
Direct cost proportional profitability	%	19.72		
Revenue proportional profitability	%	16.47		
Cost level	%	83.53		

Source: Based on own data collection, own compilation (2022)

The attainable revenue in this variant is 171,866 thHUF/ha, which is almost 14,000 thHUF higher than in the standard glasshouse.

However, the sectoral income is already lower than in the technological variant presented above, despite the higher yield and higher revenue, the additional costs mean that the activity realises a lower margin (Gross margin: 28,309 thHUF/ha). The figures converge at the level of the sectoral cash flow, where there is no relevant difference between the results of the two calculations (sectoral cash flow: 55,559 thHUF/ha). The efficiency indicators also deteriorate as a result of lower yield and higher costs, with a direct production cost of 219.41 HUF/kg, which is about 5% higher than in the normal glass covered system. The direct cost proportional profitability was found to be 19.72%. The investment-economy analysis concluded that the investment is worthwhile, with a NPV of 217,389 thHUF/ha. Between the two investments, while the investment capital requirement is 50,000 thHUF/ha higher for the more modern version, the difference in NPV is only 1,000 thHUF/ha and that too in favour of the standard glass. The results of the other dynamic indicators are slightly lower than those of the version presented earlier, but still clearly support the investment (*IRR: 9.9%; PI: 1.46; DPP: year 12*).

The investment-economy analysis was also performed in this case assuming 50% subsidy, where the results showed clear economic viability (*NPV: 454 889 thHUF/ha; IRR: 23.0%; PI: 2.9; DPP: year 5*). In the sensitivity analyses, the standardized regression coefficients for both the gross margin and the total direct production costs were the same as in the

previous model, i.e. the most significant variables were the same. Scenario analysis shows that in the pessimistic case, production is already loss-making, since the value of the gross margin is negative: -17,899 thHUF/ha. The efficiency indicators have also shifted in a negative direction. However, it can be concluded that a change in the negative direction in this version would result in a significantly higher loss (~65%). The results of the critical value analysis showed that a deterioration in yield and sales price of 16.5% would already make production loss-making, which is 4% points below the critical value of the normal glass plant, i.e., implying an operation of higher risks. This level of deterioration is certainly worth monitoring, as a plant disease or the appearance of a larger quantity of tomatoes on the market could result in such a drop in yield and price. Based on the calculations of the investment profitability, it can be concluded that the investment would no longer be feasible under the pessimistic scenario, neither with 100% self-financing (NPV: -358,470 thHUF/ha) nor with 50% (NPV: - 120,970 thHUF/ha), both cases with negative dynamic investment profitability indicators. The critical value analysis showed that with a deterioration of yields and sales prices of around 10%, the investment would be uneconomic.

In the third calculation, I examined the results of a normal glass covered greenhouse, but in this activity, I was no longer looking at the traditional (round), but the production of snack tomatoes, which are now in increasing demand. It should be noted that the snack tomato variety is not grown in diffuse glass covered greenhouses for botanical and biological reasons, so only the normal glasshouse version was analysed in this thesis.

The direct production costs would be most similar to the costs of the diffused glasshouse, also showing a direct production cost of 144,093 thHUF/ha. The high costs are basically due to the higher number of vines, which means that the live labour requirement is higher than for truss (round) tomatoes. While snack tomatoes have 4.8 vines/m², the maximum for truss tomatoes is 3.5 vines/m². There is no difference in the number of stems between the two varieties. Material and personnel costs account for the largest share of costs, with a combined share of 68.1%. The most significant items in the breakdown by work operations are the same as in the two previous studies, with planting (17.1%; 24,686 thHUF/ha), direct costs of other operations (17.0%; 24,555 thHUF/ha) and depreciation (16.5%; 23,750 thHUF/ha) accounting for the largest shares. A comparison of yields with the previous two versions is not relevant in this case, as we are talking about tomatoes with a size of 10-12

grams, so they can clearly produce much lower yields, but this implies higher selling prices. The average yield over 3 years was 21.3 kg/m², with an average selling price of 865.23 HUF/kg. The resulting revenue that can be attained is 184,293 thHUF/ha. The gross margin is 40,200 thHUF/ha, therefore the highest attainable profit in terms of sectoral income is in this activity. Examining the efficiency indicators, I found that the direct production cost is 676.5 HUF/kg and the direct cost proportionate profitability is 27.9%. This is highest of the 3 versions examined.

Table 4. Results and efficiency of production

Snack tomato in normal glass covered greenhouse

Name	Unit	Value/ha	Value/m ²	Value/kg
Specific yield	kg/m ²	21.30		
Mean selling price	HUF/kg	865.23		
TOTAL REVENUE	HUF	184,293,990.0	18,429.4	865.2
TOTAL DIRECT COST	HUF	144,093,196.5	14,409.3	676.5
GROSS MARGIN	HUF	40,200,793.5	4,020.1	188.7
Sectoral level cash-flow	HUF	63,950,793.5	6,395.1	300.2
Capital efficiency indicators (CCIs)				
Direct production cost	HUF/kg	676.5		
Direct cost proportional profitability	%	27.9		
Revenue proportional profitability	%	21.8		
Cost level	%	78.2		

Source: Based on own data collection, own compilation (2022)

The results of the investment profitability studies also supported the implementation of the investment in this night, with the highest NPV of 321,968 thHUF/ha. The cost of investment capital is the same as the boundary condition of the first version, so C₀ is not affected by variety. The other indicators are also very favourable, with an IRR of 12.1%, a PI of 1.68 and the shortest payback period in this case, DPP: 10 years. The results of the 50% investment subsidy were, of course, even higher.

The standardised regression coefficient in this activity also yielded the same results, with the largest variables being yield (0.81), price (0.33) and personnel costs (0.80). Reviewing the sensitivity analysis, I would again highlight the pessimistic scenario, as in this case the activity would not be economically viable either, but in this case the marginal amount would be only -1,256 thHUF/ha, so that the snack tomato would produce the smallest loss of the three cultivation variants studied. The sector can be considered more stable in the sense that the greatest deterioration in yield and selling price would be allowed here, as a reduction of 21.8% would only render production uneconomic. As regards the sensitivity analysis related

to the investment analysis, it should be pointed out that in the pessimistic case, a negative NPV would result for a 100% self-financed investment, but even in the pessimistic case, the investment would not be rejected even with a 50% investment subsidy, the NPV would be 42,819 thHUF/ha at the end of the useful lifespan of the investment.

The following main conclusions can be drawn from a comparison of the economic parameters of the three production methods analysed:

- The total cost of production of snack tomatoes was 144,093 thHUF/ha, which is the same as the cost in the diffuse glass covered growing system. The production cost of the normal glasshouse was 126,475 thHUF/ha. When looking at the total direct production costs, it can be seen that the more modern equipment (diffuse glass) is more costly for truss (round) tomatoes. One reason for this is the higher harvesting and maintenance costs due to higher yields (*31,272 thHUF/ha for diffuse glass; 27,697 thHUF/ha for normal glass*) and the higher consumption of liquid carbon dioxide (*17,791 thHUF/ha for diffuse glass; 11,525 thHUF/ha for normal glass*). Furthermore, the costs are strongly increased by the higher depreciation costs resulting from the higher investment costs, i.e., 27,250 thHUF/ha for diffuse glass and 23,750 thHUF/ha for standard glass.
- In terms of sectoral income, the most profitable is the production of snack tomatoes, with a yield of 40,200 thHUF/ha, 11,891 thHUF/ha higher than the production of tomatoes in diffused glass and 8,285 thHUF/ha higher than the production of tomatoes under normal glass (round). The value of direct cost proportionate profitability was also the most favourable for snack tomato cultivation, at 27.9%. The value of the indicator was 25.2% for normal glass covered cultivation and the least favourable under diffuse glass, at 19.7%.
- The investment capital requirement was 47,500 HUF/m² in normal glass covered installations, and it was higher for diffuse glass covered glasshouse, with 7,000 HUF/m². The results of the investment-economy analysis show that the highest NPV is obtained with the production of snack tomatoes, with an investment-economy index of 321,968 thHUF/ha, with almost identical results for the diffuse and normal glass covered greenhouse for truss (round) tomatoes. Also, in terms of the profitability index, the snack tomato performs best, with a value of 1.68, compared with 1.46 for

the other two versions. The IRR, i.e., the internal rate of return, is also the most favourable for the snack tomato (12.1%), 2% higher than for the other versions studied (10%). Also, in terms of payback periods, the results for truss (round) tomatoes are positive in the 12th year, while for snack tomatoes the NPV is positive as early as in the 10th year. All indicators would support the implementation of the investment in all three cases. There is no significant difference between the two versions of the truss (round) tomato cultivation, despite the 10% higher yields of the diffuse glass.

Therefore, I refused my H2 hypothesis which stated that "Among the variants tested, the snack tomato (under a normal glasshouse) has the most favourable capital efficiency, followed by the truss (round) tomato under diffuse glass and finally the truss (round) tomato under normal glass." I refute the ranking of the hypothesized ranking in terms of capital efficiency, since the results of snack tomatoes and normal glass covered greenhouses are the most favourable and the capital efficiency of the diffuse glass equipment is the least favourable.

3. Assessment of the labour efficiency of the different technical and technological variants currently available and considered state-of-the-art in the domestic context, for truss (round) and snack tomato varieties.

My previous comprehensive analyses have shown that the more modern the growing equipment, the less labour was required for each (completely different) technological variant: the large airspace block plastic has a much better labour efficiency than the plastic tent, and the greenhouse has a more favourable labour efficiency than the block plastic. This thesis is now only concerned with glasshouse production activities and their different technical variants, but in this case the differences in labour use are not so marked.

Table 5. Labour efficiency indicators*Truss (round) tomato in normal glass covered greenhouse*

Name	Unit	Value/ha
Direct production cost	HUF/kg	209.74
workhours per 1 ha	workhours/ha	15,209.50
wages per 1 ha	HUF/ha	31,635,760.00
workhours per 1 kg crop	workhours/kg	0.03
wages per 1 kg crop	HUF/kg	52.46
workhours per 1 mill. HUF (GM)	workhours/1MHUF	476.55
wages per 1 mill. HUF (GM)	HUF/1MHUF	991,224.40

Source: Based on own data collection, own compilation (2022)

For the standard glass covered truss (round) tomato, the quantity of workhours used is 15,210 workhours/ha, which can be directly allocated to the production, at a cost of 31,635 thHUF/ha in personnel. Among operations, the highest workhour requirement is that of plant care (44.6%) and harvesting (42.9%). Looking at the efficiency indicators, it can be seen that the workhour need per kg of crop is 0.03, which corresponds to a personnel cost of 52.46 HUF/kg. In terms of direct costs, this means that only personnel costs account for 25.01% of the total cost of 209.74 HUF/kg. To achieve a gross margin of 1 M HUF, 476.55 workhours are needed, which corresponds to a cost of 991 thHUF. In all the sensitivity studies, personnel costs were identified as an impact factor. A unit change in the personnel cost would result in a unit change of 0.35 for the gross margin and 0.78 for the direct production cost, based on the standardised regression coefficient. And in the critical value test, I conclude that the activity would become uneconomic only after a 100% increase in wages, which I do not think we should expect in the short run. However, the critical value analysis linked to the investment profitability analysis would only "allow" a 55% increase in wages, above which the investment would have to be abandoned. It is clear that wage developments could be a key determinant of the economics of investment in the near future. In the diffuse glass covered greenhouse study, the labour use of the truss (round) tomato is higher than the results of the greenhouse presented earlier. The amount of labour directly related to and used in production is 17,136 workhours, which corresponds to a personnel cost of 35,642 thHUF/ha.

Table 6. Labour efficiency indicators
Truss (round) tomato in diffuse glass covered greenhouse

Name	Unit	Value/ha
Direct production cost	HUF/kg	219.41
workhours per 1 ha	workhours/ha	17,135.63
wages per 1 ha	HUF/ha	35,642,100.00
workhours per 1 kg crop	workhours/kg	0.03
wages per 1 kg crop	HUF/kg	54.47
workhours per 1 mill. HUF (GM)	workhours/1MHUF	605.30
wages per 1 mill. HUF (GM)	HUF/1MHUF	1,259,032.95

Source: Based on own data collection, own compilation (2022)

The higher number of hours worked is mainly due to higher yields. Plant care and harvesting are the operations requiring the largest amount of manpower, together accounting for 88% of total personnel costs. These two cost items represent 15,079 workhours per hectare per growing season. The efficiency indicators are deteriorating regardless of the fact that this technology is considered more modern. The workhour need per 1 kg of crop is 0,03, at a cost of 54,47 HUF/kg. To achieve a profit of 1 M HUF for the sector, 605.30 workhours are needed in this case, which already represents a personnel cost of more than 1,259 thHUF. The value of the standardised coefficient is 0.34 for gross margin and 0.76 for direct cost. The results of the critical value test for production and the investment-economy analysis are similar to those for the normal glass covered version. The sectoral revenue would be zero at 80% wage growth, while the investment would be rejected at 49% wage growth. In this technological version, the evolution of personnel costs is even more significant.

In the snack tomato study, the most favourable results in terms of capital efficiency were obtained among the three options considered. However, in terms of labour efficiency, the results were less favourable than for the truss (round) tomato in the case of several indicators. This tomato variety requires 17,796 workhours per hectare per growing cycle, with the highest work-hour use and thus resulting in the highest personnel costs (37,017 thHUF/ha).

Table 7. Labour efficiency indicators
Truss (round) tomato in normal glass covered greenhouse

Name	Unit	Value/ha
Direct production cost	HUF/kg	676.5
workhours per 1 ha	workhours/ha	17,796.9
wages per 1 ha	HUF/ha	37,017,563.3
workhours per 1 kg crop	workhours/kg	0.08355
wages per 1 kg crop	HUF/kg	173.8
workhours per 1 mill. HUF (GM)	workhours/1MHUF	442.7
wages per 1 mill. HUF (GM)	HUF/1MHUF	920,816.7

Source: Based on own data collection, own compilation (2022)

Again, the most significant items are related to plant care (48%) and harvesting (26%). Here, nearly 8,900 workhours of plant care work are due to the higher number of vines. However, moving on to the efficiency indicators, it can be seen that 0.08 workhours are needed to obtain one kg of crop, which represents a cost of 173.8 HUF/kg. Personnel costs represent 25% of the direct cost, similar to the two versions presented earlier. Only the amount of man-hours needed to achieve a gross margin of 1 M HUF could surpass the other two versions, here 442.7 workhours are needed to achieve 1 M HUF of sectoral income, which represents a cost of 920 thHUF. The snack tomato was the most affected by the adverse change in the marginal amount and direct production costs, based on the standardised regression coefficient (GM:0.40; DPC: 0.80). At the critical value, it can be observed that a deterioration of 108.6% for the activity would result in a zero marginal amount, while for the investment-economy tests, a deterioration of 3,532 HUF/hour of labour, i.e., a wage increment of 69%, would make the investment uneconomic.

With the use of live labour, all technological variants can be brought into line, i.e., this efficiency parameter is comparable between production methods. The highest labour input is observed for snack tomatoes (17,796 workhours/ha), 96% of which occurs under the diffuse glass covered truss (round) tomato (17,135 workhours/ha) and only 85% under the normal glass covered greenhouse (15,209 workhours/ha). The higher labour requirement of snack tomatoes is due to the fact that while the number of vines per m² is increased to 3.6 vines per m² for truss tomatoes, the number of vines per m² for snack tomatoes is 4.8 vines per m² or higher. Personnel costs are highest for snack tomatoes (37,017 thHUF/ha) due to differences in workhours.

When examining the use of manpower, the production of snack tomatoes has the lowest labour costs to achieve an income of HUF 1 million, since in this case the value is only HUF

920 million, while the highest is observed in the case of the diffuse glass greenhouse, where the value is HUF 1,259 million. In the case of a normal glass covered greenhouse, the wage cost per HUF 1 million of sectoral income is HUF 991 million. When examining the labour hours per income, it is clear that the lowest labour input is observed for snack tomatoes (442 labour hours per 1 M HUF Gross Margin). For the production of truss (round) tomatoes, the results of the normal glass covered greenhouse are more favourable than those of the diffuse glass. While in the first version 476 workhours are needed to achieve a gross margin of 1 M HUF, in the second version 605 workhours are needed to achieve a sectoral income of 1 M HUF.

My hypothesis (**H3**) related to the objective related to labour efficiency, which is: *'Among the variants tested, the most favourable labour efficiency is obtained by growing truss (round) tomatoes under diffuse glass, followed by truss (round) tomatoes under normal glass and finally snack tomatoes under normal glass'*, was **disproved** on the basis of the results.

The most favourable labour efficiency is obtained by growing snack tomatoes (*per sectoral income of 1 M HUF*), followed by truss (round) tomatoes under normal glass and the most unfavourable results were obtained by growing under diffuse glass.

Overall, while previous studies have shown better capital and labour efficiency as technology has improved, as early as 4-5 years ago, conventional greenhouse cultivation was already uneconomic. At that time, the case for block plastic equipment was clear, as it produced better results in terms of profitability than glasshouse, with investment costs at that time being around 40% lower. In connection with the thesis, and prior to that, recalculating my earlier results (now only for block plastic), it became clear that block plastic had become uneconomic in today's economic and growing environment, and that only greenhouses and their various technical-technological variants could be viable and suitable for investment. However, when looking at the results here, it is no longer clear that more modern technology also leads to better capital or labour efficiency.

In 2022, both input prices and sales prices in the sector increased at an unprecedented rate. For this reason, the assessment devotes a separate chapter to the results of the most recent market conditions. Sales prices for truss tomatoes increased by 22% and for snack tomatoes

by 30% compared to the period previously analysed (average in the 2019-2021 period). Labour costs increased by 15%.

Table 8. Production results and efficiency for each production technology (2022 data)

Name	Unit	Truss (round) tomato in normal glass covered greenhouse	Truss (round) tomato in diffuse glass covered greenhouse	Snack tomato in normal glass covered greenhouse
		Value/ha		
Specific yield	kg/m ²	60.30	65.43	21.30
Mean selling price	HUF/kg	320.46	320.46	1,124.80
TOTAL REVENUE	HUF	193,237,158	209,676,738	239,582,187
TOTAL DIRECT COST	HUF	180,200,792	204,355,692	205,196,614
GROSS MARGIN	HUF	13,036,366	5,321,046	34,385,573
Sectoral level cash-flow	HUF	45,536,366	42,571,046	66,885,573
Capital and labour efficiency indicators				
Direct production cost	HUF/kg	298.84	312.33	963.36
Direct cost proportional profitability	%	7.23	2.60	16.76
Revenue proportional profitability	%	6.75	2.54	14.35
Cost level	%	93.25	97.46	85.65
workhours per 1 ha	workhours/ha	15,210	17,136	17,796.91
wages per 1 ha	HUF/ha	36,381,124	40,988,415	42,570,198
workhours per 1 kg crop	workhours/kg	0.03	0.03	0.08
wages per 1 kg crop	HUF/kg	60.33	62.64	199.86
workhours per 1 mill. HUF (GM)	workhours/1MHUF	1,166.70	3,220.35	517.57
wages per 1 mill. HUF (GM)	HUF/1MHUF	2,790,741	7,703,075	1,238,025

Source: based on own data collection, own compilation (2023)

The biggest change on the input side occurred in 2022, when fertiliser prices were almost 160% and pesticides, energy and other materials on average 20-30% higher than input prices in the previous period (average of 2019-2021). Investment costs have also increased, by approximately 30-40% (normal glasshouse from 47,500 HUF/m² to 65,000 HUF/m²; diffuse glass from 54,500 HUF/m² to 74,500 HUF/m²), which are mainly reflected in the cost structure of newly established greenhouses as a higher cost item. Greenhouses built in the

past with lower investment capital requirements are essentially burdened by the old depreciation costs.

The yields for the cultivation versions examined show that the yields applied were the average yields of some of the former years, there were no significant variations from year to year. Sales prices have increased to varying degrees, to 320.46 HUF/kg for truss tomatoes and 1,124.80 HUF/kg for snack tomatoes. In terms of sales revenue, snack tomatoes produced the highest result, at around 240,000 thHUF/ha. The lowest direct cost is for truss tomatoes grown under a standard greenhouse, with a cost of 180,200 thHUF/ha. The other two versions under consideration have almost the same cost, approximately 205,000 thHUF/ha. The significant difference in the amount of gross margin is clearly visible, as the truss tomato performed the worst in the greenhouse with diffuse glass, with a value of 5,321 thHUF/ha. Truss tomatoes in normal glasshouses came second, with a sectoral profit almost three times as high (13,036 thHUF/ha) as the diffuse greenhouse. The most favourable result was for snack tomatoes, with a gross margin of 34,385 thHUF/ha.

Looking at efficiency indicators, it can be seen that the direct production cost is favourable in that it is below the selling price for all three versions. The lowest specific profit is achieved under the diffuse glass covered greenhouse. The profitability as a percentage of direct costs is low in all three cases, exceeding 10% only in the case of snack tomatoes. In terms of labour efficiency, the highest labour cost is observed for snack tomatoes (42,570 thHUF/ha), but in contrast, the labour cost per 1 M HUF was the most favourable in this version, at 1,238 thHUF/ha (Table 8)

Table 9. Results of investment-profitability analysis in case of different financing

Truss (round) tomato in normal glass covered greenhouse (2022 data)

Index	Types of investment* $r = 9.71\%$; $C_0 = 65,000$ HUF/m ² ; $t = 20$ years							
	Version 1	Version 2	Version 3	Version 4	Version 5	Version 6	Version 7	Version 8
NPV (thHUF/ha)	- 254,524	70,475	- 399,611	-202,882	- 153,080	22,113	87,689	104,290
PI	0.61	1.22	-1.46	-0.75	0.06	1.14	1.54	1.64
IRR (%)	3.50	12.70	- 4.10	0.90	2.60	11.00	15.50	16.70
DPP (year)	>20.	13.	>20.	>20.	>20.	18.	12.	11.

Source: Based on own data collection, own compilation (2023)

*Version 1: 100% self-finance

Version 2: 50% self-finance - 50% non-refundable subsidy

Version 3: 25% self-finance - 75% market rate loan (17% rate) – 10-year term

Version 4: 25% self-finance - 75% subsidized loan (7.7% rate) – 10-year term

Version 5: 25% self-finance - 75% Agrár Széchenyi Beruházási Hitel Max+ (5% rate) – 10-year term

Version 6: 25% self-finance - 25% market rate loan (17% rate) – 50% non-refundable grant - 10-year term

Version 7: 25% self-finance - 25% subsidized loan (7.7% rate) – 50% non-refundable grant - 10-year term

Version 8: 25% self-finance - 25% Agrár Széchenyi Beruházási Hitel Max+ (5% rate) – 10-year term

Investment-efficiency studies are essential for a comprehensive analysis of a sector. An increase in investment costs in the magnitude of 15-20% was also observed in 2022. Taking into account the market and economic situation, the calculations were made at an imputed interest rate of 9.71%, which are the benchmark yields for current long-term government bonds (5-15 years).

The investment-economy calculations assume several financing scenarios. It can be clearly seen that only the last three versions produce a positive NPV, and that the additional indicators would support the investment only in these last three cases.

Overall, it can be concluded that the significant increase in input prices and the increase in investment costs could not be sufficiently dampened by a sales price growth of 20-25%, resulting in a significant deterioration in profitability, which clearly shows that the realisation of the investments has become practically unthinkable without non-refundable subsidies.

Table 10. Results of investment-profitability analysis in case of different financing
Truss (round) tomato in diffuse glass covered greenhouse (2022 data)

Index	Types of investment* $r = 9.71\%$; $C_0 = 74,500$ HUF/m ² ; $t=20$ years							
	Version 1	Version 2	Version 3	Version 4	Version 5	Version 6	Version 7	Version 8
NPV (thHUF/ha)	-375,277	-2,777	-541,570	-316,088	-259,007	-58,208	16,952	35,979
PI	0.50	0.99	-1.91	-0.7	-0.39	0.69	1.09	1.19
IRR (%)	1.30	9.60	-6.8	-2.4	-0.8	6.6	10.7	11.8
DPP (year)	>20.	>20.	>20.	>20.	>20.	>20.	18.	16.

Source: Based on own data collection, own compilation (2023)

*Version 1: 100% self-finance

Version 2: 50% self-finance - 50% non-refundable subsidy

Version 3: 25% self-finance - 75% market rate loan (17% rate) – 10-year term

Version 4: 25% self-finance - 75% subsidized loan (7.7% rate) – 10-year term

Version 5: 25% self-finance - 75% Agrár Széchenyi Beruházási Hitel Max+ (5% rate) – 10-year term

Version 6: 25% self-finance - 25% market rate loan (17% rate) – 50% non-refundable grant - 10-year term

Version 7: 25% self-finance - 25% subsidized loan (7.7% rate) – 50% non-refundable grant - 10-year term

Version 8: 25% self-finance - 25% Agrár Széchenyi Beruházási Hitel Max+ (5% rate) – 10-year term

It can be concluded that, given the investment cost of the diffuse glass covered greenhouse and the deteriorating profitability conditions, only non-refundable subsidies would make the investment worthwhile. However, even with the non-refundable subsidy, the NPV would still only be positive with the two loans with more favourable interest rates. The results of the dynamic investment economic indicators all support the view that only versions 6 and 7 are viable. In these two cases, the dynamic investment-economy indicators only just exceed the acceptance criterion (*Table 10*).

Overall, it can be concluded that, although the cultivation of truss tomatoes under diffuse glass covered glasshouse can achieve a positive result at the sectoral level under the studied

marginal conditions, the overall costs of the cultivation could not be covered by the production. For this reason, the investments in this version of the production can only be made with a high level of subsidies and loans at favourable interest rates.

Table 11. Results of investment-profitability analysis in case of different financing
Snack tomato in normal glass covered greenhouse (2022 data)

Index	Types of investment* $r = 9.71\%$; $C_0 = 65,000$ HUF/m ² ; $t = 20$ years							
	Version 1	Version 2	Version 3	Version 4	Version 5	Version 6	Version 7	Version 8
NPV (thHUF/ha)	-69,109	255,890	-214,197	-17,468	32,333	207,527	273,104	289,704
PI	0.89	1.79	-0.32	0.89	1.20	2.28	2.68	2.78
IRR (%)	8.10	20.00	2.3	8.9	11.2	22.4	27.7	29.2
DPP (year)	>20.	7.	>20.	>20.	18.	8.	5.	5.

Source: Based on own data collection, own compilation (2023)

*Version 1: 100% self-finance

Version 2: 50% self-finance - 50% non-refundable subsidy

Version 3: 25% self-finance - 75% market rate loan (17% rate) – 10-year term

Version 4: 25% self-finance - 75% subsidized loan (7.7% rate) – 10-year term

Version 5: 25% self-finance - 75% Agrár Széchenyi Beruházási Hitel Max+ (5% rate) – 10-year term

Version 6: 25% self-finance - 25% market rate loan (17% rate) – 50% non-refundable grant - 10-year term

Version 7: 25% self-finance - 25% subsidized loan (7.7% rate) – 50% non-refundable grant - 10-year term

Version 8: 25% self-finance - 25% Agrár Széchenyi Beruházási Hitel Max+ (5% rate) – 10-year term

In this case, the calculations of the investment economics have also been completed. I assumed an investment in a normal glass covered greenhouse, but in this production alternative, with this variety of tomato, I could calculate a more favourable profitability. The financing cases for the investment were the same as for the truss tomatoes.

In the case of snack tomatoes, it was observed that in more than half of the cases outlined, the investment would have a positive NPV. A 100% self-financed installation would result in a loss (NPV) of 69,109 HUF, with no return on investment over the assumed useful lifespan. Similarly, the results of the dynamic investment indicators in versions 3 and 4 support the assumption of no investment. Both cases are characterised by negative NPV, a payback of more than 20 years and an IRR of less than 9.71%. These versions assume 25% self-finance and 75% loan.

The versions where a 50% grant (non-refundable subsidy) is included in addition to self-finance and/or loan have produced more favourable results. In version 2 we see favourable results, here we would recover our investment in the 7th year and realise a profit of 255,890 thHUF/ha. In versions 5, 6, 7 and 8, a 25% loan is shown with different interest rates. As the interest rate on the loan taken decreases, the profit on the investment increases. For the lowest interest rate loan (without subsidy) the NPV is already positive at 32,333 thHUF/ha. With the grant and the highest interest rate loan, the NPV would be 207,527 thHUF/ha, with

the same financing rate but at the lowest interest rate, the NPV exceeds 289,704 thHUF/ha (*Table 11*).

Overall, it can be concluded that snack tomato production is profitable at sectoral level, that the investment is largely economical, and that profitability has not deteriorated to such an extent due to the sharp rise in input prices that it would become not worthwhile to install a greenhouse for the production.

In my view, a very important aspect of a complex assessment of competitiveness is that more modern cultivation technology or production methods are not necessarily introduced into cultivation just to increase efficiency, but are used to increase the volume of products, serve the market more reliably, get to market early and sell (stay on the market) for as long a season as possible in conjunction with higher or earlier yields.

4. NEW OR NOVEL RESULTS OF THE THESIS

1. I **elaborated** models for the economics of different technical and technological variants (normal glasshouse and diffuse glass greenhouse) and different tomato varieties (truss (round) tomatoes and snack tomatoes), which are suitable for the analysis and comparison of the different production methods. The model is able to take into account possible changes in economic, environmental and production technology through related sensitivity studies. A simulation model was used to determine the factors with the greatest impact on sectoral income and direct production costs.
2. I **determined** the cost and income ratios, income generating capacity and efficiency, and economic viability of each version based on primary data collection.
3. I have **established** the evolution of capital and labour efficiency of each version using natural and economic parameters and dynamic investment-economic indicators, and have shown the differences between them.
4. I have **found** that the most favourable version in terms of capital and labour efficiency is the cultivation of snack tomatoes in a normal glass covered greenhouse, while the least favourable is the cultivation in a diffuse glass covered greenhouse, which is considered more modern.

5. PRACTICAL USABILITY OF THE RESULTS

In the domestic context, current research and farm economics calculations specifically focused on greenhouse farming are not available that would examine the fresh market tomato sector from the perspective of competitiveness, capital and labour efficiency. For this reason, I consider the farm-level studies carried out to be incomplete.

The results will reveal the current situation of the sector, areas for improvement, the viability of technical and technological changes and will also help to identify future opportunities. The thesis and the studies carried out can make a significant contribution to the segment that is to be developed in the future.

The results of the research and the correlations that emerge from the studies will help farmers to make investment decisions and to decide on development directions in relation to cultivation.

In the field of education, the results of the thesis will contribute to the extension of the knowledge taught in the field of farm business analysis of agricultural sectors based on the tradition of the Debrecen School of Farm Management. They can be integrated into the curricula of the subjects Economics of Industries and Farm management.

In addition, I consider it necessary to carry out further studies to determine the impact of the type of use of each type of technical and technological production equipment on the competitiveness of the activity, its income-generating capacity and capital and labour efficiency.

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6. LIST OF OWN PUBLICATIONS ON THE TOPIC



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MTMT ID: 10067082

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