Factor proportions in ensuring the economic resilience of the Egyptian sugar industry

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Abstract. The sugar industry plays an important role in ensuring the economic and food security of Egypt. However, when elaborating plans for its development, it is not taken into account that the decisions made may affect the factor proportions that link the resource potential and production capabilities of the system, and lead to a violation of resilience. As part of our study, we consider the issues of providing resilience to the sugar industry, which enables us to focus on its ability to ensure the continuity of reproduction processes on a constant or increasing scale in the face of changing environmental factors. This article aims at presenting a toolkit for measuring how a change in factorial proportions in the sugar industry will affect the level of its economic resilience. The study proposes the use of a parametric relative break-even model to calculate break-even production conditions. In this paper, we considered factorial proportions between the three main parameters (price, cost, sales volume) that determine the relative break-even of production. We identified factors, which carry both risks and opportunities for the resilience of the Egyptian sugar industry: changing world demand for sugar; world sugar prices adjustments; etc. The results show that the put-forward model enables to anticipate the after-effect of managerial decisions at the stage of elaborating plans for the development of the sugar producing industry in terms of their impact on resilience in altering market conjuncture.

1 Introduction

The industry of sugar producing is one of the critical sectors of the Egyptian economy. It is an important source of foreign exchange earnings and provides a significant contribution to Gross Domestic Product (GDP). So, in 2021, Egyptian exports of sugar and sugar confectionery amounted to 307.67 million US dollars (5.6% of total exports) [1].

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to the International Sugar Organization (ISO), Egypt currently produces 1.47% of world sugar production. However, despite the significant volumes of sugar production, due to the large volumes of its domestic consumption by the population for personal needs and in industrial food production, more than 20% of consumed sugar is exported from other countries [2]. Therefore, the resilient development of the sugar industry is of great importance for Egypt, ensuring its economic and national security. High dependence on sugar exporting countries poses a threat to the strategic interests of Egypt’s socio-economic development, as it creates risks of increased political subordination.

The income of more than 500 thousand families depends on the activities of sugar industry enterprises in Egypt, as well as related industries. Therefore, the resilience of sugar industry development is important for the Egyptian economy in terms of maintaining the economic and food security of the country.

The ongoing health education companies and activities lead to curbing sugar consumption per person, the projected population growth in Asia and Africa enables to predict that the total sugar consumption in the world will not decrease. Therefore, the main sugar-producing countries continue to consider the possibility of increasing the volume of sugar production. In Africa, expectations of sugar production growth are largely associated with Egypt. In 2021, the Egyptian Government allocated 76 thousand hectares for a project aimed at increasing the acreage of sugar beet and introduced some measures in order to increase the yield of sugar cane and sugar beet [3]. However, unstable sugar prices due to the abolition of their minimum value in 2017, high production costs, worn-out infrastructure, as well as a high level of competition in the world market pose significant risks to the resilient development of sugar industry in Egypt.

Resilient development of the sugar producing industry requires developing interactions between value chains and production and supply chains. Such interactions involve the use of a variety of business models that “lengthen” or “broaden” the value chain [1].

The concept of resilient and balanced development, which forms the basis of the author's research, is based on the adaptive type of stability of the socio-economic system - its ability not only to respond to emerging external influences, but also to carry out certain proactive actions by anticipating or forecasting the emergence of possible challenges. Achieving such resilience is possible only if there are certain factor proportions connecting the resource potential and production possibilities of the sugar industry.

Accordingly, this article is aimed at presenting a tool for measuring a change in factor proportions in the sugar industry will affect the level of its economic resilience. The author's hypothesis is that the factor model which defines the boundary of the relative break-even of production enables to predict the consequences of managerial decision-making for the economic resilience of the sugar industry.

2 Review of references

Analysis of scientific sources shows that the term “resilient development” is currently represented by more than 100 definitions, which can be divided in the groups on the basis of the highlighted aspect. The first group comprises definitions that emphasize the economic aspect: this approach is typical for researchers in industrialized countries. The emphasis on the economic aspect is reflected in the willingness to provide significant and permanent reductions in the consumption of energy and economic resources, as well as in promoting radical changes in the prevailing lifestyle of the population especially concerning consumption and production.
The second group includes definitions that emphasize the social and humanitarian aspect: sustainable development is considered as “a comprehensive process that is
developed based on comprehensive planning of various economic and social aspects of society."

The third group embraces definitions that focus on the technical aspect, highlighting the need to use “clean production” technologies that are resource-saving and minimally pollute the environment.

When studying the parameters of development of the sugar producing industry, researchers often consider the issue of ensuring resilient development of the entire industrial ecosystem of enterprises and organizations. The resilience of the sugar producing is associated with new paradigms and trends: bio-generation, ecological chemistry, closed-cycle economics, etc. Most often, researchers consider the ecological framework of the sustainability of the industry [2-4]. At the same time, scientists associate the sustainability of the sugar industry with technological capabilities that determine the volume of use of natural resources and, as a result, the level of impact on the environment. As H. Aguilar-Rivera notes the sustainability of the sugar industry “is the result of the interaction of technologies, the suitability of land, the environment, management methods, the use of by-products, socio-economic and geographical constraints of stakeholders” [5, p. 149].

In order to increase the sustainability of the sugar industry, researchers are considering the possibilities of implementing various closed-cycle economic models involving industrial symbiosis for the valorization of waste and by-products of sugar [6, 7]. For example, given the high energy intensity of sugar production as an alternative energy supply, the possibilities of using sugar production waste are being considered [8, 9].

In contrast to the term sustainability, the term resilience is used in the study of the ability of the economic system to ensure growth in the conditions of emerging shocks and disturbances of various nature (financial and geopolitical crises, coronacrisis, etc.). The study of resilience of economic systems is based on the theory of equilibrium, according to which a stable system is characterized by the ability to maintain an equilibrium state in conditions of shocks or absorb disturbances and move to a new state of equilibrium. Within this study the authors consider the issues of ensuring the resilience of the sugar producing industry, which enables us to focus on its ability to ensure the continuity of reproductive processes on a constant or increasing scale in conditions of changing environmental factors.

Static and dynamic methods are used to assess economic resilience. Static methods are based on the assumption that the factor proportions linking the resource potential and production capabilities of the system are considered as constant values. Accordingly, the static resilience of the sugar industry can be achieved in a balance of supply and demand in the sugar market. Various static methods of analysis are often used in studying factors affecting the development strategy of agricultural enterprises. However, for the economic system the dynamic state is more significant than the static one, i.e. the state of the developing system. Dynamic resilience is provided by rational factor proportions that determine the dynamics of production capabilities.

The authors suggest that the concept of sustainability is very multifaceted and maintaining sustainability should be associated both with the idea of ensuring a balanced development of economic, social and environmental subsystems, and with the concept of adaptability. In spite of the fact that sustainable “green” development and resilient development are two different concepts, their main provisions can be integrated into the mechanism for resilient development of the sugar industry that we are developing. This enables us to consider the resilient development of the sugar industry as its ability to...
influence the break-even of production in conditions of constant changes in environmental factors, to ensure socio-economic efficiency and environmentally friendly production.

The parameters of development of sugar producing industry are determined by such indicators as: the number of sugar factories and their productivity; the level of sucrose extraction; the average duration of the production cycle; losses in bagasse, molasses and filtered sludge, waste volumes, etc. [10]. These parameters depend on the technological features of sugar production, while the influence of the relationship between the technological and economic activities of sugar production on Resilience is not considered. However, it is precisely these relationships, expressed in factor proportions, that determine the possibilities of achieving dynamic Resilience in the long term [11, 12].

Underestimation of the effect of changing factor proportions on the parameters of the dynamic equilibrium of the sugar producing industry increases the risk of making improper strategic decisions that will lead to a decrease in its Resilience. This increases the relevance of our research, which is aimed at filling this gap.

3 Methods and data

To assess the influence of internal factor proportions on the dynamic Resilience of the sugar industry, we propose to use a parametric model defining the boundary of the relative break-even of production, developed by Yu. Bogatinym, V. Shvandar [see 11]. That is, the relative break-even indicator reflects the possibilities of industry economic growth in the conditions of ongoing changes, and, therefore, can be considered as a Resilience indicator.

The parametric model of relative break-even production looks like this:

\[ I = \frac{b(pd-g)+(1-r)(b-1-f)}{p-1} \]

where indicators b, p, d, g, r and f are defined as possible indices of changes in production profitability, price, cost, share of fixed and variable costs, respectively.

The conditions for maintaining break-even production for each parameter included in the model can be written as follows:

\[ d > \frac{bg+(p-r)-(1-r)(b-f)}{bp} \]

\[ g < \frac{bd-(p-r)+(1-r)(b-f)}{b} \]

\[ b > \frac{p-r+f(1-r)}{pd-g+(1-r)} \]

The authors consider these conditions as criteria for the resilient development of the sugar producing industry. If these conditions are not met, the state of the industry may be assessed as unstable. An indicator characterizing the level of resilience as a whole for all components will be defined as an index of compliance of the parameter’s actual value with the criterion one. At the same time, for the parameters of production volume and price, the excess of actual values over the criterion values reflects the resilience of development. Due to the presence of an inverse relationship the excess of the actual value over the criterion value reflects a low degree of costs stability; accordingly, when determining the index, its inversion should be carried out, i.e., the inverse value should be used.

Accordingly, the economic resilience index will be determined as the geometric mean value of the indices of compliance of actual parameters with their criterion values. The advantage of this model is its ability to determine the compensatory change of one factor in response to changing another factor to maintain a certain level of profit [13].
4 Research result

Sugar producing industry development in Egypt: the current condition and prospects.

Currently, Egypt produces about 2.5 million tons of sugar [14]. The share of people employed in the sugar industry is approaching 30%. In Egypt, the food processing sector contributes 24.5% of GDP and 23.2% of labor value added. Egypt's food industry exports increased to approximately $3.4 billion in 2019, achieving a growth rate of 10%, with an increase of $300 million compared to exports in 2018 ($3.1 billion). In 2020, Egypt's food exports rose to $2.6 billion. The volume of sugar production in the country is also increasing. So, in 2017/18 it amounted to 2320 thousand tons, and already according to data for November 2021/22 – 2855 thousand tons [15].

It is necessary to highlight that the pandemic and its after-effects have made the sugar producing industry one of the most important sectors for the Egyptian economy. The impact of the pandemic helped to realize the concept of self-sufficiency in sugar production, as many countries have taken measures to limit or stop food imports to cope with the demand of their citizens. In addition, during the pandemic, significant attention was paid to the development of interactions between sugar factories and local agriculture, which also contributed to strengthening the local economy.

Sugar exports reached their maximum in 2018, but in recent years it has declined slightly. The indicators of sugar exports and imports are shown in Figure 1. FAS Cairo predicts an increase in sugar production in 2022/23 by 2.5% (70 thousand tons) and bringing production volumes to 2.92 million tons. Figure 2 shows the volume of sugar production and consumption in Egypt over the past five years.
According to the statistical data over the recent years there has been a noticeable shift of Arab countries to approaching self-sufficiency in most food products, many of which have been exported, sugar products in this respect are not an exception. For example, in 2015, Egypt’s sugar self-sufficiency rate was 76.5%, in 2020 Egypt reached 80% self-sufficiency in sugar, in 2021–already at 89%, and the country plans to reach 100% self-sufficiency by 2030. This was a natural result of the government’s interest in stimulating the development of national sugar production.

In fact, domestic agricultural producers currently fully satisfy the demand for sugar raw materials.

Focusing on the idea that the resilience of the sugar producing industry implies maintaining the ability to ensure economic growth in the face of changing environmental factors, there can be identified the following main changes causing both risks and opportunities for the Resilience of the sugar industry in Egypt.

1. Changing global demand for sugar. FAO’s preliminary forecasts for the global sugar market indicate that sugar demand will grow, increasing by 1.9% after the decline associated with the coronacrisis. This is due to population growth, despite the current global trend of reducing sugar consumption per capita.

2. Changes in world sugar prices. According to FAO forecasts world sugar prices will rise. This is due both to fears of a reduction in its production against the backdrop of growing demand, and due to rising prices for ethanol, which contributes to the widespread use of sugar cane. Thus, in October 2021, sugar prices were 40% higher than in October 2020. According to analysts at Trading Economics, the expected increase in sugar prices in 2022 will be about 6% (from 18.73 to 19.84 cents per pound).

3. Changes in the costs associated with the need to modernize sugar production processes. The current condition of the Egyptian sugar producing industry is featured by high production costs, associated with the use of outdated equipment and steam boilers, as well as the uneconomical size of mills. The use of more modern equipment will reduce costs per unit of production.

4. Lagging production of sugar beets and sugar cane from production needs due to a decrease in sown areas or crop failure will not provide the production of sugar in the volumes required by the market. So, according to E.A. Bader’s research the elasticity of the response of net profit when the area of sugar cane and sugar beet lags is 0.57 and 0.40, respectively. Despite the increasing acreage of sugar crops, this risk may be due to the influence of natural and climatic factors, as well as a decrease in yield.

To analyze how these changes can affect the state of Resilience of the sugar industry, we will determine the boundaries of the relative break-even of production.
Relative break-even analysis of the sugar producing industry.

With the help of formulas 2–4, we will determine the conditions for break-even production of the sugar producing industry for the current economic condition. The values of the indicators for calculations are determined as follows (Table 1).

### Table 1. Indicators for calculating relative break-even production

<table>
<thead>
<tr>
<th>Indicator</th>
<th>Indicator value</th>
<th>Basis for establishing the value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rate of change in output and sales of finished goods</td>
<td>B1 = 0.025</td>
<td>in accordance with the projected growth of output by 2.5% to bring the self-sufficiency rate to 100%</td>
</tr>
<tr>
<td>Commercial output profitability ratio</td>
<td>P1 = 0.14</td>
<td>weighted average value of the profitability of sugar production</td>
</tr>
<tr>
<td>Ratio of change in sales price of commercial products</td>
<td>D1 = 0.06</td>
<td>in accordance with the projected price increase of 6%</td>
</tr>
<tr>
<td>Ratio of change in the cost of production under the influence of its variable components</td>
<td>g1 = annual change value is determined by research data (Bader, 2017)</td>
<td></td>
</tr>
<tr>
<td>Variable cost ratio in the base period</td>
<td>R0 = 0.75</td>
<td>according to the Sugar Association</td>
</tr>
<tr>
<td>Fixed cost change ratio</td>
<td>F1 = Let us assume that fixed costs will not change</td>
<td></td>
</tr>
</tbody>
</table>

The results of calculating the conditions for break-even production in the sugar industry are as follows (Table 2).

### Table 2. Results of calculating the conditions for break-even production

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Break-even condition</th>
</tr>
</thead>
<tbody>
<tr>
<td>P</td>
<td>d &gt; 1.21</td>
</tr>
<tr>
<td>C</td>
<td>g &lt; 0.83</td>
</tr>
<tr>
<td>O</td>
<td>b &gt; 1.40</td>
</tr>
</tbody>
</table>

The results obtained mean the following: Resilience of the Egyptian sugar industry in the long term, while maintaining current economic trends, can be ensured if the following conditions are met: an increase in world sugar prices of at least 21% with constant costs and production / sales volumes; reducing the cost of sugar production by at least 17% with constant prices and volumes of production / sales; a growth in volumes of sugar production / sales of at least 40% with constant prices for sugar and sugar production cost.

5 Discussion

To the authors’ perspective, the obtained values of the relative break-even parameters can be used as strategic guidelines for developing the national sugar producing industry under various scenarios taking into consideration the situation on the world sugar market. Based on the results obtained, we can offer the following recommendations that should be considered when forming a strategy for the resilient development of the sugar producing industry.

1. The prospects for increasing the resilience of the development of the Egyptian sugar producing industry are largely determined by the possibilities of the production process, 02009 (2024)
modernizing, which will enable: a) to reduce production costs; b) to decrease the level of production waste; b) to increase production volumes. Thus, there will be obtained not only economic, but also social and environmental effects.

2. Taking into account the risks of deteriorating sugar market conditions (increasing competition, falling prices, etc.), the prospects for the sugar industry development are largely related to strategic partnering initiative (including cross-country partnerships) that enable to stabilize supply chains, as well as get into new markets related not only to sugar products, but also to sugar by-products.

3. Working out measures and directions aimed at the strategic development of the sugar industry, it is necessary to take into account the resulting changes in the parameters of the development of the sugar industry, characterizing factor proportions, which will affect the resilience of its strategic development.

Thus, the given demonstration example of testing the proposed tools for assessing the resilience of sugar industry development shows its efficiency in solving the problems of identifying problematic measures and directions. Existing tools for assessing development sustainability are more focused on assessing the static state of sustainability, assuming that the factor proportions connecting the resource potential and production capabilities of the system are unchanged.

The possibilities of using a parametric model of relative break-even to determine Resilience parameters are demonstrated by a number of researchers when justifying the prospects for the development of the industry in a competitive world market [17–19].

The study enables us to assess the current safety margin of the sugar industry, as well as predict various scenarios for the development of the situation (when implementing modernization projects or when external factors change) from the point of view of their impact on Resilience.

The current safety margin of the sugar industry can be determined based on the calculation of the insurance ratio, which is determined by the ratio of the volume of sugar production to the volume of its sales, at which a break-even state occurs. To do this, let us transform formula (1). The resulting formula (5) reflects the safety margin of the sugar industry in terms of sugar sales volume.

\[ K_{b_b} = \frac{b(pd-g)+(1-r)b}{(p-1)+(1-r)(1+f)} \]

The projected growth in sugar production in the Egyptian sugar industry is 2.5% (b=1.025); the profitability ratio of sugar production is p=1.14; the cost of sugar production as a result of modernizing equipment and replacing steam boilers will decrease by 5% (g = 0.85), while fixed costs will not change (f = 1), and world sugar prices will increase by 10% (d = 1.1), then the insurance ratio for the relative break-even of coal mining production (with the established variable ratio value of 0.75) will be equal to 1.047. This means that the planned results of the development of the Egyptian sugar industry enable to create a certain margin of safety for the sugar industry. And if the volume of sugar sales due to various external factors decreases by no more than 4.7%, then the Egyptian sugar industry will maintain the state of Resilience.

The proposed model also enables to predict the consequences of making management decisions as part of the implementation of the development strategy of the sugar industry in terms of their impact on Resilience in various conditions (for example, when world sugar prices change). Thus, for example, if through modernization of equipment and the use of more advanced technologies, the cost of sugar production can be reduced by 5%, and world prices for sugar will increase by 10%, then to ensure break-even production it is necessary to increase production volumes by more than 16%. If we consider another scenario in which production costs are also reduced by 5% and sugar prices increase by 20%, then, for example, if through modernization of equipment and the use of more advanced technologies, the cost of sugar production can be reduced by 5%, and world prices for sugar will increase by 10%, then to ensure break-even production it is necessary to increase production volumes by more than 16%.
even sugar production will be achieved even if sugar output and sales are reduced by 4%. Almost all scientists emphasize the need for modernization of sugar industry and the development of inter-industry interactions. For example, K. Vimal, K. Churi and others conclude that the implementation of a closed-loop model in an industrial ecosystem enables increasing their Resilience due to reducing costs and increasing supply chain stability [20].

The study by S. Bathrinath, M. Dhanasekar et al. also notes that the main risks of Resilience of the sugar industry are associated with high production costs, use of outdated equipment, as well as fluctuations in production trends [21]. B. Shawazipour, J. Stray, T. Stewart emphasize the need for strategic supply planning to achieve resilience in sugar production under conditions of uncertainty [22].

Conclusions

The author's methodology takes into consideration the parameters setting the conditions for resilient development of industry in the strategic aspect. In particular, the results obtained enable us to draw attention to the factors that play the pivotal role in maintaining resilient development of the sugar industry.

The presented study draws our attention to the fact that the main prospects for the sugar industry development in Egypt are associated with the possibilities of modernization transformations in this industry, as well as with the increase in world sugar prices. These findings are compatible with the objectives set in the Egyptian Sugar Industry Development Plan: increase in productivity of sugarcane and sugar beet areas; rise in sugar production profitability by rationalizing the cost structure and modernizing equipment; transport costs reduction. However, given the instability of the situation in the sugar market, expressed in fluctuations in demand and world prices for sugar, in addition to these measures, we recommend regional and sectoral management to pay attention to the need of implementing business models of a circular economy between sugar factories and industrial enterprises consuming by-products and waste from sugar production. The development of such interaction seems possible at the international level within the framework of “Arab–Arab” integration between countries that can complement their potential in the production of sugar and sugar by-products. The implementation of circular economy projects will help maintain the stability of supply chains, as well as the demand for sugar products.

Although the author's study appears to make some contributions to the study of the economics of the sugar industry, it also has some limitations. This article examined the factor proportions between the three main parameters (price, costs, sales volume) that determine the relative break-even of production. Studying other factors influencing the dynamic equilibrium state (for example the amount of government support, taxes, etc.) will provide more information and have far-reaching consequences.

References


