Sugar Tech (Jan–Feb 2024) 26(1):295–304
https://doi.org/10.1007/s12355-023-01342-4

RESEARCH ARTICLE

Future Development of Sugar Market in the European Union in the Period 2023–2032

Mansoor Maitah[1] · Petr Procházka[1] · Stanislav Rojík[1] · Simona Činčalová[2] · Karel Malec[1] · Luboš Smutka[1] · Zdeňka Gebeltová[1] · Robert Koželský[3] · Kamil Maitah[1] · Karel Tomšík[1]

Received: 14 November 2022 / Accepted: 29 October 2023 / Published online: 27 December 2023

Abstract

The European Union is the world's largest producer of sugar beet and one of the main consumer markets in the world. The EU market is very specific as for 50 years, it was one of the most regulated markets in the agri-food sector. For more than three decades, the Union maintained an extremely costly supply management regime in its domestic sugar market through heavy price support and import duties. This system resulted in domestic prices being three times higher than the world market prices and a surplus of production, which could only be exported thanks to substantial subsidies. The aim of this article is to identify the trends and determinants of the EU sugar market to predict its future development as accurately as possible. The research method used is a two-equation econometric model determining the supply of sugar and its price on the European Union market. The results of the econometric model show that sugar supply in the EU market is determined by the volume of sugar production, initial sugar stocks, import of raw sugar, and sugar beet yield per hectare. Furthermore, the model implies that the price of sugar is determined by the sugar price in the previous period and by political changes. The econometric model served as a basis for the calculation of predicted volume of sugar supply and sugar prices inside the European Union. The prediction implies that between 2023 and 2032, sugar supply will decline by 4.5%. At the same time, the price of sugar on the EU market will increase by 11.5% in the period considered.

Keywords Sugar · European Union · International trade · Prediction

Introduction

Sugar is widely consumed globally as a food sweetener, and with its irreplaceable role in the global food market, it is one of the most important commodities. Many sectors are closely linked to sugar production, such as the food and beverage industry (Staszak and Wieszczycka 2022), pharmaceutical industry (Mallakpour and Azadi 2021), and other industrial sectors. It is also a popular topic with researchers around the world (Solomon et al. 2020; Hornowski et al. 2020; Kassem

✉ Mansoor Maitah
maitah@pef.czu.cz

Petr Procházka
pprochazka@pef.czu.cz

Stanislav Rojík
rojiks@pef.czu.cz

Simona Činčalová
simona.cincalova@vspj.cz

Karel Malec
maleck@pef.czu.cz

Luboš Smutka
smutka@pef.czu.cz

Zdeňka Gebeltová
gebeltova@pef.czu.cz

Robert Koželský
kozelsky@is.peuni.cz

Kamil Maitah
maitahk@pef.czu.cz

Karel Tomšík
tomsik@pef.czu.cz

[1] Czech University of Life Sciences Prague, Prague, Czech Republic

[2] College of Polytechnics, Jihlava, Czech Republic

[3] Panevropská Univerzita, Prague, Czech Republic

et al. 2020). The agricultural sector has a specific role in different national economies in Europe: despite the relatively low share of trade in agricultural products in the total foreign trade, it is of special importance for the European Union (Clar et al. 2018). Thanks to its specific character, sugar is one of the Union's strategic commodities, where it remains the primary household and food industry sweetener (Wal et al. 2018). The main principle of the industry lies in farmers together with sugar producers making sure that consumers inside the EU get quality food at affordable prices. At the same time, all processes must be in line with the strict environmental protection and quality standards of the EU (Onyshchuk 2016). Most European sugar producers either make sugar from sugar beet grown by local farmers or refine the raw cane sugar imported (Wojtczak et al. 2014). At the same time, biofuel policy has created new usage possibilities for sugar beet, especially the production of bioethanol and biogas (Grahovac et al. 2012). As a result, sugar beet has become an important energy crop as well. Most EU sugar beet is grown in the northern half of Europe, offering a more suitable climate (European Commission 2022a, b). The main areas are in northern France, Germany, Netherlands, Belgium, and Poland (Maitah et al. 2015), or outside the EU, e.g. in Russia (Maitah and Smutka 2016). This is clear from the map in Fig. 1.

The European Union is the world-leading producer of sugar beet and one of the main consumer markets in the world (OECD 2022). The EU market is very specific as for 50 years, it was one of the most regulated markets in the agricultural and food sectors. For more than three decades, the Union maintained an extremely expensive supply management system on its domestic sugar market through significant price support and import duties (European Commission 2017). As a result, domestic prices were three times higher than on the global market. Another problem was surplus production, which could only be exported thanks to large subsidies (Guimarães Nobre et al. 2019). However, the situation started changing with successive reforms of the European sugar market, especially with the one in 2006. The minimum sugar price inside the Union was reduced, among other things, and production quotas were reduced as well (Kim 2011; Hornowski et al. 2020). In the end, these were abolished completely in 2017. Due to the reforms, sugar prices within the Union became more in line with those on the global market, and the entire sector had to adapt to new market conditions. This led to a massive increase in sugar production. Overproduction applied not only to the European Union, but to the whole world. This phenomenon causes difficulties to European sugar refiners as it brings a decrease in prices including the export ones, at which sugar is exported to the world market. The fall in prices has only stopped recently, even though it was more due to market shocks such as the outbreak of the war in Ukraine than due to standard market mechanisms (United Nations 2022). The importance of the sugar industry is illustrated by the fact that in the EU, there are currently around 145,000 sugar beet growers in 19 member states with more than 100 factories (Hosnedlová 2017). Refineries employ nearly 24,000 people in areas with few other job opportunities and support more than 339,000 other job opportunities within the entire supply chain, such as, for instance, technology and research institutes, manufacturers of machinery, etc. This increases the employment rate in some of the most vulnerable rural regions of the EU. At the same time, the EU sugar industry directly and indirectly contributes EUR 3.6 billion and EUR 15.6 billion to the Union's GDP, respectively (CEFS 2017). The increasing negative impact of human activities on the environment leads to global efforts to reduce greenhouse gas emissions (Jagadeshet al. 2020). A prominent example of this effort is the Paris Agreement of December 2015. With this agreement, the EU committed to intensify its efforts for transformation to a low-carbon economy. Biofuel policy has created new usage possibilities for sugar beet, especially the production of bioethanol and biogas (Mashoko et al. 2010; Nguyen et al. 2010). As a result, sugar beet has become an important energy crop as well. In bioethanol production, the EU significantly lags behind the USA and Brazil (Bastos 2018). The raw material for the production of biogas can be the whole sugar beet plants, its leaves, or by-products resulting from sugar production. Unfortunately, the production of biogas is made difficult by long-term storage of roots (bulbs) and leaves and their mineral contamination during harvesting (Martínez-Guido et al. 2016). The evolution of sugar prices on the world market and its transmission to

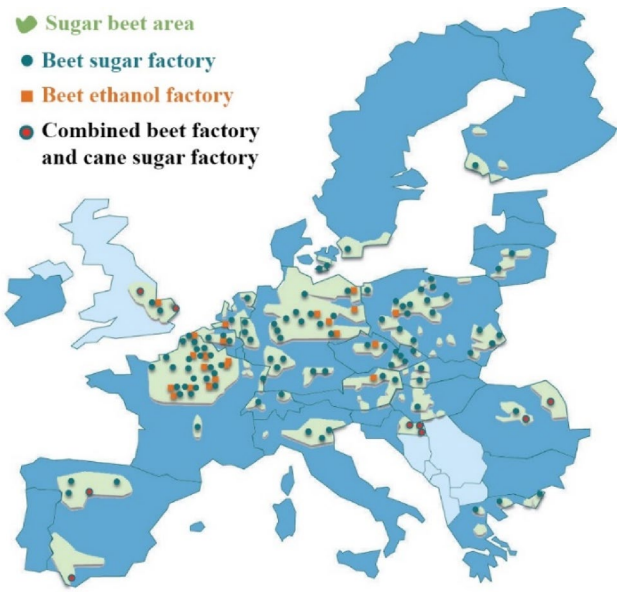

Fig. 1 Beet-growing areas and refineries in Europe

the European market has played and will play an increasingly important role. The sugar market, its evolution, and trends have been the subject of several studies. According to Sulaiman et al. (2019), sugar consumption and demand for sugar in Indonesia will continue to increase due to the population and economic growth. Economic situation in other important countries describes also Maitah et al. (2015) or Hodrab et al. (2016). According to Tomlinson (2013), it is necessary to double crop production by 2050 to feed the world's growing population. The main challenges Indonesian sugar production faces is the inefficiency of farms, lack of quality varieties, and obsolete refineries (Sulaiman et al. 2019). It is expected that sugar consumption in South Asian countries will increase as well (Milovanovic and Smutka 2016). The study identifies and assesses key factors in sugar production and future trends in sugar-producing countries. It was established that for most countries, sugar production is determined by sugar cane production, sugar consumption, and country population. According to Schick (2020), it is necessary to reduce production costs to maintain the competitiveness of the sugar industry. According to the study's author, the best way is to further increase the processing capacity of the individual factories. A simplified mathematical model explores the effects of transport costs, labour costs, and fixed costs on the optimum capacity of refineries.

Considering the evolution of the world sugar market, it should be pointed out according to Maitah and Smutka (2016) that even though white sugar is a perfectly homogeneous product, its global price is not uniform. There are very significant price differences between the different regions due to different sugar industry policies in the individual countries. Another factor affecting sugar prices and their differences on the international and inter-regional levels is the fact that different countries can produce sugar at different costs. There is a very significant difference in efficiency and profitability of sugar production between countries producing this commodity by processing sugar beet and those producing sugar from sugar cane. The global sugar market is highly concentrated (Vijayakumar and Bozward 2021). The concentration of market power is especially high for sugar production and export. The main global sugar market industry players are Latin American countries and countries in the Asia/Pacific region. A comparative advantage over the global market is mainly distributed among Latin America, South-East Asia, and certain African countries. It should be noted that there are great differences in the export sugar prices between different regions. Authors of several studies tried to predict the development of the sugar market. For instance, according to Kaburlasos et al. (2002), an exact and timely forecast of annual sugar beet yield is important for the sugar industry as it serves as a basis for efficient planning of the harvest campaign. The study presents intelligent clustering techniques to be used for effective prediction of the annual sugar beet yield for the sugar industry. Experiments in the study show that intelligent clustering techniques can provide better estimates of sugar production than alternative prediction methods including the energy conservation system model (Association and of Sugar Manufacturers 2017; The EU Sugar Industry 2017, 2022; Maitah et al. 2016).

Material and Methods

The aim of this article is to identify the trends and determinants of the EU sugar market to predict as accurately as possible its future development. This aim can be further divided into sub-aims:

I. To propose an econometric model to identify the main factors determining the volume of sugar supply and sugar prices within the EU internal market.
II. Based on the econometric model, to predict the development of the Union's trade in sugar for 2023–2032.

The above-mentioned aim was set based on hypotheses to be tested. The hypotheses were formulated based on economic literature and scientific publications focusing on the sugar market.

Hypothesis H_1 provides variables determining the supply of sugar on the Union market:

- $H_{1.1}$ Sugar beet yield per hectare.
- $H_{1.2}$ Sugar stocks.
- $H_{1.3}$ Sugar production.
- $H_{1.4}$ Sugar import.
- $H_{1.5}$ Price of imported sugar.

Hypothesis H_2 provides variables determining the price of sugar on the Union market:

- $H_{2.1}$ The price of sugar is dependent on its previous development.
- $H_{2.2}$ Defined by supply and demand, the market mechanism was deformed due to regulation in the form of production quotas limiting free trade in the European Union until 2017.

Furthermore, it is expected that on the global and European markets, there is a correlation between prices of white sugar and prices of raw sugar, and price changes thus manifest themselves in both directions.

The research method used is a two-equation linear model with two dependent variables and several independent variables for the period of 1999–2022. Sugar supply within the European Union is a dependent variable in the first equation to be explained in the model. In the second equation, sugar

supply is an independent variable explaining the price of sugar on the Union market. The economic model can be expressed as follows:

$$y_1 = \text{fce}\,(x_2, x_3, x_4, x_5 x_6)$$

$$y_2 = \text{fce}\,(y_1, x_8, x_9, x_{10})$$

where

y_1—sugar supply

y_2—sugar price

x_1—first equation constant

x_2—sugar beet yield per hectare

x_3—beet sugar production

x_4—initial sugar stocks

x_5—raw sugar import

x_6—price of the raw sugar imported in the previous period

x_7—second equation constant

x_8—sugar price in the previous period

x_9—demand for sugar (calculated as per capita sugar consumption)

$x10$—political changes (artificial variable)

As there are delayed variables—the price of the raw sugar imported in the previous period and sugar price in the previous period in the first and second equations, respectively—the model is dynamic. A two-equation linear model was proposed based on assumptions arising from economic theory and economic model:

$$\beta_1 y_1 = \gamma_{11} x_1 + \gamma_{12} x_2 + \gamma_{13} x_3 + \gamma_{14} x_4 + \gamma_{15} x_5 - \gamma_{16} x_6 + u_1$$

$$\beta_2 y_2 = \gamma_{17} x_7 - \beta_1 y_1 + \gamma_{18} x_8 + \gamma_{19} x_9 - \gamma_{20} x_{10} + u_2$$

where additionally:

β_1, β_2—dependent variable parameter

γ_{11}, γ_{20}—independent variable parameters

u_1, u_2—random variable

Parameters are estimated using the least square regression method providing objective and consistent parameter estimates. The random variable represents an error term—measurement errors, omitting an explanatory variable, non-measurable quantities affecting consumption. The model was quantified, and economic, statistical, and econometric verifications were performed. Provided that all previous modelling stages were successful, the proposed model is applied in the final stage. This involves the prediction of future values. To this end, a dynamic prediction method was used.

An artificial variable was introduced in the proposed model, expressing the impact of political changes, such as reforms of the common agricultural policy. This variable involves information that is qualitative in nature and cannot be measured directly. The purpose of the artificial variable is to capture shocks in data. It only contains data values of 0 or 1. A value of 1 represents important reforms or other occurrences affecting foreign trade relations, having had a significant impact on the development of trade in sugar within the European Union. The following events were included, in this respect:

- The EU 2006 sugar reform taking place until 2010. The reform changed the logic of sugar trade regulation. At the same time, this period was marked by a great economic recession and global food crisis.
- The abolition of sugar production quotas in 2017 (as of September 30), which had been applicable in the European Community since 1968.

The data come from databases and reports of the European Commission, FAO, and USDA. The used data representing sugar are marked as centrifuged sugar. This is an intermediate product which is further processed into refined sugar. The data are expressed on an annual basis and represent the sum of the individual EU member states. Until 2003, it had been EU-15. Since 2017, Great Britain has been deducted (EU-27) to account for the impact of Brexit.

Results

Before quantifying the model, it is necessary to exclude the possibility of multicollinearity. Multicollinearity means a high or moderate degree of correlation between independent variables, which can lead to misleading results and limited research conclusions. Multicollinearity can be identified when the correlation coefficient is higher than or equal to 0.85 in absolute terms. The correlation matrices provided for in Tables 1, 2 contain correlation coefficients of variables from both equations of the proposed model. The matrices confirm that there is no multicollinearity in the data.

What follows is a linear regression analysis to examine relationships between variables. The quantification outputs are shown in Tables 3, 4.

The quantified two-equation linear model is as follows:

$$y_1 = -1466.77x_1 + 31.8119x_2 + 0.970953x_3 + 1.04301x_4 + 1.01901x_5 - 0.841893x_6$$

$$\beta_2 y_2 = 351.576x_7 - 0.00688457y_1 + 0.676573x_8 - 8.91819x_9 - 54.5021x_{10}$$

Subsequently, the feasibility of the model was verified. As a first step, the proposed model was examined at the statistical level. As a second step, it was verified whether the model fulfils the conditions of a traditional linear regression model. In short, what was tested was the significance of variables,

Table 1 Correlation coefficients of the first equation

Sugar beet yield	Sugar beet production	Initial sugar stocks	Raw sugar import	Import price in the previous year	
$\mathbf{x_2}$	$\mathbf{x_3}$	$\mathbf{x_4}$	$\mathbf{x_5}$	$\mathbf{x_6}$	
1,0000	− 0.4879	− 0.3320	0.2992	0.1935	$\mathbf{x_2}$
	1,0000	0.3621	-0.2036	0.1395	$\mathbf{x_3}$
		1,0000	0.4085	0.4639	$\mathbf{x_4}$
			1,0000	0.4318	$\mathbf{x_5}$
				1,0000	$\mathbf{x_6}$

Bold repersents the correlation coefficient of the independent variables and how significant is the dependency between them

Table 2 Correlation coefficients of the second equation

Sugar supply	Sugar price in the previous year	Per capita sugar consumption	Political changes	
$\mathbf{y_1}$	$\mathbf{x_8}$	$\mathbf{x_9}$	$\mathbf{x_{10}}$	
1,0000	0.6624	0.4639	0.1259	$\mathbf{y_1}$
	1,0000	− 0.2051	0.1041	$\mathbf{x_8}$
		1,0000	0.0135	$\mathbf{x_9}$
			1,0000	$\mathbf{x_{10}}$

Bold repersents the correlation coefficient of the independent variables and how significant is the dependency between them

Table 3 Estimated parameters of the first equation

Coefficient	Std. Error	*t*-ratio	*p* value	
− 1466.77	707.903	− 2.193	0.0417	$\mathbf{x_1}$ **(const.)**
31.8119	6.55811	1.788	0.0906	$\mathbf{x_2}$
0.970953	0.0519610	4.892	0.0001	$\mathbf{x_3}$
1.04301	0.0280105	4.198	0.0012	$\mathbf{x_4}$
1.01901	0.0989848	4.559	0.0003	$\mathbf{x_5}$
− 0.841893	1.01325	− 0.8309	0.4169	$\mathbf{x_6}$
Mean dependent var		22,830.17		
Sum squared resid		747,535.6		
R-squared		0.822952		
F(5, 23)		68.98631		
Log-likelihood		− 186.2053		
Schwarz criterion		391.4790		
Rho		0.213215		
S.D. dependent var		2598.835		
S.E. of regression		654.2298		
Adjusted *R*-squared		0.729961		
P value(F)		0.004280		
Akaike criterion		384.4107		
Hannan–Quinn		386.2859		
Durbin–Watson		1.458834		

Bold repersents the correlation coefficient of the independent variables and how significant is the dependency between them

Table 4 Estimated parameters of the second equation

Coefficient	Std. Error	*t*-ratio	*p* value	
351.576	238.952	1.471	0.1576	$\mathbf{x_7}$ **(const.)**
0.00688457	0.00773236	0.8904	0.3844	$\mathbf{y_1}$
0.676573	0.184677	3.664	0.0017	$\mathbf{x_8}$
− 8.91819	6.63458	− 1.344	0.1947	$\mathbf{x_9}$
− 54.5021	29.0226	− 1.878	0.0758	$\mathbf{x_{10}}$
Mean dependent var		531.0418		
Sum squared resid		78,034.13		
R-squared		0.715447		
F(5, 23)		11.94286		
Log-likelihood		− 131.0967		
Schwarz criterion		278.0837		
Rho		0.405483		
S.D. dependent var		109.1935		
S.E. of regression		64.08634		
Adjusted *R*-squared		0.655541		
P value(F)		0.000051		
Akaike criterion		272.1934		
Hannan–Quinn		273.7561		
Durbin–Watson		1.184764		

Bold repersents the correlation coefficient of the independent variables and how significant is the dependency between them

the conclusiveness of the model, and meeting the conditions for the use of testing methods. The tests operate with a 95% confidence interval.

Statistical verification means statistical assessment of feasibility of the parameters and the whole model. The coefficient of determination (R^2) expresses the quality rate of the regression model. For the first equation, R^2 is equal to 0.822952, which means that 82% of sugar supply in the European Union is explained by the given variables. For the second equation, R^2 is equal to 0.715447, which expresses that 72% of sugar prices within the Union is explained by the given variables. The proposed two-equation linear model can be considered statistically significant. This indicates that input data were properly structured.

Table 5 Econometric tests of the first equation

	Breusch–Godfrey test	Breusch–Pagan test	White test	Frequency distribution
P value	0.878	0.128078	0.253964	0.13477
Significance level	0,05	0,05	0,05	0,05
Null hypothesis	Accepted	Accepted	Accepted	Accepted

Table 6 Econometric tests of the second equation

	Breusch–Godfrey test	Breusch–Pagan test	White test	Frequency distribution
P value	0.561	0.517663	0.580184	0.11653
Significance level	0,05	0,05	0,05	0,05
Null hypothesis	Accepted	Accepted	Accepted	Accepted

The statistical significance of the individual parameters is evaluated based on the calculated *p* value. With a significance level of 0.05, statistically significant variables of the first equation include the volume of beet sugar production, initial sugar stocks, and imported raw sugar. Yield per hectare appears to be a less statistically significant variable but can still be considered statistically significant. By contrast, the price of the raw sugar imported appears to be statistically insignificant. This is not in line with hypothesis $H_{1.5}$, but it reflects the fact that sugar import into the European Union is mainly based on preferential trade agreements. These agreements have mainly been concluded with certain countries from the African, Caribbean, and Pacific regions which benefit from their very attractive access to the European market.

Statistically significant variables in the second equation include the price of sugar in the previous period and political changes. By contrast, supply and demand appear to be statistically insignificant. This is in line with hypothesis H_2 claiming that the price of sugar is dependent on its previous development and that the market mechanism of the sugar market inside the EU was deformed due to regulation in the form of production quotas limiting free trade in the European Union until 2017. The high value of the artificial variable representing political changes suggests that the price was determined by regulations rather than market driven.

For the model to be applicable, it needs to be verified in econometric terms. The econometric verification involves the testing of several aspects of the model: the autocorrelation of residuals, heteroscedasticity, and normality of residuals. Several tests were performed to this purpose; their results are shown in Tables 5, 6. The absence of autocorrelation was confirmed by the Breusch–Godfrey test. The heteroscedasticity of the model was verified by the Breusch–Pagan test and subsequently confirmed by the White test. To confirm the normality of residuals, the Jarque–Bera test was used.

Table 7 Predicted values of dependent variables

	Prediction of EU sugar supply	Prediction of EU sugar price
	thsnd/t	€/t
	y2	y2
2023	21,251	421.2
2024	20,490	455.5
2025	19,569	531.8
2026	19,316	484.6
2027	19,761	485.6
2028	19,284	497.5
2029	19,140	521.6
2030	19,077	573.9
2031	18,968	509.7
2032	19,212	505.1

In general, one of the prominent instruments of econometric modelling is the possibility to create predictions. The purpose is to predict the value of an explanatory variable outside the period considered. The proposed model involves the prediction of the volume of sugar supply and sugar prices inside the European Union until 2032. The calculated values are shown in Table 7.

At first, prediction of sugar supply inside the European Union was calculated based on the first equation of the two-equation model. In Fig. 2, the volume for the previous period (until 2023) is in blue, and the calculated prediction for 2023–2032 is in red. According to the prediction, sugar supply on the EU market between 2022 and 2032 will decrease by 0.46% per year (calculated as compound annual growth rate). Over the entire period, the volume should decrease by

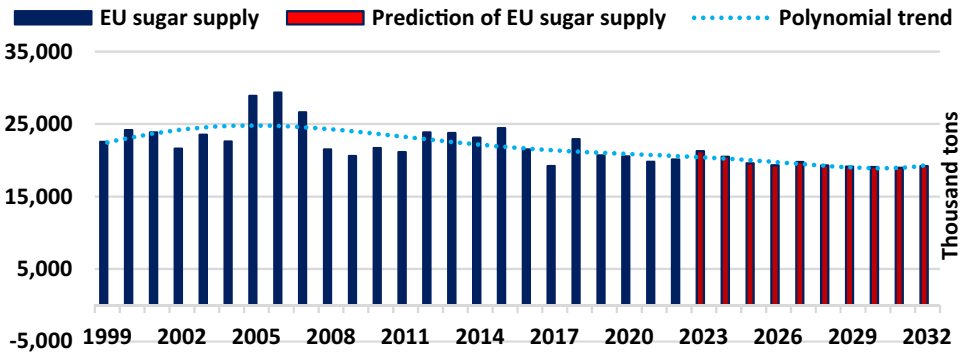

Fig. 2 Sugar supply inside the EU until 2032

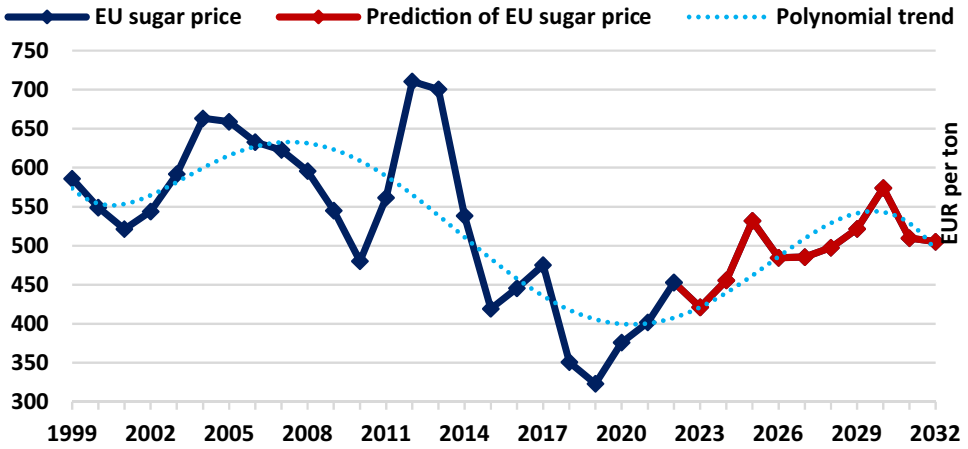

Fig. 3 Sugar prices inside the EU until 2032

4.5%. The average year-on-year drop will be around 83.2 thousand tons. In 2032, the volume of sugar available on the European market should be equal to 19.2 million tons.

Based on the second equation of the two-equation model, prediction of the dependent variable of sugar prices inside the European Union was calculated. In Fig. 3, prices for the previous period (until 2022) are in blue, and their predicted value for 2023–2032 is in red. According to the prediction, sugar prices on the EU market between 2023 and 2032 will increase by 1.1% per year (calculated as compound annual growth rate). Over the entire period, the price should increase by 11.5%. The average year-on-year price increase will be around EUR 4.7 per ton. In the period considered, the price should reach the highest level in 2030; specifically, EUR 573.9. In 2032, the price of sugar on the European market should be around EUR 505.1 per ton of sugar. With these values, the price would go back to the level before the quota system was abolished on the EU market.

Discussion

An expected challenge the European sugar sector will face is the fact that Europeans begin to consume less sugar, replacing it with other sweeteners (Chatelan et al. 2021). This trend can be observed globally as well, see, for instance, the Canadian studies (Goodman et al. 2021; Liu et al. 2020). Probably, the most common alternative sweetener is honey or different kinds of syrups (Goran et al. 2019; Siebenhaller et al. 2018). Consumers are increasingly concerned about the sugar content of food and beverages due to a high rate of obesity and health-related problems (such as diabetes, cardiovascular diseases, or cancer) (Manzanares Mileo 2021). This phenomenon is enhanced by the fact that more and more EU member states have introduced a "sugar tax", primarily related to non-alcoholic sweetened beverages. The idea behind this tax is simple: the higher the sugar content in a specified drink volume, the higher the tax payable. In 2021, this type of tax was applicable in the following EU countries: Belgium, Estonia, Finland, France, Ireland, Latvia, Hungary, Poland, Portugal, and Spain. At the same time, the tax is an attractive subject for several researchers (Crosbie et al. 2022; Thow et al. 2022).

The European Commission notes that the overall sugar consumption in the EU countries will decrease by 5% by 2030 (EC 2020). The decreasing human consumption of sugar should be only partially replaced by non-caloric sweeteners and adding more isoglucose to processed food. Also, the forecast published by OECD-FAO (2022) came to the same conclusion of decreasing human sugar

consumption in the European Union. Furthermore, the European Commission expects that sugar prices on the EU market will continue to rise until 2030. The increase in sugar prices should affect the rest of the world as well. Both predictions of the important organizations are in line with the results of the study. European and global studies alike agree with the premise of decreasing sugar consumption and increasing prices (Welsh et al. 2011; Perrar et al. 2019; Kotyza et al. 2019). The decrease in domestic consumption should logically result in an increase in exports outside the European Union. This assumption is further enhanced by the growing global consumption of sugar, especially in developing countries (Veselá and Severová 2021). Anyway, it can be assumed at least in the short-term that the position of European sugar traders will worsen because of the massively growing energy prices due to the Ukraine crisis. Energy costs are an important cost factor for sugar production and transport. Sugar processing in refineries consumes a large amount of energy. At the same time, prices of fertilizers and agricultural chemicals are growing at a record pace as well. This could lead to greater use of sugar crops for non-food purposes, especially in connection with the European Green Deal. Even though the sugar beet sector is a less important provider of biomass for the production of first-generation biofuels than the cereals sector, the income received from this activity can be very important for sugar beet growers. This aspect is currently further enhanced by the fact of high oil prices, forcing governments across Europe to look for various energy alternatives.

Conclusion

The results of the econometric model show that sugar supply in the EU market is determined by sugar production, initial sugar stocks, import of raw sugar, and sugar beet yield. Furthermore, the model implies that the price of sugar is significantly determined by the sugar price in the previous period and by political changes. By contrast, the model variables representing sugar supply and demand appear to be statistically insignificant. However, this is due to the limitation of free trade and market mechanism through the system of production quotas, which was applicable during most of the period considered (until 2017). The calculated prediction implies that between 2023 and 2032, sugar supply on the EU market will decrease by 0.46% per year (calculated as CAGR). Over the entire period considered, the supply will decrease by 4.5%. The average year-on-year drop will be 83.2 thousand tons. Furthermore, the prediction implies that between 2023 and 2032, sugar prices on the EU market will increase by 1.1% per year (calculated as CAGR). Over the entire period considered, the prices will increase by 11.5%. The average year-on-year price increase will be EUR 4.7 per ton. The problem of the European sugar sector is that Europeans begin to consume less sugar. With regard to the predicted development of the EU sugar market, it will be necessary to focus more on the export of sugar outside the Union and on using sugar crops for non-food purposes. This should improve the economic viability of sugar beet growers and several downstream industries.

References

Bastos, R.G. 2018. Biofuels from microalgae: bioethanol. *Trends in Biotechnology. Energy from Microalgae*. https://doi.org/10.1007/978-3-319-69093-3_11.

Chatelan, A., M. Rouche, A. Dzielska, T. Legacq, A.S. Fismen, C. Kelly, A. Zaborskis, J. Kopcakova, A. Tsareva, M. Kalman, and K. Castetbon. 2021. Time trends in consumption of sugar-sweetened beverages and related socioeconomic differences among adolescents in eastern Europe: signs of a nutrition transition? *The American Journal of Clinical Nutrition* 114 (4): 1476–1485. https://doi.org/10.1093/ajcn/nqab175.

Clar, E., M. Miguel-Retortillo, and V. Pinilla. 2018. the spanish path of agrarian change, 1950–2005: from authoritarian to export-oriented productivism. *Journal of Agrarian Change* 18 (2): 324–247. https://doi.org/10.1111/joac.12220.

Crosbie, E. 2022. Examining the policy process of sugar-sweetened beverage taxation in Ireland. *Health Policy* 126 (8): 738–743. https://doi.org/10.1016/j.healthpol.2022.06.002.

European Association of Sugar Manufacturers. 2017. *The EU Sugar Industry at a Glance.* Brussels. https://www.cefs.org. Accessed 30 November 2022.

European Commission. 2017. *The End of the Sugar Production Quotas in the EU.* Brussels. https://ec.europa.eu/commission/presscorner/detail/en/MEMO_17_3488. Accessed 30 November 2022.

European Commission. 2020. *EU Agricultural Outlook for Markets, Income and Environment 2020–2030.* Brussels. https://agriculture.ec.europa.eu/news/eu-agricultural-outlook-2020-30-agri-food-sector-shown-resilience-still-covid-19-recovery-have-long-2020-12-16_en#moreinformation. Accessed 30 November 2022.

European Commission. 2022. *Study on the Adaptation Strategies of the Sugar Supply Chain after the End of the Sugar Quotas : Final Report.* Brussels. https://op.europa.eu/en/publication-detail/-/publication/c8a80147-7f1f-11ec-8c40-01aa75ed71a1/language-en. Accessed 22 November 2022.

European Commission. 2022. *Sugar.* Brussels. 2022. https://agriculture.ec.europa.eu/farming/crop-productions-and-plant-based-products/sugar_en. Accessed 22 November 2022.

Goodman, S., L. Vanderlee, A. Jones, C. White, and D. Hammond. 2021. Perceived healthiness of sweeteners among young adults in Canada. *Canadian Journal of Dietetic Practice and Research* 82 (2): 90–94. https://doi.org/10.3148/cjdpr-2020-030.

Goran, M.I., J.F. Plows, and E.E. Ventura. 2019. Effects of consuming sugars and alternative sweeteners during pregnancy on maternal and child health: evidence for a secondhand sugar effect. *Proceedings of the Nutrition Society* 78 (3): 262–271. https://doi.org/10.1017/S002966511800263X.

Grahovac, J.A., J.M. Dodic, S.N. Dodic, S.D. Popov, D.K. Vučurović, and A.I. Jokić. 2012. Future trends of bioethanol co-production in serbian sugar plants. *Renewable and Sustainable Energy Reviews* 16 (5): 3270–3274. https://doi.org/10.1016/j.rser.2012.02.040.

Guimarães Nobre, G.G., J.E. Hunink, B. Baruth, J.C.J.H. Aerts, and P.J. Ward. 2019. Translating large-scale climate variability into crop production forecast in europe. *Scientific Reports* 9: 1277. https://doi.org/10.1038/s41598-018-38091-4.

Hodrab, R., M. Maitah, and L. Smutka. 2016. The effect of information and communication technology on economic growth: Arab world case. *International Journal of Economics and Financial Issues* 6 (2): 765–775.

Hornowski, A.P., L. Smutka. Kotyza, and K. Pawlak. 2020. Concentration in the czech and polish sugar markets. *Sugar Industry* 145 (4): 224–233. https://doi.org/10.36961/si24265.

Hosnedlová, P. 2017. The end of sugar regulation: Will we sweeten more at a lower price? (Konec regulací cukru: Budeme víc sladit za nižší cenu?) EURACTIV.cz. 2017. https://euractiv.cz/section/aktualne-v-eu/news/konec-regulaci-cukru-budeme-vic-sladit-za-nizsi-cenu/. Accessed 25 November 2022.

Jagadesh, P., M.A. Ramachandra, and R. Murugesan. 2020. Effect of processed sugar cane bagasse ash on mechanical and fracture properties of blended mortar. *Construction and Building Materials* 262: 120846. https://doi.org/10.1016/j.conbuildmat.2020.120846.

Kaburlasos, V.G., V. Spais, V. Petridis, L. Petrou, S. Kazarlis, N. Maslaris, and A. Kallinakis. 2002. Intelligent clustering techniques for prediction of sugar production. *Mathematics and Computers in Simulation* 60 (3–5): 159–168. https://doi.org/10.1016/S0378-4754(02)00011-3.

Kassem, H.S., B.A. Alotaibi, and S. Bagadeem. 2020. Strategic planning approach to the development of contract farming in the egyptian sugar industry. *Journal of Agricultural Extension* 24 (4): 171–183. https://doi.org/10.4314/jae.v24i4.17.

Kim, D.J. 2011. Clutching the ladder of development european sugar reform in poland. *Anthropological Journal of European Cultures* 20 (1): 29–47. https://doi.org/10.3167/ajec.2011.200103.

Kotyza, P., L. Smutka, and K. Pawlak. 2019. Changes in sugar beet production in the czech republic and poland after the year 2000. *Journal of Central European Agriculture* 20 (3): 1023–1043. https://doi.org/10.5513/JCEA01/20.3.2313.

Liu, S., L.L. Munasinghe, A. Ohinmaa, and P.J. Veugelers. 2020. Added, free and total sugar content and consumption of foods and beverages in Canada. *Health Reports* 31 (10): 14–24. https://doi.org/10.25318/82-003-X202001000002-ENG.

Maitah, M., N. Saleem, K. Malec, M. Boubaker, and S. Gouda. 2015. Economic value added and stock market development in Egypt. *Asian Social Science* 11 (3): 126–134. https://doi.org/10.5539/ass.v11n3p126.

Maitah, M., and L. Smutka. 2016. Restoration and growth of the Russian sugar market. *Sugar Tech* 18 (2): 115–123. https://doi.org/10.1007/s12355-015-0383-0.

Maitah, M., H. Řezbová, L. Smutka, and K. Tomšík. 2016. European sugar production and its control in the world market. *Sugar Tech* 18 (3): 236–241. https://doi.org/10.1007/s12355-016-0439-9.

Mallakpour, S., and E. Azadi. 2021. Nanofiltration membranes for food and pharmaceutical industries. *Emergent Materials* 5 (5): 1329–1343. https://doi.org/10.1007/s42247-021-00290-7.

Martínez-Guido, S.I., J.B. Gonzalez-Campos, J.M. Ponce-Ortega, F. Napoles-Rivera, and M.M. El-Halwagi. 2016. Optimal reconfiguration of a sugar cane industry to yield an integrated biorefinery. *Clean Technologies and Environmental Policy* 18 (2): 553–562. https://doi.org/10.1007/s10098-015-1039-1.

Mashoko, L., Ch. Mbohwa, and V.M. Thomas. 2010. LCA of the South African sugar industry. *Journal of Environmental Planning and Management* 53 (6): 793–807. https://doi.org/10.1080/09640568.2010.488120.

Mileo, M.M. 2021. Sweet debates in seventeenth-century barcelona. *The Historical Journal* 64 (3): 515–532. https://doi.org/10.1017/S0018246X2000028X.

Milovanovic, V., and L. Smutka. 2016. South Asian countries in the global sugar market: a critical assessment. *Sugar Tech* 18 (6): 647–658. https://doi.org/10.1007/s12355-016-0436-z.

Nguyen, T.L.T., S.H. Gheewala, and M. Sagisaka. 2010. Greenhouse gas savings potential of sugar cane bio-energy systems. *Journal of Cleaner Production* 18 (5): 412–418. https://doi.org/10.1016/j.jclepro.2009.12.012.

OECD. 2022. *OECD-FAO agricultural outlook 2022–2031*. Paris: OECD. https://doi.org/10.1787/f1b0b29c-en.

Onyshchuk, Y. 2016. The development strategy of the sugar industry in the context of European integration of Ukraine. *Baltic Journal of Economic Studies* 2 (1): 88–95. https://doi.org/10.3025/2256-0742/2016-2-1-88-95.

Perrar, I., A.M. Schadow, S. Schmitting, A.E. Buyken, and U. Alexy. 2019. Time and age trends in free sugar intake from food groups among children and adolescents between 1985 and 2016. *Nutrients* 12 (1): 20. https://doi.org/10.3390/nu12010020.

Schick, R. 2020. Considerations on the optimal processing capacity of beet sugar factories. *Sugar Industry* 145 (6): 363–379. https://doi.org/10.36961/si24469.

Siebenhaller, S., J. Gentes, A. Infantes, C. Muhle-Goll, F. Kirschhöfer, G. Brenner-Weiß, K. Ochsenreither, and Ch. Syldatk. 2018. Lipase-catalyzed synthesis of sugar esters in honey and agave syrup. *Frontiers in Chemistry* 6: 24. https://doi.org/10.3389/fchem.2018.00024.

Solomon, S., G.P. Rao, and M. Swapna. 2020. Impact of COVID-19 on Indian sugar industry. *Sugar Tech* 22 (4): 547–551. https://doi.org/10.1007/s12355-020-00846-7.

Staszak, K., and K. Wieszczycka. 2022. Membrane applications in the food industry. *Physical Sciences Reviews*. https://doi.org/10.1515/psr-2021-0050.

Sulaiman, A.A., Y. Sulaeman, N. Mustikasari, D. Nursyamsi, and A.M. Syakir. 2019. Increasing sugar production in indonesia through land suitability analysis and sugar mill restructuring. *Land* 8 (4): 61. https://doi.org/10.3390/land8040061.

Thow, A.M., H.L. Rippin, G. Mulcahy, K. Duffey, and K. Wickramasinghe. 2022. Sugar-sweetened beverage taxes in Europe: learning for the future. *European Journal of Public Health* 32 (2): 273–280. https://doi.org/10.1093/eurpub/ckab211.

Tomlinson, I. 2013. Doubling food production to feed the 9 billion: a critical perspective on a key discourse of food security in the UK. *Journal of Rural Studies* 29: 81–90. https://doi.org/10.1016/j.jrurstud.2011.09.001.

United Nations. 2022. Ukraine War Drives International Food Prices to New All-Time High. 2022. *News United Nations*. https://news.un.org/en/story/2022/04/1115852. Accessed 28 November 2022.

Veselá, K., and L. Severová. 2021. Evaluation and trend of sugar import and development (Zhodnocení vývoje a trendu dovozu a vývozu cukru). *Listy Cukrovarnické a Řepařské* 137 (7–8): 278–282.

Vijayakumar, A.N., and D. Bozward. 2021. International market integration and competitiveness of Indian sugar. *Global Business Review*. https://doi.org/10.1177/0972150920988646.

Wal, P., R.S. Pal, and A. Wal. 2018. A review on the sugar alternates. *International Journal of Pharmaceutical Sciences and Research* 10 (4): 1595–1604. https://doi.org/10.13040/IJPSR.0975-8232.10(4).1595-04.

Welsh, J.A., A.J. Sharma, L. Grellinger, and M.B. Vos. 2011. Consumption of added sugars is decreasing in the United States. *American Journal of Clinical Nutrition* 94 (3): 726–734. https://doi.org/10.3945/ajcn.111.018366.

Wojtczak, M., A. Antczak, and K. Lisik. 2014. Starch content in various types of cane sugars as a criterion of quality and authenticity. *International Journal of Food Properties* 17 (3): 610–616. https://doi.org/10.1080/10942912.2012.654565.