JOURNAL
OF EUROPEAN ECONOMY
Vol. 22. № 4 (87). October–December 2023
Publication of West Ukrainian National University

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ASSESSMENT OF CYCLICAL FLUCTUATIONS IN THE SHARE OF HIGH-TECH PRODUCTS IN THE U.K. FOREIGN TRADE

Abstract

The paper presents an original approach to assessing cyclical fluctuations in the share of high-tech products in the foreign trade of the United Kingdom of Great Britain and the Northern Ireland. This approach can serve as a foundation for decision-making at a state level regarding issues of regulating Ukrainian development in innovation, science, and technology. It also reveals the economic content and distinguishes the influence of separate structural components (linear, accelerated, and cyclical growth) on the changes in the share of high-tech products in the foreign trade. Further, the analysis also determines two important relative indicators: share of high-tech exports in total U.K. manufactured exports and share of high-tech exports in the country's GDP. The dynamics cycles of high-tech exports in the United Kingdom with periods of 4.2 and 4.3 years are determined and the extent of the cyclical component's influence on the overall trend is calculated. This paper is part of a research project that uses the same original

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approach to analyze various countries with significant high-tech exports on the global scale.

Key Words:

high-tech; high-tech products; export; mathematical modelling; dynamic indicators; cyclicality.

JEL: C51, E32, O33.

3 figures, 13 tables, 41 references.

Problem Statement and Literature Review

This article is a part of a large comprehensive study of the quantifiable impact of a country's scientific and technological potential on its strategic development and is among the first to analyze the trends in the production and export of high-tech products to different countries of the world.

Foreign trade is one of the main components that contribute to the national GDPs. Exports in foreign trade reflect a certain competitiveness of a given country's products on the world market. On the other hand, the higher the level of technological sophistication and knowledge intensity of products, the higher their competitiveness (Porter, 1990; Alemu, 2013). Thus, high-tech exports show the development level of production, science and the potential for the country's future development (Salikhova, 2012).

According to the OECD classification set forth in SITC Rev.4, high-tech products, i.e., products whose manufacture is associated with high R&D intensity (Hatzichronoglou, 1997), include products from such industries as aerospace, pharmaceuticals, electronics, telecommunications, chemicals, as well as the production of scientific instruments, computers, electrical machinery, some types of non-electrical machinery and weapons (Galindo-Rueda & Verger, 2016; Molnárová & Reiter, 2022).

Of course, high-tech production is possible if the country has a strong scientific and technological capacity. H. Dobrov (Tonkal & Dobrov, 1987) studied the fundamental issues of shaping and developing this potential, while Ross (2017) considered possible types of technological development of the future.

Chinese (Yang & Zhu, 2021) and American (Haltiwanger et al., 2014) researchers have studied the issues of ensuring the development of high-tech sectors of the economy. Özsoy et al. (2022) focused on the impact of the digitalization of society on high-tech exports. The impact of the latter on economic growth has been studied for Turkey (Ustabaş & Ersin, 2016; Ege & Ege, 2017), the Philippines (Garces & Adriatico, 2019), Japan (Marukawa, 2013), Israel (Rivlin, 2010), the European Union (Srholec, 2007), OECD countries (Kabaklarli et al, 2018; Şahin & Şahin, 2021; Ersin et al., 2022), and Asian countries (Siddiqui, 2022). However, the issue of cyclicality in the behavior of high-tech exports has not been studied.

The article is aimed at assessing the cyclical fluctuations in the share of high-tech products in the U.K. foreign trade.

For this purpose, the following tasks are set. First, to analyze the patterns in the changes in high-tech exports, namely to identify the linear, accelerated, and cyclical growth in these developments. Second, to estimate the influence of the cyclical component on the changes in high-tech exports. Third, to consider how such a structure changes if high-tech exports are considered as a share of total manufactured exports and as a share of GDP, and to compare it with the GDP growth structure of the country as a whole.

Methodology

The scientific literature includes various approaches to assessing economic cycles: parametric and nonparametric time series approach (Saini et al., 2021), pairwise maximum entropy model (Xi et al., 2014), threshold-minimum dominating set approach (Antonakakis et al., 2016), a model with short-run (SRR) and long-run (LRR) consumption risk (He & Leippold, 2020), statistical testing using the Chi-squared test (Palaszcă, 2012), three-stage least squares (Hsu et al., 2011), real business-cycle model (Bäurle & Burren, 2011), multiresolution wavelet analysis (Yogo, 2008), impulse response function and variance decomposition (Manzoor, 2021), vector error correction model (Mandelman et al., 2011), dynamic factor model with time-varying factor loadings and stochastic volatility (Gupta et al., 2018), the method of multiple scales (Li et al., 2008), method of applying geometric Brownian motion (Yang, 2020), multidimensional multilevel factor model (Breitung & Eickmeier, 2015), VAR model (Yan & Huang, 2020), and others.

However, we suggest using an approach based on correlation and regression analysis with the inclusion of the cyclical component to obtain the numerical values of the cyclical component and its parameters (Oliynyk, 2005; Belov & Svystun, 2022). For the analysis of M1-M5, 5 types of models were selected in order of increasing complexity: a simple linear model, a model with acceleration, a linear model with a cycle, a one-step accelerated development model, and a two-step accelerated development model.

Table 1

Types of econometric models for regression analysis of high-tech exports

Model	Formula	Name
M1	y=a+b*x	Linear
M2	y=a+b*x+c*x^2	Linear with acceleration
M3	y=a+b*x+c*sin(d*x+e)	Linear with a cycle
M4	y=a+b*x+c*x^2+d*sin(e*x+f)	Linear with acceleration and one cycle
M5	y=a+b*x+c*x^2+d*sin(e*x+f)+g*sin(h*x+i)	Linear with acceleration and two cycles

The term «accelerated development» refers to the acceleration of movement in the natural sciences, mathematically it is represented as the parameter c * x ^ 2, the acceleration itself will be equal to 2s.

The economic properties of the parameters in the regression equations for models M1-M5 are presented in Table 2.

The study was conducted in the following sequence. First, we selected the indicators for the modeling, identified the parameters of the selected types of economic and mathematical models and analyzed their statistical properties for the first indicator. Next, we compared the results with actual data, after which we selected the best economic and mathematical model. this model was analyzed and the degree of influence of the cyclical component was calculated. We performed similar steps for the other indicators and analyzed the obtained results.

Table 2

Economic properties of the regression equation parameters

Model parameters					Economic properties	Units
M1	M2	M3	M4	M5		
The linear component of the model determines the linear trend in the studied indicator						
a	a	a	a	a	Initial value of the studied indicator	USD 2010
b	b	b	b	b	Average rate of change in the studied indicator	USD 2010 / year
Non-linear model components:						
1. Acceleration						
–	c	–	c	c	Average acceleration of the change in the studied indicator	USD 2010 / 2 year
2. Cycles						
–	–	C*Sin(D*X+E)	d*sin(e*x +f)	d*sin(e*x +f)	1st harmonica	USD 2010
–	–	c	d	d	Amplitude of cyclical fluctuations – maximum deviation	USD 2010
–	–	d	i	i	Angular frequency	radian
–	–	i	f	f	Initial phase of the cycle	radian
–	–	T	T	T	Fluctuation period	year
–	–	–	–	g*sin(h*x+i)	2nd harmonica	
–	–	–	–	g	Amplitude of cyclical fluctuations – maximum deviation	USD 2010
–	–	–	–	h	Angular frequency	radian
–	–	–	–	я	Initial phase of the cycle	radian
–	–	–	–	н2	Fluctuation frequency	times
–	–	–	–	T2	Fluctuation period	year

Source: original elaboration based on data from Belov (2023).

Research Results and Discussion

Selection of input data

The study is based on the example of the United Kingdom. The United Kingdom is a member of the European Union. and a country with a highly developed post-industrial economy and robust scientific and technological capacity. The input data are presented in Table 3.

Table 3

Changes in key indicators

Year	High-technology exports (constant USD 2010 billion)	High-technology exports (% of manufactured exports)	High-technology exports (% of GDP)	GDP (constant USD 2010 billion)	Manufactured exports (constant USD 2010 billion)
2007	71.8558	20.8646	2.2264	3227.5022	344.3912
2008	70.3724	20.6006	2.3025	3056.4073	341.6034
2009	49.3745	20.4516	2.0121	2453.9028	241.4212
2010	66.7143	23.2865	2.6778	2491.3975	286.4937
2011	73.6047	23.2889	2.8422	2589.7465	316.0500
2012	69.8298	23.4468	2.7028	2583.5820	297.8223
2013	70.2548	23.5744	2.6808	2620.6193	298.0135
2014	70.9546	22.1922	2.4799	2861.1962	319.7279
2015	69.1100	22.3228	2.5411	2719.6548	309.5945
2016	67.0074	23.5459	2.7339	2450.9678	284.5822
2017	65.5192	22.6067	2.7461	2385.8633	289.8216
2018	65.9403	22.3196	2.6260	2511.0609	295.4371
2019	65.5848	23.0833	2.6914	2436.8532	284.1227
2020	48.9268	22.9972	2.1498	2275.8741	212.7516
2021	52.4352	23.8537	2.1301	2461.6884	219.8201

Source: calculated based on data from The World Bank (n.d.) and Bureau of Statistics (n.d.).

Due to the fact that in September 2019 the definition in the World Development Indicators database was updated to SITC Rev.4 from SITC Rev. 3, the data on the World Bank website (The World Bank, n.d.) are available only from 2007. There is also another indicator – the share of high-tech exports in manufactured exports. Data on GDP growth for the same period were taken from the same website. To adjust the statistics for inflation by recalculating them to 2010 prices, we used data from the US inflation website (Bureau of Statistics, n.d.). The share of high-tech exports in GDP was calculated based on the above data.

Analysis and evaluation of high-tech export dynamics

Estimation of the parameters of economic and mathematical models according to Table 1 was performed using the cross-platform solution for curve fitting and data analysis – CurveExpert 1.38.

Table 4

Parameter estimation of econometric models assessing the high-tech exports in the United Kingdom

	M1	M2	M3	M4	M5
Coefficient Data	a =71.3859	a =61.2094	a =71.0248	a =59.1188	a =55.5824
	b =-0.7775	b =2.8142	b =-0.6769	b =3.1821	b =3.9282
		c =-0.2245	c =-5.6813	c =-0.2353	c =-0.2664
			d =1.0952	d =-6.1863	d =36.0444
			e =4.5158	e =7.9816	e =1.5050
				f =-72.8424	f =1.0301
					g =34.1555
					h =1.4557
					i =-1.6645
Standard Error	7.6074	6.7359	7.1714579	5.5055591	4.3996583
Correlation Coefficient	0.4286	0.6397	0.6648055	0.8390474	0.9348697
Comments:			The fit converged to a tolerance of 0.001 in 36 iterations. No weighting used.	The fit converged to a tolerance of 0.001 in 42 iterations. No weighting used.	The iteration count of 100 was exceeded. The fit failed to converge to tolerance of 0.001000 (CHI2 at 116.141959). No weighting used.

Source: calculated based on data from The World Bank (n.d.) and Bureau of Statistics (n.d.).

As we can see, the correlation coefficient increases with the complexity of the model type. The conventional linear model (M1) has a K correlation of 0.2963, and the linear model with acceleration and two harmonics (M5) has a K correlation of 0.9234 (Table 4). It should be noted that the M4 and M5 models, i.e., the models that take into account cyclical components, produce the highest values of the correlation coefficient, which suggests fluctuations in the high-tech export performance in the United Kingdom. This also means that the high-tech exports in the United Kingdom in 2007-2020 were characterized by both a linear trend and the presence of acceleration (in this case, it has a negative value, which characterizes a slowdown in development) and a cyclical component.

Table 5 shows the projected values of high-tech exports for the three years until 2023. All models show a projected decline in high-tech exports in 2023 to USD 50.973 billion in 2010 prices.

Table 5

Forecast of high-tech exports in the United Kingdom based on the obtained models

Year	M1	M2	M3	M4	M5	Y
2007	70.608	63.799	73.886	67.614	72.710	71.856
2008	69.831	65.940	67.339	66.549	66.553	70.372
2009	69.053	67.632	63.321	60.488	55.229	49.375
2010	68.276	68.874	65.454	67.618	62.995	66.714
2011	67.498	69.668	70.692	75.325	74.925	73.605
2012	66.721	70.013	72.621	68.634	72.360	69.830
2013	65.943	69.909	68.416	63.969	66.406	70.255
2014	65.166	69.356	61.902	72.126	69.308	70.955
2015	64.388	68.354	59.409	73.932	71.126	69.110
2016	63.611	66.903	62.905	63.472	66.083	67.007
2017	62.833	65.003	67.866	61.425	65.587	65.519
2018	62.056	62.654	68.180	68.441	69.654	65.940
2019	61.278	59.856	62.771	63.676	62.981	65.585
2020	60.500	56.609	56.771	51.786	49.906	48.927
2021	59.723	52.914	55.951	52.429	51.661	52.435
2022	58.945	48.769	60.467	55.947	61.568	
2023	58.168	44.175	64.688	45.138	50.973	

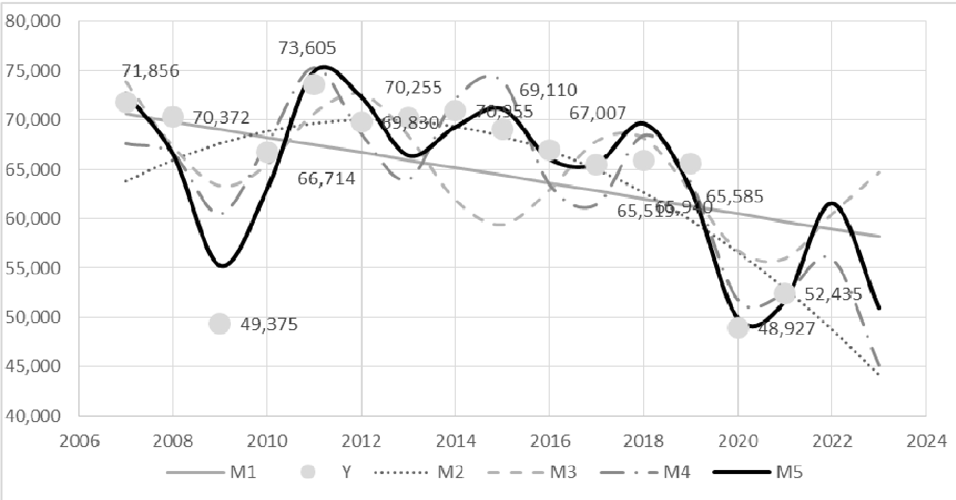
Source: calculated based on data from The World Bank (n.d.) and Bureau of Statistics (n.d.).

A comparison of the obtained models and forecasts is shown in Fig. 4, where Y stands for actual data, and the lines show the trends of the computational models.

Taking into account the correlation coefficients, for further analysis we choose the model with the highest value – M5. In economic terms, this means that there are two cycles.

Figure 1

Comparison of the obtained models and forecast of the U.K. high-tech exports until 2023



A comparison of the cyclical properties of the M3-M5 models is shown in Table 6.

Table 6

Characteristics of the cyclical component of the studied models (M3-M5)

Parameter	M3	M4	M5 (1st)	M5 (2nd)
Angular frequency, radians	1.095	7.982	1.505	1.456
Frequency, times in year	0.174	1.270	0.240	0.232
Period, years	5.737	0.787	4.175	4.316
Phase, radians	4.516	-72.842	1.030	-1.665
Offset, period fraction	0.719	-11.593	0.164	-0.265
Offset, years	4.123	-9.126	0.684	-1.143
Offset, months	49.5	-109.5	8.2	-13.7
Amplitude, billion US$ 2010	-5.681	-6.186	36.044	34.156

Source: calculated based on data from The World Bank (n.d.) and Bureau of Statistics (n.d.).

The results of Table 6 show that in some cases the calculations yielded negative values of the cyclical frequency and, accordingly, the fluctuation period. At this stage of the study, to determine the economic value of the parameters of the obtained models, we take the absolute values of the fluctuation period modulo. The models show the presence of fluctuations in the dynamics of high-tech exports in the United Kingdom. However, they have different periods and initial offsets relative to the point (year) of the beginning of the observations.

Based on the calculations, the M5 model is identified as the model that best describes the trends in the U.K. high-tech exports.

In order to understand how the cyclical component affects the changes in high-tech exports, we calculate the impact of each of the components of the M5 model in absolute (Table 7) and relative (Table 8) values, as well as the error (deviation) of the calculated values from the actual ones.

Table 8 also shows the mean, median, maximum, and minimum for each of the components. It should be noted that, given the nature of the cyclical component, the mean and median values are close to zero, which does not give us information about their impact. At the same time, the maximum and minimum values show us the scale of the impact that the cyclical component has on the high-tech exports.

Table 7

Analysis of the structure of the M5 model of HtE dynamics in constant USD 2010 billion

Year	a	bx	cx^2	d*sin(e*x+f)	g*sin(h*x+i)	Yteor	Y	Δ
2007	55.5824	3.9282	-0.2664	20.5455	-7.0798	72.7099	71.8558	-0.8541
2008	55.5824	7.8564	-1.0655	-28.1997	32.3798	66.5533	70.3724	3.8191
2009	55.5824	11.7846	-2.3974	-24.2560	14.5156	55.2292	49.3745	-5.8547
2010	55.5824	15.7128	-4.2620	25.0082	-29.0464	62.9950	66.7143	3.7193
2011	55.5824	19.6409	-6.6593	27.5465	-21.1860	74.9246	73.6047	-1.3199
2012	55.5824	23.5691	-9.5894	-21.3836	24.1811	72.3596	69.8298	-2.5298
2013	55.5824	27.4973	-13.0523	-30.3602	26.7390	66.4063	70.2548	3.8486
2014	55.5824	31.4255	-17.0478	17.3889	-18.0407	69.3083	70.9546	1.6463
2015	55.5824	35.3537	-21.5762	32.6482	-30.8819	71.1261	69.1100	-2.0161
2016	55.5824	39.2819	-26.6373	-13.0931	10.9488	66.0827	67.0074	0.9247
2017	55.5824	43.2101	-32.2311	-34.3709	33.3963	65.5867	65.5192	-0.0675
2018	55.5824	47.1383	-38.3576	8.5707	-3.2796	69.6541	65.9403	-3.7138
2019	55.5824	51.0665	-45.0170	35.4986	-34.1494	62.9811	65.5848	2.6037
2020	55.5824	54.9947	-52.2090	-3.8998	-4.5626	49.9056	48.9268	-0.9787
2021	55.5824	58.9228	-59.9338	-36.0118	33.1016	51.6612		
2022	55.5824	62.8510	-68.1914	-0.8385	12.1642	61.5677		
2023	55.5824	66.7792	-76.9817	35.9014	-30.3082	50.9732		

Source: calculated based on data from The World Bank (n.d.) and Bureau of Statistics (n.d.).

Table 8

Analysis of the structure of the dynamics of the M5 model and HtE in %

Year	a	bx	cx^2	d*sin(e*x+f)	g*sin(h*x+i)	Yteor	Y	Δ
2007	77.4%	5.5%	-0.4%	28.6%	-9.9%	101.2%	100.0%	-1.2%
2008	79.0%	11.2%	-1.5%	-40.1%	46.0%	94.6%	100.0%	5.4%
2009	112.6%	23.9%	-4.9%	-49.1%	29.4%	111.9%	100.0%	-11.9%
2010	83.3%	23.6%	-6.4%	37.5%	-43.5%	94.4%	100.0%	5.6%
2011	75.5%	26.7%	-9.0%	37.4%	-28.8%	101.8%	100.0%	-1.8%
2012	79.6%	33.8%	-13.7%	-30.6%	34.6%	103.6%	100.0%	-3.6%
2013	79.1%	39.1%	-18.6%	-43.2%	38.1%	94.5%	100.0%	5.5%
2014	78.3%	44.3%	-24.0%	24.5%	-25.4%	97.7%	100.0%	2.3%
2015	80.4%	51.2%	-31.2%	47.2%	-44.7%	102.9%	100.0%	-2.9%
2016	82.9%	58.6%	-39.8%	-19.5%	16.3%	98.6%	100.0%	1.4%
2017	84.8%	66.0%	-49.2%	-52.5%	51.0%	100.1%	100.0%	-0.1%
2018	84.3%	71.5%	-58.2%	13.0%	-5.0%	105.6%	100.0%	-5.6%
2019	84.7%	77.9%	-68.6%	54.1%	-52.1%	96.0%	100.0%	4.0%
2020	113.6%	112.4%	-106.7%	-8.0%	-9.3%	102.0%	100.0%	-2.0%
2021	106.0%	112.4%	-114.3%	-68.7%	63.1%	98.5%	100.0%	0.0%
Average	85.4%	46.1%	-30.9%	0.0%	-0.2%	100.4%	100.0%	-0.4%
Me	81.7%	41.7%	-21.3%	2.5%	-7.1%	100.6%	100.0%	-0.6%
Max	113.6%	112.4%	-0.4%	54.1%	51.0%	111.9%	100.0%	5.6%
Min	75.5%	5.5%	-106.7%	-52.5%	-52.1%	94.4%	100.0%	-11.9%

Source: calculated based on data from The World Bank (n.d.) and Bureau of Statistics (n.d.).

The following conclusion is emerging: the cyclical component significantly affects the overall trend of high-tech exports in the United Kingdom. Thus, the first harmonica has an effect in the range from -51.4% to +54.8%, but in the near future its positive impact will increase. The second harmonica has approximately the same effect from -57.6% to +55.9%, and its negative impact will increase in the near future. That is, the harmonicas offset each other's influence throughout the analyzed period (Fig. 2).

Figure1

Comparison of the cyclical components of high-tech exports

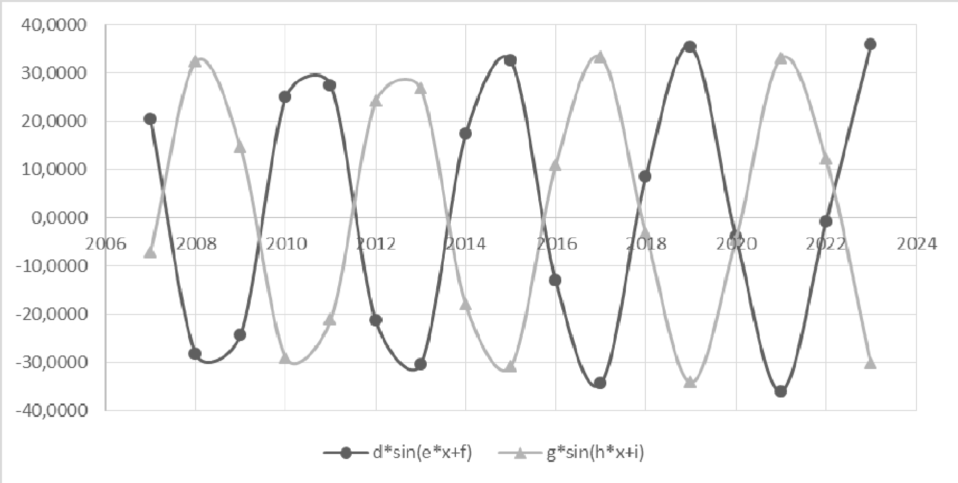


Table 8 allows us to estimate the impact of each component of model 5 on the U.K. high-tech exports and compare it with the standard error describing other random factors. Their impact ranges from -12.1% to +6.1%. The critical values (maximum and minimum) of the cyclical component significantly exceed the critical values of random factors. The United Kingdom's high-tech exports have a certain permanent base, which is an important positive component. Turning to specific facts, we can assume that it is most likely determined by long-term supply agreements with its business partners. Secondly, they have certain constant growth rates, the impact of which on the trend is growing linearly. It can be assumed that these are the so-called business plans – projects for expanding exports from year to year from the territory of a given country, introducing new types, forms, etc. of high-tech products – linear growth. Thirdly, the impact of factors that inhibit the trend is growing exponentially. There can be many such factors, e.g., a decrease in the qualification of employees, continuously changing market conditions throughout the entire period under study, technological difficulties, administrative laws and regulations that slow down exports, the growing influence of competitors, market saturation, etc. Further, cyclical factors are the same as the aforementioned inhibiting factors, but they develop cyclically. Finally, random factors include everything else, mostly random events – accidents, mistakes in logistics, production, financial flows, psychology, etc.

The baseline level of high-tech exports is USD 55.580 billion, which ranges from 75.51% to 113.60% of its performance over the study period (Tables 9 and 10).

The linear rate of high-tech exports ranges from 3,928 to 54,995 billion USD, which is from 5.47% to 112.40% of its performance over the study period. The acceleration of high-tech exports provides from -52.209 to -0.266 billion USD, which is from -106.71% to -0.37% of its dynamics over the study period. The linear component of the dynamics (a + bx) of high-tech exports provides from 59,511 to 110,577 billion USD, which is from 82.82% to 226.00% of its dynamics for the period under study.

Table 9

Analysis of the impact of components on the high-tech exports in billion USD 2010

Year	Linear	Nonlinear	Cyclical	Linear + Nonlinear
2007	59.5106	-0.2664	13.4657	59.2442
2008	63.4387	-1.0655	4.1801	62.3733
2009	67.3669	-2.3974	-9.7404	64.9696
2010	71.2951	-4.2620	-4.0382	67.0332
2011	75.2233	-6.6593	6.3606	68.5640
2012	79.1515	-9.5894	2.7975	69.5621
2013	83.0797	-13.0523	-3.6212	70.0274
2014	87.0079	-17.0478	-0.6518	69.9600
2015	90.9361	-21.5762	1.7662	69.3599
2016	94.8643	-26.6373	-2.1443	68.2270
2017	98.7924	-32.2311	-0.9747	66.5614
2018	107206	-38.3576	5.2911	64.3630
2019	106.6488	-45.0170	1.3492	61.6319
2020	110.5770	-52.2090	-8.4624	58.3680
2021	114.5052	-59.9338	-2.9101	54.5714
2022	118.4334	-68.1914	11.3256	50.2420
2023	122.3616	-76.9817	5.5932	45.3799

Source: calculated based on data from The World Bank (n.d.) and Bureau of Statistics (n.d.).

Table 10

Impact of components on the high-tech exports as a share of the total

Year	Linear	Acceleration	Cyclical	Linear + Acceleration
2007	82.8%	-0.4%	18.7%	82.4%
2008	90.1%	-1.5%	5.9%	88.6%
2009	136.4%	-4.9%	-19.7%	131.6%
2010	106.9%	-6.4%	-6.1%	100.5%
2011	102.2%	-9.0%	8.6%	93.2%
2012	113.3%	-13.7%	4.0%	99.6%
2013	118.3%	-18.6%	-5.2%	99.7%
2014	122.6%	-24.0%	-0.9%	98.6%
2015	131.6%	-31.2%	2.6%	100.4%
2016	141.6%	-39.8%	-3.2%	101.8%
2017	150.8%	-49.2%	-1.5%	101.6%
2018	155.8%	-58.2%	8.0%	97.6%
2019	162.6%	-68.6%	2.1%	94.0%
2020	226.0%	-106.7%	-17.3%	119.3%
2021	218.4%	-114.3%	-5.5%	104.1%
Min	82.8%	-106.7%	-19.7%	82.4%
Max	226.0%	-0.4%	18.7%	131.6%

Source: calculated based on data from The World Bank (n.d.) and Bureau of Statistics (n.d.).

The total impact of the cyclical component of high-tech exports ranges from -9,740 to 13,466 billion USD (constant as of 2010), which varies from -19.73% to 18.74% of its performance over the study period.

The impact of other factors of high-tech exports accounts for -5.855 to 3.849 billion USD, which ranges from -11.86% to 5.57% of the changes in the high-tech exports over the study period.

Analysis and assessment of the high-tech exports (% of manufactured exports)

Next, we model the development of high technology relative to total U.K. manufactured exports over the same period. The overall results are presented in Tables 11 and 12 and Fig. 3.

Table 11

Estimation of the econometric model parameters that assess the changes in the share of high-tech exports in the U.K. manufactured exports in 2007-2020

	M1	M2	M3	M4	M5
Coefficient Data	a =21.3768	a =20.3687	a =21.0914	a =20.3639	a =21.4789
	b =0.1482	b =0.5040	b =0.1956	b =0.5326	b =0.2918
		c =-0.0222	c =0.9659	c =-0.0250	c =-0.0138
			d =-0.5184	d =0.6629	d =1.2786
			e =4.7311	e =1.2619	e =1.0497
				f =1.4344	f =3.2825
					g =1.3566
					h =0.8755
					i =1.9459
Standard Error	0.9301	0.8759	0.7333591	0.8162844	0.6470273
Correlation Coefficient	0.5945	0.6861	0.8311631	0.8094838	0.9249882
Comments:			The fit converged to a tolerance of 0.001 in 14 iterations. No weighting used.	The fit converged to a tolerance of 0.001 in 15 iterations. No weighting used.	The fit converged to a tolerance of 0.001 in 69 iterations. No weighting used.

Source: calculated based on data from The World Bank (n.d.) and Bureau of Statistics (n.d.).

Table 12

Structure of the impact of components on the changes in the share of high-tech exports in the U.K. manufactured exports

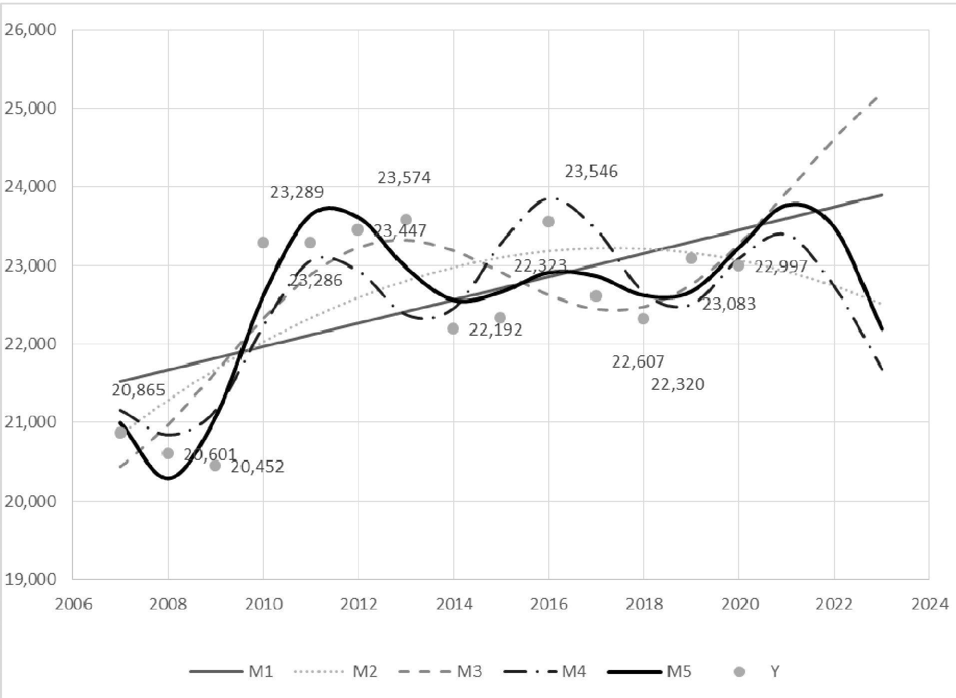
Year	Linear	Acceleration	Cyclical	Linear + Acceleration
2007	104.3%	-0.1%	-3.6%	104.3%
2008	107.1%	-0.3%	-8.3%	106.8%
2009	109.3%	-0.6%	-5.6%	108.7%
2010	97.3%	-1.0%	0.8%	96.3%
2011	98.5%	-1.5%	4.5%	97.0%
2012	99.1%	-2.1%	3.7%	97.0%
2013	99.8%	-2.9%	0.5%	96.9%

Year	Linear	Acceleration	Cyclical	Linear + Acceleration
2014	107.3%	-4.0%	-1.7%	103.3%
2015	108.0%	-5.0%	-1.4%	103.0%
2016	103.6%	-5.9%	-0.4%	97.7%
2017	109.2%	-7.4%	-0.7%	101.8%
2018	111.9%	-8.9%	-1.7%	103.0%
2019	109.5%	-10.1%	-1.2%	99.4%
2020	111.2%	-11.8%	1.6%	99.4%
2021	108.4%	-13.1%	4.3%	95.3%

Source: calculated based on data from The World Bank (n.d.) and Bureau of Statistics (n.d.).

Figure 3

Comparison of the obtained models and forecast of the changes in the share of high-tech exports in the U.K. manufactured exports until 2023



The baseline level of high-tech exports (% of manufactured exports) is 21.480%, which ranges from 91.11% to 105.02% of its trend over the study period. The linear rate of high-tech exports (% of manufactured exports) ranges from 0.292 to 4.086%, which is from 1.40% to 17.77% of its performance over the study period. The acceleration of high-tech exports (% of manufactured exports) provides from -2.712 to -0.014%, which is from -11.79% to -0.07% of its dynamics over the study period.

The 1st harmonica of high-tech exports (% of manufactured exports) accounts for -1.201 to 1.198%, which is -5.69% to 5.11% of their change over the study period. 2The 2nd harmonica of high-tech exports (% of manufactured exports) accounts for -1.343 to 1.354%, which is -6.57% to 5.89% of their change over the study period. The total impact of the cyclical component of high-tech exports (% of manufactured exports) ranges from -1.718 to 1.051%, which is from -8.34% to 4.51% of their changes over the study period.

The impact of other factors of high-tech exports (% of manufactured exports) ranges from -0.624 to 0.677%, which is from -3.05% to 2.91% of their changes over the study period.

Since the rate is greater than zero, there is an increase in the trend of high-tech exports (% of manufactured exports). Since the acceleration is less than zero, there is a slowdown in the trend of high-tech exports (% of exports of manufactured goods).

The amplitude of the 1st harmonica is greater than zero, so we can speak of the initial positive impact of the cyclical factor on the high-tech exports (% of exports of manufactured products). It will become negative after 0.25 periods, i.e., after 1.50 years, and the maximum negative impact will be after 0.5 periods, i.e., after 2.99 years.

The amplitude of the 2nd harmonica is greater than zero, so we can speak of the initial positive impact of the cyclical factor on the high-tech exports (% of exports of manufactured products). It will become negative after 0.25 periods, i.e., after 1.79 years, and the maximum negative impact will be after 0.5 periods, i.e., after 3.59 years.

Assessment and comparison of the impact of cyclical components on the indicator performance

Let us compare the cyclical components of the changes in high-tech exports, the share of high-tech exports in total manufactured exports, the share of high-tech exports in the country's GDP, and GDP and manufactured exports (Table 13).

Once again, since some indicators showed negative values for the fluctuation period, and since the economic sense of negative fluctuation frequencies is to determine the direction of these fluctuations, and mathematically the sine function is replaced by cosine, at this stage of the study we conditionally take into account only the absolute frequency and fluctuation period.

Table 13

Analysis of the impact of the cyclical component on the studied indicators

Parameter	High-technology exports (billion USD, constant 2010)	High-technology exports (% of manufactured exports)	High-technology exports (% of GDP)	GDP (billion USD, constant 2010)	Manufactured exports (billion USD, constant 2010)
1st harmonica					
Angular frequency, radians	1.50	1.05	1.05	12.84	8.032
Frequency, times in year	0.24	0.17	0.17	2.04	1.278
Period, years	4.17	5.99	5.99	0.49	0.782
Phase, radians	1.03	3.28	2.28	-146.74	183.176
Offset, period fraction	0.16	0.52	0.36	-23.35	29.153
Offset, years	0.68	3.13	2.17	-11.43	-22.806
Offset, months	8.21	37.53	26.02	-137.10	-273.673
Amplitude,	36.04	1.28	0.10	850.96	-25.224
Effect on dynamics, max, %	54.13%	5.11%	3.59%	37.25%	7.96%
Effect on dynamics, min, %	-52.46%	-5.69%	-4.60%	-34.16%	-11.84%
2nd harmonica					
Angular frequency, radians	1.46	0.88	1.02	13.49	12.890
Frequency, times in year	0.23	0.14	0.16	2.15	2.051
Period, years	4.32	7.18	6.15	0.47	0.487
Phase, radians	-1.66	1.95	2.14	-149.77	-205.779
Offset, period fraction	-0.26	0.31	0.34	-23.84	-32.751
Offset, years	-1.14	2.22	2.10	-11.10	-15.965
Offset, months	-13.72	26.67	25.20	-133.21	-191.578
Amplitude,	34.16	1.36	0.10	179.59	-87.153
Effect on dynamics, max, %	50.97%	5.89%	3.82%	7.80%	30.51%
Effect on dynamics, min, %	-52.07%	-6.57%	-4.54%	-7.36%	-24.04%
The total effect of the cyclical component on the dynamics of the indicator, max, %	105.10%	11.00%	7.41%	45.05%	38.47%
The total effect of the cyclical component on the dynamics of the indicator, min, %	-104.53%	-12.26%	-9.13%	-41.52%	-35.88%
Total weighted effect of the cyclical component on the dynamics of the indicator, max, %	18.74%	4.51%	6.75%	45.05%	33.90%
Total weighted effect of the cyclical component on the dynamics of the indicator, min, %	-19.73%	-8.34%	-8.44%	-38.64%	-30.07%

Source: calculated based on data from The World Bank (n.d.) and Bureau of Statistics (n.d.).

What factors can create a cyclical impact? Inflation (all calculations are done using 2010 prices) and seasonal fluctuations (data are taken for the whole year, not quarterly) are excluded. Fluctuations in high-tech exports are due to a combination of industries – aerospace, engineering, IT and pharmaceuticals – among the most knowledge-intensive sectors. These cycles can reflect both the life cycle of new types of high-tech goods being created, introduced and released to the global market and, on the other hand, market conditions and demand for these products from national producers.

Notably, the changes in high-tech exports are strongly influenced by cyclical components, but their total impact has been mitigated to the level of +-19-20%. These cycles have fluctuation periods of 4.5 and 4.3 years, which indicates the influence of short-term processes. The initial phase of fluctuations is -1.1 and +0.8 years, i.e., the fluctuating component of the 1st harmonica began to influence the high-tech exports around 2006, and the second around 2008.

The next indicator is the share of high-tech exports in the United Kingdom's total industrial exports.

Here we observe a lesser degree of influence of cyclical components on the indicator: from -2.51% to +3% (1st harmonica), and from -3.03% to +2.68% (2nd harmonica), which produces a -5.11% to +4.99% effect when combined. The fluctuation period of both harmonicas is the same, 4-7 times shorter than in the first case, i.e., 0.6-1.1 years. In other words, the share of high-tech exports in total manufactured exports is less subject to cyclical fluctuations than their absolute change.

If we consider the changes in the share of high-tech exports in the U.K. GDP (also adjusted for inflation, recalculated in 2010 prices), we find that, in relation to GDP, fluctuations had approximately the same impact as on the changes in the share of high-tech exports in total manufactured exports: from -8.47% to +6.8%. The harmonic fluctuations had almost identical periods of 5.99 and 6.15 years, fluctuation amplitudes of 0.1 and 0.1, initial phases of 2.17 and 2.1 years, which indicates similarities in the nature of fluctuations with the average period of 6 years.

UK manufactured exports are more susceptible to cyclical fluctuations than its high-tech exports. Moreover, the negative impact of the cyclical component is 1.5 times higher and reaches -30.07%, while the positive impact is 1.75 times higher at +33.9%.

Conclusions

This study has revealed the presence of cyclical components in the development of high-tech exports of the UK in 2007-2020 with a period of 4.5 and 4.3 years. This is 5-10% shorter than in Germany, 1.5 times faster than in Austria and 2 times faster than in Poland and the Netherlands, and 3 times faster than in

Ukraine. The shorter this period, the faster the development of the high-tech sector of the country's economy.

We also identified cyclical components in the performance of derivative indicators such as the share of high-tech exports in total manufactured exports (two harmonicas with periods of 0.6 and 1.14 years) and the share in the country's GDP (two harmonicas with an average period of 6 years). This suggests that relative indicators fluctuate in a different pattern than the absolute indicator.

The overall impact of the cyclical component on the high-tech export trend is significant – in the range of +/- 20%. It should be noted that the positive and negative effects are almost equal. The total impact of the cyclical component on the change in the share of high-tech exports in manufactured exports is 4 times less, at +/- 5%, and the impact on its share in GDP is 3 times lower, at +/- 7%.

Prospects for further research are related to the study of an array of factors, calculation of their cyclical features and identification of the factors that have a similar period, phase and cyclical frequency while influencing the development of high-tech exports.

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Received: September 1, 2023.
Reviewed: September 28, 2023.
Accepted: November 6, 2023.