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Dynamic interactions among exchange rate, natural gas demand, production in manufacturing and battery industry export – evidence from Hungary

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Abstract: In the context of the current global economic transformation, the rapid rise of the electric vehicle industry has made the battery industry a new focus of competition among countries. Despite its relatively small economic and demographic size, Hungary has garnered significant academic interest by emerging as the world's third-largest battery producer in 2021. The study employed a dynamic vector autoregressive (VAR) model to determine that fluctuations in the Hungarian exchange rate have a notable immediate influence on exports in the battery business， which suggests that changes in exchange rates directly affect international competitiveness. The battery sector is experiencing a progressive increase in the influence of fluctuations in natural gas demand, particularly in terms of their impact on production costs and supply chains. The battery industry has had substantial advancements in technological innovation and production efficiency as a direct result of the expansion in manufacturing production. And Hungary's total industrial development is significantly influenced by the long-term effects of export expansion in the battery industry.

Keywords: *Exchange rate fluctuation, natural gas demand, manufacturing development, battery industry export, Hungary*

JEL Codes: *L62, E44, O14, C22*

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Introduction

The global energy revolution and shifts in the automotive sector are currently underway, with the electric vehicle (EV) market experiencing tremendous growth as a result of its environmentally sustainable and technologically advanced features (Kumar & Alok, 2020). As the core component of EVs, the development of the battery industry has become a new focus of competition among countries. More and more countries around the world have invested resources and technologies to accelerate the development of the battery industry, hoping to occupy a place in this rapidly growing market.

In the middle of this worldwide phenomenon, Hungary, a nation with a relatively small economy and population, has demonstrated extraordinary accomplishments. As of 2021, Hungary has achieved the dual accomplishment of becoming the third largest battery manufacturer globally and establishing a significant presence in the international battery sector (Bhutada, 2022). This disparity has sparked extensive discourse and apprehension within the academic community and industrial practitioners.

However, despite Hungary's notable progress in the battery sector, there is a lack of comprehensive research on the crucial elements that influence its development and their impact on the dynamics of the Hungarian battery industry. The exploration of the interdependencies among macroeconomic factors, including exchange rate volatility, natural gas consumption, manufacturing output, and the growth of the battery sector, and their collective impact on Hungary's macroeconomic conditions and international trade position remains incomplete.

Based on the background, the primary research objective is to investigate the dynamic economic factors that have contributed to the rapid growth of the Hungarian battery sector. The study intends to specifically investigate the interplay among macroeconomic variables, including exchange rate changes, natural gas demand, manufacturing production, and the development of the Hungarian battery industry.

The main research questions are: What is the impact of exchange rate changes on the Hungarian battery industry? How will variations in energy demand, particularly in relation to natural gas, affect the battery industry? What is the relationship between changes in manufacturing production and the country's battery industry?

To answer the above question, this study employs a dynamic vector autoregressive (VAR) model to examine monthly time series data from the Eurostat database, spanning from January 2018 to August 2023. To achieve data stationarity and mitigate heteroscedasticity, logarithmic transformation and first differencing are applied to all variables. Impulse response functions and variance decomposition are used to elucidate the interplay and temporal evolution of these factors. The results to these inquiries will facilitate a deeper comprehension of the historical context and future potential of the Hungarian battery sector, while also furnishing a theoretical and empirical foundation for devising more efficacious industrial strategies and macroeconomic policies.

The paper is structured as follows: The second section comprises a literature review, examining pertinent theoretical frameworks and empirical studies. Subsequently, an account of the data and methodology is provided. The fourth part entails the examination and interpretation of the results obtained from the research. And the final one is a summary.

Conceptual and contextual background

Exchange rate fluctuations and foreign trade

The correlation between changes in exchange rates and international trade is an intricate and diverse subject that has been widely examined in the realm of international economics. Fluctuations in exchange rates can impact the pricing of commodities in global marketplaces. When a nation's currency experiences depreciation, its exports become more affordable and competitive in international markets, which may lead to an increase in exports (Cooper, 2019; Aisyah & Renggani, 2021). On the other hand, when a currency appreciates, it leads to a decrease in the cost of imports and an increase in the cost of exports, so impacting the trade balance. Tunc et al. (2018) emphasized that fluctuations in exchange rates will have a substantial impact on the import and export commerce. The researchers examined the correlation between the U.S. real exchange rate and foreign trade to investigate the impact of the U.S. dollar exchange rate on U.S. international trade statistics. The conclusive findings indicate that the decrease in the actual exchange rate observed in the U.S. domestic economic market is advantageous for its participation in international market trade to enhance its export competitiveness.

Furthermore, abrupt fluctuations in currency exchange rates might not only disturb established trade alliances, but also compel export-focused enterprises to modify their supply chain tactics or shift their manufacturing facilities. The study conducted by Anisak and Mohamad (2020) reveals that export-oriented companies can mitigate profit losses resulting from the appreciation of the local currency by strategically sourcing raw materials from the same location where their products are sold. This is made possible by leveraging changes in income due to local exchange rate fluctuations. Enterprises build new production bases to prevent their own interests from being affected by exchange rate changes, and at the same time reduce the foreign trade volume of the home country.

Natural gas demand and manufacturing production

As an important energy source, natural gas plays a central role in global manufacturing. With the growing global demand for sustainable and clean energy, natural gas is increasingly important in promoting the development of manufacturing and supporting technological innovation. Research by Ahmad & Zhang (2020) shows that natural gas supply and demand are closely related to the growth and efficiency of manufacturing, especially in energy-intensive industries.

Natural gas price fluctuations have a significant impact on manufacturing output and costs. Low natural gas prices stimulate consumer demand, help reduce production costs, and improve the global competitiveness of the manufacturing industry (Brändle et al., 2021). Price instability may increase a company's operational risks and affect investment decisions. In the case of rising natural gas prices, some manufacturing industries that rely on natural gas as their main energy source may face rising costs and compressed profits.

Stable demand for natural gas also helps maintain stable supply chains for manufacturing production. It helps maintain consistent energy costs, which is especially important in energy-intensive manufacturing industries where energy costs directly impact production costs and final product pricing. In addition, the reliability of natural gas supply ensures the continuity and efficiency of the production process, thereby avoiding production delays or shutdowns due to supply disruptions, which is critical to meeting market demand. Stable natural gas prices and supplies also support companies in making accurate long-term planning and investment decisions, especially when it comes to new technologies and facility upgrades. Moreover, as a relatively clean energy source, the stability of demand for natural gas is crucial to establishing and maintaining confidence in the energy market and manufacturing manufacturers. Frequent fluctuations in energy demand and supply can damage a company's market position and reputation (Riera et al., 2023).

Manufacturing production and battery industry development

Recently, due to the rising global demand for sustainable energy and electric vehicles, the battery industry has emerged as a significant driver of economic growth worldwide. The growth of the battery industry has been significantly influenced by advancements in manufacturing, particularly in the high-tech and energy fields. This association has been examined and verified in numerous scholarly investigations.

The battery industry has significant growth due to technological advancements in the manufacturing sector (Olabi et al., 2023). The advent of novel materials and advanced production techniques has led to substantial enhancements in battery performance, such as heightened energy density, diminished cost, and prolonged lifespan. These technological improvements not only improve the competitiveness of battery products, but also stimulate new market demand, particularly in the areas of electric vehicles and renewable energy storage. Technological advancements in lithium-ion batteries have significantly bolstered the widespread use of electric vehicles.

The total progress of the manufacturing sector is also closely linked to the expansion of the battery business. Countries with a robust manufacturing sector frequently experience accelerated growth in the battery industry. The reason for this is that these countries possess superior supply chains, state-of-the-art industrial facilities, and extensive technical and engineering knowledge. China, South Korea, and Japan have experienced significant expansion in the battery business and achieved worldwide market leadership due to their robust manufacturing bases (Bridge & Faigen, 2022).

The battery sector has been significantly influenced by the trend of globalization as well. The integration of global supply chains enables battery manufacturers to optimize the utilization of global resources like as raw materials, capital, and technology, leading to enhanced production efficiency and cost reduction (Rajaeifar et al., 2022). This not only facilitates the growth of the battery sector but also enhances its international export capacities. Globalization has facilitated the entry of battery makers into new markets, particularly the electric car sector in Asia, Europe, and North America (Bubbico, 2023).

Furthermore, the advancement of the battery sector is also driven by environmental policies and market demand. With the increasing worldwide emphasis on lowering carbon emissions and encouraging sustainable development, there is a rising need from both governments and markets for battery solutions that are efficient and ecologically benign. This has stimulated the study, development, and manufacture of battery technologies, consequently bolstering the export expansion of the battery sector.

Current literature reveals comprehensive research findings on the correlation between exchange rate fluctuations and trade development, natural gas demand and manufacturing development, and manufacturing development and the battery industry. However, there is still a need for further significant studies. There are research gaps, particularly when it comes to the dynamic interactions at the junction of these domains. Existing research mostly examines the influence of exchange rate variations on overall imports and exports in general trade, with less investigation into the specific effects on the battery industry's exports. Furthermore, while the influence of natural gas demand on manufacturing has been extensively examined, there remains a scarcity of research on the precise impact of natural gas demand on the growth of the battery industry, particularly in relation to battery production and export capacities across various regions. However, the potential correlation between the advancement of manufacturing and the rise of the battery business has not been thoroughly investigated. This work seeks to address the existing research deficiencies by examining the Hungarian battery sector as a case study. It employs dynamic VAR methodology to undertake a comprehensive examination of the dynamic relationship between exchange rate changes, natural gas demand, manufacturing development, and industrial exports.

Data and Methodology

Data

The research period spans 68 monthly time series data, ranging from January 2018 to August 2023. Variables that are considered are battery industry export, exchange rates, natural gas demand, and manufacturing production statistics, which are all sourced from the Eurostat database. The battery sector[2] is classified under the Combined Nomenclature (CN) into two main groups, namely 8506 and 8507 (Éltető, 2023). Figure 1 demonstrates the significant growth of Hungary's imports and exports of

[2] Eurostat URL: https://tinyurl.com/2e52ye5a

battery products over the study period. Hungary has consistently maintained a trade surplus for an extended duration, and this trend is continuing to expand. For this reason, only the correlation between the export of battery products and other variables are examined. The term "exchange rate" specifically pertains to the rate at which the euro can be exchanged for the Hungarian forint (EUR/HUF)[3]. It is a gauge of Hungary's level of trade in the world economy and its position in the global financial markets. The demand for natural gas reflects domestic demand and has an impact on its supply. Considering the significant reliance on natural gas in the production of battery products and its role in Hungary's energy mix[4], it can provide insight into the impact of energy market changes on Hungary's industrial output and battery product exports. The production in the manufacturing industry serves as a measure of Hungary's manufacturing capacity and is a crucial indicator for evaluating the country's economic state and industrial well-being[5]. To mitigate potential non-stationarity and enhance the precision of the study, all variables are applied a logarithmic transformation and first-order difference.

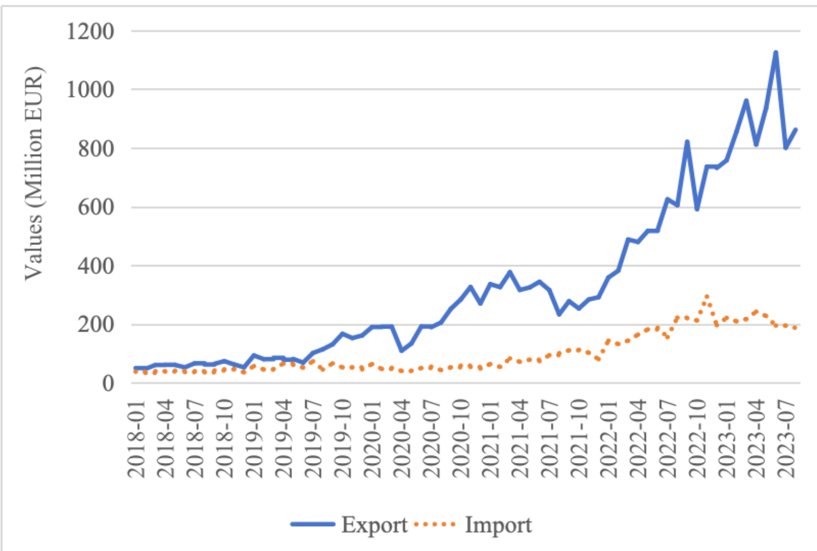

Figure 1. Trade values of battery products in Hungary from 2018 M01 to 2023 M08
Source: Plotted based on Eurostat's Comext data

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[3] Eurostat. URL: https://tinyurl.com/mvmr7awn
[4] Eurostat. URL: https://tinyurl.com/bdn45sah
[5] Eurostat URL: https://tinyurl.com/ysexchcb

Methodology

This study used a dynamic vector autoregressive (VAR) model to investigate the dynamic relationships among EUR/HUF exchange rate, natural gas demand, manufacturing production, and battery industry exports in Hungary. The model is a commonly employed method in econometrics for analyzing multivariate time series data, which is introduced by economist Christopher Sims during the 1980s, seeking to comprehend and measure the dynamic interconnections among various economic factors. The fundamental characteristic of the VAR model is that it represents the present value of each variable as a function of the previous values of all other variables in the model, enabling the past value of any variable to impact the present value of all other variables. This strategy offers the benefit of not only capturing the immediate effects between variables but also uncovering the long-term dynamic interactions between them. The VAR(p) model, which has a lag period of p, can be represented as:

$$Y_t = A_1 Y_{t-1} + A_2 Y_{t-2} + \cdots + A_p Y_{t-p} + \mu_t \tag{1}$$

where Y_t is a vector with dimensions nx1, which represents the values of all variables at time t. A_1, A_2,…, A_p are the matrix of coefficients. μ_t is the error term. p represents the lag order.

Within the VAR model, each economic variable functions as a component of an equation, thus several systems of equations are formed. It is called a dynamic model as the lagged value of the dependent variable is also used as an independent variable. Every equation in the model includes past values of all variables being studied and a residual term. The lag order of the model, which refers to the number of lag values, is often determined using statistical approaches such as the information criteria. The error term of the VAR model encompasses additional exogenous factors that exert influence beyond the variables incorporated inside the model.

Essential diagnostic techniques for VAR models encompass unit root tests to assess the stationarity of the data, normality of error terms, homoskedasticity, and tests to detect the absence of autocorrelation of the error term. Furthermore, the impulse response function (IRF) and variance decomposition are crucial tools for examining the dynamic interaction between variables in the VAR model. IRF examines the impact of a disturbance in one variable on other variables over a period of time, whereas variance decomposition examines how the variability in the forecast error of each variable at different time points is accounted for by disturbances in other variables in the model.

However, although the VAR model offers a comprehensive approach to evaluate the interactions and feedback mechanisms among different variables, it has its constraints. For instance, the VAR model relies on the linear assumption, indicating that the connection between variables is constant and follows a straight line, which hinders its capacity to capture the intricate and complex patterns that may be present in economic data. Furthermore, while the VAR model excels in elucidating the dynamic interplay among variables, its forecasts and analysis are heavily reliant on past data. The model's projections may be influenced when confronted with structural changes or unexpected new shocks in the future.

Results

The results of calculations derived from the theoretical model are presented in a three-step process. Firstly, providing the basic statistics of the logarithmic changes of variables. Then, presenting equations obtained from model fittings, and the results of tests that assess non-autocorrelation, non-heteroskedasticity, and normal distribution of error terms. Ultimately, impulse response functions and variance decompositions are graphed (Kiss et al., 2020).

Basic statistics

Data stationarity is a fundamental need for conducting time series analysis. As illustrated in Table 2, it is determined that all p-values for the unit root test are below 0.01, which provides a significant rejection of the null hypothesis and suggests that all the variables utilized in the dynamic VAR model analysis are in fact stationary., it is observed that the p-values of the unit root test are all below 0.01. This strong rejection of the null hypothesis indicates that the variables incorporated in the VAR model analysis are all stable. Additionally, in certain instances, variables adhere to the standard normal distribution.

Test	variable	ΔLogbpev	ΔLogpimi	ΔLogngd	ΔLogeuhu
Central moments	average	0.04	0.00	-0.02	0.00
	standard deviation	0.18	0.12	0.29	0.02
	skewness	-0.36	-0.82	-0.10	0.35
	kurtosis	4.27	5.08	3.23	3.32
Normal distribution	Jarque-Bera (p)	0.09	0.00	0.93	0.50
Autocorrelation	Ljung-Box (p)	0.02	0.01	0.00	0.91
Heteroscedasticity	ARCH-LM (p)	0.01	0.00	0.00	0.90
Unit-root	ADF (p)	0.00	0.00	0.01	0.00

Table 1. Basic statistics of input variables
Source: Plotted with Matlab2023a MFE toolbox and Eviews 11 software

Dynamic VAR model

The time lag order of the dynamic VAR model was established based on the information criteria (IC). The Schwarz IC suggested a 0-month time lag, whereas the Hannan-Quinn IC proposed a 1-month time lag. Additionally, it relies on the assumption of the error terms following a normal distribution and being non-autocorrelated. The LR, FPE, and AIC criteria indicated a 6-month temporal delay. Based on the optimal lag length determination criteria, the model opted to employ a time lag of 6 months.

Dynamic VAR model with a 6-month lag is reliable. As depicted in Figure 2 below, the inverse root diagram of the AR characteristic polynomial reveals that all roots are situated within the unit circle at present. This indicates that the VAR model being estimated is stable.

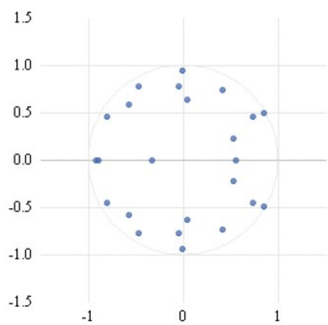


Figure 2. Inverse Roots of AR Characteristic Polynomial
Source: Plotted with Eviews 11 software

Based on the model diagnosis presented in Table 3, the LM test indicates that the error term of the VAR equation satisfies the assumption of non-autocorrelation overall. Additionally, the White test demonstrates that the error term meets the requirement of non-heteroscedasticity. Furthermore, the Jarque-Bera test confirms that the error term follows a normal distribution.

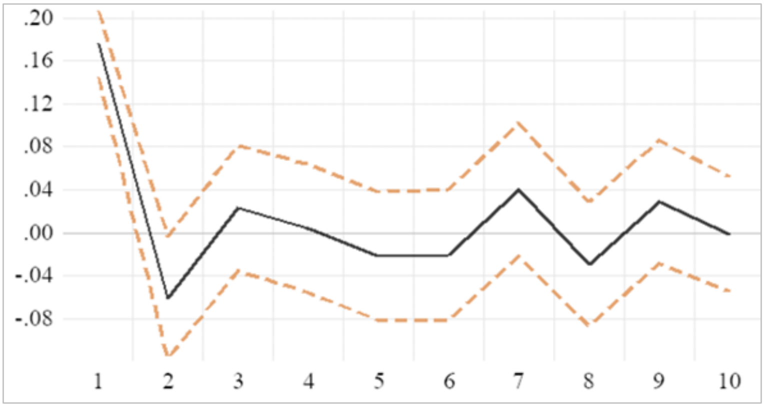
		time lag	p-value		time lag	p-value
LM-test	h-time lag	1	0.0145	1:h time lag	1	0.0145
		2	0.6069		2	0.0358
		3	0.8289		3	0.1105
		4	0.0915		4	0.0191
		5	0.8271		5	0.1232
		6	0.4897		6	0.1048
		7	0.3040		7	0.4032
Jarque-Bera test		Joint	0.8451	White test	Joint	0.9170

Table 2. Examination of error terms of the two VAR equations: non-autocorrelation, non-heteroskedasticity and normal distribution
Source: Plotted with Eviews 11 software

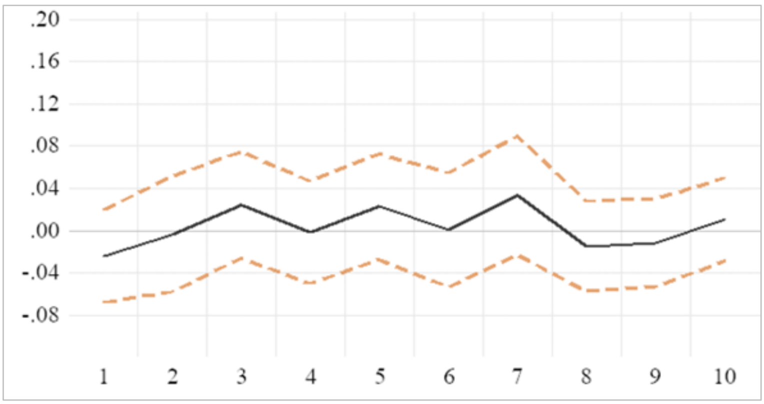
Impulse response functions and variance decomposition

Impulse response functions (IRFs) are frequently employed in time series analysis to comprehend the temporal evolution of an economic or financial variable when another variable experiences a unit shock. Figure 3 displays a graphical representation where the horizontal axis represents the months following the impact, while the vertical axes reflect variations in the growth rate of battery product exports. Due to space constraints and a desire to emphasize the main point, the sole response variable included in this article is the growth rate of battery product exports.

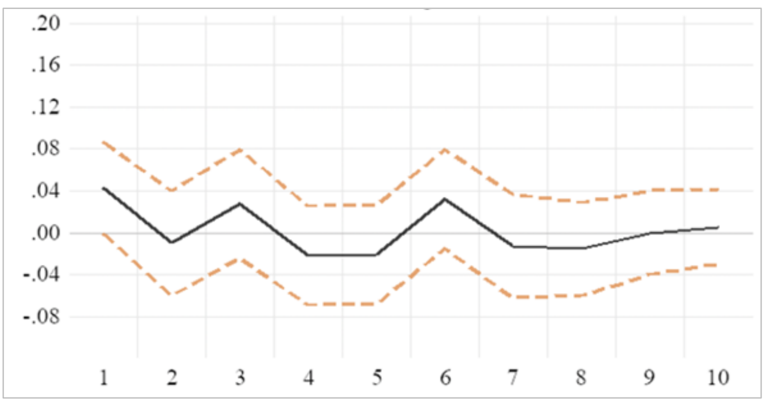
Response of battery products export on shock of battery products export



Response of battery products export on shock of EUR/HUF rate



Response of battery products export on shock of natural gas demand



Response of battery products export on shock of production in manufacturing

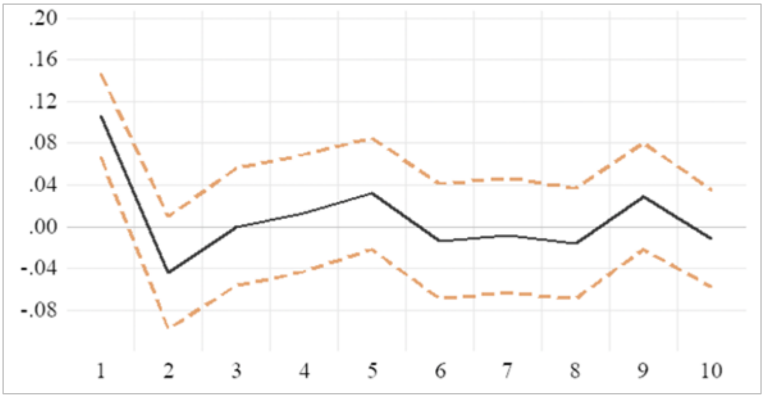


Figure 3. Impulse response functions of the dynamic VAR model
Note: Black solid lines indicate impulse response functions,
while 95% (±2 S.E.) confidence intervals are shown in the dotted lines.
Source: Plotted with Eviews11 software

The export growth rate of battery products is responsive to its own effects. During the initial month, the battery product export growth rate exhibits the highest response to the self-shock, which thereafter decreases rapidly. By the second month, there is a negative response, suggesting a fall in the growth rate of battery product exports following the initial shock. Over time, the response undergoes oscillations and reaches a state of stability, fluctuating above and below the zero line, which indicates that the impact of the shock steadily diminishes and eventually becomes negligible. This suggests the inherent ability of the battery product market to regulate itself. The initial favorable reaction could be attributed to the anticipations of market participants of forthcoming price surges, resulting in a temporary upswing in export growth rates. Nevertheless, this surge is not viable in the long term as the market will promptly rectify this irregularity, leading to a decline in export growth rates.

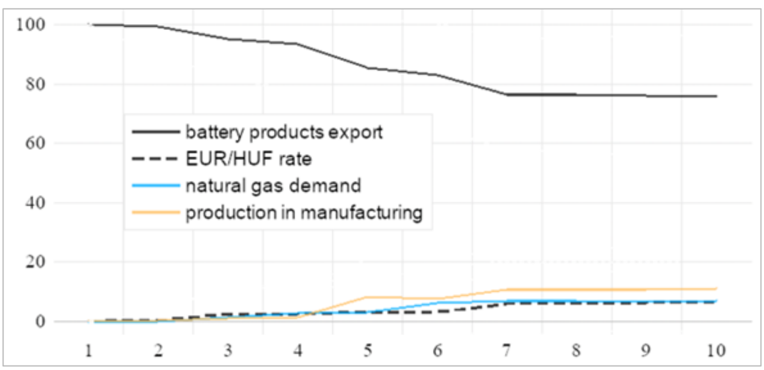
From the correlation between the growth rate of battery product exports and the Euro/Hungarian Forint (EUR/HUF) exchange rate, it can be observed that in the first month following the impact, the growth rate of battery product exports shows a slightly positive response to the impact of the EUR/HUF exchange rate. Over the subsequent months, this response exhibits a more optimistic trend, suggesting that the export growth rate of this product experienced an upturn in response to shocks in the EUR/HUF exchange rate. During the 5th epoch, the reaction reaches its maximum and thereafter begins to decrease. After some time, the response gradually diminishes and starts to oscillate about the zero line, signifying a reduction in the impact of the shock as time passes. The nexus between fluctuations in exchange rates and the growth rate of exports additionally points to alterations in price competitiveness. When the EUR/HUF exchange rate depreciates, i.e., the euro loses value compared to the Hungarian forint, it could lead to a decrease in the price of battery products offered in Hungary to the international market, which, in turn, may boost abroad demand for these items and increase exports. Nevertheless, the invigorating influence of this effect is brief, indicating that additional elements like market saturation or counterparty responses may promptly counterbalance the early consequences of fluctuations in currency rates.

Shocks to the demand for natural gas also affect the growth rate of exports of battery products. Following the initial shock, the export growth rate of battery products shows a modest upward response to the increase in natural gas demand, albeit not significantly. Consequently, the response swings and cycles between positive and negative values, indicating that the export growth rate of export inconsistently reacts to changes in demand at different time intervals. After approximately 4 months, the response gradually diminishes to nearly zero and remains momentarily before the growth rate starts fluctuating between positive and negative values once more. It means that the influence of fluctuations in natural gas demand on the growth rate of battery product exports is dynamic and constantly evolving. By the tenth month, the reaction had once again approached zero, suggesting that the long-term effect of the natural gas demand shock on the growth rate of battery product exports had diminished. The variability in response indicates that while fluctuations in natural gas demand initially affected the growth rates of battery product exports, this impact was inconsistent and differed over time. This could be attributed to the susceptibility of battery manufacturing to energy price variations, whereby fluctuations in energy prices can impact production expenses and export competitiveness.

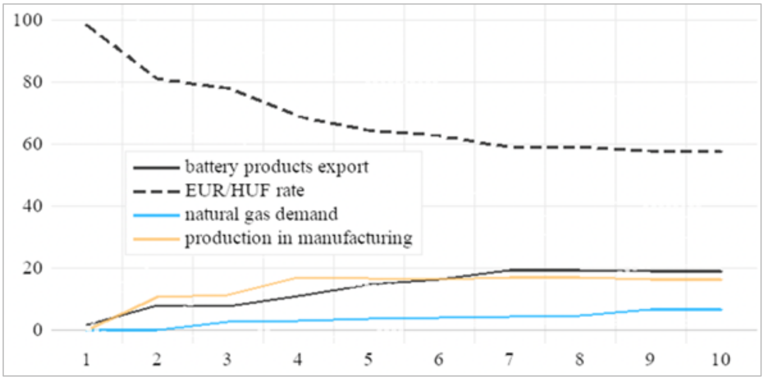
Finally, from the perspective of the impact of manufacturing production on the export growth rate of battery products, the initial response in the first month was a small positive value, followed by a rapid decline to a negative value. Subsequently, the answer exhibited a slow ascent, returning to positive territory. From the 6th month onwards, the reaction stabilizes and varies about the zero line, suggesting that the shock to manufacturing output has a minimal long-term effect on the export growth rate of battery products. The decline in the growth rate of battery product exports in manufacturing output may be attributed to production fluctuations that have led to temporary disruptions or uncertainty in the supply chain, thereby impacting export capacities. Subsequently, as time progresses, market adaptations and improvements in the supply chain may contribute to the recovery of export levels, resulting in a stabilization of the reaction at zero, which also demonstrates the market's ability to withstand variations in production of manufacturing industry.

Moreover, to measure the contribution level of past unexpected shocks on various variables on the error in predicting future outcomes, variance decomposition can be employed. Figure 4 demonstrates that while the growth rates of battery product exports, fluctuations in the EUR/HUF exchange rate, changes in natural gas consumption, and fluctuations in manufacturing production are mostly influenced by their own historical shocks and the contribution declines along with the time, there are also noteworthy interconnections among them. The oscillations in the EUR/HUF exchange rate, changes in natural gas demand, and fluctuations in manufacturing production lack strong causal explanations for each other, which might be due to market segmentation, the distinctiveness of supply and demand dynamics, or the indirect nature of their connection. The weak association may also be influenced by the data and the chosen methodology. However, the influence of exporting battery products on manufacturing production grows increasingly substantial. This could be attributed to the fact that the battery industry is a significant sector with high growth rate within the manufacturing industry, and its performance has a direct impact on the general well-being of the manufacturing industry.

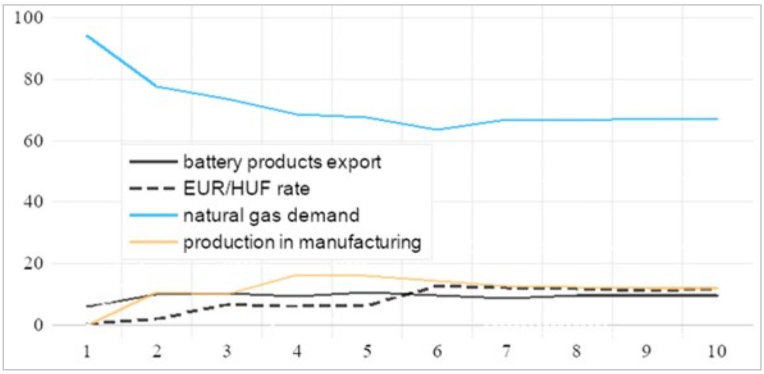
Per cent | Variance decomposition for the battery Products export



Per cent | Variance decomposition for the EUR/HUF rate



Per cent | Variance Decomposition of naturalgas demand



Per cent | Variance Decomposition of production in manufacturing

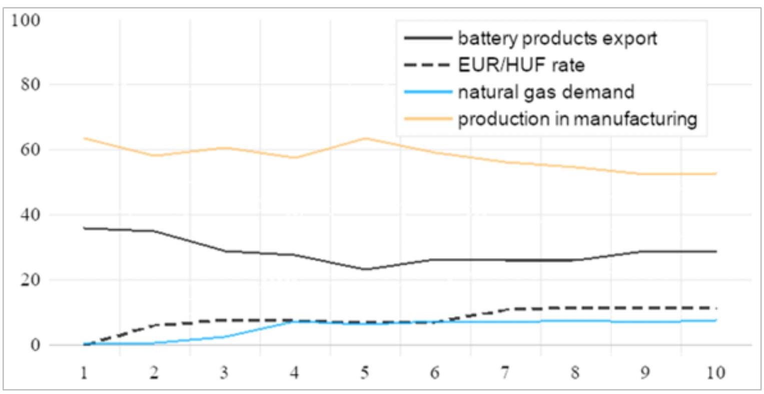


Figure 4. Variance decomposition for the battery products export
Source: Plotted with Eviews11 software

Summary

Based on time series data from January 2018 to August 2023, this article uses a dynamic VAR model to analyze how exchange rate fluctuations, natural gas demand, and production in manufacturing dynamically affect Hungary's battery industry exports. It is found that the impact of exchange rate fluctuations on the export of the battery industry is dual, including both the improvement of price competitiveness and the potential risks caused by increased market uncertainty. As a key industrial energy source, natural gas's price and demand stability significantly affect the production costs and operating efficiency of the battery industry. The technological innovation and overall development level of the manufacturing industry provide the basis for the technological progress and market expansion of the battery industry. In addition, the export of the battery industry will also have a greater impact on the fluctuations of Hungary's manufacturing industry. Judging from the impact of factors, it is mainly short-term. This reflects the self-regulatory nature of factor markets.

Compared with the existing literature, this study provides a more comprehensive framework that situates the battery industry within the interactive influence of macroeconomic factors. Unlike studies that focus solely on one aspect, this article emphasizes the interdependence and complexity among exchange rates, energy demand, and industrial policy. This has certain enlightening significance for policy makers. In order to promote the sustainable development of the Hungarian battery industry and enhance its international competitiveness, the policymakers could consider implementing a stable exchange rate management strategy to reduce the negative impact of exchange rate fluctuations on battery industry exports. Corporate exporters can also use financial instruments to manage the risk of exchange rate fluctuations. Ensuring the stability of gas supply and demand is also crucial, which involves not only increasing domestic gas production but also diversifying import sources and building strategic energy reserves. In addition, the government should provide financial incentives and R&D support to promote technological innovation in the manufacturing industry, especially the battery industry. It can also promote the creation of a favorable environment to attract venture in the battery industry and related high-tech fields, to help the domestic battery industry grow and develop.

However, although this paper provides some key insights, there are limitations, mainly reflected in the study's reliance on currently available data sets, which may have limited the depth and breadth of the analysis. Methodological choices are based on linear models, which cannot reflect the impact of non-linear relationships. Furthermore, the research focuses primarily on Hungary as a case study and may not fully cover the unique economic and cultural characteristics of the battery industry in different countries or regions. Future research directions could be to use a wider dataset from different countries or regions to enhance the generalizability and applicability of the study. In addition, studying the relationship between the development of the battery industry and other sectors is also a good research direction.

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