A Snapshot of Where We Are. A Gross Domestic Product Analysis Related to Household Energy Price Index in the European Union

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Abstract

This is one of the few articles that investigate the relation between GDP and electricity and gas evolution, especially given the events in the last three years.

The evolution of GDP related to the Household Energy Price Index in the European Union (27 countries) is analyzed with the help of VAR model and the variance decomposition, historical variance decomposition and Granger Causality test under VAR which provide proof that HEPI for electricity has a more significant contribution to GDP than HEPI for gas.

Key words: GDP, HEPI, COVID-19, war, VAR model
J.E.L. classification: B21, B22, B23, C19, E01, N74

1. Introduction

The worldwide economy has faced several shocks in the last three years starting with a medical crisis caused by the COVID-19 virus when on 31st of December several cases of pneumonia were reported in Wuhan, China and continued with Russia's aggression on Ukraine since 24th February 2022. These events have caused tensions in the economy and affected in first several industries, employment, household income, electricity and gas prices and many others as a result of the measures taken by governments in order to avoid the spread of the COVID-19 virus and as well help contain it and second supply chain disruptions for electricity, gas and food due to the war in Ukraine.

Given that the Gross Domestic Product (GDP) is one of the indicators that provides an overall picture of the economic situation, as well as considering the fact that I have not identified in the literature articles that analyze the relationship between GDP and electricity and gas prices especially since 2020, at which point the world economy has suffered among the biggest shocks since the economic crisis of 2007-2009, I have it as an opportunity to analyze the GDP evolution related to the Household Energy Price Index (HEPI) in EU27 in order to determine how much did the HEPI for electricity and gas evolution contributed to the GDP volatility.

2. Literature review

Pandemics and wars are part of our history and their effects have been analyzed on several occasions. Two studies by Chankova and Daly (2021) and Buelens and Zdarek (2022) found that wars tend to result in higher inflation. Chankova and Daly (2021) analyzed inflation after wars and pandemics and found that while wars lead to higher inflation and bond yields, pandemics do not, although inflation tends to remain weak after significant pandemics, while Buelens and Zdarek (2022) suggested that supply disruptions caused by pandemics could also lead to high inflation volatility and might reappear due to the war in Ukraine.

Gagnon et al. (2023) used in their study a panel data regression to investigate the quarterly growth of real GDP in 90 countries between Q1 2020 - Q4 2021 relative to the COVID-19 pandemic. They found that COVID-19 deaths had a minimal effect on GDP, while the stringency of government-imposed lockdown measures to limit the spread of the virus had a significant influence on economic activity. The impact of the pandemic differed between rich and poor countries, with COVID-19

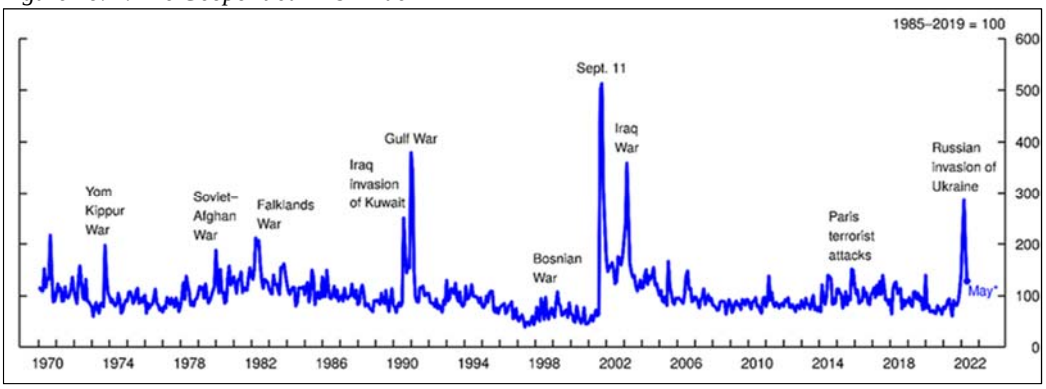
deaths having a slightly greater effect on GDP in advanced economies, but with no statistical significance, while in contrast, lockdown restrictions had a more detrimental effect on the economic activity of emerging and developing economies.

In his 2022 paper, Stefánski examines the impact of pandemics on GDP per capita over time and across 33 different countries by looking at the effects of wars and weather conditions, using a dataset dating back to the thirteenth century. His findings reveal that the effects of pandemics vary depending on their scale and timing, as well as the country in question and positive effects on income following the Black Death and Spanish Flu pandemics, particularly in Northern Europe. This suggests that only the largest and most unexpected pandemics have a positive impact on income. While Escosura and Rodríguez-Caballero (2022) analyzed the GDP and population growth of six European countries between 1270-1870 using the long memory approach and structural breaks, regimes, persistence and concluded that the most enduring shocks happened during the Black Death and the two world wars of the twentieth century.

Liu, Gao (2022) analyzed something similar by turning their attention to GDP growth in USA and found that the World Uncertainty Index (WUI) is a good predictor in the COVID-19 pandemic period.

The Caldara-Iacoviello geopolitical risk (GPR) index is a measurement of geopolitical tensions based on the newspaper articles published related to news of wars, risks of war, and major terrorist events and it can be noticed in *Figure no. 1* that the spike recorded by the Russians aggression on Ukraine is among the highest values recorded in the last 50 year, being surpassed only by the Gulf and Iraq Wars, respectively the 11th September terrorist attack, tensions which can be expected to spill out in the economy.

Figure no. 1. The Geopolitical Risk Index



Source: (Caldara, Dario, Sarah C., Matteo I., Maddie P., 2022).

Kuik *et al.* (2022) and Adolfsen *et al.* (2022) discuss the impact of the Russian invasion of Ukraine on energy prices and markets. Kuik *et al.* (2022) mention that the invasion worsened supply-side issues, leading to a price rally that started in 2021. Adolfsen *et al.* (2022) focus on the war in Ukraine and its impact on energy prices and volatility, highlighting concerns price fluctuations in the energy sector due to disruptions to energy supplies and sanctions applied to Russian.

Bida and Ruda (2022) utilized forecast analysis to estimate the GDP in Ukraine and observed that the losses from the 2022 war range from 35% to 50% of the GDP. The optimistic estimates suggest that it may take some time for Ukraine to recover and reach its pre-war GDP level.

A summary of other relevant articles can be found in *Table no. 1* below.

Table no. 1 Brief review of early studies

Author(s)	Period, Geographical Region and Quantitative Methods	Outcomes
Kaufmann (2023)	-Q1M42020-Q12022. -Switzerland. -forecast, bayesian analysis.	-yearly GDP growth forecasts serve as a good estimator, in particular at the outbreak of the pandemic. -starting September the projections of the Covid-19 outbreak is expected to have a lasting negative impact on GDP, while, the projections starting in December suggest a rapid return to pre-crisis levels of GDP.
Abosedra *et al.* (2020)	-1960–2017. -120 countries of the World. -VAR models and variance decompositions.	-countries with high-income growth are net transmitters of GDP growth volatility, while countries with low-income growth are net recipients. -low-income growth countries require several years to absorb global GDP growth shocks.
Alfarra and Hagag (2022)	-1960-2019. -USA, China. -forecasting, time series analysis, ARIMA model.	-both USA and China experienced GDP growth rates of around 6% and 10% for 2020 and 2021, respectively. -the COVID-19 pandemic appears to have minimal impact on countries that rely heavily on technology and the digital economy.
Habibi *el at.* (2022)	-January 2019 to December 2020. -China. -regression.	-the existence of COVID-19 within China has consequences that extend beyond its borders and have a global impact.
Peña and García (2023)	-2006-2022. -Mexic. -DSGE model.	-during the Global Financial Crisis (GFC), approximately 49.0% of the output gap contraction was caused by financial shocks, whereas during the COVID-19 pandemic, the demand shock was approximately 45.1%, financial shocks 32.2%, and productivity shock 22.3%, all severely impacted the dynamic of GDP. -the main drivers of Mexico's recent economic contraction were not only more diverse but also larger in absolute terms compared to those observed during the GFC.
Jena *et al.* (2021)	-April–June 2020 -USA, Mexico, Germany, Italy, Spain, France, India, and Japan. -artificial neural network forecaster.	- signifiant drops in GDP accros all countries were found. -the impact is even more significant when considering the annualized GDP growth, with most countries expected to have double-digit negative growth rates.

Source: (Authors' work based on the literature review.)

3. Research methodology

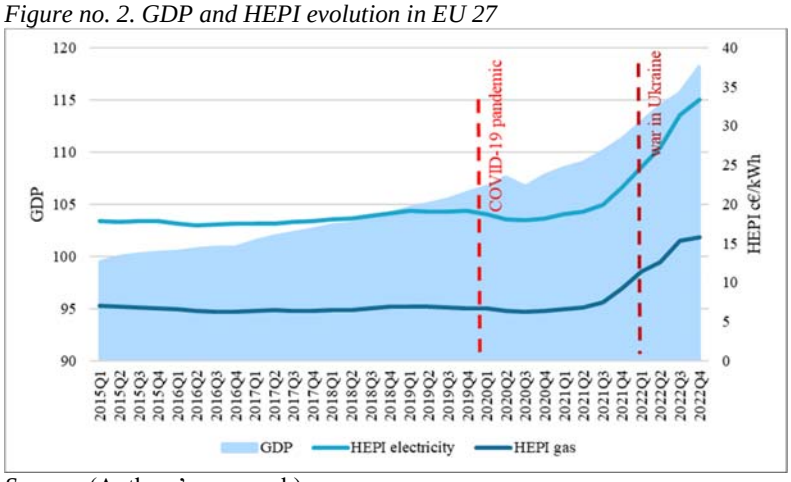
The data consists of quarterly observations, for the period Q1 2015 – Q4 2022 and a graphical representation can be seen in *Figure no. 2* below. The data source for the HEPI indicator is the Energy Price Index website and it is expressed in c€/kwh, and for GDP (seasonally and calendar adjusted) the data source is Eurostat website.

Given that the GDP is the total economic output for each year it is fair to assume that an increase in HEPI (electricity and gas) will in turn lead to a rise in GDP. The increase in GDP had a constant growth between 0,01% and 0.66% up to Q4 2019 related to the previous quarter, while with the start of the pandemic the GDP increase recorded a more accelerated growth related to the previous quarter between 0,46% and 1,17% for Q1 2020-Q4 2021 period with exception of Q3 2020 when a decrease of 0,83% was recorded which might be related to the vaccination campaign for COVID-19, overall the growth recorded in Q4 2020 related to Q3 2019 was 4,90% while for HEPI electricity 15,44%,

respectively for HEPI gas 36,13%.

Since the start of the war in Ukraine in Q1 2022 the GDP the growth slope is steeper and for Q4 2022 a 11,35% increase is recorded related to Q4 2019, respectively 6,14% related to Q42021, while for HEPI electricity a 74,08% increase is recorded related to Q4 2019, respectively 50,81% related to Q42021 and HEPI gas a 134,04% increase is recorded related to Q4 2019, respectively 71,93% related to Q42021.

Figure no. 2. GDP and HEPI evolution in EU 27



Source: (Authors' own work).

For the empirical analysis I used EViews 10 program and applied a log-transformation to GDP and HEPI in order to stabilize the model.

I employed the VAR model for the data series selected, including impulse response, variance decomposition and historical decomposition to determine the dependance of GDP relative to HEPI for electricity and gas in EU27.

For the Granger Causality test under VAR, I have established two hypotheses

- **Hypothesis 1** (H1) - An increase in HEPI leads to an increase in GDP for a level of significance greater than 5% and
- **Hypothesis 2** (H2) - The HEPI evolution adversely influences the GDP for a greater than for a level of significance below 5%.

4. Findings

Firstly, I ran the common sample statistics and given the results for all the selected indices and the:

a) skewness indicator that measures the symmetry of the data is
   - lower than 1 (positive skewed) for GDP meaning that the data is slightly skewed,
   - greater than 1 for HEPI electricity and gas (positive skewed) meaning that the data is extremely skewed,

b) kurtosis indicator which refers to the tailedness of the series (how often the outliers occur) is
   - under 3 for GDP meaning that the series is platykurtic (lower tail) reflecting that most data points are present in high proximity to the mean,
   - over 3 for HEPI electricity and gas meaning that HEPI electricity and gas data series are leptokurtic (heavy tailed distribution) which can account for more changes for outliers.

Table no. 2 Common sample

Date: 05/12/23 Time: 20:19
Sample: 2015Q1 2022Q4

	LOG GDP EU27	LOG HEPI EU27 ELECTRICITY	LOG HEPI EU27 GAS
Mean	4.657505	2.966438	1.989723
Median	4.648352	2.901238	1.902852
Maximum	4.772167	3.508057	2.754934
Minimum	4.599766	2.853016	1.828306
Std. Dev.	0.046286	0.166607	0.253709
Skewness	0.807880	2.202270	2.150815
Kurtosis	2.801796	6.786209	6.242533
Jarque-Bera	3.533284	44.98047	38.69073
Probability	0.170906	0.000000	0.000000
Sum	149.0402	94.92601	63.67113
Sum Sq. ...	0.066413	0.860497	1.995423
Observations	32	32	32

Source: (Authors' own research).

Based on the results obtained for the statistical tests under the VAR Lag order selection criteria as presented in *Table no. 3* I selected a number of four lags for the VAR model and the results from *Figure no. 3* provide insight on the models' stability (the majority of the roots are lying inside the unit circle).

Table no. 3 VAR Lag Order Selection

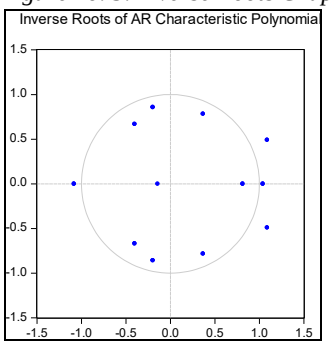
VAR Lag Order Selection Criteria
Endogenous variables: LOG GDP EU27 LOG HEPI EU27 ELECTRICITY LOG HEPI EU27 GAS
Exogenous variables: C
Date: 05/12/23 Time: 20:19
Sample: 2015Q1 2022Q4
Included observations: 28

Lag	LogL	LR	FPE	AIC	SC	HQ
0	135.8318	NA	1.52e-08	-9.487988	-9.345252	-9.444352
1	255.7756	205.6179	5.53e-12	-17.41255	-16.84160	-17.23800
2	277.6509	32.81295	2.27e-12	-18.33221	**-17.33306***	-18.02676
3	287.7521	12.98727	2.24e-12	-18.41087	-16.98351	-17.97451
4	304.5710	**18.02016***	**1.46e-12***	**-18.96935***	-17.11378	**-18.40209***

* indicates lag order selected by the criterion
LR: sequential modified LR test statistic (each test at 5% level)
FPE: Final prediction error
AIC: Akaike information criterion
SC: Schwarz information criterion
HQ: Hannan-Quinn information criterion

Source: (Authors' own research).

Figure no. 3. Inverse Roots Graph

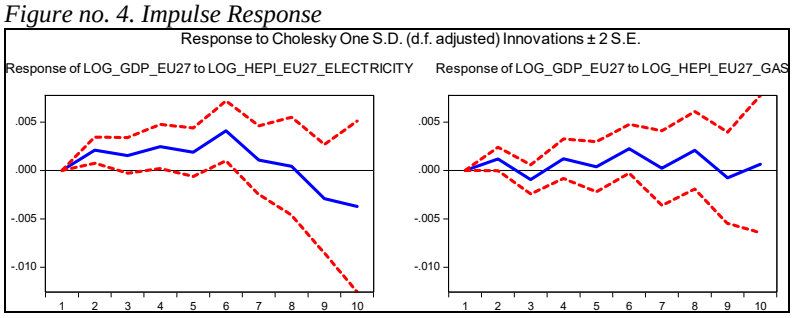


Source: (Authors' own research).

In order to determine the direction and magnitude of the effects of a shock on GDP over time, I deployed the impulse response by analyzing the *(a)* increase or decrease of the variable after the shock, *(b)* slope of the lines and *(c)* persistence of the effects of the shock on each variable.

It can be noticed in *Figure no. 4* that overall, the GDP follows the same trend as the HEPI for electricity and gas, an increase, respectively a decrease of HEPI leading to an evolution of GDP in line with them, however the slope is greater and more abrupt related to HEPI for electricity than to gas as well as the persistence, nevertheless the volatility of GDP is higher related to HEPI for gas.

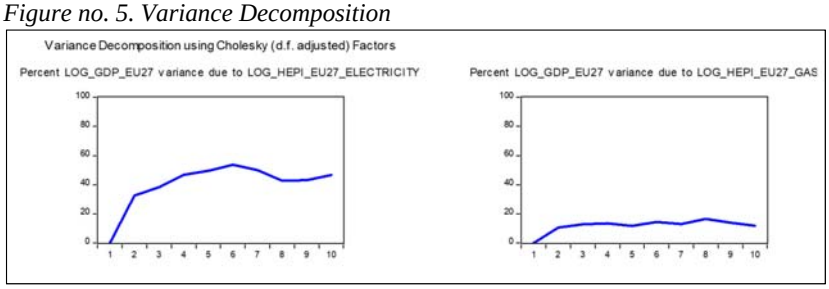
Figure no. 4. Impulse Response



Source: (Authors' own research).

In order to determine how much of the variation in GDP can be attributed to HEPI electricity and gas over time I deployed the variance decomposition for which the results are presented in *Figure no. 5*. The GDP variation is explained by the HEPI electricity up to 60%, respectively by the HEPI gas up to 20%, which adding on the results obtained previously for the impulse response it can be said that HEPI for electricity has a greater influence on the evolution of the GDP, which can be correlated as well to the higher prices for electricity than gas.

Figure no. 5. Variance Decomposition

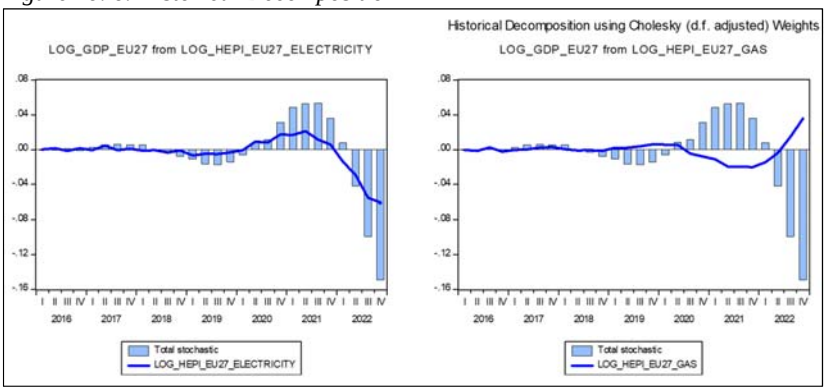


Source: (Authors' own research).

The historical variance decomposition graph will allow me to observe the contribution of HEPI for electricity, respectively gas to the total variation in GDP and how it has changed over the analyzed period of time.

According to the historical decomposition variation the contribution of HEPI electricity to the total variation in the GDP starts to become noticeable with the year 2019 and a greater variation is noticed starting with Q4 2020 when a significant increase in the number of people infected with COVID-19 virus was registered. The biggest variance is recorded starting with Q2 2022 when a negative total stochastic and descending trend for GDP is noticed, which would indicate that the forecast error variance of the GDP model has decreased over time, as well the fact that this could mean that the variable is becoming less important over time or that it is influencing the other variables in the model less strongly as time goes on which does not reflect the reality give that the electricity prices have continues to increase and will need further future analysis.

Figure no. 6. Historical Decomposition



Source: (Authors' own research).

On the other hand, the contribution of HEPI gas to the total variation in the GDP the total stochastic and HEPI gas variable have opposed trends which could be justified by the fact that an increase in the gas prices lead to a decrease in consumption and vice-versa, however this as well is to be further researched.

Based on the two hypotheses establishes at the beginning, it can be noticed in Table no. 4 below that a causality relation is found for GDP related to HEPI for a 33,11% level of significance meaning that an increase in electricity prices will in turn lead to an increase in GDP.

On the other hand, although the level of significance related to HEPI gas is under the level of significance it is very close, registering a value of 4,89% which means that the evolution of gas prices should not be neglected in future analysis of the evolution of variables that are dependent on gas consumptions.

Table no. 4 VAR Granger Causality

VAR Granger Causality/Block Exogeneity Wald Tests
Date: 05/12/23 Time: 20:24
Sample: 2015Q1 2022Q4
Included observations: 28

Dependent variable: LOG_GDP_EU27

Excluded	Chi-sq	df	Prob.
LOG_HEPI_EU27_ELECTRICITY	4.597505	4	**0.3311**
LOG_HEPI_EU27_GAS	9.543707	4	0.0489
All	40.65765	8	0.0000

Source: (Authors' own research).

5. Conclusions

The purpose of this article was to analyze the evolution of GDP given the tensions that the economy has faced lately from an energy perspective since the start of the COVID-19 pandemic, respectively since Russia's aggression on Ukraine.

The impulse response results provide proof of a positive correlation of the GDP with HEPI electricity and gas, an increase or decrease in the electricity and/or gas prices leading to an evolution of GDP in the same direction, however a stronger reaction of GDP was noticed related to HEPI for electricity than gas even though the HEPI for gas lead to higher volatility of GDP.

Important insights are provided by the variance decomposition results, the HEPI for electricity has a greater contribution to the increase in GDP than the HEPI for gas, explaining up to 60%, respectively 20% of GDP evolution. Similar findings were noted by Buelens and Zdarek (2022) whom concluded that supply disruptions caused by the pandemics lead to high inflation volatility which is reflected in the household consumption a component of GDP, phenomenon that according to the authors is likely to reappear as a result of the Russian's aggression on Ukraine.

Given the historical variance decomposition results obtained, it can be said that HEPI for electricity started to have a noticeable contribution to the GDP variation even since the first year of pandemic and constantly increased in the second year of the pandemics, while after the war in Ukraine began does not reflect the reality which means that the current model deployed has limitations and future analysis is needed.

Regarding future research directions I will extend this current research in order to address the current limitations identified by adding in the analysis the GDP components household consumption, government spending, investment and the trade output (exports minus imports) as well as inflation in order to better capture the evolution of the economic output related to the evolution of other independent variables.

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