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Inflation, oil prices, and economic activity in recent crisis: Evidence from the UK

Rizwan Ahmed [a], Xihui Haviour Chen [b,*], Chamaiporn Kumpamool [c], Dung T.K. Nguyen [d]

[a] Kent Business School, University of Kent, United Kingdom
[b] Edinburgh Business School, The Centre for Social and Economic Data Analytics (CSEDA), Heriot-Watt University, Edinburgh, United Kingdom
[c] Faculty of Business Administration and Accountancy, Khon Kaen University, Khon Kaen, Thailand
[d] School of Banking and Finance, National Economics University, Hanoi, Vietnam

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ABSTRACT

This study examines the link between inflation and the macroeconomy such as output, trade balance and unemployment as reflected through crude oil prices. Using monthly data from the UK spanning January 2010 to June 2022, we apply a combination of three analyses including the VAR model, time-varying VAR analysis, and time-varying panel model with robustness. The results reveal that in the event of inflation shocks the other economic indicators decrease initially. However, Brent crude oil shocks are the quickest in responding to surging inflation compared to other proxies, rebounding to a positive level in only one month. Furthermore, the impact of inflation shocks is strong in the first quarter but diminishes in the long run. This information can be used to inform and assist policymakers to develop policies that mitigate the negative effects of inflation in the short term. Our findings also have important implications for businesses operating in the UK in making strategic decisions.

1. Introduction

Inflation has always been one of the concerns of economists. Economic agents make most of their decisions based on expectations of inflation as inflation has impacts on both economic and social development (Bernoth and Ider, 2021; Salisu et al., 2017). With respect to the recent COVID-19 pandemic, there are various factors that may be linked with the level of inflation, such as GDP, oil prices, exchange rates, interest rates, taxes, trade balance and unemployment rates (Blot et al., 2022).

The outbreak of COVID-19 saw governments impose restrictions on economic activities all over the world. Western countries were no exception. In order to minimise the spread and the risk of contagion, measures to reduce mobility were introduced leading to a sharp decline in personal consumption (of crude oil?) in 2020: 12.7% for the EU area, 20% in Spain and 12% in Italy and France (Blot et al., 2022). As a result, gross domestic product (GDP) fell by 6.7% in the Euro area in 2020. Meanwhile, inflation reached its highest level since the end of 2011, reaching 3% in August 2021 compared to −0.3% at the end of 2020. Researchers agree that the rise in inflation is partly related to energy prices (see Ivrendi and Guloglu, 2010; Mallick and Mohsin, 2016; Salisu et al., 2017; Talha et al., 2021), particularly the increase in the price of oil in 2021 (Blot et al., 2022). Bernoth and Ider (2021) concur with this viewpoint. They emphasised that the current rise in inflation is as a result of the recovery of energy prices after their collapse and the reversal of VAT reductions in several European countries.

One of the factors that is often discussed with regard to inflation is unemployment. However, the correlation between unemployment rates and inflation in the Euro area is very low, so it is impossible to make a clear statement, especially during the COVID-19 pandemic (Bernoth and Ider, 2021). In consideration of inflation in the US, the failure rate of SMEs during the COVID crisis was significantly higher than that of other types of businesses. Therefore, a decrease in supply from small and medium enterprises would contribute to a decrease in world exports, which would in turn contribute to an increase in inflation in the US (Kalemli-Ozcan et al., 2020).

Considering the facts above, it is vital to investigate the linkages between inflation and the macroeconomy through with respect to the oil price during the recent crises (e.g., COVID-19). Meanwhile, UK inflation has hit a 41-year high causing the economy to potentially face the longest recession in its history. Therefore, this paper examines the influence of inflation in the United Kingdom (UK) on the aforementioned

* Corresponding author.
E-mail addresses: r.ahmed@kent.ac.uk (R. Ahmed), Xihui.chen@hw.ac.uk (X.H. Chen), chamaiporn@kku.ac.th (C. Kumpamool), dungntk@neu.edu.vn (D.T.K. Nguyen).

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factors, including gross domestic product (GDP), trade balance, unemployment, and brent crude oil price. Our work represents a novel contribution to existing literature. First, our paper applies a combination of three analyses under the framework of the vector autoregressive (VAR) model including the VAR model, time-varying VAR analysis, and a time-varying panel model with robustness. VAR, as a relevant measure of risk, either by regulation or by choice, is a natural approach given that it has become a common instrument for assessing and controlling risk in practice (Esmaeili and Rafei, 2021; Galadima and Aminu, 2019). Second, our results show that in response to a shock of inflation, GDP, trade balance, unemployment, and the price of Brent crude oil tend to decrease at the beginning period of this shock. However, Brent crude oil shocks appear to be the fastest to adjust to spiking inflation because they take only one month to rebound to a positive level as opposed to the other proxies. Third, it is surprising that from 2010 to 2020, with the exception of the European sovereign financial crisis in 2012 and the second wave of the COVID-19 epidemic, the percentage change in unemployment declined consistently. Finally, results from the simulations of orthogonalised impulse response function (IRF) and time-varying impulse response function (IRF) of the four proxies; including the percentage change in GDP, trade balance, unemployment, and Brent crude oil, to the inflation shock, indicates that GDP, trade balance, unemployment, and the price of Brent crude oil all decreased in percentage during the early stages of the shock. After that, it dies out in the long term. For practitioners and policymakers who need to understand the effects of inflation shocks on important macroeconomic factors, this study has crucial implications. It is particularly relevant for short-term economic activities (e.g., business investment, consumer spending and employment rates).

From a policy perspective, this paper makes some significant contributions in understanding the role that oil prices play in driving inflation. Since oil is a crucial component in the manufacture of many goods and services (Bank of England, 2021), changes in oil prices are likely have a substantial impact on the cost of various products and services (Charfeddine and Barkat, 2020; Herrera et al., 2019; Wei and Guo, 2016). As a result, examining the connection between oil prices and inflation provides policymakers with crucial information on how to control inflation. As a further contribution to the research, this paper highlights the effects of oil price shocks on other economic variables, such as GDP growth, trade balances, and exchange rates. Researchers may provide light on the possible implications of oil price shocks for different economic sectors by examining the dynamics of these linkages and assist policymakers in creating ways that reduce these effects (Cukrowski, 2004; Ullah et al., 2021). Finally, research on inflation, oil prices, and other economic factors can be used to construct macroeconomic models to facilitate an understanding of how the world economy behaves (Nasir et al., 2020). These models may be used to simulate various economic situations and suggest appropriate policy responses.

The remainder of the paper is structured whereby the second section presents the literature review on the linkages between inflation and economic activity as well as oil prices. The third section describes the data and details the methodology used in the study. Section four reports the empirical findings and the fifth section provides a conclusion and suggests policy implications.

2. Literature review

2.1. Theoretical underpinnings and research background

There are several theories (e.g., the Phillips curve economic theory, aggregate demand-aggregate supply model, the theory of rational expectations, and the quantity theory of money) in macroeconomics which provide a basis for investigating the relationship between energy consumption, inflation and economic growth. These theories are vital in shaping understanding of macroeconomic factors on energy consumption and inflation.

One such theory is the Phillips curve economic theory, which posits an inverse relationship between inflation and unemployment rates. According to this theory, a decrease in unemployment leads to an increase in inflation, and vice versa (Phillips, 1958). This implies that changes in the labour market, such as employment levels and wage rates, can significantly affect inflation (Salisu et al., 2018). Another relevant theory is the aggregate demand-aggregate supply (AD-AS) model, which explains the relationship between the overall demand and supply of goods and services in an economy. An increase in aggregate demand or a decrease in aggregate supply can lead to higher inflation levels due to excess demand and scarcity of resources. This model highlights the importance of managing the balance between demand and supply to maintain price stability and economic growth (Mankiw, 2014). Furthermore, the theory of rational expectations suggests that individuals and businesses form their expectations about future inflation rates based on available information (Muth, 1961). This theory implies that changes in energy prices, as well as other macroeconomic variables, can impact inflation expectations (Goetz et al., 2021), which in turn influence actual inflation rates (Alstadheim et al., 2021). Lastly, the quantity theory of money emphasises the relationship between the money supply, inflation, and economic growth (Friedman, 1963). According to this theory, an increase in the money supply can lead to higher inflation, as more money chases the same quantity of goods and services (Wei and Guo, 2016). This theory highlights the importance of monetary policy in managing inflation and maintaining economic stability (Jareño et al., 2023; Nasir et al., 2023).

Building on the aforementioned theoretical foundations, the empirical literature has delved into various aspects of the relationship between economic activities, energy consumption, and inflation. A plethora of studies (Nasreen et al., 2019; Mohsin et al., 2021; Munir et al., 2019; Ouyang and Li, 2018) have investigated the intricate interplay between these factors. According to the literature (Buhari et al., 2020; Magazzino et al., 2021; Nasir et al., 2018; Nguyen and Nasir, 2021; Ouyang and Li, 2018; Wu et al., 2018), a combination of stable inflation and energy consumption is crucial for fostering economic growth across countries (e.g., UK), taking into account the theoretical underpinnings. For instance, Ouyang and Li (2018) discovered a significant and positive relationship between energy consumption and financial development in China, irrespective of geographic locations. However, it is essential to consider the environmental implications of energy consumption. As a consequence of increased energy use, CO^2 emissions rise, adversely affecting the sustainability of the economy (Buhari et al., 2020; Tang et al., 2023; Zhang et al., 2023). Additionally, Talha et al. (2021) found that energy consumption, oil prices, and economic development positively and significantly impacted inflation rates in Malaysia. The heavy reliance on oil and fossil fuels for energy consumption in many countries (Shahbaz et al., 2018a, 2018b) further complicates matters. Factors such as pent-up demand for oil and services, the base effects on annual inflation growth rates, and the disruption of supply chains due to COVID-19 have led to expectations of increasing inflation rates.

In the UK, energy consumption and inflation have a critical role in shaping the economy. For instance, energy policies and investments in renewable energy sources can impact the overall inflation rate and economic growth. The UK's transition towards a low-carbon economy has brought about new challenges and opportunities, with implications for inflation and economic activity (Nasir et al., 2020; Rehman et al., 2020). The heavy reliance on oil and fossil fuels for energy consumption in many countries, including the UK, further complicates matters. Factors such as pent-up demand for oil and services, the base effects on annual inflation growth rates, and the disruption of supply chains due to COVID-19 have led to expectations of increasing inflation rates (Jareño et al., 2023; Nasir et al., 2023). In the UK context, Brexit has added an additional layer of complexity, with implications for trade, energy prices, and inflation (Bank of England, 2021).

Policymakers face the daunting task of determining the best course of

action to achieve sustainable economic development while mitigating inflation (Bernoth and Ider, 2021; Blot et al., 2022; Tang et al., 2023; Zhang et al., 2023). Environmental degradation, manifested through increased energy consumption and a scarcity of energy resources, contributes to rising energy prices and an escalating cost of living. This highlights the need for a more critical examination of the interdependencies between economic activities, energy consumption, and inflation in order to develop informed policy decisions that account for both economic growth and environmental sustainability. To better understand the complex relationships among these factors and to inform policy decisions, this paper sets out a conceptual framework (See Fig. 1) that integrates the key variables and their interdependencies. The framework is grounded in the theoretical underpinnings discussed above and is informed by the empirical findings from the existing literature. The framework highlights the role of inflation shocks, the immediate impact on the macroeconomic variables, such as GDP, trade balance, unemployment, and Brent crude oil prices, and the subsequent adjustments and implications for economic growth. By examining = monthly data from the UK and employing robust analytical methods, this study aims to provide insights into the short-term and long-term impact of inflation on the UK economy, specifically through the lens of crude oil prices. This conceptual framework serves as a foundation for the subsequent analysis and discussion in this paper.

2.2. Energy consumption, inflation, and economic growth

As stated, research on energy consumption and economic growth may help policymakers formulate appropriate policies specific to the characteristics of the country to moderate inflation. For example, Wang et al. (2019) found that energy prices, energy consumption, GDP, and urbanisation are interdependent with a long-term effect in 186 countries. Furthermore, urbanisation has the greatest impact on the consumption of energy among the other variables. Wang et al. (2019) recommended that upper-middle income countries (e.g., Albania, Brazil, Cuba, and Malaysia) with a growing urban population need to be aware that their high energy consumption may result in tightening monetary conditions, rising global inflation, and slowing economic growth. Galadima and Aminu (2019) reported that changes in real GDP and the money supply affect natural gas consumption both in the short- and long-run, whereas changes in inflation affect it more in the short-term. To meet the increasing demand for energy consumption and the already high inflation, Nigerian regulators are advised to adjust monetary policy to regulate the money supply and maintain inflation at a stable level (Galadima and Aminu, 2019; Iyke, 2015). Looking specifically at Nigeria, Iyke (2015) found that inflation has a negative and significant impact on economic growth, as well as a positive and significant impact on energy prices. Interestingly, Magazzino et al. (2021) was unable to find long-term relationships between energy consumption and economic development in Italy (a less energy-dependent economy) when using Waverlet analysis. Their results suggested that the Italian energy policies that aim to improve energy efficiency is unlikely to cause an economic recession.

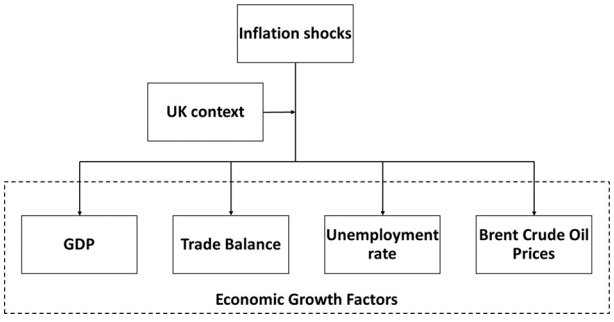

Fig. 1. Conceptual Framework.

Studies have also examined the impact of renewable energy consumption on economic activities (see Talha et al., 2021; Lawal et al., 2020; He, 2020; Tang et al., 2023). High inflation results in negative economic impacts, including low investment levels, slow economic growth, depreciation of consumer savings, and a high cost of living. Scholars (e.g., Acheampong et al., 2022; Lorusso and Pieroni, 2018; Wu et al., 2018) have argued that energy security can be improved by replacing traditional energy sources (e.g., fossil fuels) with renewable or green energy sources, which can help reverse a soaring inflation rate. As an example, for Asian developing economies, Mohsin et al. (2021) found that renewable energy consumption is associated with positive effects on GDP growth, and a reduction in carbon emissions by 0.193% when renewable energy consumption increased by 1%. For Pakistan, Luqman et al. (2019) concluded that renewable energy variables contribute positively to economic growth and nuclear energy variables contribute negatively. Additionally, there was no significant impact on its nuclear and renewable energy consumption from fluctuations in oil prices. Luqman et al. (2019) argued that policymakers should encourage the adoption of renewable energy technologies in order to address energy shortages, which will in turn help to alleviate inflationary pressures. In studying African economies, Lawal et al. (2020) used stimulus policies and concluded that economic growth and electricity consumption are significantly related. He (2020) found similar results using data from Guangzhou in China. It is important to keep in mind, however, that the inflationary surge in electricity may be related to the rise in oil and gas prices, as gas comprises 22% of electricity production.

Some studies have estimated causality between variables using methods, such as Granger causality (e.g., Nasreen et al., 2019; Ouyang and Li, 2018), which is based on prediction. The DAG (Deirected Acyclic Graph) method was used in some studies (e.g., Esmaeili and Rafei, 2021) to visualise the simultaneous relationships between variables using econometric structures, data, and existing research results. A point that has been overlooked in existing studies is that different economic conditions have not been considered when investigating the influence of energy consumption and inflation on economic growth. In order to account for the country's political and economic realities, the Markov switching model is employed in this study in order to identify various economic conditions. To the best of our knowledge, this approach has never been conducted before. It is therefore possible to present more reliable results by demonstrating the impact of fluctuations on inflation and energy consumption with specific economic characteristics.

This section has highlighted that energy consumption and inflation are interrelated, and that both have significant implications for economic growth. The impact of energy consumption on inflation and economic growth varies depending on the country's characteristics, such as income levels and urbanisation (He, 2020; Nguyen and Nasir, 2021; Wang et al., 2019). Second to this, renewable energy consumption is increasingly recognised as a key factor for achieving economic growth while mitigating inflationary pressures and reducing carbon emissions (Luqman et al., 2019; Mohsin et al., 2021; Raggad, 2021). However, the transition to renewable energy sources is not without challenges, and careful policy formulation is required to ensure energy security and economic stability. Thirdly, the literature employs a diverse range of methodological approaches, such as Granger causality and Directed Acyclic Graphs, to investigate the relationships between energy consumption, inflation and economic growth. However, most studies have overlooked the importance of the differing economic conditions in approaching their analyses, and this represents an area that warrants further exploration. Finally, the literature suggests that policymakers should adopt tailored strategies that consider the unique characteristics of each country in order to effectively manage energy consumption, inflation and economic growth (Buhari et al., 2020; Cukrowski, 2004; Herrera et al., 2019; Lorusso and Pieroni, 2018; Nasir et al., 2023). By addressing these themes and building on the existing literature, this study aims to provide a more comprehensive understanding of the

interdependencies between these macroeconomic factors in the context of the UK economy.

2.3. The impact of oil price on economic growth

Oil price fluctuations have been investigated extensively in economic studies conducted in both industrialised and emerging economies. The majority of this research (Koray, 2006; Nasreen et al., 2019; Shahbaz et al., 2018a, 2018b; Wang et al., 2019) considers the effects of oil prices on current account balances, exchange rates, economic growth, inflation dynamics and investment. Since the oil crisis in the 1970s, economists have tried to forecast the impact of oil price volatility on oil-importing and oil-exporting countries. In general, the results are inconclusive regardless of whether it is an oil-exporting or an oil-importing country. A majority of the existing literature (see Baek and Yoon, 2022; Charfeddine and Barkat, 2020; Farzanegan and Markwardt, 2009; Herrera et al., 2019; Huynh et al., 2022) has been concerned with the phenomenon of high oil prices, since prices have been on the rise for most of the last decade.

Compared to large oil-importing countries, small importers are price takers. Due to the fact that there is not a great deal of demand for oil, they are not able to have much influence over the global market (Mohsin et al., 2021; Seers, 1962; Wu et al., 2018). Therefore, they accept the oil price as a given. There is no doubt that high oil prices are linked to low economic growth in these countries. Because of the rise in energy prices, consumer spending is adversely affected through lower disposable income, resulting in higher production costs and lower profits, which, in turn, reduces the growth rate of the economy (see, e.g., Lawal et al., 2020; Luqman et al., 2019; Shahbaz et al., 2018b; Wu et al., 2018). For example, according to Nasir et al. (2018), high oil prices result in a reduction in production, consumption and investment in BRICS countries (Brazil, Russia, India, China and South Africa). Indonesia is an example of an oil-importing economy struggling to generate sufficient savings, and lacking in contingency plans, both of which are essential for ensuring healthy investment levels and sustained economic growth (Baek and Yoon, 2022). Economies with high current account deficits are destabilised by energy imports. Moreover, as oil prices increase, monetary demand also increases, resulting in a rise in inflation and a decline in investments (Acheampong et al., 2022; Shahbaz et al., 2018a).

In contrast to small oil-importing countries, large countries - those with the power to influence world oil markets - are less susceptible to oil price shocks. Although oil price fluctuations still have a negative influence on large oil-importing economies (e.g., China, Europe, India, and the U.S., Europe), the effects are relatively minor when compared with small oil-importing countries (Raggad, 2021; Wu et al., 2018). There is no doubt that any change in oil prices causes substantial revisions to the national budgets of these countries. However, As Tuzova and Qayum (2016) indicated, there may not be a severe negative impact if strong foreign capital inflows and investment, that can compensate for high oil prices, is able to mitigate the adverse effects.

In contrast, oil-exporting countries, such as Canada, Norway, OPEC countries, and Russia, benefit from high oil prices to generate high profits (Tuzova and Qayum, 2016). The Norwegian economy has been shown to benefit from oil price volatility in the past by Vatsa and Basnet (2020). Tuzova and Qayum (2016) concluded that although the oil price affects the Russian economy positively, political sanctions impose a new set of challenges on its economy. Ito (2010) found that a 1% increase in oil prices leads to a growth in Russia's GDP of 0.46%. Cukrowski (2004) argued, however, that low oil prices can destabilise the overall economy as a result of a reduction in output and revenue. Additionally, Charfeddine and Barkat (2020) found that oil revenue shocks affect output in heavily oil-dependent countries (e.g., Qatar) asymmetrically. In other words, the positive impact of oil shocks on economic growth is limited, while the adverse impact of oil shocks is vast. Similarly, Herrera et al. (2019) reported that oil price shocks in the United States are asymmetrically related to industrial production.

Some studies (Akram, 2004; Charfeddine and Barkat, 2020), found that oil prices have a significant effect on exchange rates. For example, according to Akram (2004), an increase in oil prices is related to an appreciation of exchange rates in oil-exporting countries (e.g., Russia). However, in Qatar, as oil and gas revenues increase, the real exchange rate declines (Charfeddine and Barkat, 2020). As an oil-importing country, the UK experiences a drop in GDP growth as a result of shortfalls in crude oil supplies. Lorusso and Pieroni (2018) found that UK inflation increases after an increase in oil prices. For small open economies (e.g., the Dominican Republic), Méndez-Carbajo (2010) found that rising oil prices caused local currencies to depreciate. On the other hand, Charfeddine and Barkat (2020) reported that the Qatari currency appreciated when there was an increase in oil prices.

Oil price shocks have been studied from the perspectives of both oil exporters and oil importers in several studies (e.g., Baek and Yoon, 2022; Lawal et al., 2020; Mohsin et al., 2021; Nasir et al., 2018; Nguyen and Nasir, 2021; Wang et al., 2019; Wu et al., 2018). As an example, high oil prices lowers aggregate incomes in countries that import oil and reduces foreign demand for the oil produced in those nations that export oil.

Our study is closely related to Lorusso and Pieroni (2018), as well as Ouyang and Li (2018), although our analysis contains several innovations. Lorusso and Pieroni (2018) found that the consumption of domestic oil by households and companies increases at the same time, helping local producers increase earnings. Meanwhile, based on data from 30 Chinese provinces spanning 1996 through to 2015, Ouyang and Li (2018) analysed the impacts of energy consumption on financial development by employing a VAR model in a GMM estimation (credit, foreign direct investment, money and quasi-money per capita, insurance industry revenues, and stock market value). Financial development variables were considered to be exogenous variables. The causality of oil price shocks was captured by Lorusso and Pieroni (2018) using a two-state approach. As a first step, they utilised a structural VAR (SVAR) framework in order to calculate supply and demand in the oil market. A range of UK macroeconomic aggregates was then incorporated (e.g., CPI inflation, real GDP growth, nominal interest rate, and unemployment rate) with data spanning from 1976 Q1 to 2014 Q2. In comparison with earlier research conducted in the context of the UK (e.g., Lorusso and Pieroni, 2018), our analysis covers the period from January 2010 to June 2022. To model the first difference, we use monthly data on the trade balance and Brent crude oil. GDP, CPI and unemployment are stationery at second difference. Our model treats international oil prices as an endogenous variable. Several factors contributed to the selection of these variables, including the fact that they are the most commonly used in business cycle theory and literature.

This section has set out the impact of oil price fluctuations on economic growth and how the impact significantly varies between oil-importing and oil-exporting countries (Charfeddine and Barkat, 2020; Méndez-Carbajo, 2010). While small oil-importing countries typically experience lower economic growth as a result of high oil prices, large oil-importing countries and oil-exporting countries are often less affected or may even benefit from these fluctuations. Secondly, this section has highlighted the fact that the relationship between oil prices and other macroeconomic variables, such as exchange rates, is complex and often country specific (Lawal et al., 2020; Magazzino et al., 2021; Nasir et al., 2018). In some cases, higher oil prices have been associated with currency appreciation in oil-exporting countries and depreciation in oil-importing countries. However, these relationships are not universally observed and may differ depending on a country's unique economic conditions. Lastly, the literature employs various methodological approaches to explore the impacts of oil prices on economic growth and other macroeconomic variables. While some studies utilise vector autoregression (VAR) models or structural VAR (SVAR) frameworks (Esmaeili and Rafei, 2021; Galadima and Aminu, 2019), others rely on Granger causality or two-state approaches. Despite these diverse methodologies, the findings remain inconclusive, indicating that the

relationship between oil prices and economic growth is intricate and multifaceted. Our review of the literature underscores the importance of examining the specific context and characteristics of each country when studying the impact of oil prices on economic growth. Building on the existing literature, our study aims to provide a more comprehensive understanding of these relationships in the context of the UK economy by using an updated dataset and treating international oil prices as an endogenous variable.

3. Data and methodology

3.1. Data

The datasets of our variables are based on the monthly percentage change in gross domestic product (GDP), consumer price index (CPI), trade balance, unemployment rate, and Brent crude oil (price?) in the UK. The data were collected from Thomson Reuters Datastream, with the long time series of monthly data, from January 2010 to June 2022. The natural logarithmic forms of GDP, trade balance, unemployment and Brent crude oil (prices), with the exception of CPI, are used to estimate our variables.

3.2. Method

We consider three analyses under the framework of vector autoregressive model (VAR) including the VAR model, time-varying VAR analysis, and time-varying panel model with robustness test. The VAR models are generally universal autoregressive models allowing multivariate time series and providing a coherent and creditable method for data description, structural inference, forecasting, and policy analysis (Stock and Watson, 2001). Furthermore, the VAR method can be extended to the vector error correction model and co-integrated VAR analysis (Engle and Granger, 1987; Granger, 1983; Granger and Weiss, 1983; Juselius, 2006). The time-varying coefficient linear models can be expressed in state space form, which assumes that the coefficients change over time as a Brownian motion and their estimation using kernel smoothing techniques (Casas and Fernandez-Casal, 2019). Thus, the time-varying coefficient VAR models allow continuous smooth changes to coefficients, and their assumption may match with real economics (Sims, 1980). The models are provided as follows (see Eqs. (1) to (5)).

$$GDP_t = a_t^1 + \sum_{i=1}^{2} b_{it}^1 GDP_{t-i} + \sum_{i=1}^{2} c_{it}^1 CPI_{t-i} + \sum_{i=1}^{2} d_{it}^1 TB_{t-i} + \sum_{i=1}^{2} e_{it}^1 UEM_{t-i} + \sum_{i=1}^{2} f_{it}^1 BCO_{t-i} + u_t^1 \quad (1)$$

$$CPI_t = a_t^2 + \sum_{i=1}^{2} b_{it}^2 GDP_{t-i} + \sum_{i=1}^{2} c_{it}^2 CPI_{t-i} + \sum_{i=1}^{2} d_{it}^2 TB_{t-i} + \sum_{i=1}^{2} e_{it}^2 UEM_{t-i} + \sum_{i=1}^{2} f_{it}^2 BCO_{t-i} + u_t^2 \quad (2)$$

$$TB_t = a_t^3 + \sum_{i=1}^{2} b_{it}^3 GDP_{t-i} + \sum_{i=1}^{2} c_{it}^3 CPI_{t-i} + \sum_{i=1}^{2} d_{it}^3 TB_{t-i} + \sum_{i=1}^{2} e_{it}^3 UEM_{t-i} + \sum_{i=1}^{2} f_{it}^3 BCO_{t-i} + u_t^3 \quad (3)$$

$$UEM_t = a_t^4 + \sum_{i=1}^{2} b_{it}^4 GDP_{t-i} + \sum_{i=1}^{2} c_{it}^4 CPI_{t-i} + \sum_{i=1}^{2} d_{it}^4 TB_{t-i} + \sum_{i=1}^{2} e_{it}^4 UEM_{t-i} + \sum_{i=1}^{2} f_{it}^4 BCO_{t-i} + u_t^4 \quad (4)$$

$$BCO_t = a_t^5 + \sum_{i=1}^{2} b_{it}^5 GDP_{t-i} + \sum_{i=1}^{2} c_{it}^5 CPI_{t-i} + \sum_{i=1}^{2} d_{it}^5 TB_{t-i} + \sum_{i=1}^{2} e_{it}^5 UEM_{t-i} + \sum_{i=1}^{2} f_{it}^5 BCO_{t-i} + u_t^5 \quad (5)$$

Where *GDP* is the natural logarithm of percentage change in GDP in the UK, *CPI* is inflation in the UK, *TB* is the natural logarithm of percentage change in trade balance in the UK, *UEM* is the natural logarithm of percentage change in unemployment in the UK, and *BCO* is the natural logarithm of percentage change in Brent crude oil in the UK. u_t^1, u_t^2, u_t^3, u_t^4, and u_t^5 are white noise disturbance or shock terms.

The issue of endogeneity has been frequently found in general econometric models (Xu and Lin, 2017), and therefore, it has become the focus of attention for several academic researchers (Ullah et al., 2021). Ullah et al. (2021) concluded that a bias with the endogenous problem impacts incompatible estimation and wrong inferences, which leads to misinterpretation and incorrect conclusions. Moreover, there are three causes of endogenous issues, including unobserved heterogeneity, simultaneity, and dynamic endogeneity (Ullah et al., 2018). As a result, the VAR model can help to reduce and prevent endogenous issues, as to the VAR model is able to explain the lags of the dependent variable. This can help to reduce lags in the random disturbance term as much as is feasible (Lütkepohl, 2006). Thus, the VAR method is an efficient instrument for (analysing?) policy endogeneity and it also provides a dynamic nexus between economic variables in time-series data (Freema et al., 1989; Xu and Lin, 2017). In particular, Impulse Response Function (IRF) analysis, based on the VAR model, allows complete investigation of the effect of one endogenous variable on the other endogenous variable in the system (Enders, 1995). Therefore, the VAR models are used in this study.

The VAR model has several strengths that make it more advantageous than other methods. *First,* the VAR model is useful because it requires only one model to explain and forecast multiple time-series variables (Chandra and Al-Deek, 2014). *Second,* the forecasting estimation of this method is flexible since conditions on the possible future paths of specific proxies can be determined in the model (Zivot and Wang, 2006). *Third,* this method also produces the dynamic relationships between economic variables in time-series data (Freema et al., 1989; Xu and Lin, 2017). *Fourth*, all proxies in the model are allowed to be endogenous (Adedeji et al., 2021). However, there are also disadvantages in using the VAR model. For example, this model cannot simply consolidate multiplicative and non-linear nexus compared to the structural equation modelling (SEQ) method (Freema et al., 1989). Moreover, there is no economical interpretation for each equation identified based on the model, although this issue can be resolved by producing an impulse response function (IRF) and forecasting error variance decomposition (FEVD) approach (Adedeji et al., 2021).

Nonetheless, it seems the advantages of the VAR model, outweigh the limitations. Thus, we use this model for this study, and an impulse response function (IRF) is also produced to interpret the dynamic relationships for the five proxies.

3.3. Descriptive statistics

Table 1 shows the descriptive statistics of the variables in this study. The average recorded change in GDP within the UK was 2.99%, while the average change in inflation was 4.62% over the period of January 2010 to June 2022. This indicates that the inflation was on average in terms of percentage change than GDP in the UK in more than two decades. Table 1 also shows that the average of percentage change in trade balance, unemployment, and Brent crude oil were 9.38%, 5.70%, and 4.26%, respectively.

By comparing all variables, we can see that the standard deviation of 1.65 in UK unemployment was much larger than the others. This highlights the instability of employment in the UK. In addition, the percentage change in GDP and in trade balance were left skewed and leptokurtic, which indicates the fat-tailed nature of the distribution of these two series.

Fig. 2 presents descriptive graphs for all variables used in this study. The figure shows that the growth of GDP in the UK was considerably stable before and after the COVID-19 pandemic; however, there was a sharp drop during the COVID-19 pandemic crisis as indicated on the left top raw of graph. This is consistent with Flynn et al. (2020) who found that there was a significant loss in GDP of between 9% and 25% in the UK due to the lockdown imposed in the COVID-19 pandemic. Similarly,

Table 1
Descriptive statistics.

Variables	N	Mean	Std. dev.	Median	Trimmed	Mad	Min	Max	Range	Skew	Kurtosis	Std. Error
GDP	150	2.99	0.25	3.01	3.01	0.01	0.10	3.38	3.29	−10.74	123.20	0.02
CPI	150	4.62	0.07	4.61	4.62	0.08	4.48	4.80	0.33	0.05	−0.31	0.01
Trade Balance	150	9.38	0.53	9.5	9.48	0.17	5.93	9.99	4.07	−4.37	22.62	0.04
Unemployment	150	5.70	1.65	5.10	5.63	1.63	3.60	8.50	4.90	0.40	−1.49	0.13
Brent Crude Oil	150	4.26	0.40	4.28	4.29	0.51	2.63	4.83	2.20	−0.80	1.19	0.03

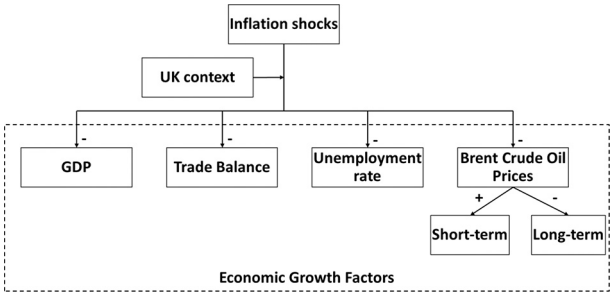

Fig. 2. Conceptual framework with data results.

the percentage change in trade balance in the UK was largely consistent before the COVID-19 pandemic, from 2010 to 2019, and it became slightly volatile during the COVID-19 pandemic crisis. Additionally, there was a considerable fluctuation in GDP in 2022, which may have resulted from the Russia-Ukraine war and economic recession (Fig. 4).

It is quite clear from Fig. 1 that inflation in the UK continuously increased from January 2010 to June 2022, indicated by the steep slope of the graph since the period of the COVID-19 pandemic on the right top raw of graph. On the other hand, it is surprising that the percentage change in unemployment continuously decreased from 2010 to 2020, even during the first wave of COVID-19 outbreak, with the exception of the European sovereign debt crisis in 2012 and the second wave of the COVID-19 outbreak. Over time, Brent crude oil prices have been significantly volatile, but they reached rock bottom in 2020, which was the second wave of the COVID-19 pandemic crisis.

3.4. Correlation matrix

Table 2 sets out the Pearson correlation between each pair of all variables in this study. The correlations of all variable series are not higher than 0.9. However, the CPI and unemployment rate are moderately correlated at −0.8548, which implies that higher inflation reduces the unemployment rate.

3.5. Stationary test

Table 3 set out the results of the Augmented Dickey Fuller (ADF) unit root test on the series, at the level first difference and second difference, since optimal lag is the first stage to measure VAR models. The results show that all variables, with the exception of GDP, are not stationarity at the level. However, these variables, with the exception of CPI, are stationary at the first difference, while CPI is stable at the second difference. Thus, we should use variables in the form of the second difference and the estimation of our VAR models is stable.

Table 3
ADF unit root tests.

Variables		Level	First diff.	Second diff.
GDP	Trend and intercept	−5.6824***	–	–
CPI	Trend and intercept	−0.1488	−0.4737	−9.1309***
Trade Balance	Trend and intercept	−2.0400	−5.3246***	–
Unemployment	Trend and intercept	−0.6857	−3.5529**	–
Brent Crude Oil	Trend and intercept	−1.2092	−5.3777***	–

Notes: *, **, *** denote statistically significant at the 10%, 5% and 1% levels, respectively.

4. Empirical results

4.1. VAR model

Table 4 sets out the results of the multivariate time series with the VAR models for the percentage change in GDP, CPI, trade balance, unemployment, and Brent crude oil. The results show that Brent Crude Oil.l1 and GDP.l2 are significantly and positively related to GDP, while CPI.l1 and Brent Crude Oil.l2 are significantly and negatively related to GDP. This is consistent with Jime'nez-Rodrı'guez and Sa'nchez (2005) who concluded that an increase in oil price results in an increase in GDP growth. On the other hand, CPI.l1 and Brent Crude Oil.l2 are significantly and negatively related to GDP. This is in the same line as Balcilar et al. (2017), who concluded that higher inflation reduces economic growth.

The table shows that CPI.l1 and Brent Crude Oil.l1 are significantly and positively related respective with CPI, but Trade Balance.l1 is significantly and negatively related respective with CPI. This is confirmed by Sek et al. (2015), who concluded that higher crude oil prices results in an increase in domestic inflation. On the other hand, Trade Balance.l1 and Trade Balance.l2 have a significantly positive effect on Trade Balance. Moreover, Unemployment.l1 is significantly and positively related r to Unemployment, while Unemployment.l2 is significantly and negatively related to Unemployment. Similarly, Brent Crude Oil.l1 has a significantly positive effect on Brent Crude Oil but GDP.l1 has a significantly negative effect on Brent Crude Oil.

Figs. 2 and 3 provide a diagram of the residuals of all equations, showing a mean close to zero and fitted values fitting the data points closely for the VAR models and time-varying VAR models respectively. For the time-varying VAR models, bandwidths are quite large with values of 20, 1.4277, 20, and 20 for GDP, CPI, trade balance, unemployment, and Brent crude oil respectively, as set out in Table 5.

Table 2
Correlation matrix.

Variables	GDP	CPI	Trade Balance	Unemployment Brent	Crude Oil
GDP	1.0000	−0.0590	−0.0628	0.0697	0.2985
CPI	−0.0590	1.0000	−0.5436	−0.8548	−0.3022
Trade Balance	−0.0628	−0.5436	1.0000	0.3743	−0.0934
Unemployment	0.0697	−0.8548	0.3743	1.0000	0.5882
Brent Crude Oil	0.2985	−0.3022	−0.0934	0.5882	1.0000

Table 4
Estimation results of VAR model.

	Dependent variable:				
	y				
	GDP	CPI	Trade Balance	Unemployment	Brent Crude Oil
	(1)	(2)	(3)	(4)	(5)
GDP.l1	0.052	-0.001	-0.148	0.044	-0.162***
	(0.056)	(0.001)	(0.128)	(0.035)	(0.051)
CPI.l1	-6.336*	0.917***	4.654	0.505	-3.204
	(3.711)	(0.085)	(8.442)	(2.306)	(3.330)
Trade Balance.l1	0.056	-0.003***	0.325***	0.009	-0.019
	(0.036)	(0.001)	(0.082)	(0.023)	(0.033)
Unemployment.l1	-0.039	0.004	-0.089	1.297***	0.021
	(0.130)	(0.003)	(0.297)	(0.081)	(0.117)
Brent Crude Oil.l1	1.411***	0.006***	-0.355	0.024	1.018***
	(0.095)	(0.002)	(0.216)	(0.059)	(0.085)
GDP.l2	0.152**	-0.0002	-0.095	-0.045	-0.037
	(0.058)	(0.001)	(0.133)	(0.036)	(0.052)
CPI.l2	6.020	0.071	-7.226	-0.749	3.487
	(3.704)	(0.085)	(8.427)	(2.302)	(3.325)
Trade Balance.l2	-0.004	-0.001	0.417***	-0.012	-0.067*
	(0.039)	(0.001)	(0.089)	(0.024)	(0.035)
Unemployment.l2	0.012	-0.005	0.044	-0.302***	0.018
	(0.133)	(0.003)	(0.303)	(0.083)	(0.119)
Brent Crude Oil.l2	-1.289***	-0.003	0.324	-0.062	-0.142
	(0.097)	(0.002)	(0.220)	(0.060)	(0.087)
Const	2.996	0.086	15.393***	1.326	0.409
	(2.323)	(0.053)	(5.284)	(1.444)	(2.085)
Observations	148	148	148	148	148
R2	0.637	0.997	0.596	0.997	0.888
Adjusted R2	0.611	0.997	0.567	0.997	0.880
Residual Std. Error (df = 137)	0.155	0.004	0.352	0.096	0.139
F Statistic (df = 10; 137)	24.093***	5,343.367**	20.219***	4,238.062***	108.536***

Notes: *, **, *** denote statistically significant at the 10%, 5% and 1% levels, respectively.

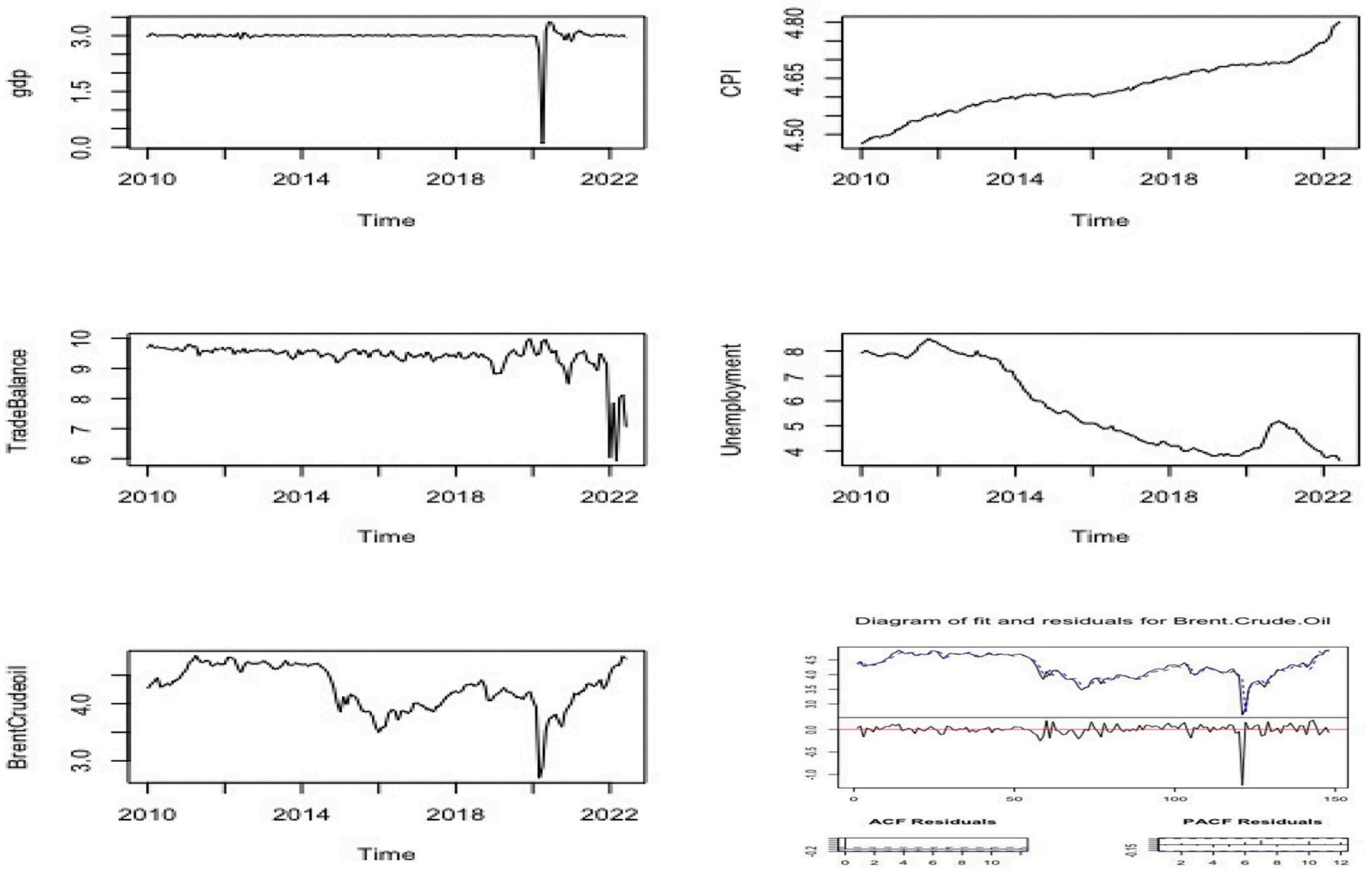

Fig. 3. Descriptive Graphs for all variables.

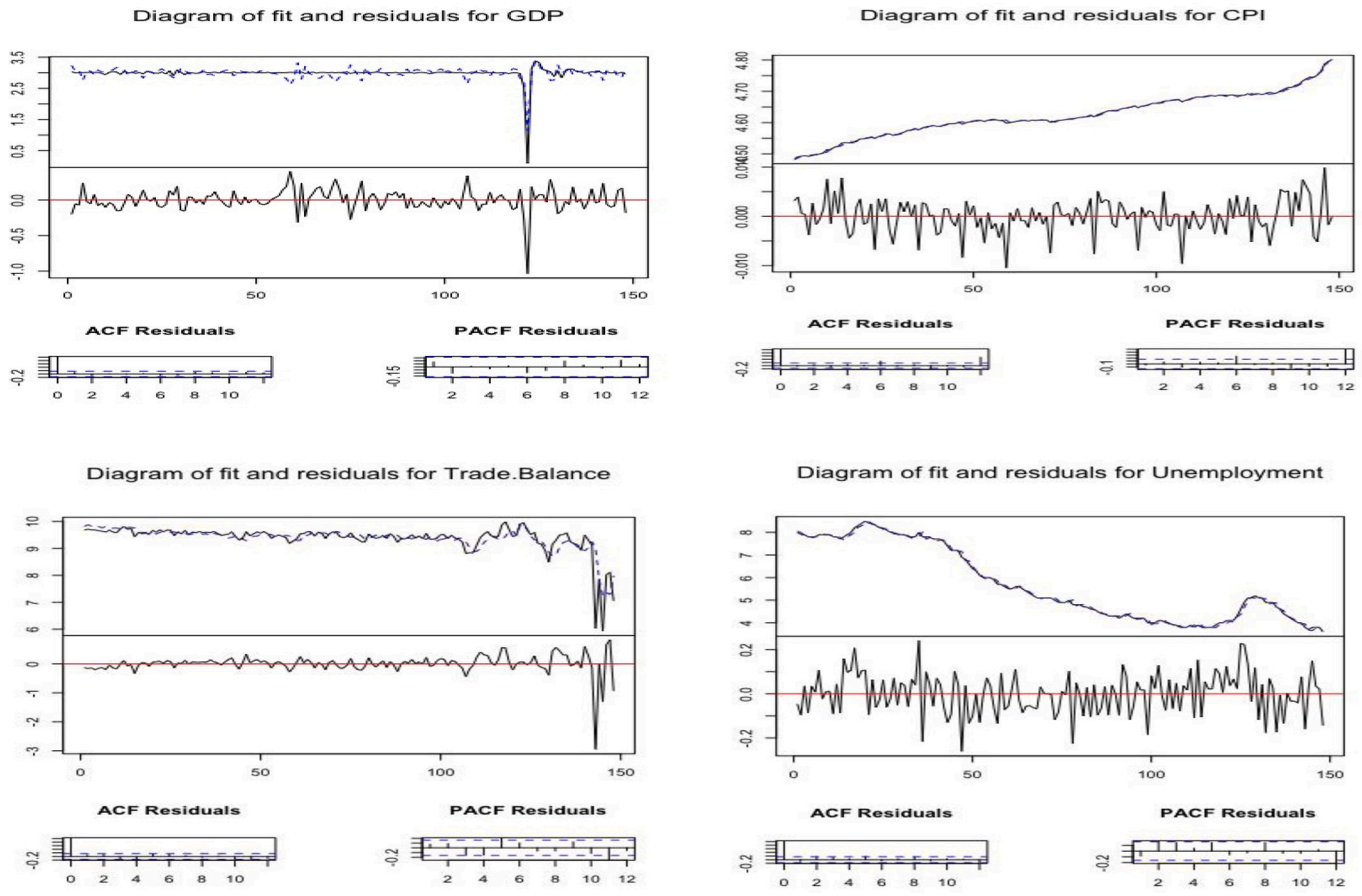

Fig. 4. VAR model fit illustration.

4.2. *Impulse–response functions*

The results from the simulations of orthogonalised impulse response function (IRF) are provided in Fig. 5 for 1 to 20 months as set out on the horizontal axis. With respect to plotting the impulse response, the two dotted lines are based on a Monte Carlo simulation with 1000 repetitions to estimate the 5th and 95th percentile bands.

The results show that a shock of one unit in inflation (CPI) produces a fluctuating effect on the growth of GDP during the first six or seven months and then a slightly positive effect during the first eight or nine months. After that, the growth of GDP reacts steadily and negatively to a shock of inflation on the left graph. This is consistent with Mallick and Mohsin (2016) who concluded that a shock from inflation can explain the variability of GDP in the US, UK, and Canada at a level of around 20% for 40 quarter horizons; however, it is terminated in the long term. This indicates that inflation shocks increase the volatility of GDP only in the short term and dying out in the long term.

The next graph shows that a shock of one unit in inflation (CPI) decreases the trade balance from one to four months. This is consistent with Gylfason (1999) who stated that high inflation is related to low export. It is postulated that an increase in inflation activates the costs of export (Seers, 1962); thus, high inflation effectively reduces export in the beginning period and also results in a decrease of trade balance. The next graph also shows that the increase of one unit in inflation shock increases the percentage change in trade balance with a slight volatility until the tenth month. Meanwhile, the shock of inflation exerts no impact on trade balance. This is consistent with Koray (2006) who concluded that trade balance positively responds to a shock of inflation only in the short term, dying in the long run, which is in line with both the Keynesian and monetarist approaches (Ivrendi and Guloglu, 2010).

For the linkage between inflation and unemployment, surprisingly, the results report that unemployment reacts negatively to a shock of inflation during the first two to four months and then positively to a shock of inflation during the first five to eight months. Afterwards, the positive shock of one unit in inflation results in a steady decrease until the twentieth months. While the results are surprising, this is consistent with Rocheteau et al. (2007) who stated that the linkages between inflation and unemployment can be both positive and negative, hinging on the utility faction based on the Phillips curve slopes. This is also in line with Greenwood and Huffman (1987) who stated that there is a negative relationship between inflation and unemployment. It is likely that a shock of inflation drives a return to work, which helps to decrease unemployment, to increase output given sufficient endogeneity in the money supply.

Focusing on the right-hand graph, the results show that a shock of inflation exerts a significantly negative effect on the Brent crude oil price in the first one or two months and then exerts a gradually positive effect until month ten. After this, the shock of one unit in inflation produces a steady and slight drop in the Brent crude oil price. This is consistent with Farzanegan and Markwardt (2009) and Salisu et al. (2017) who stated that there is a positive linkage between inflation and oil price in the long term, but there is a mixed linkage between these proxies in the short term. This is in line with Kilian and Zhou (2022) who concluded that there is no relationship between household inflation and gasoline price shocks in the long term. This indicates that Brent crude oil prices

Table 5
Bandwidths of Var model.

bw. GDP	bw. CPI	bw. Trade Balance	bw. Unemployment	bw. Brent Crude Oil
20.0000	1.4277	20.0000	20.0000	20.0000

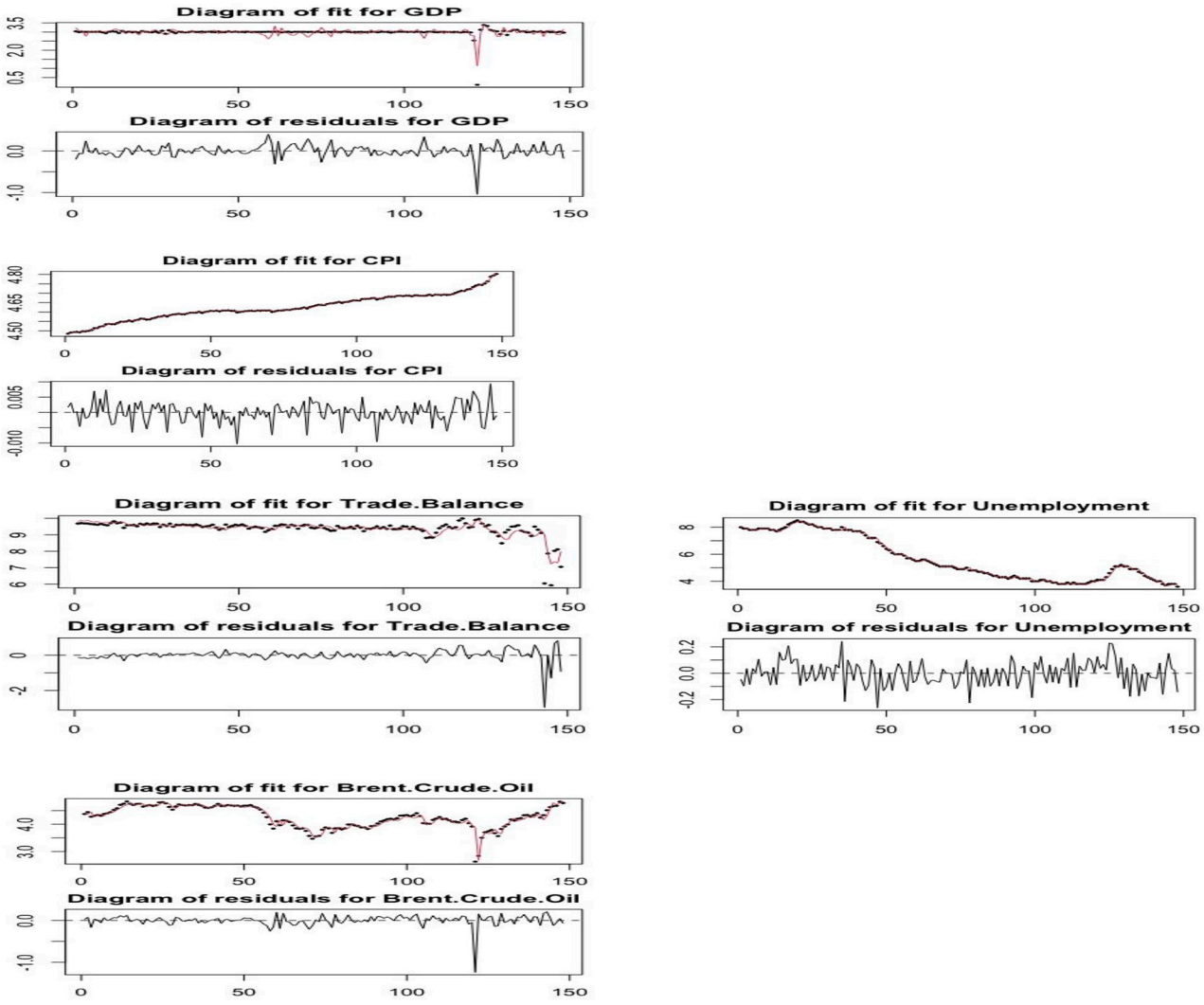

Fig. 5. tvVAR fit illustration.

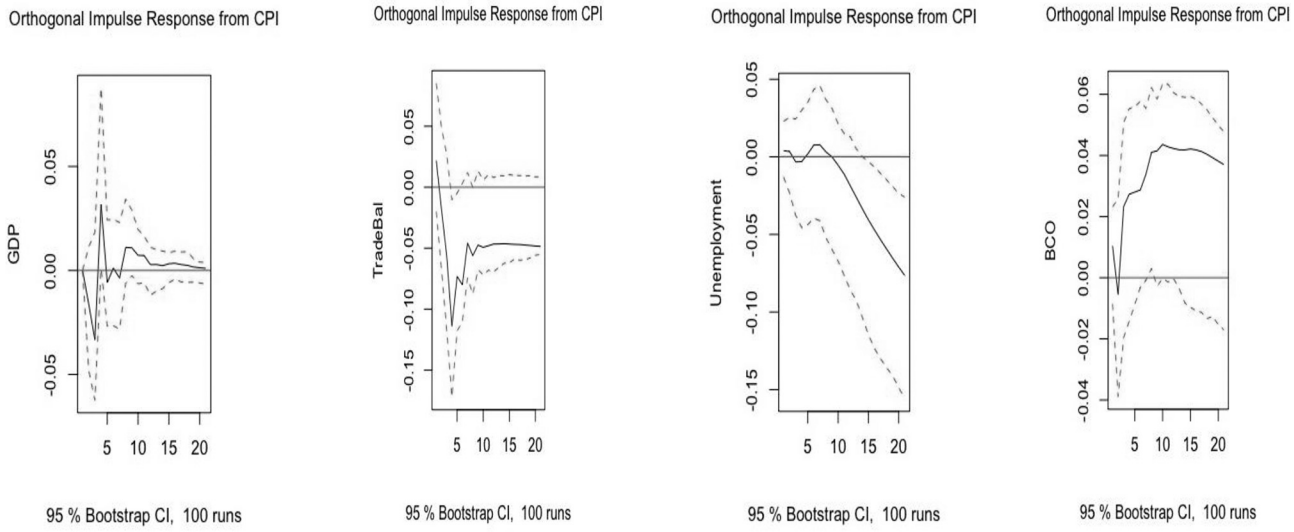

Fig. 6. VAR Impulse–response function (IRF).

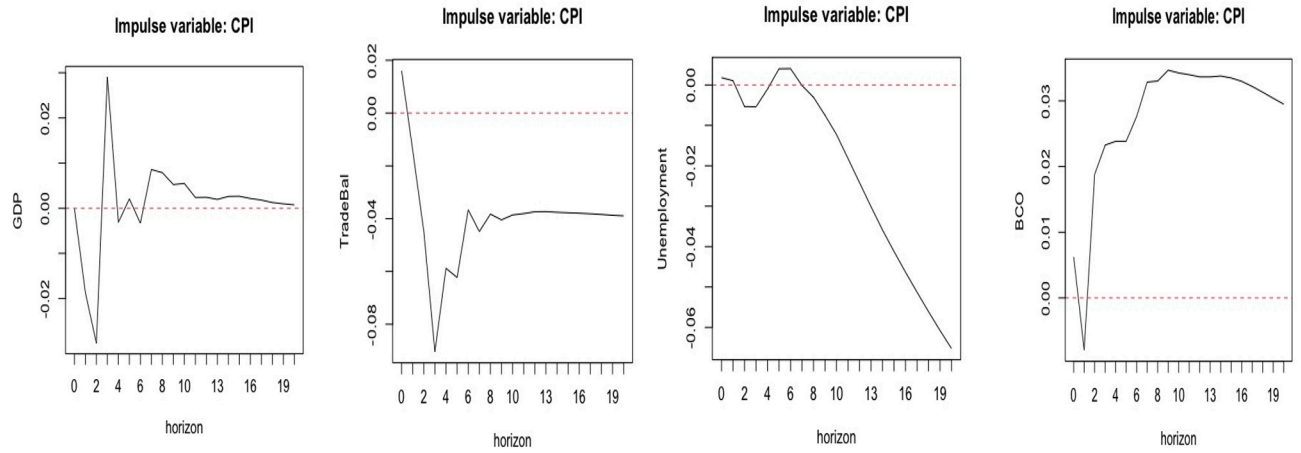

Fig. 7. Time variance VAR impulse–response function (IRF).

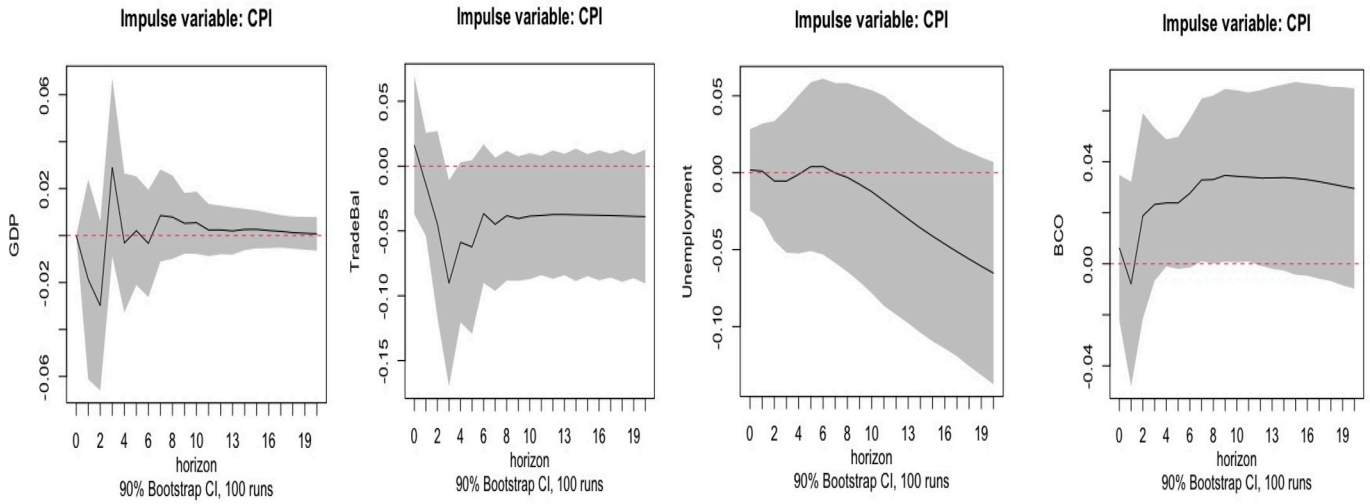

Fig. 8. Variance co-variance analysis.

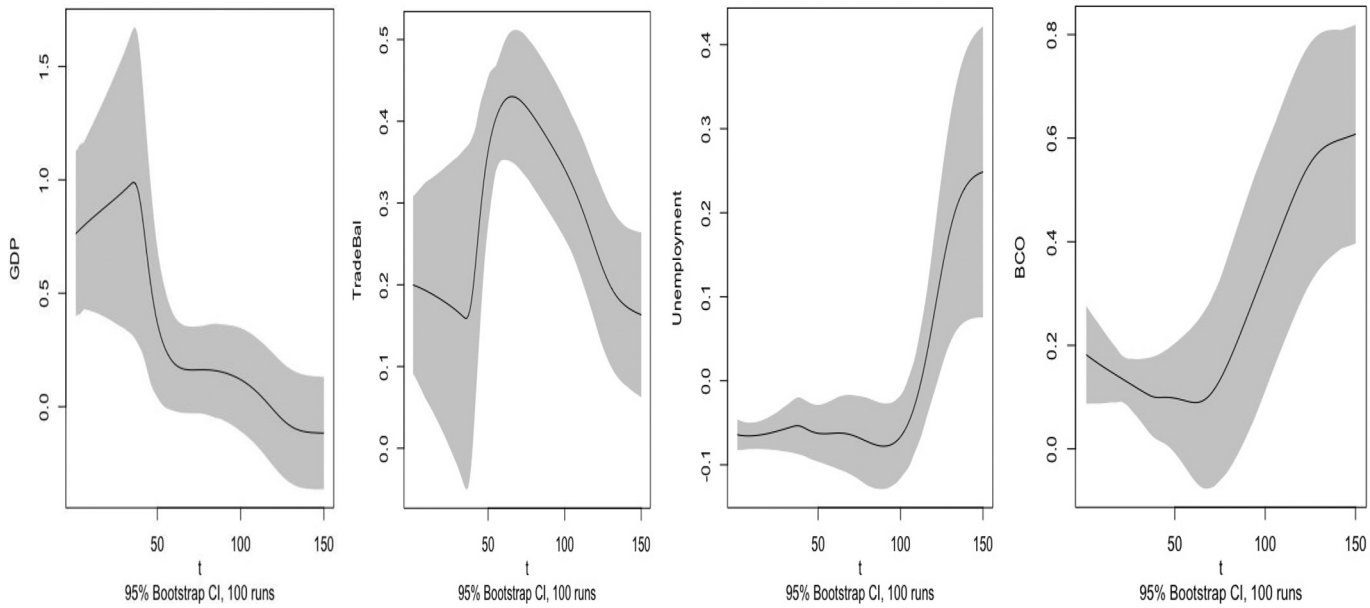

Fig. 9. Coefficients results from time-varying random fixed effects method.

increases in response to inflation shocks in the short term.

Similarly, we examine the time-varying impulse response function (IRF) of our four proxies; including the percentage change in GDP, trade balance, unemployment and Brent crude oil, to the inflation shock. The response results set out in Fig. 6 show that the movements of the time-varying impulse response function of our four proxies to the inflation shock follow the same pattern as the orthogonalised IRF in Fig. 5.

Overall, it is clear that there is a decrease in GDP, trade balance, unemployment and the price of Brent crude oil in response to a shock of inflation in the beginning period. However, it seems that the Brent crude oil prices appear to be the fastest to adjust to spiking inflation because they take only one month to rebound to a positive level compared to other proxies. One the other hand, the proportion of trade balance is more significantly impacted from the inflation shock in terms of a huge decrease in this proxy. Also significant is the fact that trade balance has the slowest speed in terms of adjusting to the inflation shock as it takes around three months to rebound to a positive level compared to other proxies. Interestingly, the trend of the response for all proxies declined in the long term but the change for unemployment is shown to decrease in the long term compared to other proxies.

4.3. Variance-covariance analysis

We also investigate the time-varying variance-covariance matrix of the error term of the four proxies; GDP, trade balance, unemployment and Brent crude oil price, and inflation. Fig. 7 sets out the estimated dynamic correlation between the percentage change in GDP, trade balance, unemployment, and Brent crude oil, and inflation from the left to right graphs. The results show that the co-movement of the variance-covariance matrix of the error term of the growth of GDP and the inflation considerably fluctuates between the values of −0.3 and 0.3 during the first four months. Then, its value stabilizes to be close to zero in the long term. This is consistent with Mallick and Mohsin (2016) who stated that the variation of economic growth can be explained by a shock from inflation only in the short term. These results are also in line with the results of the impulse response function (IRF)where the dynamic correlation between the percentage change in trade balance and inflation is negative during the first three months with a value of −0.09. This is in line with Gylfason (1999) and the results of impulse response function (IRF). After that the early months, its correlation gradually increases during the middle period of the samples but remains a negative number, becoming stable at −0.05 at the end of period. This is consistent with Koray (2006) who stated that trade balance reacts positively to a shock from inflation only in the short term. In addition, these results are also consistent with the results of impulse response function (IRF).

For the dynamic correlation between unemployment and inflation, this is close to zero during the early eight months, decreasing to negative numbers in the long term reaching a final value of −0.07 at the end of the time period. This is in line with the Phillips Curve economic theory that unemployment negatively impacts inflation rates due to an increase in labor market. These results are also consistent with the results of the impulse response function (IRF). On the other hand, the dynamic correlation between Brent crude oil shocks and inflation is slightly negative only in the early two months, increasing to be positive in the middle period. Eventually, it stabilizes in the ninth month and the long term at a value of 0.3. Interestingly, the co-movement of the variance-covariance matrix of the error term of our four proxies and inflation follow a similar pattern to the orthogonalised IRF in Fig. 5 as well as the time-varying IRF in Fig. 6.

4.4. Time-varying panel analysis

Table 6 shows the empirical results of the time-varying random fixed effects method for the linkages between GDP, trade balance, unemployment, Brent crude oil prices, and inflation (CPI). The results show that the percentage change in GDP, trade balance and unemployment

Table 6
Time-varying Panel Analysis (PLM).

CPI	Estimated Coefficients	Std. Error	t-value	Pr(>|t|)	Signif. Codes
GDP	−0.0228	0.0105	−2.1761	0.0312	*
Trade Balance	−0.0229	0.0054	−4.2093	0.0000	***
Unemployment	−0.0393	0.0022	−17.9953	0.0000	***
Brent Crude Oil	0.0443	0.0088	5.0591	0.0000	***
N	150				
Total Sum of Squares:	0.7175				
Residual Sum of Squares:	0.1284				
R-Squared:	0.8211				
Adj. R-Squared:	0.8161				
F-statistic:	166.3160***				

Notes: *, **, *** denote statistically significant at the 10%, 5% and 1% levels, respectively.

are significantly and negatively related to inflation. This indicates that when the percentage change in GDP, trade balance and unemployment increases, this there is a decrease in inflation. The results for unemployment are consistent with the Phillips Curve economic theory that a decrease in unemployment results in an increase in inflation, which indicates an inverse relationship between inflation and unemployment rates (Phillips, 1958). This implies that inflation is significantly impacted by changes in the labor market, such as employment levels and wage rates (Salisu et al., 2018). However, the results for trade balance are consistent with the aggregate demand-aggregate supply (AD-AS) model whereby changes in the overall demand and supply of goods and services, with an increase in aggregate demand or a decrease in aggregate supply, can increase inflation levels due to customer surplus and deficiency of resources (Mankiw, 2014). Moreover, the results for GDP are consistent with Iyke (2015) who stated that there is a negative relationship between economic growth and inflation in Nigeria. This implies that a decrease in inflation leads to lower price levels for goods and services in a market, and this, this, in turn, promotes the growth of the economy. On the other hand, Brent crude oil price is significantly and positively related to inflation. Accordingly, when the Brent crude oil price increases, so does inflation. This also consistent with Talha et al. (2021) and Wang et al., (2019) who stated that an increase in energy consumption or oil prices results in an increase in inflation.

Fig. 8 displays the elasticity estimates using the time-varying random fixed effects method. The results from the time-varying coefficient models of the percentage change in GDP, trade balance and unemployment are plotted with a black line with 95% confidence intervals, in grey, from the left to the right graphs respectively. The time-varying coefficients models suggest that the growth of GDP is a value under 1.0. This indicates that the growth of GDP in the UK is slower than the increase of inflation. Moreover, the value of elasticity estimates for GDP continuously decreases in the long term. In addition, the confidence intervals are larger around the early period of the samples, but they decrease in the middle and longer-term periods of the samples. This suggests that the variability in the elasticity between our two proxies decreases during the middle and long terms.

Focusing on the time-varying coefficients models for the percentage change in trade balance, the results show that it is a value under 0.5. This suggests that the percentage change in inflation is faster than the percentage change in trade balance. On the other hand, the value of elasticity estimates for the percentage change in trade balance increases in the beginning stage of the samples but it decreases in the long-term period of the samples, peaking at a value of 0.4 during the middle period of the samples. Moreover, the confidence intervals are large around the early period of the samples. This indicates that the variability in the elasticity between our two proxies is high in this period.

Next, the results of the time-varying coefficients models for the percentage change in unemployment display that there is a value under

0.3. This suggests that the percentage change in unemployment is slower than the percentage change in inflation. Furthermore, the value of elasticity estimates for unemployment is under 0 in the early period of the samples. While its value increases in the long-term period, the confidence intervals also increase. This indicates that the variability in the elasticity between our two proxies is higher in the long term.

Lastly, the results of the time-varying coefficients models for the percentage change in Brent crude oil show that there is a value under 0.6. This suggests that the percentage change in inflation is faster than the percentage change in Brent crude oil price. Moreover, even if the value slightly decreases during the beginning stage, it continuously increases in the long term. Additionally, the confidence intervals gradually become larger in the long-run period. This indicates that the variability in the elasticity between our two proxies is gradually higher for the long-term period. Fig. 9 illustrates the integration of our data findings within the conceptual framework, providing a clearer understanding of the short-term and long-term effects of inflation on the UK economy.

5. Conclusion

In conclusion, this paper discusses three analyses under the framework of vector autoregressive model (VAR) including the VAR model, time-varying VAR analysis, and time-varying panel model with the robustness test. Based on the Impulse–response functions and variance-covariance analysis, it is evident that there has been a decline in the percentage change of GDP, trade balance, unemployment, and Brent crude oil prices in response to an inflation shock at the initially. However, among these proxies, Brent crude oil appears to be the quickest to rebound from the inflation shock, taking only a month to return to a positive level. Interestingly, the trade balance is the most affected by an inflation shock, experiencing a significant decrease, and taking around three months to adjust to the shock compared to other proxies. In general, all the proxies show a declining trend in their response over the long term, but unemployment experiences the most substantial decrease in percentage change compared to other proxies, although it positively responds to an inflation shock during the first five to eight months.

The findings from the time-varying panel analysis reveal that the percentage change in GDP, trade balance and unemployment are significantly and negatively related to inflation. Conversely, there is a significant positive correlation between inflation and Brent crude oil prices. On the other hand, the rate of changes in GDP, trade balance, unemployment, and Brent crude oil is slower than that of inflation. Interestingly, while the elasticity between inflation and GDP becomes less variable over the middle and long terms, the variability in the elasticity between inflation and other proxies increases gradually during the long term.

In summary, on the basis of analysing relationships between inflation and other macroeconomic variables, including GDP, unemployment, oil price and trade balance, this study seeks to examine the correlation between the above-mentioned variables in both the short and long term as well as the percentage change in these proxies. These variables are significantly linked with rate of inflation. The results may have provided an overview of the current inflation level in the UK, and researchers may have considered these proxies in predicting the future trend of inflation. As a result, the government can use these research findings to determine economic and social development policies under the current circumstances.

The results of this study have important implications for both researchers and policymakers as well as other stakeholders. In terms of policy implications, energy shocks have significant effects on society and the macroeconomy, particularly in terms of economic expansion, inflation, and the environment. Government initiatives, tax laws, and interest rates are all affected by inflation, through channels such as consumer spending, company investment, and employment rates. Since inflation reduces the return on investment, understanding inflation is crucial for successful investing. Our findings have important implications for short-term speculators, long-term investors and policymakers in considering the co-movement between inflation and economic activity moderated by crude oil price.

The study provides new insights into how inflation shock affects the economy. This information can be used to inform future research and to develop more accurate economic models. Additionally, policymakers can also use the findings to inform their decision-making processes. For example, the study suggests that a shock to inflation can have a negative impact on the growth of GDP, and that trade balance responds positively to inflation in the short term. Policymakers can use this information to develop policies that mitigate the negative effects of inflation on economic growth, and to take advantage of short-term opportunities presented by inflation to trade balance. The study also highlights the importance of Brent crude oil price in coping with spiking inflation, which can inform energy policy decisions. Finally, the findings may have important implications for businesses operating in the UK. Businesses may need to take into account the relationship between inflation and other economic indicators when making strategic decisions. In the long term, in response to inflation shock, they might diversify supply chains to reduce their reliance on suppliers within the country or use financial instruments such as futures or options to hedge against inflation risk.

It bears mentioning that our analyses have been limited to VAR models, and exploring other methodologies such as extreme value theory or spillover methods may provide alternative insights. In addition, since we have only studied one country, it is important to note that the findings may not be generalisable to other countries or regions, and further research may be necessary to validate the results in other contexts. Also, the findings in our study are based solely on data from 2010 to 2022, which represents a limited timeframe, and caution should be exercised when interpreting the results in the context of different timeframes. To establish the consistency of the results over an extended period, additional research is required.

CRediT authorship contribution statement

Rizwan Ahmed: Conceptualization, Data curation, Methodology, Formal analysis, Investigation, Project administration, Software, Resources, Validation, Supervision, Writing – review & editing. **Xihui Haviour Chen:** Project administration, Visualization, Writing – original draft, Writing – review & editing. **Chamaiporn Kumpamool:** Formal analysis, Investigation, Methodology, Writing – original draft, Writing – review & editing. **Dung T.K. Nguyen:** Writing – original draft, Writing – review & editing.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.eneco.2023.106918.

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