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Inflation Dynamics in OECD Economies: The Role of Crude Oil Import Price, Unconventional Monetary Policy, and Post-Pandemic Demand Shocks

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Abstract

This paper examines the impact on inflation of crude oil import price (COIP), unconventional monetary policy (UMP), and post-pandemic demand shocks for a panel of 21 OECD countries, using panel vector autoregressive (pVAR) and local projection methods. The empirical result provides evidence that COIP shocks significantly contribute to increases in consumer price index (CPI) inflation, GDP deflator inflation and producer price index (PPI) inflation. UMP shocks, although less impactful than COIP shocks, also influence inflation. Furthermore, the most significant inflationary pressures in recent times have arisen from post-pandemic demand shocks, surpassing the effects of COIP and UMP shocks in the post-COIVD period. The findings highlight the critical role of supply-side and demand-side factors in shaping inflation dynamics in the OECD.

Keywords: Unconventional Monetary Policy (UMP), Crude Oil Import Price (COIP), Post-pandemic demand Shock, Inflation, panel VARs, Local Projections

1. Introduction

Recent inflation trends, with inflation reaching 40-year highs in some economies, have sparked intense discussions about the factors considered as potential causes or contributors. The IMF projected global inflation to rise from 4.7% in 2021 to 8.8% in 2022, decline

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to 6.5% in 2023 and further to 4.1% by 2024. For the panel of countries examined in this study, the average inflation rate in 2021 was approximately 4%. Given the significant economic costs of inflation, the elevated levels observed in many countries have prompted monetary authorities to intensify their efforts to bring it under control.

Regarding the ongoing debate, some suggest that the current situation is an emergence of a post-pandemic inflation inertia. Others view recent trends as an economic hangover of the global financial crisis (GFC) 2008-2009, where expansionary policies, particularly unconventional monetary policy (UMP), were employed to restore growth. There is a believe that these policies continued for far too long than necessary, hence, the bearing on recent trends. Discussion has also been centred on the contribution of oil shocks. Some economist sees the post-pandemic demand for commodities including crude oil as a crucial contributor to the recent trends in inflation.

There is a wide acceptance by many economists, and rightly so, given the evidence available, that some causal relationship exists between oil price and inflation. This view was even more popular in the 1970s, when stagflation episodes in major OECD economies were partly attributed to oil supply shocks. However, there are still some controversies on such nexus. The doubt on the oil price-inflation relationship is strengthened when one observes periods like the 1990s and 2000s, where persistent upward movements in oil prices had a less measured effect on inflation. Some large spikes in the inflation rate are clearly unrelated to oil events (see, for example, Figure Two under section three).

Moreover, some oil dates, such as the outbreak of the Iran-Iraq war in 1980, which led to a drop in oil production of about 7.2%, have had little impact on CPI inflation. The outbreak of the war in Afghanistan in 2001 and of the Iraq war of 2003 were followed by a fall in consumer prices. These events dimmed the light on the perceived effect of oil shocks on inflation. Blanchard and Gali [8] evaluate the hypothesis that the effects of oil price shock, though similar across different episodes, have coincided in time with large shocks of a very different nature (for example, large rises in other commodity prices in the 1970s, high productivity growth and world demand in the 2000s). The authors note that such a coincidence of shocks could significantly distort a proper assessment of oil shocks' impact based on a simple observation of the movements in aggregate variables around each episode. Their result, consistent with the literature, shows that the high inflation levels of the 1970s and 1980s were not due to the oil shocks alone.

A distinguishing feature of the past decade, and little over, from the previous four decades is the extensive adoption of unconventional monetary policies (UMP) by monetary authorities. The devastating effect of the GFC spawned a multitude of policy responses throughout the OECD, with major central banks aggressively lowering their policy rate (see, for example, Opoku [30]). Once the effective zero lower bound (EZLB) on the short-term nominal interest rate was reached, monetary authorities resorted to unconventional methods further stimulus to deteriorated economies. According to a report by the UK House of Commons[29], central banks have expanded their balance sheet by about 13 percent of global GDP as of year 2020. The report further states that quantitative easing (QE) now constitutes a significant share of the economy of some advanced countries: Euroarea (EMU) about 32% of GDP, the United Kingdom about 40% of GDP, United States totals around 30% of GDP and Japan about 106% of GDP.

The latest rounds of QE coincided with several events such as supply-chain disruptions and post-pandemic surge in demand. Therefore, under the circumstances reminiscent of the 1970s, in terms of the behaviour of some macroeconomic aggregates and the coincidence of shocks of different nature, one could postulate that the primary cause of the recent high levels of inflation may not be due to one single factor, but a sequence and host of events, including oil shocks and the outcomes of expansionary policies, which have been and are still of first-order importance to monetary authorities in tackling crisis-crippled economies. In other words, several events contributed to a larger inflation pass-through that we have seen recently.

The precise effect of coincidental events or shocks, for example, oil price shocks and UMP shocks, are unclear and not entirely addressed in the literature. Therefore, in the spirit of Bernanke et al. [6], one is tempted to ask: what portion of economic and price fluctuation is due to oil price shocks, per se, and what portion is due to unconventional monetary policy employed in recent times as expansionary measures? Disentangling those factors driving inflation to high levels is important for gauging the future direction of any economy, particularly for policy makers faced with policy trade-off decisions between inflation and unemployment. Against this backdrop, this paper contributes to the literature by disentangling the effects of the abovementioned shocks on inflation rates.

First, I test for inflation persistence in the OECD with a univariate autoregressive model, using quarterly data that span 1993q1 to 2008q1. The choice of this baseline sample period is motivated by a multiple breakpoints test, which finds a structural break in the oil price-inflation relationship around 2008q4. Results are also reported for the full sample period that spans 1993q1 to 2021q4.

I then explore other themes using panel vector autoregressive (PVAR) and panel local projection methods. The panel, comprising 21 OECD countries, enables me to test relevant hypotheses under a generalised framework, other than being limited to the United States, which is what most of the literature has done. The adopted techniques can isolate the response of inflation measures used in this paper to coincidental shocks. Thus, by orthogonalising the response, I can identify the effect of one shock at a time while holding other shocks constant. Another contribution of the paper is how it traces out the effect of UMP shock by examining the dynamic response of inflation to an associated dummy variable that I embed in the system. This approach resolves the structural break problem that earlier studies had to contend with.

The results of autoregressive (AR) models for CPI inflation over different sample periods reveal high inflation persistence in OECD economies. The results indicate that past inflation significantly predicts future inflation, with notable autoregressive effects lasting up to three or four quarters. This persistence is observed across pre- and post-2008 sample periods and during the 2020-2021 period, indicating that inflation dynamics have remained consistent despite structural breaks caused by events like the Global Financial Crisis (GFC) and COVID-19. Further results based on the impulse response functions of the pVAR and local projection models suggest the following:

(1) COIP shocks lead to significant and immediate increases in CPI inflation, GDP deflator inflation, and PPI inflation. Forecast error variance decomposition (FEVD) indicates that COIP shocks explain a substantial portion of the variance in PPI inflation (up

to 28% by the tenth quarter) and CPI inflation (11%), suggesting that crude oil import price shocks play a significant role in driving inflation, particularly in producer prices.

(2) UMPs have a statistically significant impact on inflation. UMP shocks lead to a rise in all three measures of inflation. While the inflationary effects of a UMP shock are less pronounced than COIP shocks, UMP shocks still contribute significantly to inflation variance, particularly in CPI inflation (around 3% at longer horizons).

(3) The post-COVID demand shocks played a significant role in the recent inflation surge, with its impact being even stronger than COIP and UMP shocks during the sample period.

(4) Central banks responded more aggressively to COVID-19 than COIP shocks. UMP responses to the COVID-19 shock were sharp and sustained, while the response to COIP shock was relatively moderate and gradual.

The rest of the paper is organised as follows. Section 2 briefly reviews the literature. Section 3 discusses the data, some basic facts and the empirical methodology. Section 4 presents the estimation results of the pVAR and local projection models and some robustness checks. Section 5 concludes the paper.

2. Literature

The relationship between oil price shocks and inflation has been a central topic in macroeconomic research since the 1970s. I briefly review four key strands of the literature relevant to this study.

The first strand of literature examines the direct effects of oil price shocks on inflation. Several studies have established a positive correlation between oil prices and inflation across different countries. For instance, Blancard and Gali[8] find larger effects of oil price shocks on inflation for pre and post-1984 periods for most countries they considered. De Gregorio et al. [14] provide a variety of estimates of the degree of pass-through from oil prices to inflation, and its changes over time, for many countries. The authors claim that the pass-through from oil prices to general price levels has declined in recent decades, mainly due to reduced oil intensity, exchange rate pass-through, a more favourable inflation environment, and strong world demand. Khiam et al. [40] find that oil price shocks significantly drive inflation in South Asian economies, with positive price shocks having a lasting impact than negative shocks. Similarly, Sangyup Choi et al. [10] note that a 10% rise in global oil prices leads to a 0.4 percentage point increase in domestic inflation, though this effect diminishes over time. Valadkhani [38] finds that rising oil prices have had more immediate and positive impacts on consumer energy prices in Canada and the U.S. since the Western U.S. Energy Crisis of 2000. Despite consensus on the relationship between oil prices and inflation, there is substantial debate regarding the underlying mechanisms driving this relationship.

The second strand of research explores how the effects of oil price shocks on inflation and economic activity have changed over time. Studies such as Hamilton [18] and Blanchard and Gali [8] highlight the weakening of the relationship between oil prices and economic activity. Blanchard and Gali argue that the problem of mixed findings could be attributed to the time-varying impacts of oil prices on the economy. Herrera and Pesavento [22] confirm the changing impact of oil price shocks on the U.S. economy. Their result from an estimated SVAR model shows that real oil prices have a larger and longer-lived effect on output growth, the aggregate price level, manufacturing sales' growth and inventory investment in the pre-Volcker period, 1959q1–1979q2.

The third strand of research focuses on the asymmetric effects of oil price changes on inflation. Early work by Mork [28] demonstrates that oil price increases have a significantly greater impact on macroeconomic variables, including inflation than oil price decreases. Hamilton [19] supported this view, showing that oil price increases are more predictive of inflation than decreases, which tend to have limited effects. This asymmetry is observed in various regions, with Cunado and Perez de [13] reporting such dynamics in six Asian countries, and Lardic and Mignon [25] finding similar results in the U.S. and Europe. Salisu et al. [34] also find that oil prices have a greater impact on inflation in net oil importing countries than oil exporting countries, with asymmetries playing a greater role in oil exporting nations.

The fourth strand investigates the role of monetary policy in moderating the inflationary effects of oil price shocks. Studies such as Bernanke et al. [6] decompose the effects of oil price shocks into those directly resulting from oil prices and those arising from monetary policy responses. Their findings suggest that the impact of oil price shocks on inflation is significantly influenced by the central bank's reaction. Other studies, including Clarida, Gali and Gertler [11], Hamilton and Herrera [21], Leduc and Sill [26] and Bachmeier [4] reinforce the idea that monetary policy plays a crucial role in transmitting oil price shocks to inflation.

Beyond oil price shocks, this paper also connects to the literature on unconventional monetary policy (UMP) and its effects on inflation. The widespread adoption of UMP tools such as quantitative easing (QE), negative interest rate policies, and forward guidance has increased academic interest in their macroeconomic effects. Gagnon et al. [16] find that QE significantly lowered long-term yields in the U.S., which helped boost inflation. Baumeister and Benati[5] and Weale and Wieladek [39] observed similar positive effects on inflation in the U.S. and U.K., although the magnitude was modest. However, Thornton[36] questioned the effectiveness of QE in influencing real economic variables, including inflation, leading to mixed conclusions in the literature.

This paper contributes to the literature by disentangling the inflationary effects of three key shocks: UMP, COIP, and post-pandemic demand shocks. Unlike previous studies focusing on individual countries, primarily the U.S., this paper uses a panel approach across OECD economies, allowing for greater generalisability and a more comprehensive understanding of the inflationary dynamics in response to these shocks. The cross-sectional variation in the data allows for exploring heterogeneity in inflation responses across economies, providing new insights into the macroeconomic effects of these shocks.

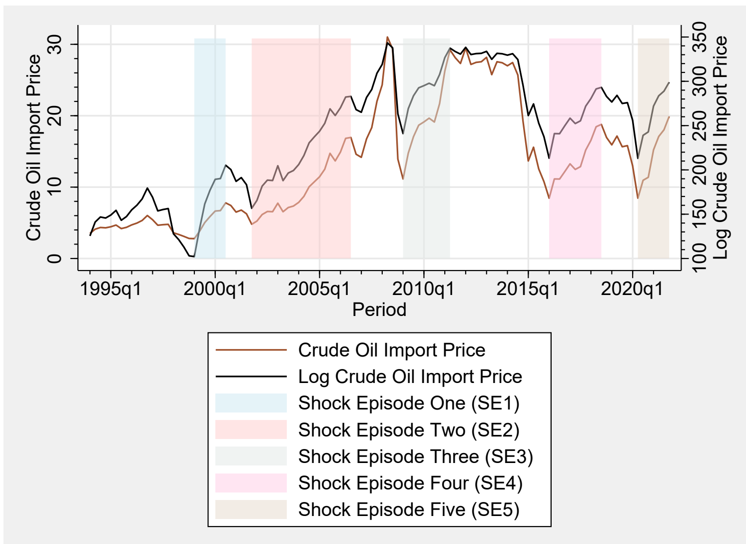
3. Analysis

This section presents some stylised facts, the data and the empirical methodology employed. It concludes with a discussion of the estimated results and the test of robustness.

3.1. Stylised Facts

Figure 1 below shows the evolution of the average crude oil import price (COIP) and its log (LCOIP) from 1993q1 to 2021q4 for a panel of 21 countries. COIP comes from the International Energy Agency's (IEA) crude oil import register and is measured in

U.S. dollars per barrel. As can be seen from the figure, COIP is characterised by large and persistent fluctuations, punctuated with occasional sharp-run ups and spikes and, in some cases, prolonged rises. The shaded areas in the figure correspond to the five large oil shock episodes that have been identified using Blanchard and Gali's [8] criterion for the definition of oil shocks.[1]. Figure 1 also displays LCOIP (COIP measured in natural logarithms and multiplied by 100 to reflect percentage changes), which gives a much better understanding of the magnitude of the changes in the real import prices of crude oil. Figure 1 shows large percentage changes in the real import prices of crude oil.

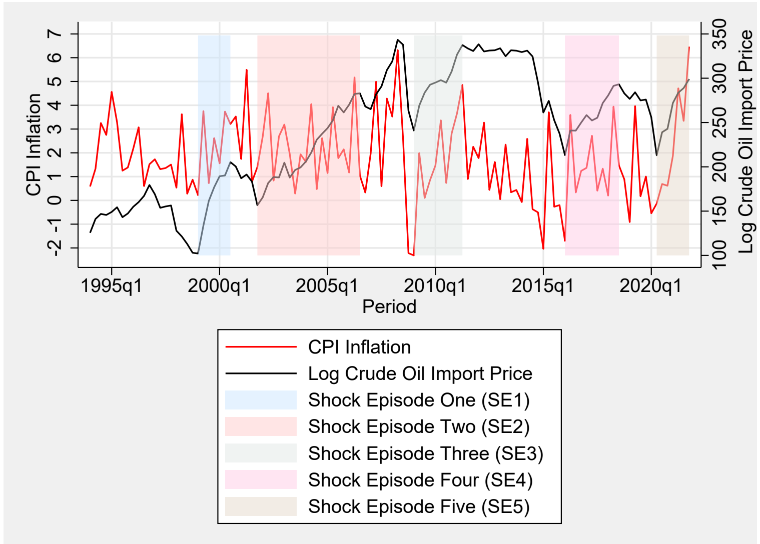


(a)

Figure 1: Crude Oil Import Price ($ per barrel) and Log Crude Oil Import Price

Blanchard and Gali's definition of oil shock gives five shock episodes for the panel: 1999, 2002, 2009, 2016 and 2020, highlighted in Figure 1(a). For convenience, I refer to these shock episodes as SE1, SE2, SE3, SE4, and SE5. Their definition leaves out the dramatic escalation of oil prices in 2008 due to its sharp decline later in the year, influenced significantly by the onset of the GFC 2008-2009, which dampened demand for crude oil as economies worldwide contracted. The tumultuous fluctuations in crude oil prices during 2008 exemplify the extreme volatility of the global oil market. We

[1] The authors define a large oil shock as "an episode involving a cumulative change in the (log) price of oil above 50%, sustained for more than four quarters"



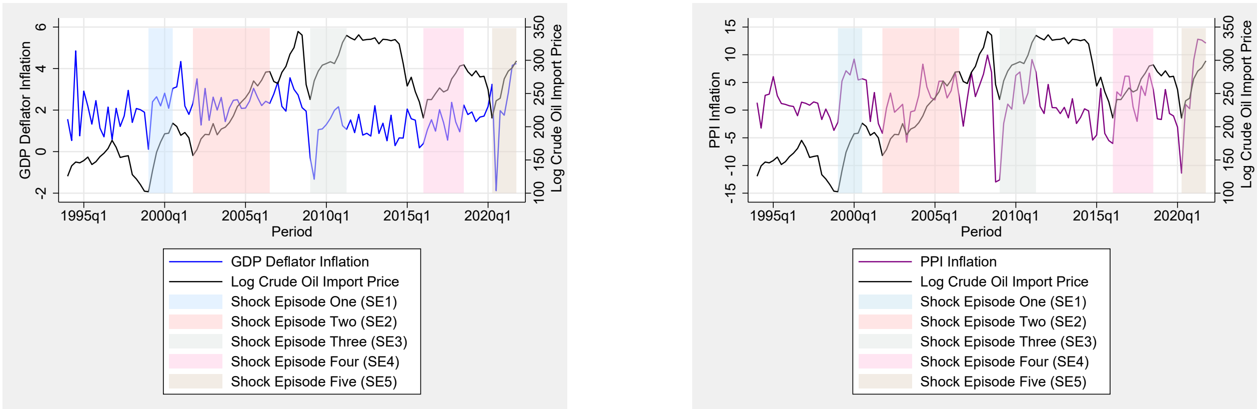
(a)

Figure 2: Log Crude Oil Import Price and CPI Inflation

observe that the oil price increases in 2002 occurred in small but persistent price increases extending over almost five years. It could also be observed that SE3 has a prolonged effect.

Figures 2 and 3 show the evolution of (log) crude oil import prices and inflation measures from 1993q1 to 2021q1. The data clearly show that the five identified oil shock episodes are closely associated with rising inflation patterns. As depicted in Figure 2(a), all oil shock episodes coincide with a marked increase in CPI inflation. The relationship between oil shocks and inflation becomes even more evident in Figures 2 (b) and (c), where GDP deflator inflation and PPI inflation are used as alternative inflation measures, providing a stronger correlation between the shock episodes and inflationary trends.

The above facts support the hypothesis that oil shocks have coincided with rising inflation. SE3 (2009) and SE5 (2020), in particular, correspond to significant global economic events - the Global Financial Crisis and COVID-19 pandemic, respectively. The various measures, such as unconventional monetary policy (UMP) measures employed by many countries during these periods, may have exacerbated or mitigated the effects of oil shocks. To disentangle these effects, I will now conduct a detailed analysis of the co-movements between oil prices, unconventional monetary policies and inflation in the



(b) (c)

Figure 3: Log Crude Oil Import Price, GDP Deflator Inflation and PPI Inflation

next section.

3.2. *Data*

Appendix B details the variables, in quarterly frequencies, and their sources. The consumer price index (CPI), producer price index (PPI), unemployment rate, unit labour cost, real effective exchange rate, crude oil import prices, and real GDP data are sourced from the Economic Co-operation and Development (OECD) database. Data for the GDP deflator comes from FRED. Appendix E outlines the various unconventional monetary policy measures adopted by the countries in the panel, including the dates of adoption. The series used for the empirical estimations are in quarterly growth rates (annualised, except the stock variables), covering the sample period from 1993q1 to 2021q1 for 21 OECD countries. Appendix C (Tables 9 and 10) provides summary statistics of the variables, and Appendix D presents the correlations among them. The results indicate a modest positive correlation (0.3) between crude oil import prices and both CPI inflation.

3.3. *Estimations*

In this Section, I examine the inflationary effects of three shocks - COIP, UMP and post-Covid demand shocks using pVAR and panel local projection methods for the panel of 21 countries (See appendix A for the list of countries in the panel).

To begin, I test the stationarity property of each variable using Pesaran's [31] second-generation panel unit root test (PURT). The second-generation tests are employed due to the significant cross-sectional correlation observed among all variables, as indicated by the Pesaran [32] test for cross-sectional dependence. The PURT is an important preliminary test for pVAR estimation. As noted by Blundell and Bond [9] in the univariate case and Abrigo and Love [1] for the multivariate case, the GMM estimators suffer from the problem of the weak instrument when the variable being modelled is a near unit root. The null hypothesis of PURT assumes that all series are non-stationary. The PURT results, in levels and first differences, are shown in Appendix D. COIP and PPI are $I(0)$ in levels. All the variables are $I(0)$ in first difference.

I then test for structural breaks in the series. Ditzen et al. [15] notes that identifying structural changes due to events like the GFC 2007-2008 and COVID - 19, is a crucial step in time series and panel data analysis. A breakpoint test reveals a break at 2008q4, with 2008q2 and 2009q2 as confidence bands. Therefore, the baseline model uses a sample period of 1993q1 to 2008q1.

Next, I estimate autoregressive (AR) models of CPI inflation, covering three distinct periods: 1993q1 - 2008q1, 1993q1 - 2021q4 and 2020q1 - 2021q1. My primary objective is to understand the degree of inflation persistence in OECD countries across these periods. The p^{th} order autoregressive model $(\text{AR}(p))$ can be written as

$$\Delta CPIinf_{i,t} = \alpha_i + \beta_1 \Delta CPIinf_{i,t-1} + \beta_2 \Delta CPIinf_{i,t-2} + \ldots + \beta_p \Delta CPIinf_{i,t-p} + \epsilon_{i,t} \qquad (1)$$

where ΔCPIinf_{it} denotes the quarterly change in CPI inflation (annualised). I use quarterly changes to deal with the problem of strong serial correlation of CPIinf_{it}. The $(\text{AR}(p))$ model uses p lags of ΔCPIinf as regressors. Panel fixed and random effect models that account for potential heterogeneity across the countries are estimated.

Tables 5, 6, and 7 present the estimation results for different sample periods. These tables summarise the estimated coefficients of CPI inflation, along with their standard errors and significance levels. Four models are estimated in each table: two fixed effect models and two random effect models. The result of the AR models, showing the magnitude of large autoregressive roots, demonstrate significant persistence in CPI inflation, with notable autocorrelation up to three or four quarters. This persistence is observed across the different time periods considered. The models with four lags provide better explanatory power, as indicated by higher $\bar{R}^2$ values. These findings suggest that past annualised inflation rates have a substantial and predictable impact on current or future inflation.

Finally, I analyse the inflationary effects of the three shocks of interest using pVAR and local projection estimation methods. Incorporating fixed effects, the pVAR model accounts for unobservable heterogeneity across individual units, capturing the unique characteristics of each country. It also addresses the endogeneity of all variables, overcoming the limitations faced by traditional VAR models in handling panel data (Zhao and Park [41]). The estimation uses the generalised method of moments (GMM) procedure, suitable for shorter time dimensions. The estimated k-variate homogeneous panel VAR of order p with panel-specific fixed effect can be represented by the following system of linear equations[2]

$$\mathbf{Y}_{it} = \mathbf{A}_1\mathbf{Y}_{it-1} + \mathbf{A}_2\mathbf{Y}_{it-2} + \cdots + \mathbf{A}_p\mathbf{Y}_{it-p} + \mathbf{B}\mathbf{X}_{it} + \mathbf{u}_i + \mathbf{e}_{it} \tag{2}$$

$$i \in \{1, 2, \ldots, N\}, \quad t \in \{1, 2, \ldots, T_i\}$$

where $\mathbf{Y}_{it}$ is a vector of $(1 \times k)$ of dependence variables, $\mathbf{X}_{it}$ is a $(1 \times l)$ vector of endogenous covariates, $\mathbf{u}_i$ and $\mathbf{e}_{it}$ are $(1 \times k)$ vectors of dependent variable-specific panel fixed-effects and idiosyncratic errors, respectively. The $(k \times k)$ matrices $\mathbf{A}_1, \mathbf{A}_2$ and the $(l \times k)$ matrix $\mathbf{B}$ are the parameters to be estimated under the assumption that the innovations are of the characteristics

$$\mathbf{E}\left(\mathbf{e}_{it}\right) = 0, \mathbf{E}\left(\mathbf{e}'_{it}e_{it}\right) = \Sigma, \mathbf{E}\left(\mathbf{e}'_{it}\mathbf{e}_{is}\right) = 0 \forall t > s$$

3.3.1. Are Oil Shocks Inflationary?

To answer the question, I examine the oil price–inflation relationship by estimating the impact on CPI inflation, GDP deflator inflation and PPI inflation of COIP shocks for the panel of 21 countries during the period 1993q1–2008q1. I fit a second-order reduced form pVAR model (i.e., $p = 2$), with the first four lags as instruments, that minimises the

[2] Abrigo and Love [1] for panel VAR modelling and estimation.

moment and model selection criteria (MMSC) of Andrews and Lu [2]. The pVAR model is based on equation 4.2, and incorporates six endogenous variables: exchange rate, CPI inflation, GDP deflator inflation, unit labour cost, GDP growth, and unemployment rate. My identification assumption is similar to Blanchard and Gali [8], where the innovations (shocks) to the oil price are exogenous with respect to the contemporaneous values of other variables in the system. This implies a recursive (or Cholesky) ordering, where COIP is ordered first, meaning it is not contemporaneously affected by shocks to the remaining variables. While my primary focus is on COIP shocks, the inclusion of other macroeconomic variables serves to control for their influence on inflation.

Lütkepohl [27] and Hamilton [20] show that a VAR model is considered stable when all the eigenvalues of its companion matrix have moduli strictly less than one. From the stability check in Figure 4 below, all the eigenvalues lie inside the unit circle. A stability check ensures that the pVAR model is invertible and can be represented as an infinite-order vector moving average (VMA). This invertibility provides a well-defined interpretation for the estimated impulse response functions (IRFs) and forecast error variance decompositions (FEVDs).

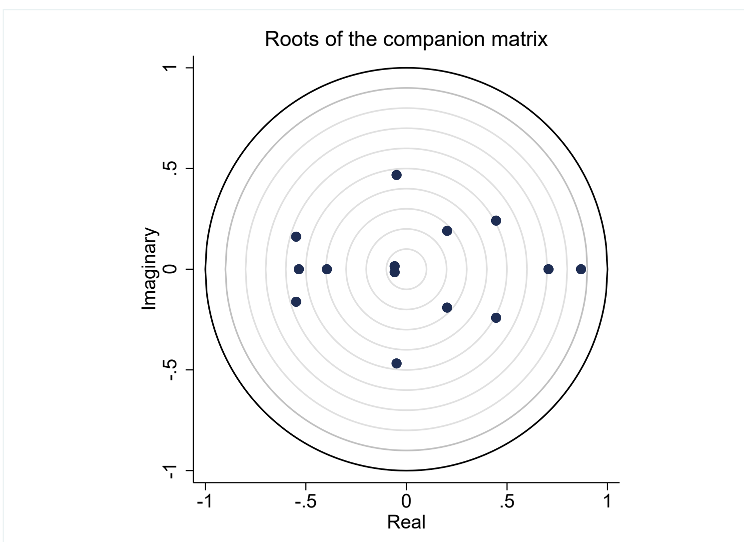


Figure 4: Eigenvalue stability condition of the pVAR model

The figures below display the estimated orthogonalised impulse response functions

(OIRFs) and the cumulative orthogonalised impulse response functions (COIRFs) of the inflation measures to COIP shocks over a 10-quarter horizon. The confidence intervals on both sides of the point estimates are calculated using Monte Carlo simulation.

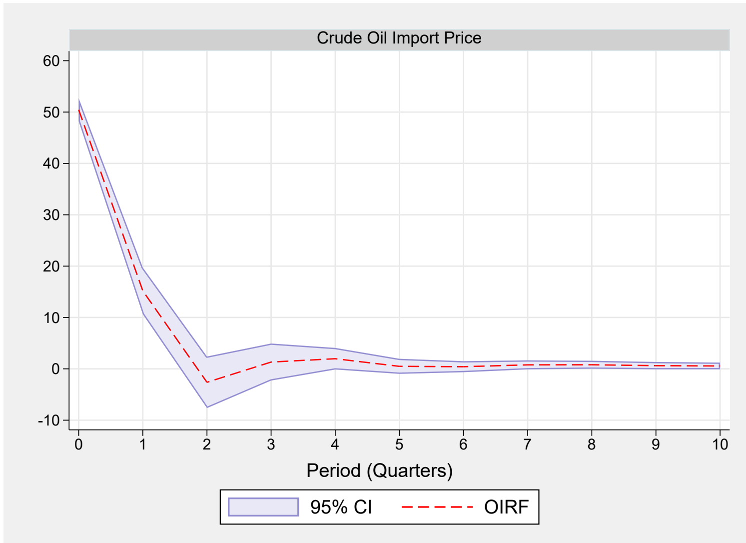
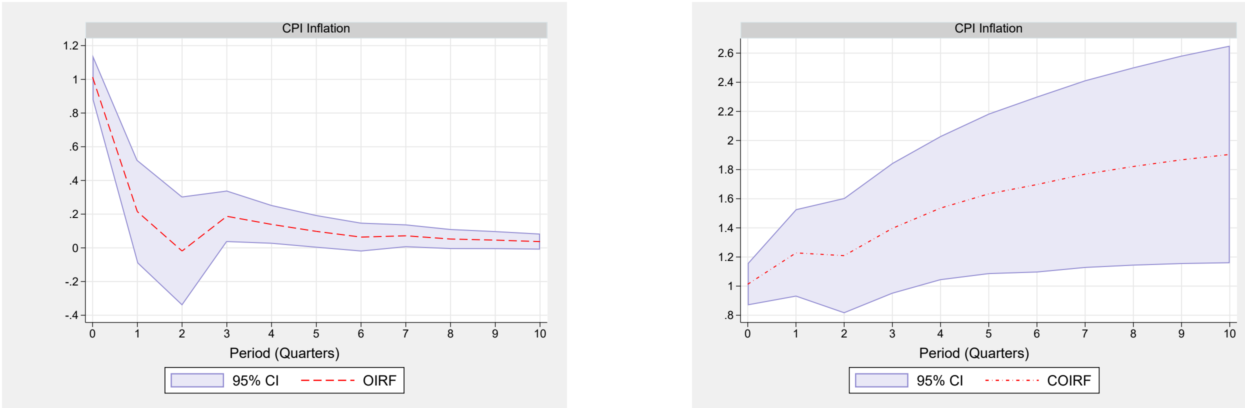


Figure 5: Response of Oil Price to own Shock

Figure 5 shows how COIP reacts sharply and positively to the COIP shocks. This rapid peak suggests that the market adjusts quickly to the new price levels, with most of the shocks' effects being absorbed almost immediately. This indicates the high elasticity of crude oil prices to global oil price shocks, where the adjustments in import prices are swift and concentrated early on. After the initial spike, the response of the COIP begins to decline relatively quickly. By the second quarter, the price starts to revert toward its pre-shock level. By the fifth quarter, the import price has almost fully returned to its baseline. This quick reversion indicates that the COIP shocks do not have a long-lasting impact on crude oil import prices, and the market absorbs any disruptions caused by the shock within a relatively short period.

Figure 6(a) shows an immediate pass-through effect of the COIP shocks on inflation. The IRF indicate that the COIP shocks put upward pressure on consumer prices right from the onset. After peaking in the first quarter, CPI inflation begins to decline steadily over the following quarters. By the fourth quarter, COIP shocks' effect on CPI inflation



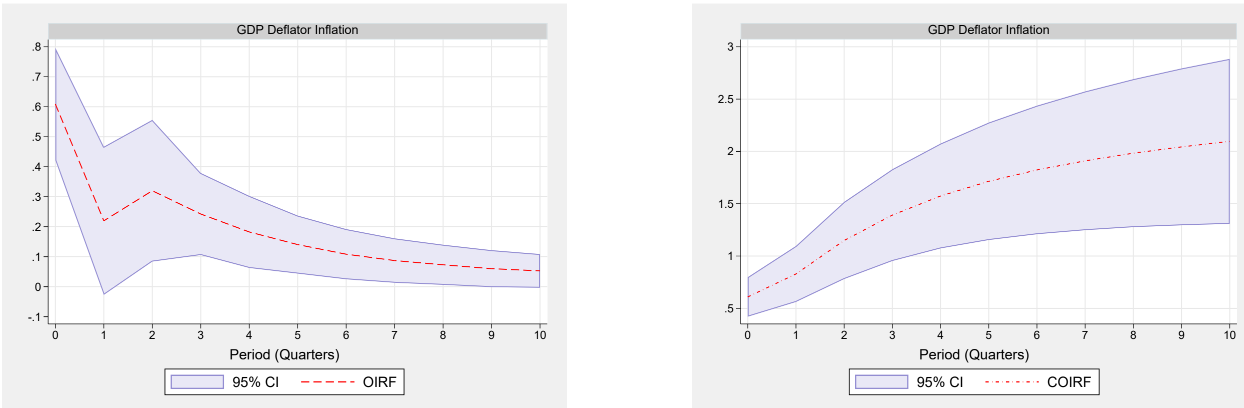
(a) (b)

Figure 6: Responses of CPI Inflation to COIP Shocks

decreased significantly but remained positive. This suggests that while the initial impact of the shock is strong, the inflationary effect gradually diminishes with time. The economy appears to adjust to its baseline inflation rate by the tenth quarter, showing that the COIP shock only temporarily impacts CPI inflation. Figure 6(b) demonstrates that the cumulative effect of COIP shocks on inflation is substantial and persistent. The cumulative impact steadily increases over several quarters, showing no signs of a clear plateau even by the tenth quarter. This sustained growth suggests that the inflationary consequences of an oil price shock are not only immediate but also long-lasting, with cumulative effects that continue to build over an extended period. The result here concurs with the findings of Cunado and Perez de Gracia [13], Blanchard and Gali [8] and Cologni and Manera [12].

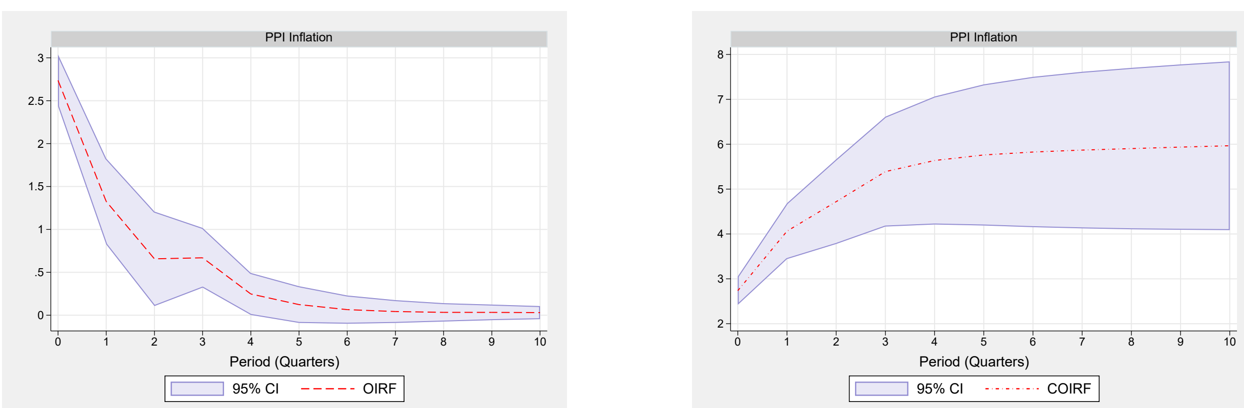
Figure 7(a) shows an initial rise in GDP deflator inflation following COIP shocks, followed by a sharp decline. The response briefly rebounds in the second quarter before gradually decreasing over the subsequent periods. Although the impact of the shock diminishes over time, it does not return to the baseline immediately. By the tenth quarter, the response is still slightly above zero, indicating that the inflationary effects of the shock persist, albeit at a much-reduced level. The cumulative response of GDP deflator inflation to the COIP shocks, shown in Figure 8(b), suggests that COIP shocks have a swift impact on the broader price levels captured by the GDP deflator inflation.

The OIRF in Figure 8(a) shows that COIP shocks trigger an immediate and significant



(a) (b)

Figure 7: Response of GDP Deflator Inflation to COIP Shocks



(a) (b)

Figure 8: Response of PPI Inflation to COIP Shocks

rise in PPI inflation, indicating the initial sensitivity of producer prices to changes in energy costs. However, the response of PPI inflation declines sharply after the initial surge, returning to its baseline by the sixth quarter. This suggests that the impact of COIP shocks on PPI inflation is temporary. Figure 8(b) shows an upward trajectory of PPI inflation following the COIP shocks, underscoring the prolonged inflationary pressures of rising energy costs. This cumulative response reflects the sustained and long-term impact of COIP shocks on producer prices, with the inflationary effects persisting over an extended period.

To examine the role of COIP shocks in fluctuations of the variables of interest (CPI inflation, GDP deflator inflation and PPI inflation), forecast error variance decomposition (FEVD) is then calculated and analysed. The contribution of a variable m to the h-step ahead forecast-error variance of variable n may be calculated as [3]

$$\sum_{i=0}^{h-1} \boldsymbol{\theta}_{mn}^2 = \sum_{i=1}^{h-1} \left(\mathbf{i}_n' \mathbf{P} \Phi_i' \mathbf{i}_m\right)^2 \tag{3}$$

where i_s is the sth column of I_k.

The contributions are often normalised relative to the h-step ahead forecast-error variance of the target variable n

$$\sum_{i=0}^{h-1} \theta_n^2 = \sum_{i=1}^{h-1} \mathbf{i}_n' \Phi_i' \Sigma \Phi_i \mathbf{i}_n \tag{4}$$

Table 1 presents the results of FED for the baseline model at selected horizons (2, 4, 8 and 10). Crude oil prices are largely driven by its own shocks, although this influence decreases slightly over time as other factors, such as exchange rates and CPI inflation, begin to play a larger role. The COIP shocks have a relatively significant impact on CPI inflation, explaining over 11% of its variance even at longer horizons. This suggests that oil price shocks are important drivers of CPI inflation. COIP shocks contribute modestly to the variance in GDP deflator inflation, with an average contribution of about 5.2%. When the model is estimated with PPI inflation, COIP shocks play a significant role in driving PPI inflation, with a contribution of about 27.7% in the second quarter and

[3] See, for example, Abrigo and Love[1] for more details.

around 28.4% by the tenth quarter, indicating that oil price shocks have persistent effects on producer prices.

The FEVD results regarding the contribution of COIP shocks to CPI inflation variability align with findings from several studies in the existing literature. For instance, Jiménez-Rodríguez and Sánchez[23] examine the effects of oil price shocks on GDP and inflation across a panel of OECD countries and find that oil price shocks have a substantial impact on inflation but a more muted effect on GDP. Berument, Ceylan, and Dogan[7] study a panel of Middle Eastern and North African countries and find similar results that oil price shocks significantly contribute to inflation variance. However, their effect on GDP growth is limited.

3.3.2. *Are UMP Shocks Inflationary?*

This section explores the inflationary effects of UMPs extensively implemented from the aftermath of the Global Financial Crisis in 2008 through to 2021. I use a binary approach to UMP. Central banks' websites are used to determine UMP implementation dates. Table 11 provides detailed information pertaining to the dating. Based on this information, I construct binary variables that take a value of one for any quarter during which any form of unconventional monetary policy measure was implemented by the countries in the panel and zero otherwise[4]. To examine the effect UMP shocks on the macroeconomic variables of interest, I embed the created UMP dummy variable in a standard pVAR model[5]. This binary approach is particularly effective in addressing challenges related to structural breaks and discontinuities in variables that are commonly encountered in many studies.

I fit a reduced form second-order pVAR model using the first four lags of the endogenous variables as instruments. The variables are ordered: crude oil import price, UMP, exchange rate, CPI inflation, GDP deflator inflation, GDP growth, and employment rate. The UMP shock is identified using a Cholesky decomposition, which imposes a recursive structure on the pVAR. This ordering means that UMPs respond to oil price shock while acknowledging that the anticipation and speculation surrounding UMPs can significantly and contemporaneously influence inflation outcomes within the same quarter. Specifically, UMP announcements can drastically shift investor and consumer expectations, leading to immediate and significant changes in spending, investment, and saving behaviour. The estimation covers the sample period 2008q1 to 2021q4.

Figure 9 shows that the UMPs shock have an immediate and pronounced impact on itself. Upon impact, the response rises sharply, then falls significantly in the following quarter. After this sharp decline, the response rebounds in the subsequent quarter before beginning a gradual decline. However, the response does not return to the baseline

[4]It is important to note that this analysis does not distinguish between different types of UMPs, such as balance sheet policies (including 'quantitative easing (QE)', forward guidance, and negative policy rates.

[5]Valerie [33] uses a similar approach to examine the impact of government spending shocks on consumption and real wages.

within the 10 quarters observed, suggesting that the effects of the shock are not entirely short-lived and continue to exert influence over time.

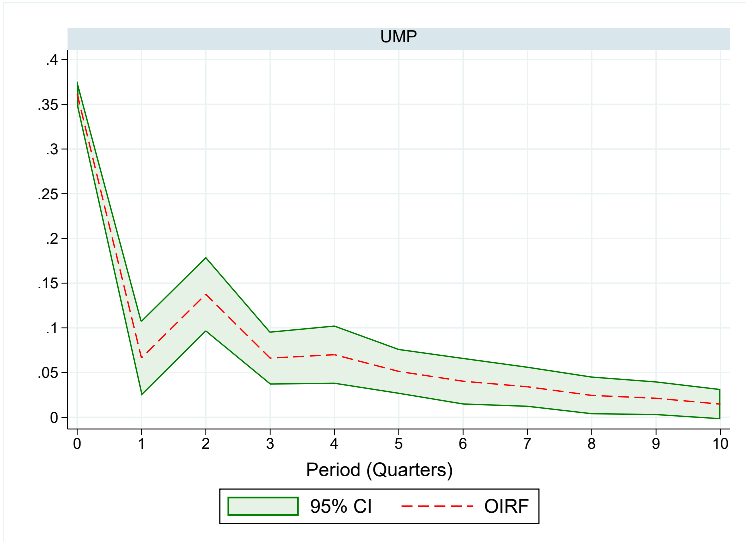
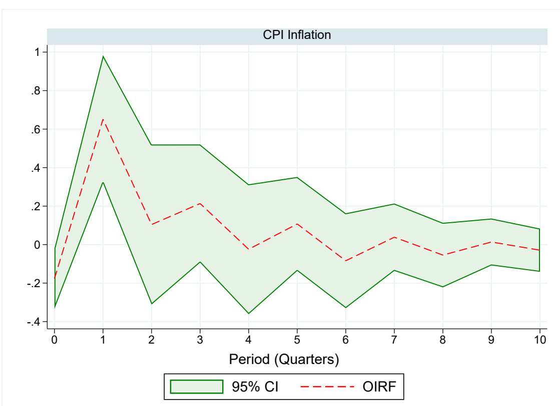
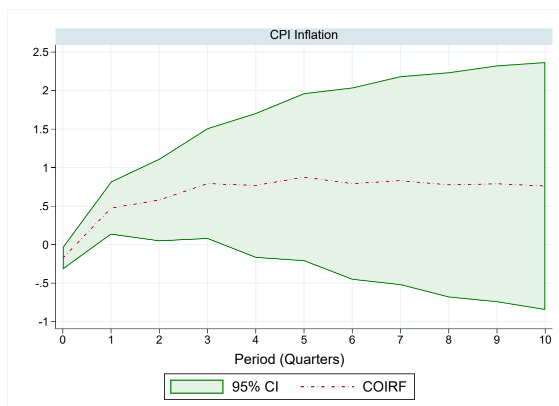


Figure 9: Response of UMP to own Shock



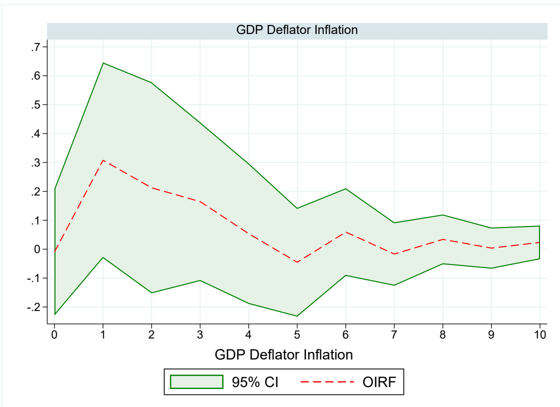
(a)



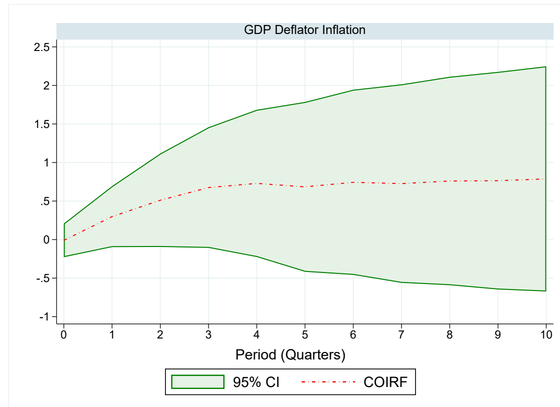
(b)

Figure 10: Responses of CPI Inflation to UMP Shock

Figure 10(a) shows the response of CPI inflation to UMP shocks. Initially, CPI inflation drops slightly but rises sharply in the first quarter. This is followed by a decline in the subsequent quarter. The UMP shocks induce noticeable fluctuations in CPI inflation, reflecting alternating increases and decreases in the response over time. Figure 10(b) depicts the cumulative response of CPI inflation to UMP shocks. Initially, CPI inflation experiences a slight decline after the shock. This is followed by a rise in the first quarter, with the response peaking around the fifth quarter. After reaching this peak, CPI inflation remains stable, indicating that UMP shocks has a permanent effect on inflation over the observed period.



(a)



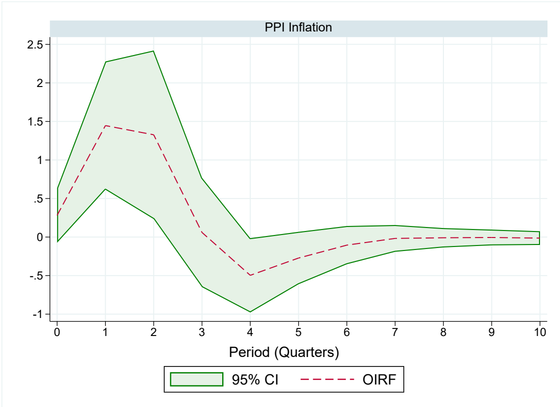
(b)

Figure 11: Responses of GDP Deflator Inflation to UMP Shock

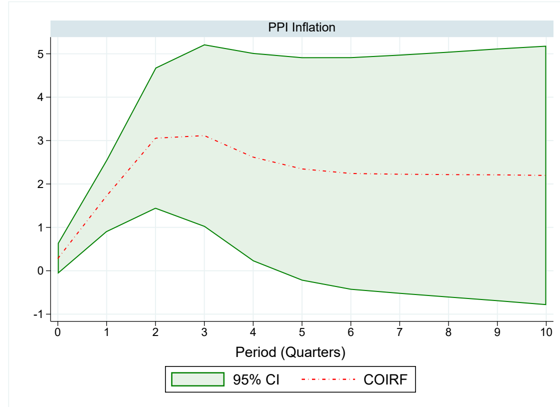
According to Figure 11(a), the initial response of GDP deflator inflation to the UMP shocks is muted. GDP deflator inflation then rises sharply in the first quarter before beginning a downward trend. From the fifth quarter onwards, the response fluctuates slightly. The cumulative response in Figure 11(b) shows a muted initial reaction of GDP deflator inflation to the shock. However, it gradually increases and stabilises by the third quarter, indicating a lasting impact of UMP shocks on GDP deflator inflation.

Figure 12 illustrates the response of PPI inflation to a UMP shock over time. The OIRF shows a non-linear reaction, with PPI inflation rising sharply following the shock. It peaks in the first quarter, then gradually declines, turning negative after the third quarter. By the sixth quarter, the response has returned to its pre-shock level. However, as shown in Figure 12(b), the cumulative effect reveals that UMP shocks have a persistent inflationary impact on producer prices, indicating that the effects accumulate and compound over time.

Table 2 presents the FED results for horizons 2, 4, 8 and 10. The UMP shock contributes more significantly to the variance CPI inflation (around 3%) than GDP deflator inflation, where its effect is much smaller (around 0.5% to 0.8%). The influence of UMP



(a)



(b)

Figure 12: Responses of PPI Inflation to UMP Shock

measures remains modest but persistent over time, with a more substantial and consistent impact on consumer price inflation than on the broader measure of GDP deflator inflation. Moreover, the UMP shock plays a modest but persistent role in explaining the variance of PPI inflation. The contribution starts at around 3.28% in the second quarter and gradually increases to 5.15% by the tenth quarter, indicating that UMP measures continue to influence producer prices over time.

3.3.3. *What Caused Recent Inflation Surge?*

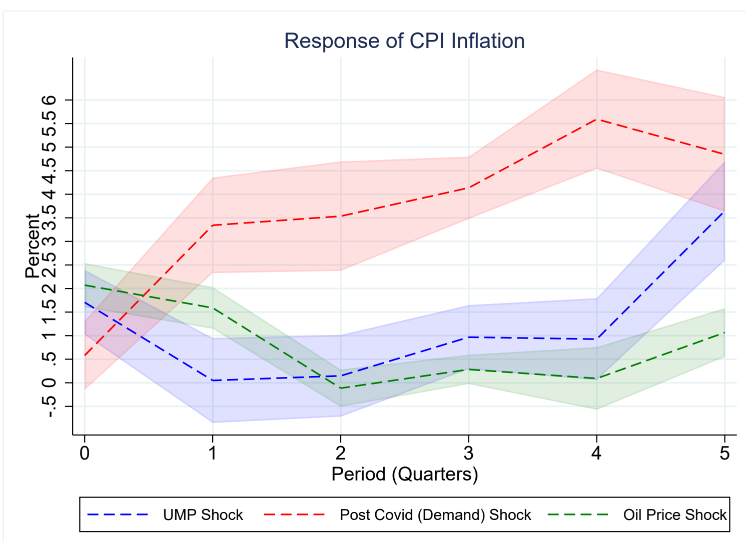
An examination of the inflation graphs in Figures 2 and 3, during oil shock episode five (SE5), shows that from 2020q1 onwards, inflation surged alongside rising crude oil import prices. One may attribute this surge to the post-pandemic demand and the Russia-Ukraine war. However, Tables 10 and 11 in the appendix reveal that this period also saw the widespread implementation of UMP measures by the countries in the panel, which may deemed as a potential cause of this spike. To answer the question posed by the title of this section, one needs to disentangle the inflationary effects of the three shocks - Oil, UMP, and post-COVID demand shocks.

To analyse the contribution of potential shocks to the post-pandemic surge in inflation, I adopt Ugarte-Ruiz's [37] panel version of Jordà's[24] local projection method to estimate impulse-response functions (IRFs). This method is advantageous because it does not impose the dynamic restrictions typically embedded in models like vector autoregressions (VAR) or autoregressive-distributed lag (ARDL) specifications (Stock and Watson[35], Auerbach and Gorodnichenko[3]). The baseline regression model can be specified as follows

$$y_{i,t+h} - y_{i,t-1} = \alpha_i + \beta_h S^j_{i,t} + \gamma_h X_{i,t} + \varepsilon_{i,t+h} \tag{5}$$

$$\text{IRF}(h) = \hat{\beta}_h$$

where $yi, t+h$ denotes the dependent variable of interest (CPI inflation, GDP deflator inflation and PPI Inflation) at horizon h, and t and i index time and countries, respectively. The term α_i captures country-fixed effects to control for unobserved cross-country heterogeneity. $S^j_{i,t}$ denote the impulse variable, with j indicating the specific shock being estimated (e.g., j = 1 for UMP shock, j = 2 for Oil Price shock, and j = 3 for Post-Pandemic Demand shock). $X_{i,t}$ is a vector of controls, which includes the other two shocks when one shock is being estimated and a lagged dependent variable. The h-step ahead error term is denoted by $\varepsilon_{i,t+h}$. Including lagged dependent variables within $X_{i,t}$ helps account for the inflation persistence, as evidenced by the estimation results of equation 4.4. The post-pandemic demand shock is captured using a binary variable, which takes a value of one during the post-COVID period.

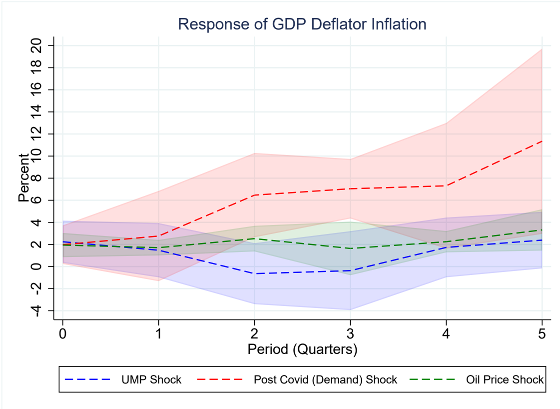


(a)

Figure 13: Post-Covid CPI Inflation Surge

Figure 13 shows the IRFs of CPI inflation to three distinct shocks: the UMP, the post-COVID demand, and the oil price shocks. All three shocks lead to an immediate increase in CPI inflation. However, the intensity and persistence of the effects vary across shocks, reflecting differences in how each shock influences supply, demand, or monetary conditions. The UMP shocks result in a statistically significant and rapid inflationary response. After the initial spike, CPI inflation returns to its baseline in the first quarter, followed by a gradual rise. By the third and fourth quarters, the response stabilises before experiencing a sharp rise in the fourth quarter. This pattern suggests that while the UMP shocks may have a moderate initial impact, it gain considerable momentum over time, particularly after the fourth quarter, leading to a delayed but significant inflationary effect. In contrast, the post-COVID demand shocks cause a less significant immediate effect than the UMP and oil price shocks. The initial rise reflects the strong demand surge as economies reopened, with supply chains struggling to meet the sudden increase in demand. CPI inflation rises sharply by the first quarter, increases gradually, and peaks by the fourth quarter before declining. This pattern reflects the typical post-pandemic surge in demand as consumers re-entered the market. However, the oil price shocks have the most immediate and substantial impact on CPI inflation. This sharp rise is driven by the direct effect of increasing energy costs on the prices of goods and services. After the initial rise, the inflationary response begins to taper off as energy markets and broader supply chains adjust to the shock. Interestingly, CPI inflation starts to rise again gradually from the first quarter onward, highlighting the persistent effect of energy price shocks on inflation.

Figure 14(a) presents the IRFs for GDP deflator inflation following three distinct shocks: the UMP, post-COVID demand, and COIP shocks. While the immediate effects of all three shocks on GDP deflator inflation are similar in magnitude, their longer-term impacts differ significantly. The UMP shock initially causes an increase in GDP deflator inflation. However, the response reveals a non-linear pattern: inflation rises in the first period, turns significantly negative in the second and third periods, and eventually stabilises. The post-COVID demand shock leads to an immediate rise in the deflator inflation and has the most sustained and pronounced impact over time compared to



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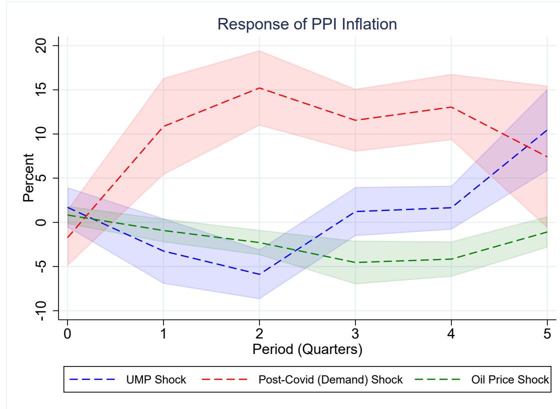


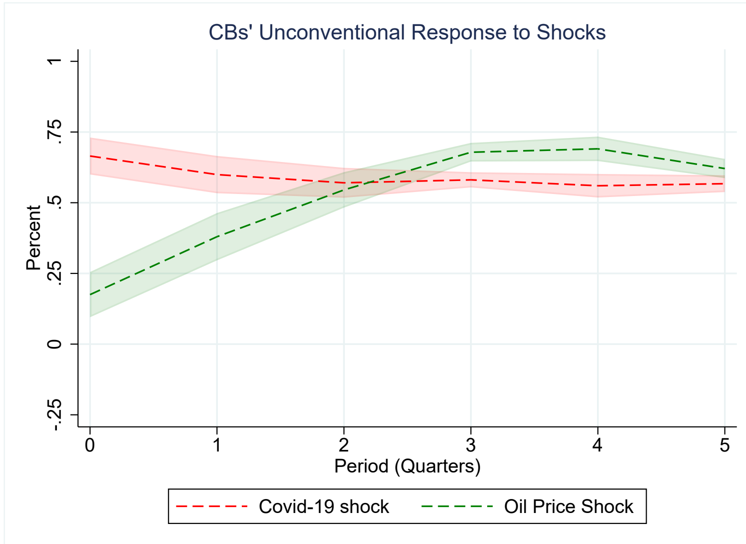
(b)

Figure 14: PPI and GDP Deflator Inflations in the Post-Covid Era

the other two shocks. It remains consistently elevated, staying above the UMP and oil price shocks throughout the observed period. The oil price shock prompts an initial rise in GDP deflator inflation, followed by a slight dip and a gradual rise starting from the second quarter.

The IRFs for PPI inflation in Figure 14(b) depict distinct impacts of the three shocks. The UMP shock displays a non-linear effect on PPI inflation: initially, there is a slight increase in PPI inflation. However, after this initial rise, the response turns negative, likely due to delayed transmission effects or market adjustments leading to deflationary pressures. This negative response is brief; from the second quarter onward, PPI inflation rises again. The post-COVID demand shocks exert the most substantial and persistent upward pressure on PPI inflation over time, driven by heightened demand and supply chain disruptions following the pandemic. In contrast, after causing an immediate rise in PPI inflation, the oil price shock embarks on a downward trend until the third quarter, when it gradually rises. This trajectory reflects the immediate impact of energy cost increases and the gradual adjustment by firms as they adapt to prolonged higher energy prices.

The results so far suggest that the post-pandemic inflation surge is driven by a combination of factors, with significant contributions from UMP measures, post-pandemic demand recovery, and rising oil prices.



(a)

Figure 15: Central Banks Unconventional Responses

Central Banks' (CBs) Response to Shocks. I explore the unconventional responses of central banks in OECD countries to COVID-19 and COIP shocks. Figure 15 illustrates how central banks in OECD countries employed UMP measures in response to COVID-19 and COIP shocks. The comparison between UMP responses to the COVID-19 and COIP shocks reveals that central banks responded more aggressively to the COVID-19 shock. The initial UMP response to the COVID shock was sharp, driven by the need to stimulate economic recovery, support demand, and stabilise markets after the pandemic's disruptions. The response surges immediately upon impact but gradually declines until the second quarter, after which it stabilises. This suggests that while central banks initially scaled back their interventions as the economic recovery gained traction, persistent challenges such as supply chain disruptions and post-pandemic inflation pressures led to a steady level of continued support. The stabilisation in policy indicates that central banks found a balanced stance, maintaining measures to ensure economic stability without further intensifying or reducing interventions.

3.4. Robustness

In addition to using different inflation measures in the initial estimations, I performed several robustness checks to ensure the stability of the results. The figures in Appendix

G present the IRFs and CIRFs, illustrating the impact of crude oil import price (COIP) shocks on CPI inflation, GDP deflator inflation, and PPI inflation. This analysis extends the sample period from 1993q1–2008q1 to 1993q1–2021q4 and incorporates four lags into the pVAR model. The results largely align with the baseline findings in Section 4.3.1, confirming that a COIP shock leads to increases in CPI, GDP deflator, and PPI inflation.

Similarly, the figures in Appendix G show the IRFs and CIRFs for the impact of UMP shocks on the same inflation measures when the lag length is extended to four. The findings are consistent with the baseline results, showing that UMP shocks cause an immediate rise in all three inflation measures. A notable pattern in these inflation measures, when four lags are included, is a sharp initial rise following the shocks, a drop in the first quarter, and a subsequent upward trend, peaking around the fourth and fifth quarters.

Additionally, after estimating the reduced-form pVAR models, I assess whether past values of COIP and UMP can predict the inflation measures considered in this study, controlling for the past values of these variables. The results from the Granger causality test [17] indicate that COIPs and UMPs Granger-cause CPI inflation, GDP deflator inflation, and PPI inflation.

4. Conclusion

This paper investigates the inflationary effects of three major shocks - Crude Oil Import Prices (COIP), Unconventional Monetary Policy (UMP), and post-pandemic demand shocks for a panel of 21 OECD countries, employing panel vector autoregressive (pVAR) and local projection methods. The results provide evidence of inflationary pressures driven by these shocks, albeit with notable differences in the magnitude and persistence of their impacts across different inflation measures.

First, the results reveal that COIP shocks exert substantial upward pressure on inflation, particularly in the early quarters following the shock. This effect is most pronounced in CPI inflation and PPI inflation, highlighting the sensitivity of both consumer and producer prices to changes in energy costs. The forecast error variance decomposition (FEVD) results show that COIP shocks account for a significant share of inflation volatility, particularly for producer prices, where the pass-through from oil prices is stronger.

The study also finds that UMP shocks have meaningful effects on inflation, though their impact is relatively modest compared to COIP shocks. UMP measures tend to raise CPI inflation in the short term, reflecting their role in boosting aggregate demand through lower borrowing costs and enhanced liquidity. However, the FEVD analysis indicates that the contribution of UMP shocks to inflation volatility is smaller than that of COIP shocks, suggesting that while monetary policy can influence inflation, its capacity to drive inflation is more limited when compared to supply-side shocks like changes in oil prices.

Notably, post-pandemic demand shocks emerge as a critical driver of the recent inflation surge, with their effects surpassing those of both COIP and UMP shocks in the post-COVID period. The results suggest that rapid recovery in demand following the COVID-19 pandemic, combined with severe supply chain disruptions, placed significant upward pressure on prices. The results also suggest that this demand-side inflation is not only immediate but also persistent, as evidenced by the sustained rise in CPI inflation over several quarters. Other estimations results show that central banks in OECD economies responded more aggressively to the COVID-19 shock with unconventional monetary policies than crude oil shocks. This finding underscores the complexity of managing inflation in the face of simultaneous demand surges and supply constraints.

This study contributes to the literature by disentangling the relative contributions of COIP, UMP, and post-pandemic demand shocks to inflation within a unified empirical framework. Unlike previous studies focusing on single-country analyses, this paper's panel approach enables a more comprehensive assessment of inflation dynamics across OECD economies, accounting for cross-country heterogeneity in both inflation responses and policy frameworks. The findings have important policy implications, particularly for central banks, which must balance the inflationary effects of supply-side shocks, such as oil prices, with demand-side pressures in the wake of extraordinary economic events like the COVID-19 pandemic.

Future research could investigate the interaction between unconventional monetary policy and other inflationary drivers, such as fiscal stimulus measures and global supply chain developments. Incorporating these factors could provide a more balanced understanding of the inflationary process in OECD economies, particularly as they navigate the challenges of post-pandemic recovery and structural changes in global trade and production.

TABLES AND FIGURES

Table 1: Forecast Error Variance Decomposition - MODEL 1

Response	Horizon (Quarters)	**Crude Oil Import Prices**	**Exchange Rate**	**CPI Inflation**	**GDP Deflator Inflation**	**Unit Labour Cost**	**GDP Growth**	**Unemployment Rate**
Crude Oil Import Prices	2	83.23	0.13	2.05	0.27	0.08	4.30	9.93
	4	71.92	3.84	7.65	0.32	0.14	6.28	9.84
	8	71.20	3.85	7.60	0.43	0.17	6.94	9.81
	10	71.05	3.84	7.56	0.47	0.17	7.08	9.80
Exchange Rate	2	0.44	98.24	0.00	0.01	0.02	0.10	1.18
	4	0.45	89.97	3.71	0.54	0.80	1.72	2.81
	8	0.70	87.10	4.35	1.39	0.82	2.59	3.06
	10	0.74	86.79	4.33	1.47	0.82	2.78	3.06
CPI Inflation	2	12.02	3.95	59.64	2.50	0.22	2.79	18.87
	4	11.17	3.88	54.84	3.70	0.28	4.72	21.42
	8	11.12	3.74	52.99	4.20	0.31	6.08	21.56
	10	11.12	3.73	52.76	4.26	0.31	6.32	21.49
GDP Deflator Inflation	2	4.27	0.31	3.54	80.34	0.03	4.40	7.12
	4	5.19	0.42	3.37	76.90	0.13	6.98	7.17
	8	5.56	0.45	3.48	74.58	0.15	8.92	6.87
	10	5.60	0.44	3.46	74.21	0.15	9.29	6.85
Unit Labour Cost	2	1.61	0.20	3.12	3.55	88.21	0.74	2.57
	4	1.74	0.29	3.19	3.87	86.42	1.25	3.24
	8	1.82	0.29	3.20	4.08	85.45	1.93	3.24
	10	1.84	0.29	3.19	4.11	85.27	2.06	3.24
GDP Growth	2	1.42	0.27	0.57	3.87	19.55	73.25	1.07
	4	2.77	0.37	1.18	5.03	16.77	72.23	1.66
	8	3.47	0.34	1.13	6.25	14.98	71.02	2.80
	10	3.59	0.34	1.11	6.44	14.68	70.84	3.01
Unemployment Rate	2	0.73	0.47	0.36	0.67	0.05	5.14	92.58
	4	0.78	0.54	0.99	0.84	0.22	9.55	87.09
	8	1.15	0.51	1.07	1.17	0.22	13.37	82.51
	10	1.25	0.50	1.06	1.31	0.21	14.16	81.50

Table 2: Forecast Error Variance Decomposition - MODEL 2

Response	Horizon (Quarters)	**Crude Oil Import Prices**	**UMP**	**Exchange Rate**	**CPI Inflation**	**GDP Deflator Inflation**	**GDP Growth**	**Unemployment Rate**
Crude Oil Import Prices	2	88.63	0.41	0.90	0.26	0.18	0.10	9.52
	4	77.84	0.91	0.86	2.32	0.38	2.09	15.60
	8	71.07	1.69	0.87	2.24	0.42	3.37	20.35
	10	70.96	1.82	0.87	2.26	0.42	3.36	20.30
UMP	2	1.49	95.53	0.12	0.06	0.70	0.69	1.41
	4	1.32	91.10	0.68	1.07	0.61	1.32	3.91
	8	1.38	88.56	0.63	2.03	0.58	1.67	5.14
	10	1.46	88.42	0.62	2.14	0.58	1.67	5.11
Exchange Rate	2	6.84	1.09	84.35	1.20	0.06	0.00	6.46
	4	12.51	1.37	73.71	1.42	0.45	0.81	9.73
	8	12.66	1.46	72.41	1.47	0.47	0.98	10.54
	10	12.66	1.47	72.38	1.47	0.47	0.99	10.56
CPI Inflation	2	26.16	3.47	0.65	48.70	1.35	0.89	18.78
	4	25.38	3.03	0.56	43.05	1.24	3.34	23.41
	8	24.88	3.07	0.64	42.87	1.27	3.37	23.89
	10	24.87	3.09	0.64	42.87	1.27	3.37	23.88
GDP Deflator Inflation	2	6.60	0.50	0.98	5.54	72.96	5.68	7.74
	4	8.66	0.79	1.86	5.25	65.53	5.36	12.54
	8	8.99	0.82	1.86	5.53	64.59	5.42	12.79
	10	8.99	0.83	1.86	5.53	64.58	5.42	12.79
GDP Growth	2	11.74	16.21	0.42	2.88	0.75	64.12	3.88
	4	11.41	23.28	0.80	3.51	0.86	56.43	3.72
	8	11.55	23.11	0.87	3.63	0.87	55.97	3.99
	10	11.55	23.11	0.87	3.64	0.87	55.96	3.99
Unemployment Rate	2	14.02	2.82	0.10	1.28	1.69	16.29	63.80
	4	12.46	4.42	0.49	1.38	1.41	14.90	64.94
	8	12.41	6.58	0.50	1.77	1.36	14.45	62.93
	10	12.39	6.80	0.50	1.79	1.36	14.41	62.75

Table 3: Autoregressive Models (AR) of Inflation (1993q1-2008q1)

	(1)	(2)	(3)	(4)
	Fixed Effect	Random Effect	Fixed Effect	Random Effect
	Δ CPI Inflation $_t$	Δ CPI Inflation $_t$	Δ CPI Inflation $_t$	Δ CPI Inflation $_t$
Δ CPI Inflation $_{t-1}$	-0.753^{***}	-0.753^{***}	-0.887^{***}	-0.883^{***}
	(0.019)	(0.019)	(0.030)	(0.030)
Δ CPI Inflation $_{t-2}$			-0.635^{***}	-0.630^{***}
			(0.037)	(0.037)
Δ CPI Inflation $_{t-3}$			-0.557^{***}	-0.552^{***}
			(0.037)	(0.037)
Δ CPI Inflation $_{t-4}$			0.104^{***}	0.107^{***}
			(0.030)	(0.030)
Constant	0.007^{***}	0.007^{***}	0.009^{***}	0.09^{***}
	(0.018)	(0.018)	(0.014)	(0.014)
$\bar{R}^2$	0.573	0.573	0.754	0.754
Number of Observations	1,218	1,218	1,155	1,155

t Standard errors in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 4: Autoregressive Models (AR) of Inflation (1993q1-2021q4)

	(1)	(2)	(3)	(4)
	Fixed Effect	Random Effect	Fixed Effect	Random Effect
	Δ CPI Inflation $_t$	Δ CPI Inflation $_t$	Δ CPI Inflation $_t$	Δ CPI Inflation $_t$
Δ CPI Inflation $_{t-1}$	-0.717^{***}	-0.717^{***}	-0.734^{***}	-0.733^{***}
	(0.014)	(0.014)	(0.021)	(0.021)
Δ CPI Inflation $_{t-2}$			-0.477^{***}	-0.476^{***}
			(0.024)	(0.024)
Δ CPI Inflation $_{t-3}$			-0.490^{***}	-0.489^{***}
			(0.024)	(0.024)
Δ CPI Inflation $_{t-4}$			0.154^{***}	0.155^{***}
			(0.021)	(0.021)
Constant	0.008^{***}	0.008^{***}	0.011^{***}	0.011^{***}
	(0.014)	(0.014)	(0.011)	(0.011)
$\bar{R}^2$	0.513	0.513	0.703	0.704
Number of Observations	2,373	2,373	2,310	2,310

t Standard errors in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 5: Autoregressive Models (AR) of Inflation (2020q1-2021q4)

	(1) Fixed Effect Δ CPI Inflation $_t$	(2) Random Effect Δ CPI Inflation $_t$	(3) Fixed Effect Δ CPI Inflation $_t$	(4) Random Effect Δ CPI Inflation $_t$
Δ CPI Inflation $_{t-1}$	-0.745^{***}	-0.743^{***}	-0.704^{***}	-0.692^{***}
	(0.061)	(0.057)	(0.087)	(0.082)
Δ CPI Inflation $_{t-2}$			-0.122	-0.106
			(0.102)	(0.095)
Δ CPI Inflation $_{t-3}$			-0.161	-0.148
			(0.104)	(0.098)
Δ CPI Inflation $_{t-4}$			0.086	0.093
			(0.086)	(0.080)
Constant	0.914^{***}	0.913^{***}	0.965^{***}	0.954^{***}
	(0.225)	(0.213)	(0.214)	(0.011)
$\bar{R}^2$	0.504	0.504	0.537	0.537
Number of Observations	168	168	168	168

t Standard errors in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Appendix A LIST OF COUNTRIES IN THE PANEL

Australia (AUS)	Austria (AUT)
Belgium (BEL)	Canada (CAN)
Switzerland (CHE)	Germany (DEU)
Denmark (DEN)	Spain (ESP)
Finland (FIN)	France (FRA)
United Kingdom (GBR)	Greece (GRC)
Ireland (IRE)	Italy (ITA)
Japan (JPN)	Netherlands (NLD)
Norway (NOR)	New Zealand (NZL)
Portugal (PRT)	Sweden (SWE)
United States of America (USA)	

Appendix B VARIABLE DESCRIPTIONS AND DATA SOURCES

CPI Inflation - $cpiinf$: Inflation measured by consumer price index (CPI) is defined as the change in the prices of a basket of goods and services that are typically purchased by specific groups of households. Source: OECD.

GDP Deflator Inflation - $gdpdefinf$: This is measured as the percentage change in the GDP Deflator. The GDP Deflator is the ratio of nominal GDP to real GDP. Source: FRED.

PPI - $ppiinf$: This is measured as the percentage change in the producer price indices (PPI). PPI in manufacturing measure the rate of change in prices of products sold as they leave the producer. PPIs provide measures of average movements of prices received by the producers of various commodities. Source: OECD.

Unemployment Rate - $unemp$: This is measured in numbers of unemployed people as a percentage of the labour force and it is seasonally adjusted. Source: OECD.

Unit Labour Cost - ulc: Unit labour costs measure the average cost of labour per unit of output, calculated as the ratio of total labour costs to real output. Source: OECD.

Exchange Rate - *er* : Exchange rates are defined as the price of one countrys' currency in relation to another country's currency. This indicator is measured in terms of national currency per US dollar. Source: OECD.

Crude Oil Import Prices - *coip* : The indicator is measured in USD per barrel of oil. The real price was calculated using the deflator for GDP at market prices and rebased with reference year 1970 = 100. Source: OECD. I used the proportional Denton method to interpolate OECD yearly data.

Real GDP - *rgdpgindx* : Gross domestic product (GDP) is the standard measure of the value added created through the production of goods and services in a country during a certain period. This indicator is based on real GDP (also called GDP at constant prices or GDP in volume). Source: OECD.

Unconventional Monetary Policy - *dumUMP* : Measured with a binary approach. Dates were used to construct dummy variables, where unity indicates the country engaged in an unconventional monetary policy (UMP) during the period under consideration, and zero otherwise. Source: Individual Country's Central Bank Websites and author's determination.

Appendix C SUMMARY STATISTICS

Table 6: Pre-GFC Period (1993q1 - 2008q1)

Variable	Observations	Mean	Standard Deviation	Minimum	Maximum
CPI inflation	1260	2.173	2.530	−6.742	18.059
GDP Deflator inflation	1196	2.237	3.204	−13.829	20.916
PPI inflation	954	2.183	4.909	−25.866	20.905
Crude Oil Import Prices	1260	11.302	47.559	−121.321	132.939
Unemployment Rate	1199	7.538	3.222	2.300	22.233
GDP Growth	1200	2.854	3.243	−10.706	24.529
Exchange Rate	1176	0.061	2.095	−10.928	13.347
Unit Labour Cost	1184	1.768	4.805	−29.401	41.024

Table 7: Full Sample Period (1993q1-2021q4)

Variable	Observations	Mean	Standard Deviation	Minimum	Maximum
CPI inflation	2415	1.809	2.696	−12.288	18.059
GDP Deflator inflation	2351	1.860	3.660	−27.886	53.380
PPI inflation	2050	1.797	6.519	−44.483	27.720
Crude Oil Import Prices	2415	5.156	60.932	−304.363	147.090
Unemployment Rate	2347	7.758	4.015	2.300	27.800
GDP Growth	2355	1.998	7.463	−94.245	76.330
Exchange Rate	2331	−0.038	2.176	−21.414	19.300
Unit Labour Cost	2336	1.537	6.392	−81.793	72.402

Table 8: Post-Covid Period: 2020q1-2021q4

Variable	Observations	Mean	Standard Deviation	Minimum	Maximum
CPI inflation	168	3.957	2.882	−3.307	14.276
GDP Deflator inflation	168	4.413	7.367	−14.621	53.380
PPI inflation	160	12.082	6.704	−7.298	27.720
Crude Oil Import Prices	168	53.361	38.436	−10.112	132.867
Unemployment Rate	168	6.663	3.211	2.733	16.400
GDP Growth	168	5.445	7.282	−16.555	34.938
Exchange Rate	168	−0.172	1.565	−4.321	4.844
Unit Labour Cost	165	1.187	9.798	−53.947	28.022

Appendix D CORRELATION

Table 9: Piarwise Correlations among Growth Rates of the Variables

	CPI inflation	Unemployment	Unit Labour Cost	PPI Inflation	Exchange Rate	Crude Oil Import Prices	Real GDP Growth	GDP Deflator Inflation	
CPI inflation	1.000								
Unemployment	−0.113*	1.000							
Unit Labour Cost	0.073	−0.008	1.000						
PPI Inflation	0.376*	−0.197*	−0.054	−0.016	1.000				
Exchange Rate	0.174*	0.010	0.040	−0.012	−0.179*	1.000			
Crude Oil Import Prices	0.318*	−0.138*	−0.151*	−0.077*	0.544*	0.117*	1.000		
Real GDP Growth	0.066	−0.235*	−0.650*	−0.029	0.208*	−0.015*	0.322*	1.000	
GDP Deflator Inflation	0.238*	−0.140*	0.270*	0.006	0.262*	0.059	0.083*	−0.112*	1.000

The star indicates a 5% significance level according to Bonferroni adjusted correlations.

Appendix E PRELIMINARY TEST

Table 10: Panel Unit Root Test (PURT) in Presence of Cross Section Dependence

Variable	t-bar	Z[t-bar]	P-value
log(CPI)	-1.250	2.718	0.997
log(GDP Deflator)		0.424	0.664
log(PPI)	-3.083	-6.510	0.000
Unemployment		-0.801	0.211
log(Unit Labour Cost)		0.788	0.785
log(Exchange Rate)	-2.087	-1.497	0.067
log(Crude Oil Import Prices)	-3.083	-6.510	0.000
log(Real GDP)		1.089	0.862
Δ log(CPI)	-5.383	-18.095	0.000
Δ log(GDP Deflator)		-21.786	0.000
Δ log(PPI)		-16.561	0.000
Δ Unemployment		-13.156	0.000
Δ log(Unit Labour Cost)		-18.446	0.000
Δ log(Real Effective Exchange Rate)	-5.393	-18.144	0.000
Δ log(Crude Oil Import Prices)	-6.162	-22.015	0.000
Δ log(Real GDP)		-17.961	0.000

Appendix F UNCONVENTIONAL MONETARY POLICY (UMP) DATING

Table 11: Unconventional Monetary Policy Measures and Dates of Adoption

Countries/Groups	Date	UMP Type/Measure
Euroarea (EMU)	2008Q2-2008Q4	3-month and 6-month LTRO
	2009Q2-2010Q2	1-year LTRO and CBPP1
	2010Q2-2012Q3	SMP
	2011Q4-2012Q4	Speech by Draghi (26 July 2012), 3-year LTRO, CBPP2, OMT, Open-ended guidance
	2014Q2-2014Q4	Negative interest rates and TLTROs, APP, ABSPP, CBPP3
	2015Q1	PSPP added to APP
	2016Q1-2018Q4	TLTRO II and CSPP added to PSPP
	2019Q4	CSPP restarted
	2020Q1-2022Q2	APP restarted
United Kingdom	2009Q1-2010Q1	QE1
	2011Q4-2012Q2	QE2
	2012Q3-2012Q4	QE3
	2013Q3	Forward Guidance
	2014Q1	Forward Guidance
	2016Q3	QE4
	2020Q1	QE5
United States	2008Q4-2010Q1	QE1 (MBS and direct obligations of GSEs)
	2010Q4-2011Q2	QE2 (QE1 Rollover and QE2 hinted)
	2012Q3-2014Q4	QE3
	2017Q2-2017Q4	Forward Guidance (Balance sheet (BS) normalisation)
	2018Q4	Forward Guidance (BS will run on autopilot)
	2019Q1, 2019Q3	Forward guidance
	2019Q4	Forward guidance
New Zealand	2020Q1	Asset Purchases

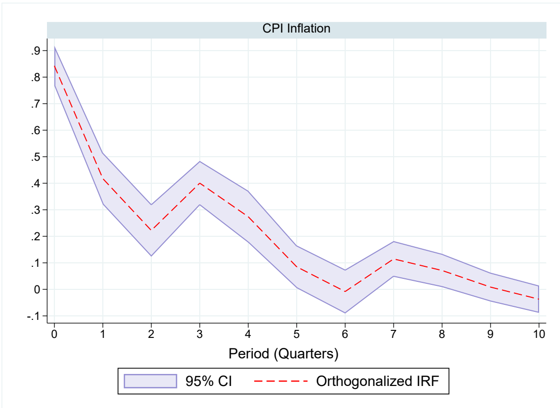
Note: LTRO = Longer-Term Refinancing Operations, CBPP = Covered Bond Purchase Programme, SMP = Securities Markets Purchase Programme, OMT = Outright Monetary Transactions, APP = Asset Purchase Programme, ABSPP = Asset-Backed Securities Purchase Programme, GSEs = Government Sponsored Enterprises, MBS = Mortgage-backed Securities, TLTROs = Targeted Longer-Term Refinancing Operations, CSPP = Corporate Sector Purchase Program.

Table 12: Unconventional Monetary Policy Measures and Dates of Adoption (Continuation)

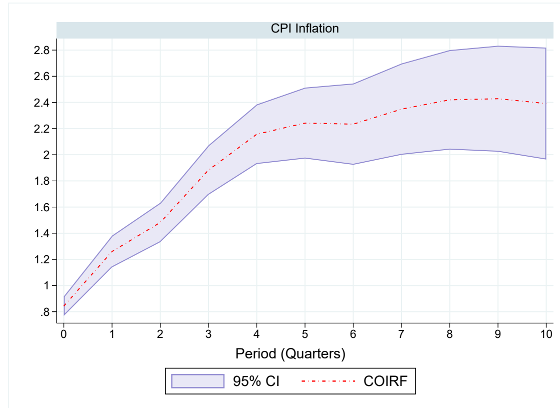
Countries/Groups	Date	UMP Type/Measure
Japan	2001Q1-2006Q1	BOJ raised its current account target
	2010Q4	Forward Guidance and Asset Purchases
	2012Q1	Forward Guidance and Asset Purchases
	2013Q1	Forward Guidance and Asset Purchases
	2013Q2	QQE1
	2014Q4	QQE2
	2016Q1-2016Q3	Negative Interest Rates, Yield Curve Control
	2018Q3	Forward Guidance
	2020Q1	Asset Purchases and ETFs
Canada	2008Q3-2008Q4	Term Purchase and Resale Agreement
	2009Q2	Forward Guidance (Conditional commitment)
	2020Q1	Asset Purchases
Sweden	2015Q1	Negative Interest Rate
Denmark	2008Q3-2011Q1	Excess-capital temporary credit facility (solvenvy scheme)
	2012Q3	Negative Interest Rate
Switzerland	2009Q3	Foreign exchange interventions/Bond purchases (LSAP1)
	2011Q3	Negative Interest Rate
Norway	2020Q1	Asset purchases

Note: QQE = Quantitative and Qualitative Easing, LSAP = Large-Scale Asset Purchase.

Appendix G Robustness

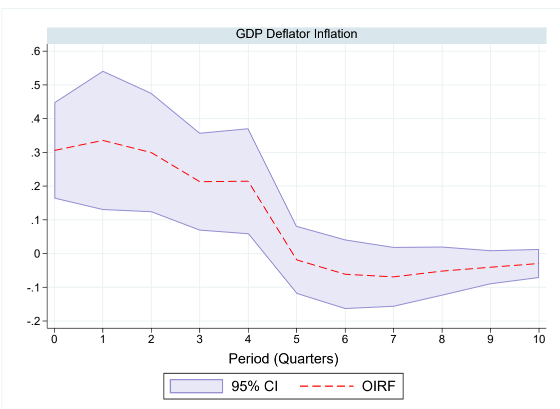


(a)

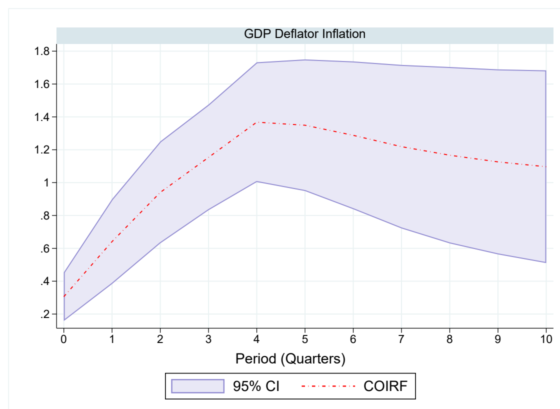


(b)

Figure 16: Responses of CPI Inflation to Oil Price Shock

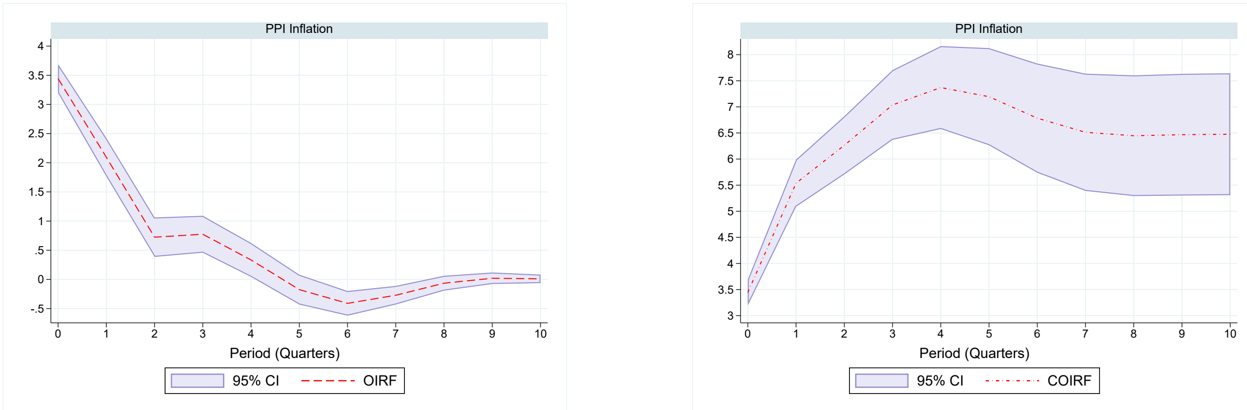


(a)



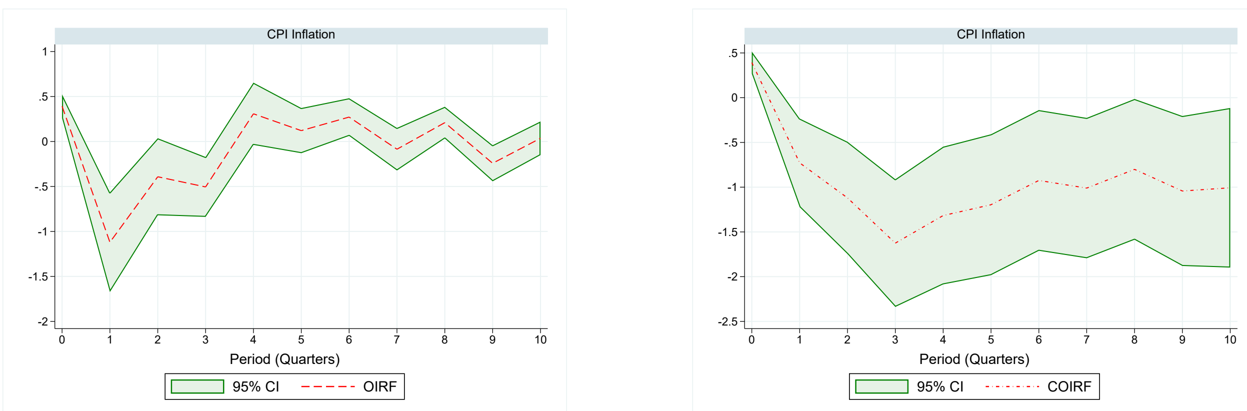
(b)

Figure 17: Responses of GDP Deflator Inflation to Oil Price Shock



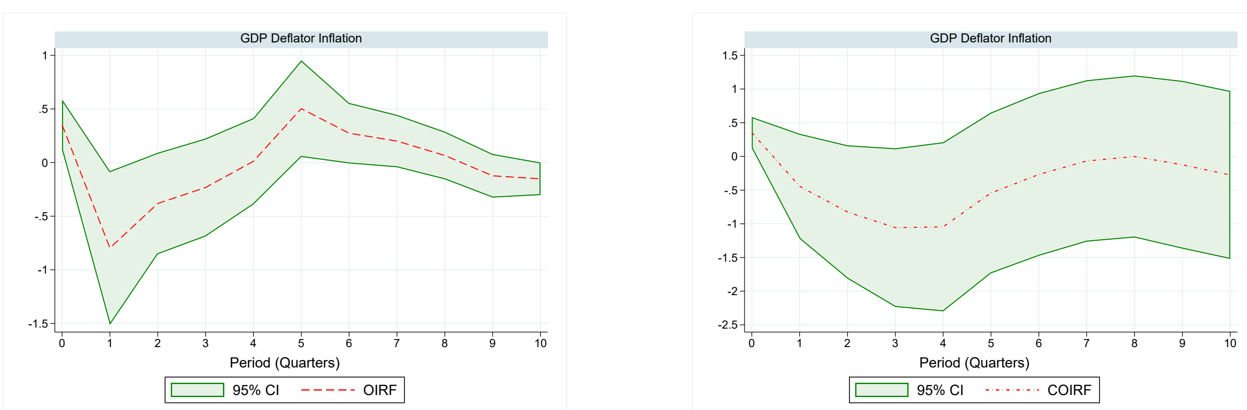
(a) (b)

Figure 18: Responses of PPI Inflation to Oil Price Shock



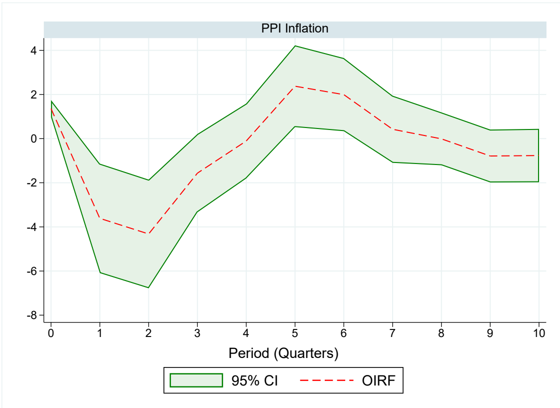
(a) (b)

Figure 19: Responses of CPI Inflation to UMP Shock

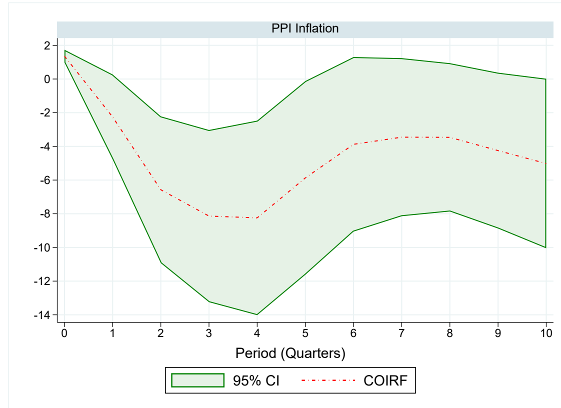


(a) (b)

Figure 20: Responses of GDP Deflator Inflation to UMP Shock



(a)



(b)

Figure 21: Responses of PPI Inflation to UMP Shock

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