The Transmission Mechanism of the European Central Bank
Unconventional Monetary Policy: A Global Assessment

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Abstract
During, and after the 2008 financial crisis, most monetary authorities in advanced economies officially adopted Unconventional Monetary Policy (UMP); that involves the mass purchase of treasury and mortgage-backed securities. This policy is intended to serve the purpose of mitigating the effects of crises, especially when the interest rate has reached the so-called Zero Lower Bound (ZLB). This study attempts to examine the transmission mechanism/channels of the European Central Bank (ECB) UMP, including both domestic and international spillover effects by employing a Global Vector Autoregressive (GVAR) model. Generally, the ECB UMP effects show encouraging and positive responses from economies within the Euro Area region while international spillover effects are mixed, probably due to the diverse nature of the monetary policy regimes deployed in the different countries, especially the emerging economies.

Keywords: unconventional monetary policy, global vector autoregressive model

1. Introduction
UMP is a form of monetary policy used when the conventional approach of adjusting the central bank rate is not an option anymore, particularly when the central bank rate has reached the so-called Zero Lower Bound or a negative value or a point at which it loses its policy effectiveness. The central bank essentially buys mortgage-backed securities or treasury securities and other financial assets in order to inject liquidity into the economy. In addition to purchases of mortgage-backed securities and other securities, the central bank also avails credit, especially to the private sector, with the objective of stimulating economic activity and reducing medium and long-term interest rates. It can also be argued that this has the effect of reducing the spread between the long and short-term interest rates. In general, UMP directly targets the cost and availability of external finance to banks, households, and non-financial institutions. This approach further ensures that inflation does not fall below the central bank’s target rate and may be used to help economies recover during recessions and crises.

This study applied the Global Vector Autoregressive model to monthly macroeconomic data of 15 countries/areas over the period 2007-2019 with the aim of investigating the domestic and international/spillover effects of the ECB UMP. Given the diversity of the countries chosen, the results were just as diverse. The equity indices showed the highest degree of responsiveness to UMP at domestic and international level. The cross-border effects are generally greater than the domestic effects for all chosen variables.

It is argued that this monetary policy approach was first deployed by Japan in the late 1980s in response to the burst of their property and stock markets. Most of the central banks in the advanced economies only adopted it after the 2007/2008 financial crisis. Emerging markets have long argued that this form of intervention is too costly and cannot be supported by their economies, and are therefore, a reserve for the developed nations. However, some of them seem to be picking interest in this form of monetary policy action. UMP is essentially an indicator that the central bank is willing to do whatever it takes to help an economy recover.

The four major central banks; ECB, US Federal Reserve (US Fed), Bank of England (BOE) and Bank of Japan (BOJ), have been the main users of Quantitative Easing (QE). This has seen the assets of these banks increase drastically since the 2007/2008 crisis, therefore, the asset growth is used as the UMP variable in this study. Ever since the global financial crisis and sovereign debt crisis, which saw a number of banks and governments experience liquidity squeezes, the ECB has played a pivotal role in stimulating and maintaining financial

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stability, acting as a Lender of Last Resort (LOLR). The ECB injected liquidity into the economy using three main types of operations; Main Refinancing Operations (MROs), Long-Term Refinancing Operations (LTROs) and Very Long-Term Refinancing Operations (VLTROs). In addition to this form of UMP, the ECB also purchased several government bonds, especially in stressed markets. This was done under the Securities Markets Programme (SMP). Several central banks have also employed a more drastic unconventional approach by lowering the interest rates to below zero as a last resort.

Much as UMP seems an easy process to get into, especially for centrals banks with sufficient financial capacity, an effective exit strategy needs to be designed once the economy rebounds and the central bank has achieved its inflation target. Smagi (2009) argues that this may not be an easy task, especially in two aspects. First, devising the right sequence of phasing out the conventional and UMP accommodation, and second, deciding on the speed at which the unconventional accommodation is removed. This has proved to be a problem for several central banks.

QE is the dominant form of UMP and is the focus of this study. However, it should be noted that there are also other forms of UMP like helicopter money and nominal GDP targeting. These forms have also been advocated for, especially in advanced economies.

Figure 2 shows how significantly the assets of the four major central banks have increased ever since the 2007/2008 financial crisis. This is a clear indication of more deployment of UMP after the central bank interest rates got to zero or near the ZLB, as shown in Figure 1. At this point, the unconventional approach may be the only option since the interest rate may not be effective in stimulating activity as earlier discussed.

![Figure 1. Central bank interest rates](image1.png)

![Figure 2. Central bank assets index](image2.png)

2. Literature Review

2.1 Conventional Monetary Policy and the Economy

Monetary policy shocks resulting from a change in money supply and adjustment of the interest rate may have ripple effects on other economic variables, ranging from, stock prices, inflation, exchange rate, GDP and others. As stated by Kim (1999), monetary policy shocks have significant short-run real effects. There is a vast and detailed literature on conventional monetary policy effects and adjustment mechanisms, some of which are discussed in this section.
Frankel and Hardouvelis (1985) develop a theoretical model of overshooting (Note 1) in commodity markets to study the effect of expected money growth (surprises) on commodities. Money surprise effects show up immediately in many commodity prices while other commodity prices are sticky. They find that, generally, the effect of money surprises is statistically significant and of mixed sign for most of the commodities, though at varying levels.

In a comprehensive contribution by Bernanke et al. (1997), the scholars add structure (Note 2) to a VAR system, and find that an important part of the effect of oil price shocks on the economy results from the tightening of monetary policy. Specifically, Bernanke et al. (2004) show that a 10% oil price increase is associated with a 150-basis point increase in the US Federal Funds rate. Anzuini et al. (2012) show that an expansionary monetary policy shock drives up commodity prices, however, the effect of US expansionary monetary policy does not appear to be overwhelmingly large. Furthermore, their findings suggest that the extraordinary monetary policy easing deployed to contrast the real effects of the financial crisis is likely to push commodity prices up, albeit to a small extent. Sousa and Zaghini (2007), in a study that covered the G7 (Note 3) countries, using a Structural VAR and controlling for interactions between variables, find that the effect of monetary policy liquidity shocks may be transmitted to commodity prices at different speeds, with some countries responding faster than others and adjusting back to equilibrium at different rates. There is indeed a time-lag necessary for these shocks to impact on price dynamics.

Eichenbaum and Evans (1995) attempt to isolate measures of exogenous shocks to monetary policy, discussing their results based on the Romer and Romer (1989) index measure of monetary policy contractions, using five (Note 4) nominal spot exchange rates, find that a contractionary shock to US monetary policy leads to; (i) a persistent and significant appreciation in the US nominal and real exchange rates. This effect is not contemporaneous, but appreciations continue for a considerable period of time and (ii) persistent and significant deviations from uncovered interest rate parity in favour of US investments.

Faust et al. (2003), using high frequency data and a VAR system, measure the impact of the surprise component FOMC (Federal Open Market Committee) meetings that were not anticipated by the markets to represent monetary policy shocks. Findings reveal that the peak timing of the exchange rate effect is quite imprecisely estimated, as in, it may come nearly immediately, a phenomenon defined as overshooting or come several years later. It is argued that, generally, the exchange rates might Granger cause money supply because monetary policy makers react to the exchange rate in setting money supply. This is supported by a good number of scholars, including Engel and West (2005). However, the reverse may also be true.

Uhlig (2005), while imposing sign restrictions on the impulse responses of prices, unborrowed reserves and federal funds rate, in response to a monetary policy shock, finds that contractionary monetary policy shocks have an ambiguous effect on real GDP, specifically moving it up and down by up to ±0.2%, with a probability of 2/3. In addition, the GDP deflator tends to fall slowly, indicating a possibility of price stickiness. The commodity price index responds quicker, falling much faster. Bernanke et al. (1997) state that identified shocks to monetary policy explain relatively little of the overall variation in output, less than 20%.

Boivin and Giannoni (2006), using a recursive VAR over the pre- and post-1980s in the US, show that unexpected exogenous changes in the federal funds rate have been followed by a smaller response of output and inflation since the beginning of the 1980s. They further add that this phenomenon is mainly attributed to a shift in monetary policy over the years rather than the behaviour of the private sector.

Rigobon and Sack (2004), defining a heteroscedasticity-based estimator of the response of asset prices to monetary policy, estimate the response of asset prices and market interest rates to monetary policy from the heteroscedasticity of policy shocks on particular dates, including days of FOMC meetings. Their results show that a 25-basis point increase in the three-month interest rate results in a 1.9% decline in the S&P 500 index and a 2.5% decline in the NASDAQ index.

Goodhart and Hofmann (2001) use VAR impulse responses and derive Financial Condition Indicators (Note 5) for the G7 countries to determine the monetary policy stance. Their findings reveal that impulse responses exhibit rather mixed signals for the sampled countries. They further add that monetary policy should also respond to property and equity price movements in order to offset their effect on the output gap.

Zheng (2013) analyses the impact and effectiveness of US conventional monetary policy using a Threshold Vector Autoregressive (TVAR) model to capture switches between the low and high financial stress regimes. Findings that the output response to monetary policy shocks is larger during periods of high financial stress than in periods of low financial stress. In addition, expansionary monetary policy continues to be effective during periods of high financial stress, when the interest rate is at the ZLB, and expansionary monetary policy moves...
the US economy from high to low financial stress by keeping interest rates and credit spreads low.

2.2 Unconventional Monetary Policy

Gambacorta et al. (2014), applying a panel VAR using monthly data of eight (Note 6) advanced economies over the period covering the onset of the global financial crisis, find that the exogenous increase in central bank balance sheets at the ZLB leads to a temporary rise in economic activity and consumer prices. Of great importance, is their conclusion that the results are similar to those expressed in literature to the effects of the more familiar conventional monetary policy.

Schenkelberg and Watzka (2013), using a SVAR approach on Japanese data, report that QE shocks lead to a significant but temporary/short-term rise in output by about 0.5% and the effect on inflation is not significantly different from zero, thus, it did not lead to an increase in inflation. They further stated that this result is of most high importance to advanced economies, where monetary policy is constrained by the ZLB.

Peersman (2011), while comparing the effects of conventional and UMP in the Euro Area using a structural VAR model, finds that the two policies have similar macroeconomic consequences. Both shocks have a hump-shaped impact on economic activity and result in permanent higher level of consumer prices. In addition, the effects of balance sheet policies on output and inflation are more sluggish.

Chen et al. (2016) examine domestic and cross-border effects of the US Federal Fund’s UMP using an estimated GVECM, and find that monetary policy and exchange rate responses have been diverse in emerging economies; responses in output, inflation and credit channels have been different too. In addition, they find that US UMP has greater impact on many emerging market economies than on the US economy itself. A phenomenon referred to as overheating, that is, a rapid and very big growth in economic activity and production. This was evident in Brazil and China.

Miyajima et al. (2014), while studying the spillover effects of US UMP to Asia, using a panel VAR, focussing on the long-term interest rate, find that the spillover manifests itself mainly through low domestic bond yields and rapid growth of domestic bank credit. This finding is consistent with Obstfeld (2015), who concludes that one of the transmission channels of international monetary policy long-term rates.

Rogers et al. (2018) use a VAR to study the spillover effects of UMP measures of four (Note 7) major central banks at the zero lower bound. They report that US monetary policy easing shocks lower domestic and foreign bond risk premia, leading to dollar depreciation and lower foreign exchange risk premia. The UK and Japan monetary policy shocks significantly lower US ten-year yields for a few quarters.

Gertler and Karadi (2011) develop a quantitative monetary DSGE model with financial intermediaries that face endogenously determined balance sheet constraints. Their findings show that the welfare benefits of UMP may be substantial if the relative efficiency costs of central bank intermediation are modest. They further add that, in a financial crisis, there are benefits of credit policy even if the nominal interest rate has reached the ZLB.

Cahn et al. (2017) examine whether central bank liquidity injection can induce banks to lend to firms in times of aggregate stress using a difference-in-differences approach, examining the causal effects of a positive credit supply shock to some firms relative to closely comparable non-treated firms. They show how banks changed their lending to these kinds of firms during the crisis. Their results reveal that the ECB’s long-term Refinancing Operations (LTROs) caused an increase in bank lending to firms by around 10%.

Santos and Winton (2008) argue that during crises, banks have an information advantage over potential borrowers and are bound to charge a higher interest rate than is justified by borrower default risk alone. They test their hypothesis by comparing pricing of bank loans for bank-dependent borrowers to that of borrowers with access to public debt markets in good and bad times. Findings revealed that, indeed, banks charge higher rates to customers with limited outside funding options by a magnitude that is significant. This acts as a deterrent to the primary objective of UMP in times of need.

Regarding unemployment, it is argued that UMP may indeed have little or only a sluggish effect. This is supported by the fact that unemployment rates in most western nations have remained persistently high, even after the implementation of QE measures after the 2008 financial crisis. This is further supported by Farmer (2012).

Rosa (2014), while studying the effect of monetary policy on the level, the volatility and trading volumes of energy futures using an event study with intraday data shows that the unanticipated Large Scale Asset Purchases (LSAPs) by the US Federal Reserve have a negative effect on oil prices. On average, a hypothetical unanticipated 100-basis point hike in the Federal Reserve rate target is associated with a 3% decrease in WTI
(West Texas Intermediate) oil prices. In addition, in a narrow window around the FOMC meeting, the cumulative financial market impact of the Federal Reserve LSAP on crude oil is equivalent to an unanticipated cut in the Federal Reserve target rate of 155 basis points. Furthermore, the channel through which monetary policy affects oil prices is mostly through the value of the US Dollar.

Kucharčuková et al. (2016) while applying a block-restricted VAR model, study the macroeconomic impact of ECB UMP on Euro Area economies and six non-EMU (Economic and Monetary Union) countries. The standard monetary VAR findings revealed that the transmission of UMP in the Euro Area is quite different than under the conventional approach; prices seem to react faster while output generally remains muted. The block-restricted VAR shows that Euro Area monetary policy does in fact spillover to the economies of non-EMU countries; exchange rates respond fast, the output effect is found for a few countries and inflation is generally unaffected.

Bluwstein and Canova (2016) examine the effect of conventional and unconventional ECB monetary policy on nine non-Euro European countries using a novel Bayesian mixed-frequency structural VAR and find that the unconventional disturbances generate a number of fluctuations; the credit channel of transmission does not play a big part, however, international spillovers are larger in countries with more advanced financial systems and a larger share of domestic banks. Important to note was that, while UMP disturbances induce significant inflation, conventional monetary policy disturbances primarily affect output. This means that a combination of conventional and unconventional measures may help to better control output and inflation dynamics.

Meinusch and Tillmann (2016), while examining the effect of US UMP using a Qual VAR linking standard business cycle dynamics with binary information on QE announcement days, show that QE has significant effects on interest rates, real economic activity, stock prices and market uncertainty. Furthermore, QE is found to be more effective in influencing real activity than conventional monetary policy.

Bowman et al. (2015) use an event study approach to analyse the effect of US UMP on sovereign yields, foreign exchange rates and stock prices in emerging markets. Their findings reveal that EME (Emerging Market Economies) asset prices, especially sovereign yields in local currency, experienced large fluctuations around UMP announcements by the US Federal Reserve. Furthermore, US monetary policy shocks that lower US sovereign yields also lower sovereign yields in most EMEs. In some cases, the effect on EME sovereign yields is even larger than the effect on US sovereign yields and is clearly significant and persistent. Also, several country-specific variables drive the vulnerability of countries to changes in US monetary policy. In particular, countries with high interest rates, CDS spreads, inflation rates, or current account deficits and those with more vulnerable banking systems seem to be more affected by changes in US financial variables.

Inoue and Okimoto (2019), while applying a smooth-transition GVAR to study the effects of UMP by BOJ and the US Federal Reserve on the financial markets, taking spill overs and a possible regime change into account. They report that the BOJ and US Fed expansionary UMP have had a significant positive effect on domestic financial markets, especially in recent years. Furthermore, regarding spillover effects, results suggested that the BOJ actions had limited effects on international financial markets. Subsequently, the US Fed’s international spillover effect was approximately ten times larger than that of the BOJ.

3. The Global Vector Autoregressive (GVAR) Model

To investigate the effect of UMP on a global scale, it is important to explore a model that tries to capture the linkages between and among countries chosen in the sample. The GVAR model is a novel technique which serves this purpose well; this is a move away from the traditional VAR analysis. The theory behind this kind of model is primarily explained in Chudik and Pesaran (2016) and Dees et al. (2007). Take a panel of $N$ cross-section units, each with $k_t$ variables observed over the time $t = 1, 2, \ldots, T$. Individual country-specific foreign variables can be estimated using:

$$X_{it} = \bar{W}_i'X_t$$  \hspace{0.5cm} (1)

It is only reasonable that countries are globally connected through trade and the financial system or capital flows. Trade data alone can serve this purpose, and so, the weights, $\bar{W}_i$, representing the degree of importance and interconnectedness countries have with each other is constructed to estimate the foreign variable counterparts of the domestic ones.

$X_{it}$ is modelled as a VARX* model augmented by star or foreign variables.

$$X_{it} = \sum_{l=1}^{p_i} \phi_{it}X_{il,t-l} + A_{it}X_{it}^* + \sum_{l=1}^{q_i} A_{il}X_{il,t-l}^* + u_{it}$$  \hspace{0.5cm} (2)

Introducing common variables, then Equation 2 becomes:

$$X_{it} = \sum_{l=1}^{p_i} \phi_{it}X_{il,t-l} + A_{it}X_{it}^* + \sum_{l=1}^{q_i} A_{il}X_{il,t-l}^* + D_{it}\omega_t + \sum_{l=1}^{d_i} D_{il}\omega_{t-l} + u_{it}$$  \hspace{0.5cm} (3)
Where \( X_{lt} \) is a domestic variables vector, \( X_{lt}^* \) is the foreign variable vector, \( \omega_t \) represents the common variables, \( p_l, q_l \) and \( s_l \) are lag lengths of domestic, foreign and common variables respectively. \( \Phi_{it}, A_{lt} \) and \( D_{lt} \) are coefficient matrices of order \( l \) and \( u_{lt} \) is a vector of idiosyncratic country-specific shocks, \( u_{lt} \sim iid(0, \sigma^2) \).

The marginal model of the dominant variables can be estimated without feedback effects from \( X_t \) as explained in the subsequent Equations.

\[
\omega_t = \sum_{l=1}^{p_l} \Phi_{al} \omega_{t-l} + \eta_{ot} \tag{4}
\]

In error correction form;

\[
\Delta \omega_t = -\alpha_{o} \beta_{o} \omega_{t-l} + \sum_{l=1}^{p_l} H_{al} \Delta \omega_{t-l} + \eta_{ot} \tag{5}
\]

where \( \alpha_{o} \beta_{o} = \sum_{l=1}^{p_l} \Phi_{al}, H_{al} = -\left( \Phi_{wl,l+1} + \Phi_{wl,l+2} + \cdots + \Phi_{wl,l+p_1-1} \right) \),

for \( l = 1, 2, \ldots, p_1 - 1 \).

In order to allow feedback effects from variables in the GVAR back to the dominant variables via cross-section averages, then, Equation 4 can be augmented with lags of \( X_{ot}^* \) giving:

\[
\omega_t = \sum_{l=1}^{p_l} \Phi_{al} \omega_{t-l} + \sum_{l=1}^{p_l} A_{al} X_{ot-l}^* + \eta_{ot} \tag{6}
\]

With no co-integration among the common variables, \( \omega_t \), and the foreign or star variables, \( X_{ot-l}^* \), Equation 6 can be rewritten in error correction form as;

\[
\Delta \omega_t = -\alpha_{o} \beta_{o} \omega_{t-l} + \sum_{l=1}^{p_l} H_{al} \Delta \omega_{t-l} + \sum_{l=1}^{p_l} A_{al} \Delta X_{ot-l}^* + \eta_{ot} \tag{7}
\]

\[
B_{al} = -(A_{wl,l+1} + A_{wl,l+2} + \cdots + A_{wl,l+q_0-1})
\]

Let \( y_t = (\omega_t, X_{it}^*)' \), vector of observable variables and stacking country-specific models in Equation 3 together with the model for common variables in Equation 6 gives;

\[
G_{y,0} y_t = \sum_{l=1}^{l} G_{y,l} y_{t-l} + u_{yt} \tag{8}
\]

\[
u_{yt} = (u_t, \eta_{ot})'
\]

\[
G_{y,0} = \begin{bmatrix} I_{m_\omega} & 0_{m_\omega \times k} \\ D_0 & G_0 \end{bmatrix}, G_{y,l} = \begin{bmatrix} \Phi_{al} & A_{al} \end{bmatrix} D_l G_l
\]

Where \( l = 1, 2, \ldots, p \). \( D_l = (D_{l1}', D_{l2}', \ldots, D_{lN_l})' \) for \( = 0, 1, \ldots, p \). \( p = max\{p_l, q_l, s_l, p_0, q_0\} \)

Note that matrix \( G_{y,0} \) is invertible if and only if \( G_0 \) is invertible. If \( G_0^{-1} \) exists, then;

\[
G_{y,0}^{-1} = \begin{bmatrix} I_{m_\omega} & 0_{m_\omega \times k} \\ -G_0^{-1} D_0 & G_0^{-1} \end{bmatrix}
\]

This is a block-lower triangular matrix. Multiplying both sides of 8 by \( G_{y,0}^{-1} \), one can obtain the following solution to the GVAR.

\[
y_t = \sum_{l=1}^{p} F_{y,l} y_{t-l} + G_{y,0}^{-1} u_{yt} \tag{9}
\]

Where \( F_{y,l} = G_{y,0}^{-1} G_{y,l} \) for \( l = 1, 2, \ldots, p \).

### 3.1 Model Specification

As noted earlier, the GVAR primarily requires the estimation of domestic variables, \( X_{lt} \), and the foreign counterpart, \( X_{lt}^* \), using a predetermined weight. In this case, the fixed trade weight matrix. The chosen domestic variables are industrial production (ip), unemployment (ur), monetary policy indicator (mp), equity price (eqty), private sector credit (credit), real effective exchange rate (reer). Two global variables to control for global business cycles, global price of Brent crude oil (poil) and global price of agricultural raw material index (pmat).

All the variables are log transformed.

\[
X_{lt} = [ip_{lt}, ur_{lt}, mp_{lt}, eqty_{lt}, credit_{lt}, reer_{lt}]'
\]

\[
X_{lt}^* = [ip_{lt}^*, ur_{lt}^*, mp_{lt}^*, eqty_{lt}^*, credit_{lt}^*, reer_{lt}^*, poil_{lt}, pmat_{lt}]'
\]

The sample includes advanced economies and emerging market economies: Euro Area (EA), United Kingdom (GB), United States (US), Canada (CA), Japan (JP), Hungary (HU), Czech Republic (CZ), Romania (RO), Turkey (TR), Brazil (BR), Chile (CL), Colombia (CO), Hong Kong (HK), South Korea (KR) and Thailand (TH).

### 3.2 Trade Weights Matrix

The fixed weight matrix to recover the foreign variables is constructed using bilateral trade flows data by
employing Equation 12.

\[ TW_{ij} = \frac{X_{ij} + M_{ij}}{TT_i} \quad (12) \]

\( TW_{ij} \) is the weight of bilateral trade between country \( i \) and country \( j \). \( X_{ij} \) and \( M_{ij} \) are the values of exports and imports between the two countries and \( TT_i \) is the total trade between country \( i \) and the partners included in the sample.

Table 1. Trade weights matrix

<table>
<thead>
<tr>
<th></th>
<th>EA</th>
<th>GB</th>
<th>US</th>
<th>CA</th>
<th>JP</th>
<th>HU</th>
<th>CZ</th>
<th>RO</th>
<th>TR</th>
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<th>CO</th>
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<td>0.007</td>
<td>0.081</td>
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The matrix is constructed based on average monthly trade data over the period 2015-2019.

Table 1 shows the weight each country/area attaches to its partners in the sample. The Euro Area, for instance, attaches a weight of 28.1% and 25.0% to its trade with the United States and United Kingdom respectively. Likewise, the most important trade partners for the United States are Canada and the Euro Area, reporting weights of 31.7% and 31.2% respectively. For the emerging markets in Europe, the Euro Area is the most important trade partner by far compared to the other countries, accounting for 61.4% to 81.9%. The United States is the dominant trade partner in Latin America and Asia, followed closely by the Euro Area.

3.3 Country-Specific Models

The co-integrating relationships in the country-specific models are presented in Table 2.

Table 2. Country-specific VARX* order and number of long-run co-integrating relationships

<table>
<thead>
<tr>
<th>Country</th>
<th>VARX*(p_i,q_i)</th>
<th>p_i</th>
<th>q_i</th>
<th>Co-integrating relationships</th>
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<tr>
<td>Euro Area</td>
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<td>2</td>
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<td>2</td>
<td>4</td>
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<td>3</td>
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<td>2</td>
<td>3</td>
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<tr>
<td>Japan</td>
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<td>5</td>
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<td>Thailand</td>
<td>1</td>
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<td>4</td>
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</tbody>
</table>

Note. \( p_i \) and \( q_i \) are the lag lengths of the domestic and foreign variables respectively.
4. Dynamic Analysis

To perform the dynamic analysis, a Generalised Impulse Response Function (GIRF) model, proposed by Koop et al. (1996) is now used. The GIRF is a good alternative to the Orthogonalised Impulse Response Function (OIRF) model developed by Sims (1980). The advantage of the GIRF over the OIRF is that it is invariant to the ordering of the variables and countries in the GV AR. The variable ordering may be easy to identify based on economic theory or other reasoning in some cases, but with a big number of countries in the sample, it becomes difficult to arrive at a proper or correct country ordering.

\[
\text{GIRF}(X_t; u_{ilt}, n) = E(X_{t+1} | u_{ilt} = \sqrt{\sigma_{ilt}, I_{l-1}}) - E(X_{t+1} | I_{t-1})
\]

\(I_{t-1}\) is the information set at time \(t - 1\), \(\sigma_{ilt}\) is the diagonal element of the variance-covariance matrix \(\Sigma_u\) corresponding to the \(l^{th}\) equation in the \(i^{th}\) country and \(n\) horizon.

Assuming that \(u_t\) has a multivariate normal distribution, then the GIRFs of a unit shock at time \(t\) to the \(l^{th}\) equation in the above model on the \(j^{th}\) variable at time \(t + n\) is given by the \(j^{th}\) element of;

\[
\text{GIRF}(X_t; u_{ilt}, n) = \left[ \frac{e_l' A_n G_0^{-1} \Sigma_u e_l}{\sigma_{ilt}^2} \right]_{j} = 0, 1, 2, \ldots; l, j = 1, 2, \ldots, k
\]

\(e_l = (0, 0, \ldots, 0, 1, 0, \ldots, 0)^t\) is a selection vector with unity as the \(l^{th}\) element in the case of a country-specific shock. For a regional shock, \(e_l\) has PPP-GDP weights that sum to one, corresponding to the shocks of each of the countries that belong to the chosen region, and zeroes elsewhere. For a global shock, \(e_l\) has PPP-GDP weights that sum to one, corresponding to particular variable shocks of each of the \(N + 1\) countries and zeroes elsewhere. The GV AR GIRFs allow for correlation of the error terms, thus, the error terms are not orthogonal.

4.1 Domestic Effects of ECB Unconventional Monetary Policy

To study the domestic effect of ECB UMP, consider a one standard error positive shock to the Euro Area monetary policy variable, in this case, the asset purchases by the ECB.

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Solid lines are bootstrap median estimates, and the dotted lines represent a 90% bootstrap confidence interval band.

Figure 1. Euro Area impulse responses to a one standard error positive shock to UMP variable
The results are presented in Figure 3 and discussed as follows. This one standard error positive shock, on impact, results to a 0.2% appreciation in the real effective exchange rate of the Euro, peaking at about 0.5% within the first 3 months, and then a gradual depreciation thereafter.

The Euro Stoxx 50 equity index is rather very responsive to the UMP shock compared to other variables, reporting a response of about 0.7% on impact and peaking at approximately 3.5% within the first 12 months.

As expected, private sector credit responds positively due to an increase in the monetary base or reserves of the commercial banks that are now able lend out more. This response peaks at about 0.5% after the first 28 months and remains that way throughout the projection period.

On to the general macroeconomic variables, unemployment responds rather slowly, steadily oscillating about the zero point until after 8 months when it starts to fall up to a maximum of about 0.7%, remaining stable along that line.

Industrial production generally responds positively, peaking at 0.7% after the first 13 months and gradually declining after that.

The domestic results are all statistically significant and reflect a positive impact of UMP; instilling confidence in the financial markets, creating more credit, creating jobs and encouraging production.

4.2 International/Cross-Border Spillover Effects of ECB Unconventional Monetary Policy

To study the international/cross-border spillovers of ECB UMP, and for better comparison of the responses in different countries/regions, the maximum impulse response of each individual economy is reported in a bar graph form as shown in Figure 4.
The responses are diverse and in either direction, except for equity prices. The diversity in responses may be due to the significant differences in the nature of advanced and emerging market economies, some regional economies may be linked in several ways. The results are discussed as follows.

Among the advanced economy currencies, the British Pound shows the highest response, appreciating by about 1.1%. The Canadian Dollar and Japanese Yen move in the opposite direction in comparison to the other 3 advanced economy currencies, depreciating instead. The Hungarian Forint registered the highest response to ECB UMP, depreciating by 1.5%. Currency responses in Latin America and Asia are rather modest in either direction, however, all three currencies in emerging Asia depreciate in response to ECB UMP.

The equity index variable shows the highest elasticity for all countries, though emerging European economies respond more than the rest, with the Hungarian BUX and Czech PX indices registering the highest maximum responses with gains of about 5.3% and 4.3% respectively. Latin America equities respond the least, and remain conservative compared to the other economies.

Private sector credit growth is observed for all advanced economies. Emerging markets register responses in either direction, with credit increasing in Romania by about 2.5% and an opposite reaction in Colombia, seeing a credit fall of up to 1.8%.

The monetary policy variable, defined by broad money supply, too, shows mixed reactions. Monetary policy practices may be very diverse in several countries, especially emerging markets, thus, the diversity in responses is rather expected. Generally, emerging market economies report higher responses than the advanced economies, with money supply in Romania growing by up to 1.6% and falling in Colombia by 1.4%. The United Kingdom reports a significant response, an increase of 0.6% compared to the other three advanced economies that seem to keep money supply at a rather controlled level, showing only minuscule responses.

Unemployment in advanced economies generally falls, except for Canada. In emerging Europe, Czech Republic registers the highest drop in unemployment at about 3.1%. All Latin America countries see an increase in unemployment. Overall, Thailand registers the highest drop in unemployment at about 3.4%.

Finally, an increase in industrial production is observed in all advanced economies. The Euro Area reports an increase of 0.7%, and diverse responses are seen in the emerging markets. Thailand reports a fall in industrial production of almost 1.5%, it is the most elastic.

It is important to note that for all variables, emerging markets seem to respond much more than the advanced economies, an indicator of more control employed in the advanced economies.

### 4.3 Global Oil Price Shock Effects

In addition to the impulse responses to UMP shock, it is also important to study results of a shock to a global variable, in this case, the oil price. Maximum impulse responses to a one standard error negative shock to the oil price are shown in Figure 5. The results also indicate a diversity of responses from the countries in the sample.
The Japanese Yen and Hungarian Forint are the most sensitive to oil price shocks, exhibiting depreciations of up to 4.2% and 4.4% respectively. The British Pound and Canadian Dollar were the least responsive to oil price shocks, appreciating by less than 1%.

As in the global responses to a UMP shock, the equity variable is the most responsive. The ROSNP index of Romania responds with a huge drop of up to 11.5%. The advanced economies’ equity market responses are within the same uniform range of 1.8% (FTSE 100) to 3% (S&P 500), all in the same direction (a drop).

Private sector credit growth in advanced economies shows a more conservative response compared to the emerging economies. For instance, considering the two extremes, private credit in Japan grows by only 0.1% while in Hungary it falls by up to 2.3%.

Advanced economies generally show an increase in money supply except for the Euro Area whose monetary policy is described by the UMP variable/ECB assets. Sensing a fall in the oil price, the ECB reduces its aggressiveness in applying UMP by up to 1.3%. Emerging economies show a diversity of responses with money supply in Brazil falling by up to 2.9% and increasing by 0.5% in Hong Kong.

Unemployment in the Euro Area and United Kingdom fall by 0.8% and 4.6% respectively while Brazil reports an increase of 6.9%, the highest response.

Lastly, industrial production, too, registers a variety of responses. Again, Brazil, reports the highest degree of responsiveness, falling by 3.7% compared to Colombia’s increase of 0.5%. All advanced economies, with the exception of the United Kingdom (increase of 0.5%), show a fall in industrial production.

4.4 Robustness Check

Several researchers have argued that UMP can be measured by the term spread between long- and short-term treasury yields, and the corporate spread between AAA rated bond yields and the effective central bank rate. As a robustness check, the central bank assets variable is replaced with the term spread between the long- and short-term bond yields; results change for certain variables, but not drastically.

It would also be helpful to allow the trade weights used to construct the foreign variables to change over time, instead of keeping it fixed. The trade weight matrix can also be replaced with another indicator of country interconnectedness, for instance, the extent to which commercial banks trade with each other/or the degree of financial interconnectedness of financial institutions.

5. Conclusion

Using a GVAR model, this study investigated the domestic and international spillover effects of ECB UMP, where the ECB UMP is defined by the ECB total asset purchases. To study the extent of shock effects to ECB UMP, Generalised Impulse response functions are presented, and the results indicated a richness of responses exhibited by the different countries/regions. Generally, ECB UMP effects showed encouraging and positive responses from economies within the Euro Area region while international spillover effects were mixed, probably due to the different nature of the monetary policy regimes deployed in the different countries, especially the emerging economies. Some countries seem to be conservative while others allow their responses to spiral away. Furthermore, country-specific responses to a global oil price shock are also studied and findings revealed that the equity indices are the most responsive in comparison to the other variables. As a robustness check, ECB UMP is described by the spread between short- and long-term bond yields; results change for certain variables, but not drastically.
Funding
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References


**Notes**

Note 1. A known change in money supply is shown to cause an instantaneous change in commodity prices that is greater than the proportionate change that describes long-run equilibrium.

Note 2. The researchers argue that it is not possible to infer effects of monetary policy rules from a standard VAR system since this approach gives little or no structural interpretation of the coefficients that make up the lags in the system. They also attempt to sort out the effects of anticipated and partially unanticipated policy changes. The researchers further acknowledge that their approach may be crude and vulnerable to the Lucas critique which argues that it is naive to try to predict the effects of a change in economic policy entirely based on relationships observed in historical data, especially data that is highly aggregated.
Note 3. USA, Euro Area, Japan, UK and Canada.
Note 4. Yen, Deutsche Mark, Lira, French Franc and UK Pound.
Note 5. A weighted average of the short-term real interest rate, the effective real exchange rate, real property and real share prices.
Note 6. Canada, Euro Area, Japan, Norway, Sweden, Switzerland, UK and USA.

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