THE SPILLOVER OF US MONETARY POLICY ON EU AGRICULTURAL PRICES: A PANEL VARX ANALYSIS

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ABSTRACT

This research examines the nexus between US monetary policy shocks and agricultural prices of the EU. Utilizing monthly prices of beef, wheat, and barley of 21 EU countries, we estimate the impact of US monetary policy shocks on these three agricultural prices in a Panel Vector Autoregression with Exogenous Variables (PVARX) framework. We find that a contractionary monetary policy shock in the US has heterogeneous effects across the storable and non-storable commodity prices in the EU. Specifically, a contractionary monetary policy shock in the US reduces EU wheat and barley prices and increases EU beef prices. However, the estimated impulse response functions of dynamic multipliers reveal that these three commodity prices return to equilibrium within two months.

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LIST OF ABBREVIATIONS

Abbreviation. ....Explanation of the Abbreviation.

BP...Beef Price

BWP..Wheat Price

EU ....European Union.

FBP ....Barley Price

GDP...Gross Domestic Product.

IMF ....International Monetary Fund.

INF ....Inflation.

IP ....Industrial Production.

PVAR..Panel Vector Autoregression.

PVARX..Panel Vector Autoregression with Exogenous Variable.

PVARX(1) ....Panel Vector Autoregression with an Exogenous Variable.

QE ....Quantitative Easing.

SVAR..Standard Vector Autoregression.

SVARX..Standard Vector Autoregression with an Exogenous Variable.

US ....United States.

USMS..United States Monetary Shock.

VAR ....Vector Autoregression.

VECM ....Vector Error Correction Model.

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1. INTRODUCTION

1.1. Background

For the last 50 years, economists have been showing active interest in understanding the interconnection between monetary policy and agricultural economics. Many studies in the US (e.g., Schuh, 1974; Barnett et al., 1983; Dorfman & Lastrapes, 1996; Amatov and Dorfman, 2017) show different channels of monetary spillover to agricultural commodity prices, though few studies find agricultural prices unaffected by the monetary changes (Batten and Belongia, 1983; and Bessler, 1984).

The discussions about the relationship between monetary policy and agricultural commodity prices take an important turn after the publication of Schuh's famous paper in 1974. Schuh (1974) emphasizes the role of the dollar exchange rate in the agriculture trade and development of the US. He says that the US dollar was undervalued right after World War II, and it became overvalued from the Korean War to the collapse of the Bretton Woods system. This overvaluation of the dollar increased the nominal price of the US exportable agricultural products and created an overall US trade deficit. He also mentions that the flexible exchange rate regime after the collapse of the Bretton Woods system was a crucial transformation for US agricultural development.

Kruger (1983) also states the importance of flexible exchange rates in agricultural production and exports. He argues that the overvaluation of the exchange rate causes discrimination in agriculture for developing countries. As agricultural production and exports are sensitive to the real exchange rate, the depreciation of the US dollar has unforeseen impacts on US agricultural trade (Kruger, 1983). He also mentions that US agricultural exports increased from US$7.3 billion (in 1970) to US$17.7 billion (in 1973) as a result of the depreciation of the dollar.

Additionally, Chambers and Just (1982) investigate the impacts of money supply changes on US agricultural production and exports, prices, and inventories through a structural model of crop markets. They indicate the elasticity of the agricultural sector with respect to the changes in domestic credit; specifically, the exports of corn and wheat are increased by more than two percent due to one percent increase in domestic credit. They also find that the contractionary monetary policy decreases the domestic agricultural prices and induces the demand for agricultural products.

Saghaian and Reed (2014) specify how expansionary monetary policy raises the price of US exportable and importable commodities. They say that expansionary monetary policy depreciates the value of the US dollar and makes the US dollar weaker internationally. As all products are traded internationally in the US dollar, this depreciation increases international demand and the price of US products. They also state that unconventional US monetary policy (like quantitative easing) increases domestic demand for goods and promotes US economic growth. Moreover, the cost of holding inventories decreases due to low-interest rates during monetary expansion. As a result, the price of storable commodities (for example, agricultural products: wheat, corn, barley, etc.) tends to increase (Saghaian and Reed, 2014).

Furthermore, agricultural prices are more flexible than prices of other products due to their homogenous nature, and these prices change more quickly with any monetary shocks than the product prices of the manufacturing and service sector (see Frankel, 1986 and Saghaian et al., 2002). Changes in monetary policy can also affect agricultural prices through energy prices; the variable costs of agricultural production, which are determined mainly by fuel and fertilizer prices, depend on multiple energy prices (Reed and Saghaian, 2018).

From the discussion above, it is now clear that there is a tight connection between monetary policy and the agricultural sector. Specifically, we can say that monetary changes in the US affect its domestic agricultural prices through different transmission channels. Now, one may be curious about the impact of US monetary policy and dollar exchange rate on agricultural prices in other countries as the dollar has been the most widely used currency in foreign exchange transactions since the signing of the Bretton Woods agreement in 1944.

1.2. Statement of the Problem

In the 1980s, economists start examining the impacts of US monetary policy on international finance due to the growing trade openness of the world economy (Reed and Saghaian 2018). Many studies show cross-border spillover of US monetary policy on foreign interests, stock prices, and exchange rates (see, for example, Rogers, 1999; Kim and Roubini, 2000; Rogers et al., 2014). Georgiadis (2016) finds a significant global spillover of US monetary policy via applying a global-VAR model. For some economies, US monetary policy even has a larger impact than their own domestic monetary policy. He also states that the size of spillovers of the US monetary policy largely depends on the partner country's trade openness, exchange rate regime, rigidities of labor markets, and presence in global value chains. Moreover, the US's position in global trade (the second largest trading nation in 2022)[1], its strong financial integration with other economies, and the superiority of its currency (88.4% of global foreign

[1] See https://ustr.gov/countries-regions#:~:text=Canada%20was%20the%20largest%20purchaser,United%20Kingdom%20(%2476.2%20billion).

exchange transaction in 2022 is involved by US dollar)[2] are the crucial factors of overall spillover from US economy (Kose et. al., 2017).

However, as the United States is the second largest agricultural trader in the world[3] and the US dollar has wide acceptance in international trade, it follows that US monetary policy could have significant spillovers to the agricultural prices of other large participants in global agricultural trade such as the European Union (largest agricultural trader), China, Canada, Brazil, Japan, etc. But there are only three studies (Taylor and Spriggs, 1989; Saghaian and Reed, 2015; Miranda-Pinto et al., 2023) that cover the cross-border impacts of US monetary policy on agricultural prices. Taylor and Spriggs (1989) show that US monetary policy influences Canadian agricultural prices in two ways: firstly, it affects through the US dollar exchange rate, and secondly, through its generated spillover in US agricultural prices. Saghaian and Reed (2015) investigate how the US Federal Reserve's purchase of long-term assets affects Canadian agricultural and energy prices. They show the heterogeneous impacts of this quantitative easing of FRED on different Canadian agricultural products like meat and cereal grains. Miranda-Pinto et al. (2023) find a significant role of US contractionary monetary policy shocks in increasing international agricultural and energy prices, though they consider only aggregated international commodity prices indices from Bloomberg L.P. rather than any country or region wise specific commodity prices in the estimation. From the discussions, we can say that there is a lack of

[2] See https://www.statista.com/chart/30838/share-us-us-dollar-in-global-economy-global-financial-transactions/#:~:text=The%20biggest%20%2D%20and%20a%20very,involved%20the%20currency%20in%202022.&text=This%20chart%20shows%20the%20share,economy%20and%20global%20financial%20transactions.

[3] See https://www.ers.usda.gov/topics/international-markets-u-s-trade/u-s-agricultural-trade/u-s-agricultural-trade-at-a-glance/

literature on examining the spillover of US monetary policy on the agricultural prices of the other largest agricultural traders.

Hence, this study aims to estimate how the shocks in US monetary policy affect the domestic agricultural commodity prices of the European Union (it is the fifth largest export destination of US agricultural products and third largest source of US agricultural imports in 2022)[4]. The unavailability of data for agricultural commodity prices of other largest agricultural trading partners (e.g. China, Brazil, Japan, and etc.) of US drives our focus solely on EU.

1.3. Objective of the Study

In this study, we examine to explore the relationship among US monetary policy shocks and agricultural commodity prices across the European Union (EU). Our target is not only to find out the overall spillover of US monetary policy on EU agricultural commodity prices but also to detect the heterogeneity of the impacts of US monetary policy shocks on different EU agricultural commodities. In doing so, we firstly synthesize the previous literatures and then we aim to contribute the existing knowledge related to US monetary policy spillover and global agricultural prices. Moreover, we also aspire to suggest pragmatic policy recommendations based on the obtained results from the study.

1.4. Organization of the Study

The whole study is divided into five chapters. Chapter 1 presents a general introduction of the topics, including background, statement of the problem, objectives, and organization of the

[4] https://www.ers.usda.gov/topics/international-markets-u-s-trade/countries-regions/

study. Chapter 2 contains a review of the existing literature surrounding the global impacts of US monetary policy. Chapter 3 includes a methodological framework of the study, descriptions, and sources of variables. In Chapter 4, empirical results of different econometric models, discussions, goodness of fit, and robustness of estimated results are presented. Finally, Chapter 5 provides concluding remarks on the basis of the empirical results found in Chapter 4, and this chapter also includes limitations of the study and policy recommendations.

2. LITERATURE REVIEW

In this chapter, we review and synthesize the literatures that examine global role of US monetary policy, inter-connection between monetary policy and agricultural economics, and US monetary policy spillover on international agricultural prices. The goal of this chapter is to trace out the knowledge gap, key findings, and future direction of research of the mentioned areas.

During the 1990s, the international monetary system observed an enormous change due to financial integration and burning globalization, and the dominance of the US economy in the international monetary system has been unaltered in spite of the collapse of Bretton Woods agreements (Miranda-Agrippino and Rey, 2020). Real economic effects of US monetary policy have been studied for a long time (Di Giovanni and Rogers, 2023). Many research studies show different channels of US monetary spillover to the global financial cycle.

Firstly, Ammar et al. (2016) state three major channels (exchange rate, domestic demand, and financial spillover) through which US monetary policy affects the global economy. They find that the overall spillover of US monetary policy is positive in some cases and negative in some cases. In this study, they also argue that the positive and negative impacts of US monetary policy on foreign economies depend on the nature of transmission channels. They say that a monetary expansion in the US can increase its domestic demand for consumption and investment. As a result, the US imports more foreign products, which enhances foreign exports and GDP. In their estimation, they get different impacts (0.05 percent decrease in GDP through the exchange rate channel; 0.05 and 0.25 percent increase in GDP through the domestic demand channel and financial spillover channel, respectively) on the foreign economy for a hypothetical expansionary monetary policy in the US which decreases 25 basis points of 10 years treasury yield. Bluedorn and Bowdler (2011) also find significant exchange rate spillovers of US monetary policy shocks in these countries. Specifically, each contractionary US monetary policy shock appreciates the US dollar exchange rate of those countries. For some countries, appreciation happens very fast (within 1 or 2 months). Moreover, they show that a positive US interest rate shock increases interest rates in those countries, though they also get positive and negative responses of foreign output with the shocks in US monetary policy.

Most importantly, Ammar et al. (2016) show that conventional and unconventional US monetary policies influence foreign bond yields similarly. However, Glick and Leduc (2013) study both unconventional and conventional monetary policies of the US and estimate their impacts on the dollar exchange rate. They mention that the exchange rate effects of the dollar for both types of policies are not easily comparable due to the heterogeneity of their nature. They also argue that conventional monetary policy captures the shock in the short-term interest rate and unconventional monetary policy captures the shock in the long-term interest rate).

Some studies also explore the differences in the responses of advanced and emerging economies with change in US monetary policy. Iacoviello and Navarro (2019) identify the reactions of 50 advanced and emerging economies to shocks in US monetary policy. Firstly, they estimate US monetary shocks by a process which is similar to a Cholesky identification in a Vector Autoregression (VAR) system; then they evaluate the responses of foreign GDP with the shocks in US monetary policy by applying the local projection method. This study finds a significant difference in the responses of foreign economies depending on their vulnerability, trade openness, and exchange rate regimes. The estimated results show that emerging economies, which are more vulnerable with respect to advanced economies, react more. Analogous to Iacoviello and Navarro (2019) and Georgiadis (2016) finds that the US monetary policy even generates a larger effect on international output than domestic output due to the economic structure and vulnerabilities of particular countries. For some economies in Africa, and Latin America, the spillovers are larger than the domestic effect in the US. Recognizing heterogenous impacts of US monetary policy on different types of countries, Arteta et al. (2015) suggest that emerging and frontier market economies should implement their fiscal and monetary policy carefully to reduce the risks generated by US monetary policy.

Furthermore, Lakdawala (2021) and Miranda-Agrippino and Rey (2020) examine how the unexpected changes in the US monetary policy affect international asset prices. Specially, Lakdawala (2021) divides the return of 31 international bonds into two components (one is a risk-neutral component, and the other is the term premium component). He finds heterogeneity in the effects of US monetary policy shocks for emerging and advanced countries. Risk-neutral components of emerging countries react to the shocks in US monetary policy. On the other hand, term premium components react with shocks in US monetary policy for advanced economies. Additionally, Miranda-Agrippino and Rey (2020) mention the US monetary policy shocks as a single important global factor that can address a large part of the variation (20% of the total variation) in world risky asset prices. They also specify global credit, financial intermediaries, and capital mobility as the factors of US monetary policy spillover across the world.

From the above discussions, we get a clear idea of the impact of the changes in US monetary policy on the global economy. It can be concluded that foreign economies, which are connected with the global financial market, are affected more or less by US monetary changes through different channels like exchange rates, mobility of capital, business, domestic and international demand, etc. Now, we discuss the literature that investigate the interconnection between US monetary policy and agriculture.

Much empirical literature confirms a significant statistical relationship between monetary measures and nominal agricultural prices (Barnett et al., 1983). Applying the Granger causality method, Barnett et al. (1983) examine the causality between US money supply and nominal agricultural prices considering monthly data from 1970 to 1978. For the money supply measure, they use three series (M1, M2, and the reserve money), and two wheat prices and a food component of the consumer price index are used to represent the agricultural prices in the estimation. They find that the M2 money supply has a significant impact on raising the food component prices index and wheat prices. However, Dorfman and Lastrapes (1996) finds that agricultural prices (crop and livestock prices) are increased in the short run with an expansionary shock M1 money supply though they consider M1 solely as money supply measure in their study. They also show that crop prices adjust more slowly than livestock prices in the long run.

Moreover, Barnett et al. (1983) suggests that money supply is not the only important variable that has a causal relationship with agricultural prices, and agricultural economists should look into finding theoretical connections between those variables. Chambers and Just (1982) shows another important channel (domestic credit) through which US monetary policy affects agriculture. This study is conducted by a three-block recursive model (agricultural block by soybean, wheat, and corn market prices; agricultural export block by the current balance of those three commodities exports; and exchange rate determination block). Chambers and Just (1982) conclude that a contractionary monetary policy followed by a decrease in the domestic credit level worsens the US position in the agricultural export market.

Nevertheless, Chalfant et al. (1986) inquired about the impact on the US agriculture sector of US monetary policy by following the Dornbusch model of overshooting. They decompose the economy into two sectors (fixed-price and flex-price). Assuming the agricultural sector is flex-price, they find that agricultural prices tend to go to their long-run equilibrium after a change in the short run with monetary policy. This overshooting process of agricultural prices is also found to be similar to the Australian agricultural sector. In this study, the authors also run a simulation model to trace out the factors affecting the overshooting of agricultural prices. The results of the simulation model suggest that the shocks in macroeconomic variables (e.g., federal deficit, government spending on the agricultural sector, etc.) also transmit to grain and livestock prices.

The studies we discussed until now cover only the impacts of conventional monetary policies of the Federal Reserve on agriculture. However, the US economy faced the worst financial crisis in the fourth quarter of 2008 since the Great Depression, and the Federal Reserve took some extraordinary monetary measures (e.g., forward guidance and quantitative easing) to boost the economy.[5] Now, some studies that examine the spillover of these extraordinary monetary policies on US agriculture are presented below.

Saghaian and Reed (2014) investigate the impact on US agricultural prices of two large-scale assets purchased by the Federal Reserve. They collect three types of agricultural prices (meats, cereal grains, and softs) containing 12 commodities. They use the historical decomposition method to trace the impacts of monetary policies on agricultural prices. According to estimated results, they find second large-scale asset purchases of the Federal Reserve have a significant role in raising most of these products. However, only two

[5] See https://www.frbsf.org/research-and-insights/publications/economic-letter/2012/11/federal-reserve-unconventional-policies/#:~:text=After%20the%20federal%20funds%20rate,and%20large%2Dscale%20asset%20purchases.

commodities out of twelve commodities' prices increased during the first large-scale asset purchase of the Federal Reserve.

Amatov and Dorfman (2017) examine the relationship between US agricultural prices and monetary policies with a special focus on the period of the Federal Reserve's unconventional monetary policies (2008 to 2013). Considering the data from 1992 to 2013 and applying the Vector Error Correction model (VECM), they get expansionary monetary policies (unconventional and conventional) that have a significant impact on raising agricultural prices and other commodity prices. In this research, they use the Federal Reserve balance sheet and treasury note yield (10 years) as the representative of monetary policy in the model. All commodity price indexes and food and beverage price indexes from the IMF are used to represent commodity prices and agricultural prices in the model. Specifically, they find that if the Federal Reserve's balance sheet is increased by 1%, the commodity prices and agricultural prices are increased by 2.2% and 2%, respectively. However, the estimated results suggest that agricultural prices take 13 months to adjust after the shocks in monetary policy, which is a longer time period than the other past literatures' result. Most importantly, the authors also mention that the prices respond higher with unconventional monetary policy period than in the conventional monetary policy period.

Though the nexus between US monetary policy and its domestic agriculture prices are well researched, we can find few studies that cover the relationship between US monetary policy and the agricultural prices of other countries. Taylor and Spriggs (1989) indicate the exchange rate of the US dollar as the single most significant factor for creating instability in Canadian agricultural prices. Considering quarterly data from 1959 to 1985, they run the VAR model with five variables (log differenced of Canadian M1 money, Canadian dollar/ US dollar, agricultural product price index and industrial product price index, and weighted world exchange rate of US dollar). The estimation shows that the 20% forecast error variance of agricultural prices is explained by the weighted world exchange rate of the US dollar. To ensure stability in Canadian agricultural prices, authority should focus not only on US agricultural policy but also on US monetary variables (Taylor and Spriggs, 1989). Sagahaian and Reed (2015) also find significant impact of US monetary policy on Canadian agricultural prices. They mainly investigate the impacts of the US Federal Reserve's two quantitative easing (QE) on Canadian commodity prices (nine agricultural commodity prices and two energy prices). The whole study is conducted using monthly data from January 2000 to June 2013. Using vector error correction model (VECM) and followed by a historical decomposition method, they find different impacts of US quantitative easing (QE) 1 and 2 on Canadian commodity prices. Specifically, all 11 Canadian commodity prices were increased during QE-2 (from 2010 to 2011); these findings are similar to (Saghaian and Reed, 2014).

Miranda-Pinto et al., (2023) conduct a study to evaluate the cross-country spillover of monetary policy in inflation. Initially, they consider the monetary policy shocks of the central bank of four large economies (the United States, the United Kingdom, Japan, and the European Union) in transmitting inflationary pressure to 24 countries. However, the monetary policy shocks' effect generated by Japan and England is found to be less significant. So, they emphasize the spillover effects from the monetary policy shocks of the US and EU, though they mention the superior role of US monetary policy and the US dollar in the global financial cycle. For estimation purposes, they collect daily prices of 39 commodities from Bloomberg L.P., and they weighted these 39 commodity prices into 11 indices such as metals, agriculture, food, energy, etc. Applying the proxy SVAR model and decomposition method, they show that a contractionary US monetary policy shock decreases 41% of the US consumer price index and 66% of other countries' consumer price index through commodity price channels. The estimated results also suggest that a US contractionary monetary policy shock reduces oil and food prices both in the US and other countries.

Most importantly, Saghaian and Reed (2015) conclude that monetary policy changes in large economies such as the United States may play a crucial role in changing commodity prices of other countries, at least in the short run. The authors also mention the counter-monetary action taken by the European Central Bank (chief monetary authority of the European Union) after the announcement of QE-2 to prevent potential liquidity spillover from the US economy and to stabilize commodity and asset markets. These insights also motivate us to study the interaction of the changes in the US monetary policy and product-wise agricultural prices of the European Union.

3. RESEARCH METHODOLOGY AND MODEL SPECIFICATION

3.1. Overview

This chapter illustrates the methodological framework of the study and data sources. In order to fulfill the objective of an econometric study, the selection of appropriate variables is crucial. Hence, this chapter starts with rationalizing the selected variables for this study. Then, the sources, definitions, graphical representations, summary statistics of the variables, and econometric approaches, including unit root test results are presented.

3.2. Selection of Variables

As the study is examining the impact of US monetary shocks on agricultural prices of the EU, we calculate US monetary shocks by following the process from Iacoviello and Navarro (2019). The description of the US monetary shocks and its calculation process are presented in section 3.4.1 and table 3.3, respectively. Additionally, Studies that focus on the nexus between monetary policy and agricultural commodity prices mainly include meat and cereal grains prices (see, for example, Saghaian and Reed, 2014; Saghaian and Reed, 2015; & Yu, 2014). So, we collect three agricultural price series (Beef, Wheat, and Barley) of EU countries for conducting this study based on European production, market depth, and the availability of data.

Firstly, European Parliamentary Research Service mention, “Beef is an important element of most European Diet and it is the third most widely consumed meat in the world.”[6] EU ranks as the fourth largest beef producer in the world after USA, Brazil, and China (Shahbandeh, 2023). Secondly, Wheat is the third most-produced cereal crop in the world (World Economic Forum,

[6] See https://www.europarl.europa.eu/thinktank/en/document/EPRS_BRI(2022)733676

2022). In 2022, the EU is the second largest producer and consumer of wheat, and they rank second in the top wheat exporters' list in the world according to International Grains Council (IGC) data. Even Wheat constitutes 45% of total cereal grain production in Europe.[7] Thirdly, barley is also an important cereal crop in the world. It is mainly used for animal feed, alcoholic, and non-alcoholic beverages. Yahoo! finance mention, "The European Union is the largest producer of barley, accounting for 34% of the global production, with 51.4 million metric ton in 2021."[8] Includes EU, China, Saudi Arabia, Canada, and Turkey are the main consumer countries of barley. Furthermore, we also include the growth of industrial production and monthly inflation of EU countries in this research with a view to disentangle macroeconomic impacts (see Bluedorn and Bowdler, 2011).

3.3. Sources of Data

The whole study is carried out using secondary data. Unbalanced monthly panel data for 21 countries (Austria, Belgium, Bulgaria Croatia, Czechia, Estonia, Finland, France, Germany, Greece, Hungary, Italy, Latvia, Lithuania, Netherlands, Poland, Portugal, Romania, Slovakia, Slovenia, and Spain) out of 27 EU countries are collected from different sources. For ten countries (Austria, Belgium, Finland, France, Germany, Greece, Italy, Netherlands, Portugal, and Spain), monthly data are collected from January 2000 to December 2022. Eleven additional countries enter the EU during our sample, so we include them starting at their admission date. For eight countries (Czechia, Estonia, Hungary, Latvia, Lithuania, Poland, Slovakia, and

[7] https://www.robert-schuman.eu/en/european-issues/0669-the-geopolitics-of-european-wheat#ancre_1
[8] https://finance.yahoo.com/news/barley-market-size-share-analysis-145000904.html#:~:text=An%20increase%20in%20the%20demand,million%20metric%20ton%20in%202021.

Slovenia), monthly data are collected from May 2004 to December 2022. For Bulgaria and Romania, monthly data are collected from January 2007 to December 2022. For Croatia, monthly are collected from July 2013 to December 2022. We drop another 6 EU countries (Denmark, Ireland, Luxemburg, Malta, Sweden, and Cyprus) because of the unavailability of data and the long break in the observations of these three agricultural prices.

Additionally, the data of selected 21 countries has some missing observations are interpolated by the average two nearest observations (17 observations are missing out of 5048 observations for Beef price series; 123 observations are missing out of 4766 observations for Wheat price series; and 162 observations are missing out of 4819 observations for Barley price series).

Table 3.1. Notation and Sources of the Variables.

Variable Name	Notation	Description	Source
US monetary Shocks ($\hat{\varepsilon}_t$) in Percentage (Monthly)	USMSt	$\hat{\varepsilon}_t = \Delta It - \hat{\beta}_0 - \hat{\beta}_1 * X1 - \hat{\beta}_2 * X2 - \hat{\beta}_3 \Delta It\text{-}1$	Calculated
		ΔIt = Wu-Xia Shadow Federal Fund Rate (monthly)	Wu and Xia, (2016)
		X1 = US industrial Production Growth (monthly)	Federal Reserve Economic Data
		X2 = US Inflation (monthly)	
Beef Price	BPit	(Euro/100kg)	European Commission
Wheat Price	BWPit	(Euro/metric ton)	
Barley Price	FBPit	(Euro/metric ton)	
Inflation (%)	INFit	Monthly (Annualized)	Eurostat
Industrial Production Index	IPit	Monthly	Eurostat

Note: i = Cross section countries, t= time.

3.4. Description and Graphical Representation of the Variables

3.4.1. US Monetary Shocks (USMSt)

US monetary shocks is the estimated residual series from the regression of the Wu-Xia shadow federal fund rate on its lagged value, industrial production growth and inflation, analogous to Iacoviello and Navarro (2019). In the process of estimating US monetary shocks, Iacoviello and Navarro (2019) firstly consider federal fund rate as dependent variable in the regression on a set of control variables. Then, they substitute federal fund rate by Wu-Xia shadow federal fund rate in order to consider the effect of zero lower bound and unconventional monetary policies.

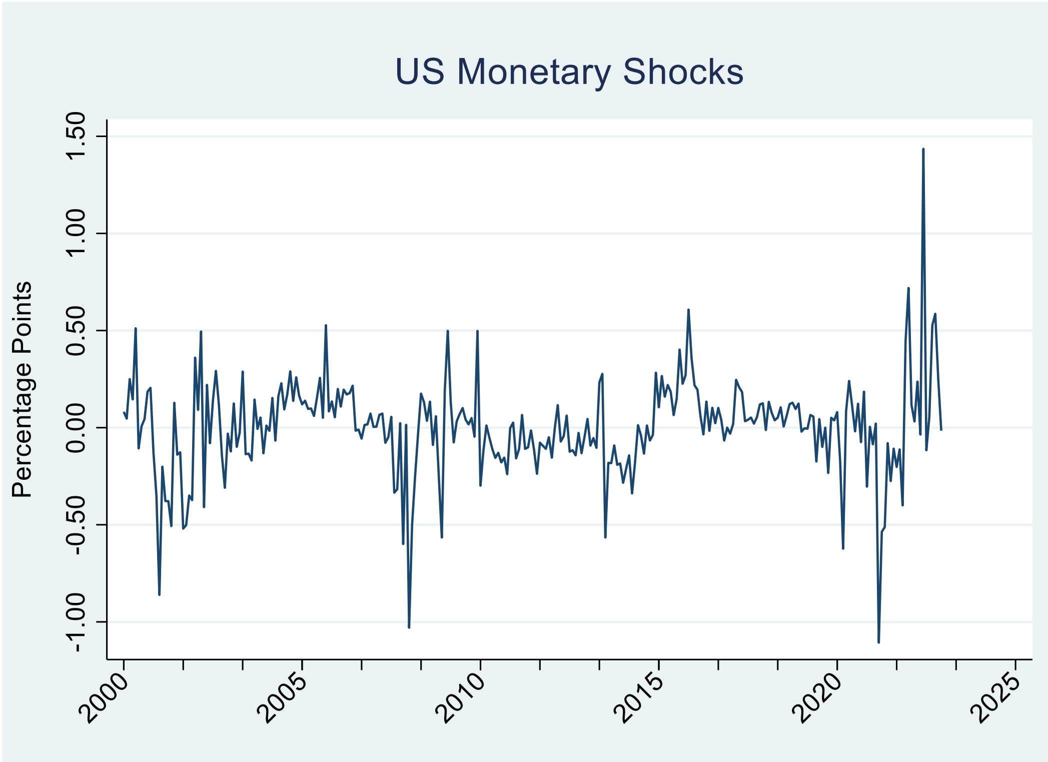

Figure 3.1. Graphical Presentations of US Monetary Shocks from Jan 2000 to Dec 2022.

The estimated shocks represent the gap between Wu-Xia shadow rate series and estimated series from regression results. A positive value of this gap explains a contractionary monetary policy when interest rate is too high and a negative value of this gap explains an expansionary monetary policy when interest rate is too low. The estimated values of US monetary shocks are presented in the figure 3.1.

We follow Iacoviello and Navarro (2019) in including US policy shocks, rather than a variable for the level of US policy, to account for the effect of expectations. When market participants make decisions, they incorporate expectations about the future based on available information. Thus, expectations of these variables, even US monetary policy, are already incorporated into their decisions. It is the unexpected component—the shock—that causes adjustments in behavior and potentially impacts foreign economies. Further, we include the US monetary policy as an exogenous variable to account for the fact that the Federal Reserve considers US variables when setting policy.

The largest contractionary shock was (1.44%) in June 2022. Federal Reserve mention that inflation was higher than the long run target of the Federal Open Market Committee (FOMC) at the first part of the year 2022, they increased the federal fund rate[9] (the effective federal fund rate of May 2022 and June 2022 were 0.76% and 1.19% respectively; the shadow federal fund rates of the same two months were 1.12% and 2.75%). The largest expansionary shock was (-1.11%) in March 2021. Though the effective federal fund rate of February 2021 and March 2021 were 0.08% and 0.07% respectively, but the shadow federal fund rate jumped from -0.47% to -1.56% during this time period.

3.4.2. Beef Price (BP_{it})

The beef price is the monthly cows' meet price (euro/100kg carcass weight) for 21 EU countries collected from the Agridata website of the Directorate-General for Agriculture and Rural Development of the European Commission. The monthly beef prices of 21 EU countries are presented in the Appendix Figure A1. Moreover, the simple average monthly beef prices of those countries are graphed below.

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[9] See https://www.federalreserve.gov/monetarypolicy/2022-06-mpr-summary.htm

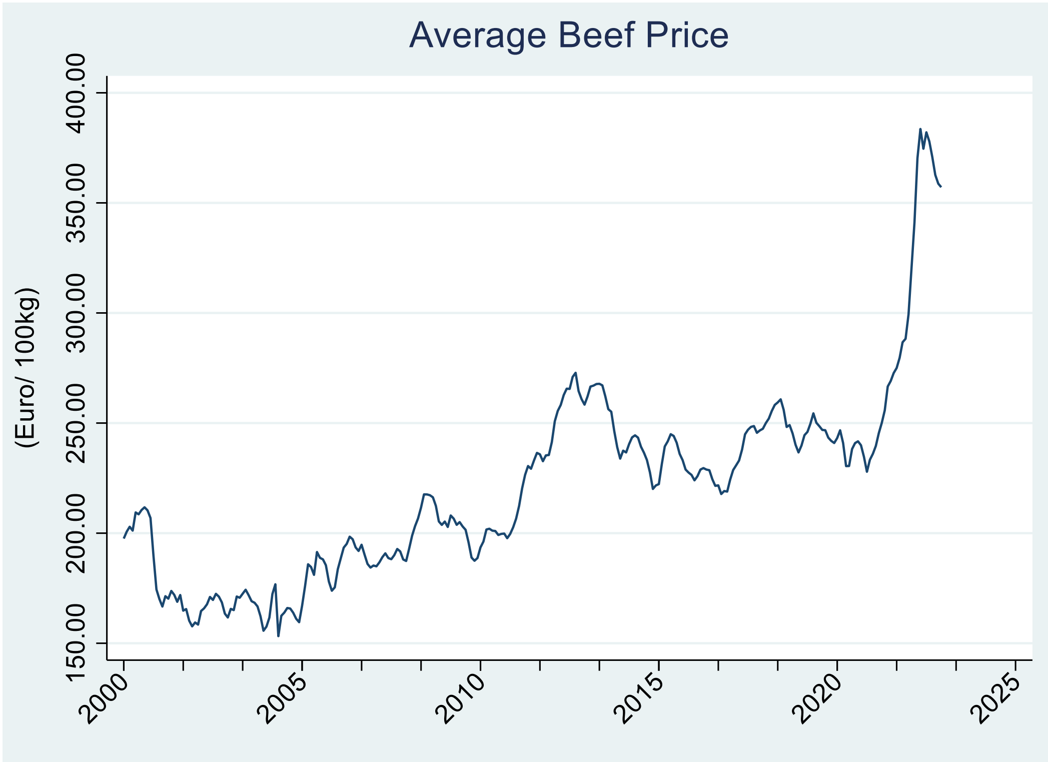

Figure 3.2. Average Monthly Beef price of 21 EU Countries from Jan 2000 to Dec 2022.

We can see an overall upward trend in average monthly beef prices for these 21 EU countries. Most importantly, we can observe a sharp increase in beef prices after the first quarter of 2020 (during the COVID-19 pandemic).

3.4.3. Wheat Price (BWP_{it})

The wheat price is the monthly bread wheat price data (euro/metric ton) for 20 EU countries (the bread wheat price data of the Netherlands is unavailable) collected from the Agridata website of the Directorate-General for Agriculture and Rural Development of the European Commission. The monthly wheat prices of 20 EU countries are presented in the

Appendix Figure A3. Moreover, the simple average monthly wheat prices of those countries are graphed below.

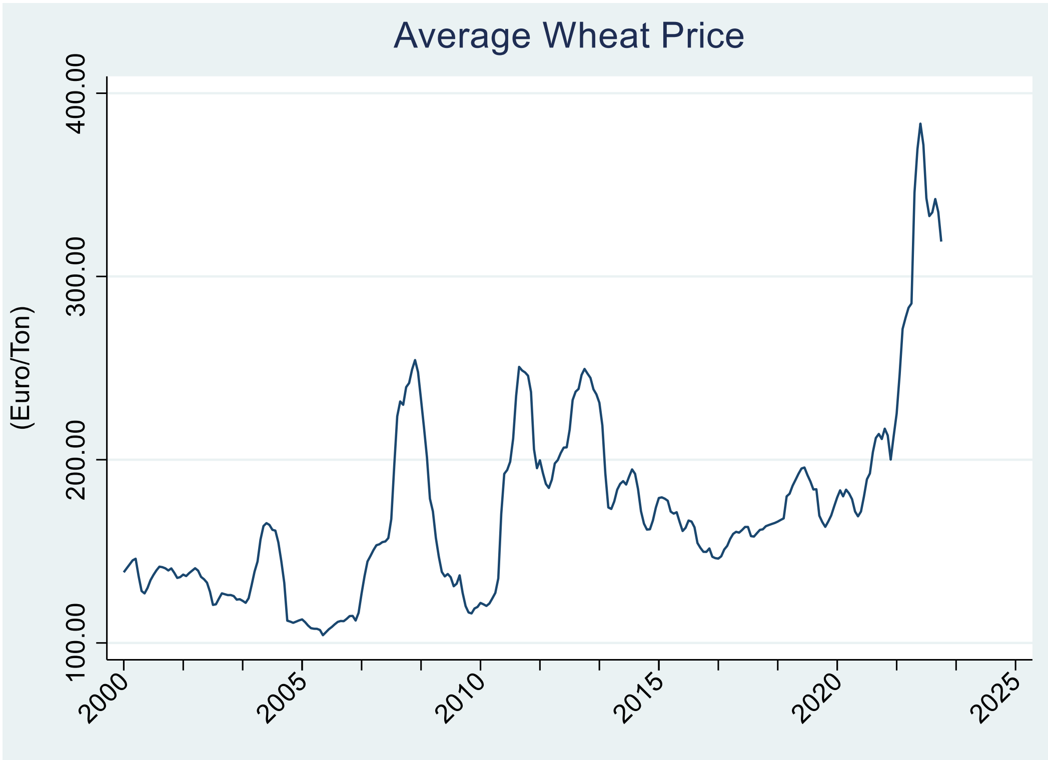

Figure 3.3. Average Monthly Wheat Price of 20 EU Countries from Jan 2000 to Dec 2022.

We cannot see any specific trends for the monthly wheat prices of those countries. However, we can see several ups and downs in bread wheat prices from 2008 to 2015 (world food prices were also unstable during this time period). After 2015, bread wheat prices were less volatile until 2020. After the first quarter of 2020, the bread prices also show a quick increase in every country.

3.4.4. Barley Price (FBP_{it})

The barley price is the monthly feed barley price data (euro/metric ton) for 20 EU countries (the feed barley price data of the Slovenia is unavailable) collected from the Agridata website of the Directorate-General for Agriculture and Rural Development of the European Commission. The monthly barley prices of 20 EU countries are presented in the Appendix Figure A2. Moreover, the simple average monthly barley prices of those countries are graphed below.

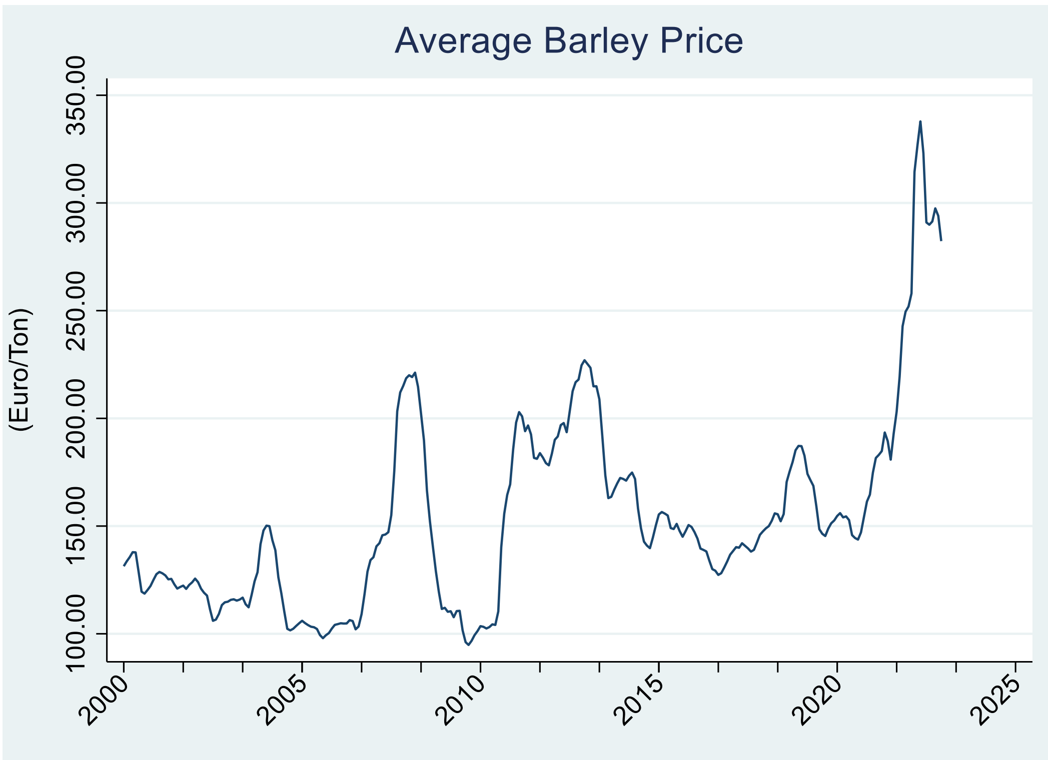

Figure 3.4. Average Monthly Barley Price of 20 EU Countries from Jan 2000 to Dec 2022.

There is no specific trend for average monthly barley price of those countries. But over the time period, we can see volatility in barley prices. The barley prices jump sharply after the first quarter of 2020 as similar as beef prices and wheat prices.

3.4.5. Industrial Production Index (IP_{it})

Industrial production is known as an economic indicator that measures the real output of industries (mining and quarrying, manufacturing, electricity, gas, air conditioning, etc.) compared to a base year. Here, we collect the monthly industrial production index data (base year 2015) for 21 EU countries from Eurostat (see Appendix Figure A4). The average monthly industrial production index of those EU countries is presented below.

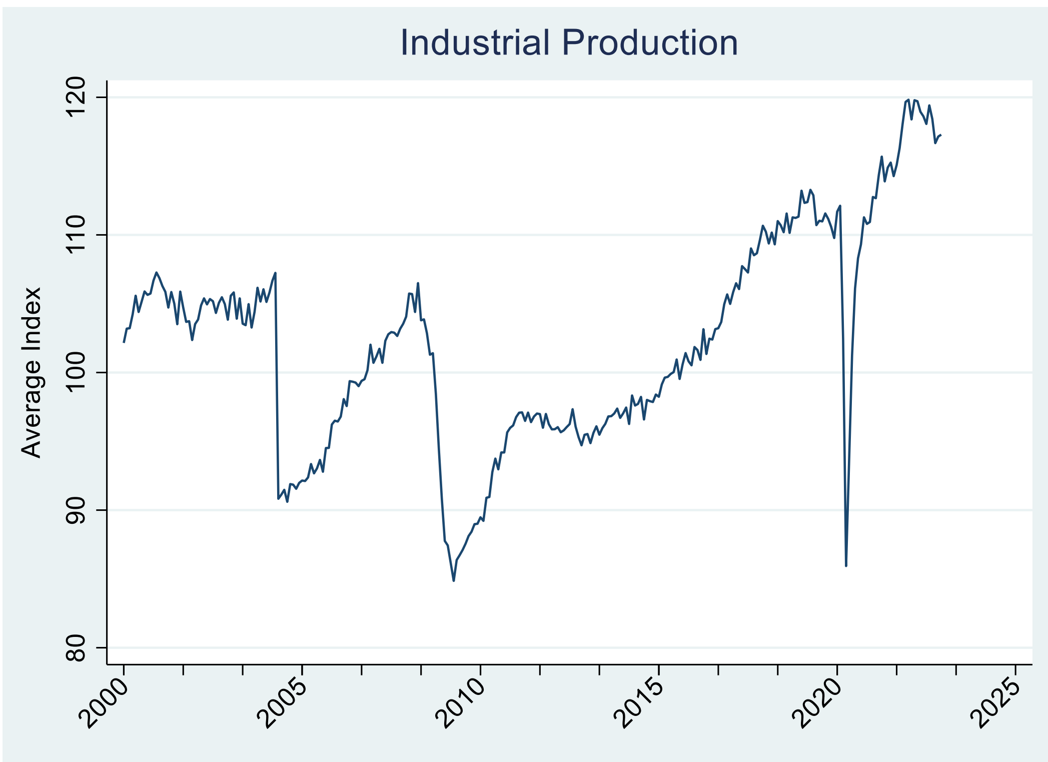

Figure 3.5. Average Monthly Industrial Production Index of 21 EU Countries.

We can see three sharp declines in the average industrial production index of EU during 2004, 2008 and 2020. We can also see a sharp upward spike after the COVID-19 pandemic shock. After 2009, there is an overall upward trend except the COVID-19 pandemic shock.

3.4.6. Inflation (INF_{it})

Monthly inflation rates in percentage, based on a harmonized index of consumer prices, are collected for 21 EU countries from Eurostat (see Appensdix Figure A5). The below graph presents the simple average inflation rates for selected 21 EU countries.

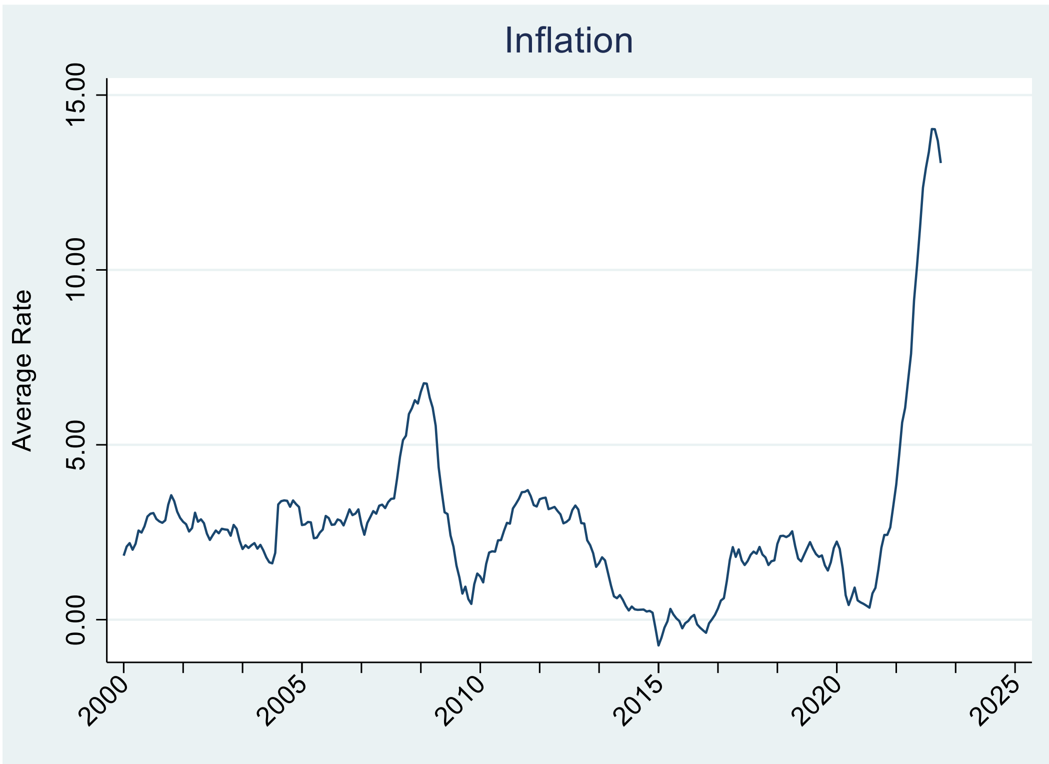

Figure 3.6. Average Monthly Inflation Rate of 21 EU Countries.

From the above figure 3.6., we cannot see any specific trend in the average inflation of these 21 EU countries until 2020. However, we can observe and upward shock in the inflation rate of EU after the COVID-19 pandemic shock in 2020.

3.5. Summary Statistics of the Variables

The summary statistics of the concerned variables are presented below. A table (3.5) presents the number of observations of variables used in this study. Moreover, we also mention the variables' mean value, standard deviation, minimum value, and maximum value.

Table 3.2. Summary Statistics of the Variables.

Variable	Observation	Mean	Standard Deviation	Min	Max
Beef Price	5050	€226.56	€56.65	€78.38 (Slovenia)	€520.38 (Netherlands)
Wheat Price	4766	€177.95	€55.71	€78.95 (Hungary)	€457.85 (Portugal)
Barley Price	4819	€157.91	€50.90	66.61 (Slovakia)	414.19 (Portugal)
Industrial Production Index	5050	102.13	16.16	51.30 (Slovakia)	166.40 (Lithuania)
Inflation	5050	2.66%	3.09%	-4.30 % (Latvia)	25.20% (Estonia)
US Monetary Shocks	276	0.0015%	0.25%	-1.11%	1.43%

Note: Wheat and Barley prices data are collected for 20 EU countries.

From the above table, the average price of beef was €226.56 per 100kg carcass weight. The minimum price of beef was €78.38 per 100kg carcass weight in May 2004 in Slovenia. The maximum price of beef was €520.38 in May 2022 in the Netherlands. The average price of wheat was €177.95 per metric ton. The minimum price of wheat in Hungary was €78.95 per metric ton in August 2005. The maximum price of wheat in Portugal was €457.85 in May 2022. The average price of barley was €157.91 per metric ton. The minimum price of barley was €66.61 per metric ton in September 2005 in Slovakia. The maximum price of barley was €414.19 in May 2022 in Portugal. The mean of industrial production index was 102.13. The minimum value of industrial production index was 51.30 in March 2005 in Slovakia. The maximum value of industrial production index was 166.40 in March 2022 in Lithuania. The average inflation rate is 2.66%. The maximum inflation rate was 25.20 percent in August 2022 in Estonia.

3.6. Model Specification

3.6.1. Econometric Approach

To understand the impact of US monetary shocks on agricultural prices of 21 EU countries, we consider three major agricultural commodity (Beef, Wheat, and Barley) prices and two macroeconomic variables (industrial production growth and inflation) in this study. It is also worth mentioning that US monetary shocks affect EU countries as an exogenous variable (see Bluedorn and Bowdler, 2011). As mentioned earlier, the interdependencies among sectors, markets, and countries and policy spillovers from one country to other countries have been rising since the liberalization of international trade and global financial market integration. Hence, examining endogenous and exogenous economic policy impacts on interdependent economies requires special econometric modeling.

Canova and Ciccarelli (2013) explain two ways of econometric modeling in those particular scenarios. The first method is known as the dynamic stochastic general equilibrium (DSGE) model, where a modeler should fully specify preferences, technologies, and constraints. However, DSGE models need a rigorous process of modeling with imposing lots of restrictions, and these models contradict the statistical properties of data. The other one is the approach of designing Panel Vector Autoregressive (PVAR) Models, which can integrate time variations, static and dynamic interconnections across cross-section units and address heterogeneities. Moreover, a special version of the PVAR model called PVARX(P) of order P (also see Kilian and Vega, 2011; Dees and Guntner, 2017; and Ahiadorme, 2022) allows to incorporate P exogenous variables in econometric research. In this research, we have one exogenous variable (US monetary shocks) and other EU variables (industrial production growth, inflation, and commodity prices), which are assumed to be endogenous initially. The endogeneity of the EU variables is justified by the results Granger-Causality Wald test results in sub-sections 4.2.1, 4.3.1, and 4.4.1. Considering all of the discussions, we can understand that the PVARX(P) model is an appropriate econometric model to achieve the desires objectives of this research.

3.6.2. Econometric Models

A general version of the fixed effects PVARX model from Juodis (2013) is presented below.

$$Y_{i,t} = \eta_i + \Phi Y_{i,t-1} + \Theta X_{i,t} + \varepsilon_{i,t}$$

Here,

$Y_{i,t}$ = (m × 1) Vector of endogenous variables.

$X_{i,t}$ = (k × 1) Vectors of exogenous variables.

Φ = (m × m) Matrix of coefficients of endogenous variables.

Θ = (m × k) Matrix of coefficients of exogenous variables.

η_i = (m × 1) Vector of fixed effects.

ε_{it} = (m × 1) Vector stochastic error term.

i =1,………..,N = Cross section units; t = 1,……….,T = Time periods.

This study is investigating the effects of US monetary shocks on a particular commodity price of EU. Hence, we consider three fixed effects Panel Vector Auto Regressive models

(PVARX (1)) with four lags for three commodity prices (Beef price, Wheat Price, and Barley Price) with one exogenous regressor (US monetary shocks). In each of PVARX(1) models, we include three endogenous variables (two macroeconomic variables and one commodity price) and one exogenous variable. In this study, we do not consider European Central Bank (ECB) monetary policy impact because it is automatically accounted by applying fixed effects Panel Vector Autoregression models. However, it is necessary to test the stationarity of panel variables before running panel regressions to avoid spurious results. So, we run the Im-Pesaran-Shin (IPS) test to check the stationarity of our variables. The results of the IPS tests are presented in the next sub-section.

3.6.3. Im-Pesaran-Shin (IPS) Test Results

Incorporating information from times series and cross-section units, the Im-Pesaran-Shin test (IPS) is known for detecting unit roots in panel data with limited time observations (Im et al., 2003). This test mainly shows the average value of Augmented Dicky-Fuller test statistics from cross section units, is used for dynamic panel models with heterogeneity (Otero, et al., 2005). We run IPS test for all of the used variables used in this study. The null and alternative hypotheses of IPS test are presented below.

H_0 : All panels contain unit roots.

H_a : Some panel are stationary.

Table 3.3. IPS Stationarity Test Results.

Variables	Test Statistics	P-Value	Comments
Beef Price	2.48	0.99	Not Stationary
Growth of Beef Price	-49.93	0.00	Stationary at 1%
Wheat Price	-1.10	0.13	Not Stationary
Growth of Wheat Price	-39.22	0.00	Stationary at 1%
Barley Price	-0.91	0.17	Not Stationary
Growth of Barley Price	-40.34	0.00	Stationary at 1%
Inflation	7.56	1.00	Not Stationary
Industrial Production	0.09	0.53	Not Stationary
Growth of Industrial Production	-64.13	0.00	Stationary at 1%

From the table 3.3., we can see that all three commodity price series and industrial production index are non-stationary at level. On the other hand, the growths (log first differenced) of these three commodity price series and industrial production index are found stationary at 1% level of significance as we can reject the null hypothesis of IPS test. However, inflation is found non-stationary at level. Despite the inflation is found non-stationary, it can be used in vector autoregression model (see Engle and Granger, 1987). Therefore, we finally we use the growth series of the three commodity prices and the growth of industrial production index, and inflation in the main estimation.

4. EMPIRICAL RESULTS AND DISCUSSIONS

4.1. Overview

This chapter presents empirical findings and discussions of regression analysis. Firstly, we portray model-wise estimation results, stability tests, impulse response functions, and Granger Causality Wald test results of three PVARX(1) models. Then, the explanations of estimated results are added.

4.2. Estimation of PVARX(1) with the Growth of Beef Price

Table 4.1. shows the estimation results of PVARX(1) with the beef price considering the variable growth of industrial production, inflation, and growth of beef price in the standard PVAR system with one month-lagged US monetary shocks as the exogenous variable. US monetary shocks have a significant (at 5%) positive impact on the growth of industrial production and beef prices. There is no significant relationship between US monetary shocks and EU inflation. Most importantly, if the US monetary shocks increase by one percentage point, the growth of the beep price of EU countries will be increased by 0.135 percentage points. This result shows that a contractionary monetary policy in the US drives the beep price of EU countries in an upward direction. This study also investigates the nexus between EU beef prices and US monetary shocks through the Impulse response function. Before that, the stability of this PVARX(1) model should be checked to get a reliable impulse response function. The inverse roots of AR characteristic polynomials are used to verify the stability of this model.

Table 4.1. Results of PVARX(1) with Beef Price.

		Dependent Variables		
		Growth of Industrial Production	Inflation	Growth of Beef Price
Lags of the Growth of Industrial Production	L1	-0.198***	-0.00841	0.100**
		(0.0466)	(0.0442)	(0.0461)
	L2	-0.200***	-0.0212	0.0343
		(0.0344)	(0.0455)	(0.0485)
	L3	-0.0957***	-0.0800*	0.0573
		(0.0276)	(0.0448)	(0.0457)
	L4	-0.0914***	0.0108	0.0634
		(0.0245)	(0.0437)	(0.0428)
Lags of Inflation	L1	0.0296	1.163***	0.238**
		(0.0384)	(0.0963)	(0.0951)
	L2	-0.0411**	-0.0953**	-0.116***
		(0.0184)	(0.0407)	(0.0370)
	L3	-0.0251	-0.000511	0.0117
		(0.0165)	(0.0348)	(0.0290)
	L4	-0.00451	-0.110***	-0.0314
		(0.0121)	(0.0234)	(0.0242)
Lags of the Growth of Beef Price	L1	0.0107	0.0496***	0.0264
		(0.0105)	(0.0175)	(0.0363)
	L2	-0.0261***	0.0346**	0.0111
		(0.00927)	(0.0157)	(0.0277)
	L3	-0.00401	0.0130	-0.00418
		(0.00861)	(0.0162)	(0.0240)
	L4	-0.00564	0.0262*	-0.0210
		(0.00908)	(0.0156)	(0.0271)
Lag of US monetary shocks	L1	0.130***	0.0652	0.135**
		(0.0349)	(0.0500)	(0.0555)
Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1				

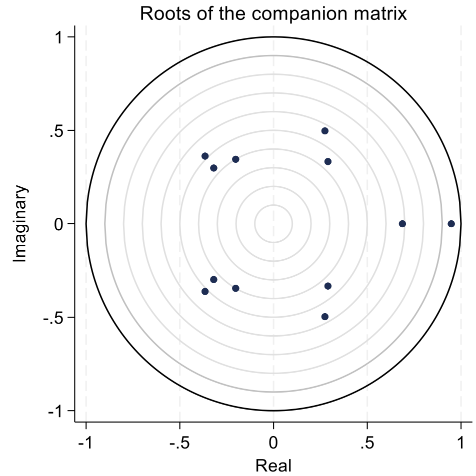

Figure 4.1. Results of Stability Test of PVARX(1) with Beef Price.

From the figure 4.1., we can see that all of the Eigenvalues or all moduli of this PVARX-1 model are found within the unit circle which justifies the stability of this model.

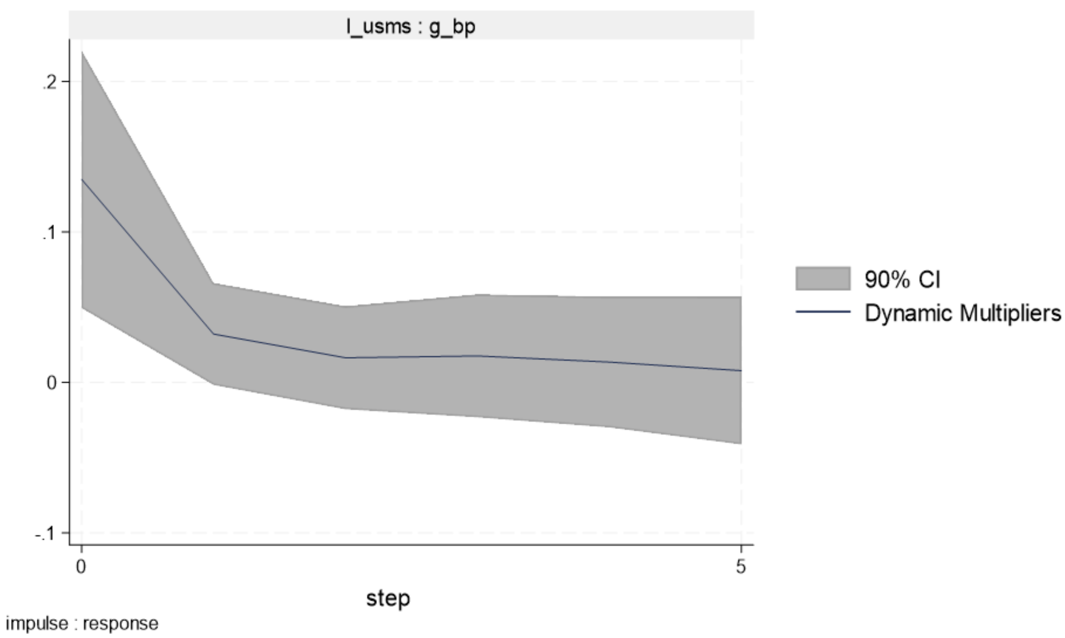

Figure 4.2. Impulse Response Function of the Growth of Beef Price with the Dynamic Multiplier Lagged US Monetary Shocks.

Figure 4.2. represents the impulse response of the growth of EU beef prices with respect to shock in the US monetary policy in a 5-month time period. As the bold color confidence bands are over the horizontal axis, we can reject the null hypothesis (the effects of a shock in one variable on another variable are not significant). So, we can write that beef price shows a significant positive response until a one-month period with respect to one standard deviation shock in the shadow federal fund rate, which also implies that a surprise increase in the federal fund rate leads to an increase in EU beef prices and the beef prices return to equilibrium after this period.

4.2.1. Granger Causality Wald Test Results of PVARX(1) with Beef Price

The null and alternative hypotheses of Panel VAR Granger Causality Wald test are described below.

H_0: Excluded variable does not Granger cause equation variable

H_a: Excluded variable Granger causes equation variable

Table 4.2. Granger Causality Test Results of PVARX(1) with Beef Price.

Null Hypothesis	Chi2	Probability	Decision
Inflation does not Granger cause Industrial Production	63.86	0.00	Bi-directional Causality
Industrial Production does not Granger cause Inflation	8.74	0.06	
Beef Price does not Granger cause Industrial Production	9.86	0.04	Uni-directional Causality
Industrial Production does not Granger cause Beef Price	6.62	0.15	
Beef Price does not Granger cause Inflation	12.29	0.01	Bi-directional Causality
Inflation does not Granger cause Beef Price	21.32	0.00	

Table 4.2. shows the Granger Causality Wald test results of the PVARX(1) model with beef price. In panel vector autoregression analysis, it is usually assumed that variables used in the regression are endogenous. The Granger Causality Wald test can justify the endogeneity by identifying short-run causality among variables (Wilson and Miljkovic, 2013). From the table, we can reject the null hypothesis of this test for 5 cases out of 6 cases. Specifically, there are bi-directional causalities among (growth of industrial production: inflation) and (growth beef price: inflation) at a 7% level of significance and lower, which suggests the eligibility of the endogeneity assumption of this model. However, there is also unidirectional causality between the growth of industrial production and the growth of beef prices.

4.3. Estimation of PVARX(1) with the Growth of Barley Price

Table 4.3. shows the estimation results of PVARX(1) with the barley price considering the variable growth of industrial production, inflation, and growth of barley price in the standard PVAR system with 1-month lagged US monetary shocks as the exogenous variable. Lagged US monetary shocks have a significant positive impact on the growth of industrial production and inflation at 1% and 10% levels, respectively. In addition, lagged US monetary shocks affect the growth of barley prices negatively at a 1% level of significance. Specifically, if the lagged US monetary shocks increase by one percentage point, the growth of feed barley prices in EU countries will be decreased by 0.236 percentage points. This result shows that a contractionary monetary policy in the US lowers the barley price of EU countries. This study also investigates the nexus between the growth of barley prices and lagged US monetary shocks through the Impulse response function with a dynamic multiplier. Before that, the stability of this PVARX(1) model is checked through the inverse roots of the AR characteristic polynomial.

Table 4.3. Results of PVARX(1) with Barley Price.

		Dependent Variables		
		Growth of Industrial Production	Inflation	Growth of Barley Price
Lags of the Growth of Industrial Production	L1	-0.175***	-0.00642	0.0705
		(0.0502)	(0.0441)	(0.0471)
	L2	-0.190***	0.00124	0.0960**
		(0.0368)	(0.0452)	(0.0483)
	L3	-0.115***	-0.0724*	0.0786*
		(0.0279)	(0.0421)	(0.0474)
	L4	-0.0828***	0.0223	0.0957**
		(0.0251)	(0.0417)	(0.0457)
Lags of Inflation	L1	0.0168	1.180***	0.0345
		(0.0373)	(0.0963)	(0.0964)
	L2	-0.0328*	-0.0825**	-0.0115
		(0.0179)	(0.0410)	(0.0412)
	L3	-0.0229	-0.0102	-0.00929
		(0.0169)	(0.0364)	(0.0368)
	L4	0.00173	-0.107***	-0.0305
		(0.0120)	(0.0240)	(0.0248)
Lags of the Growth of Barley Price	L1	0.0211**	0.0413*	0.236***
		(0.0100)	(0.0228)	(0.0296)
	L2	0.00641	0.0365**	-0.00347
		(0.00786)	(0.0150)	(0.0197)
	L3	0.0242***	0.0366***	0.0215
		(0.00743)	(0.0141)	(0.0179)
	L4	0.0107	0.0275**	-0.000558
		(0.00678)	(0.0132)	(0.0164)
Lag of US monetary shocks	L1	0.144***	0.0962*	-0.236***
		(0.0357)	(0.0531)	(0.0640)
Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1				

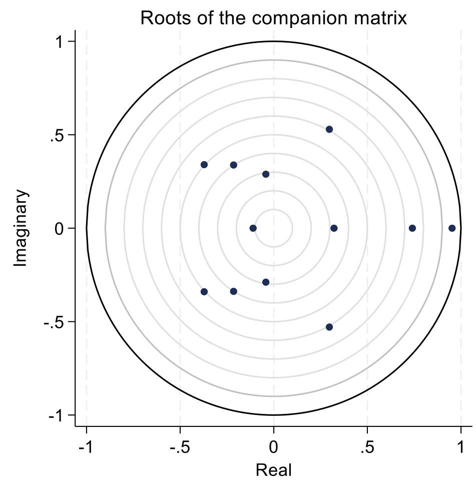

Figure 4.3. Results of Stability Test of PVARX(1) with Barley Price.

From the figure 4.3., we can see that all of the Eigenvalues or all moduli of this PVARX(1) model are found within the unit circle which justifies the stability of this model.

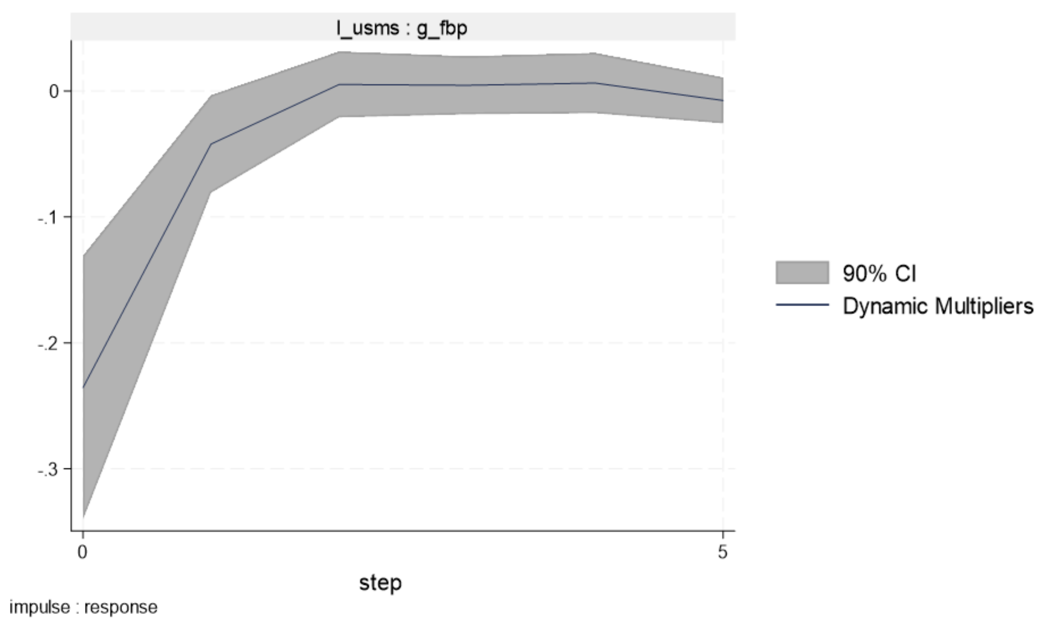

Figure 4.4. Impulse Response Function of the Growth of Barley Price with the Dynamic Multiplier Lagged US Monetary Shocks.

The above figure 4.4. represents the impulse response of barley prices with respect to a shock in the US monetary policy in a 5-month time period. Most importantly, the barley prices of the EU show a significant negative response until the 1-month period with respect to one standard deviation shock in the federal fund rate, which also implies that a surprise increase in the federal fund rate leads to a decrease in the barley prices of the EU and the barley prices return to equilibrium after this period. Analogously, an expansionary monetary shock in the US raises barley prices in the EU.

4.3.1. Granger Causality Wald Test Results of PVARX(1) with Barley Price

The null and alternative hypotheses of Panel VAR Granger Causality Wald test are described below.

H_0: Excluded variable does not Granger cause equation variable

H_a: Excluded variable Granger causes equation variable

Table 4.4. Granger Causality Test Results of PVARX(1) with Barley Price.

Null Hypothesis	Chi2	Probability	Decision
Inflation does not Granger cause Industrial Production	41.32	0.00	Bi-directional Causality
Industrial Production does not Granger cause Inflation	9.24	0.05	
Barley Price does not Granger cause Industrial Production	16.83	0.00	Uni-directional Causality
Industrial Production does not Granger cause Barley Price	4.85	0.30	
Barley Price does not Granger cause Inflation	19.18	0.00	Bi-directional Causality
Inflation does not Granger cause Barley Price	9.38	0.05	

Table 4.4. shows the Granger Causality Wald test results of the PVARX(1) model with the barley price**.** From the table, we can reject the null hypothesis of this test for 5 cases out of 6 cases. Specifically, there are bi-directional causalities among (growth of industrial production: inflation) and (growth of barley price and inflation) at a 6% level of significance and lower, which suggests the eligibility of the endogeneity assumption of this PVARX(1) model. However, there is also unidirectional causality between the growth of industrial production and the growth of barley prices.

4.4. Estimation of PVARX(1) with the Growth of Wheat Price

Table 4.5. shows the estimation results of PVARX(1) with wheat price considering the growth of industrial production, inflation, and the growth of wheat price in the standard PVAR system with 1-month lagged US monetary shocks as the exogenous variable. US monetary shocks have a significant positive impact on the growth of industrial production and inflation at 1% and 5% levels, respectively. Moreover, US monetary shocks affect the growth of wheat prices negatively at a 1% level of significance. Specifically, if the lagged US monetary shocks increase by one percentage point, the growth of wheat prices in EU countries will be decreased by 0.204 percentage points. This result shows that a contractionary monetary policy in the US lowers the wheat prices of EU countries. This study also investigates the nexus between wheat price and the US monetary shocks through the Granger Causality test and Impulse response function. Before that, the stability of this PVARX(1) model is checked through the inverse roots of the AR characteristic polynomial.

Table 4.5. Results of PVARX(1) with Wheat Price.

		Dependent Variables		
		Growth of Industrial Production	Inflation	Growth of Wheat Price
Lags of the Growth of Industrial Production	L1	-0.191***	-6.42e-05	0.0689*
		(0.0480)	(0.0388)	(0.0419)
	L2	-0.200***	-0.0121	0.0810*
		(0.0354)	(0.0390)	(0.0443)
	L3	-0.0945***	-0.0848**	0.109**
		(0.0276)	(0.0385)	(0.0427)
	L4	-0.0950***	0.00198	0.118***
		(0.0240)	(0.0359)	(0.0411)
Lags of Inflation	L1	0.0263	1.154***	0.0980
		(0.0352)	(0.0798)	(0.0895)
	L2	-0.0364**	-0.0694*	-0.0731*
		(0.0185)	(0.0371)	(0.0431)
	L3	-0.0311*	0.00145	0.0111
		(0.0174)	(0.0324)	(0.0370)
	L4	0.00403	-0.116***	-0.0254
		(0.0121)	(0.0223)	(0.0262)
Lags of the Growth of Wheat Price	L1	0.0206*	0.0617***	0.288***
		(0.0106)	(0.0204)	(0.0272)
	L2	0.00751	0.0408***	-0.0103
		(0.00831)	(0.0143)	(0.0182)
	L3	0.00874	0.0339***	-0.0120
		(0.00727)	(0.0126)	(0.0158)
	L4	0.0108	0.00857	0.0318*
		(0.00748)	(0.0115)	(0.0166)
Lag of US monetary shocks	L1	0.144***	0.103**	**-0.204*** **
		(0.0373)	(0.0483)	(0.0591)
Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1				

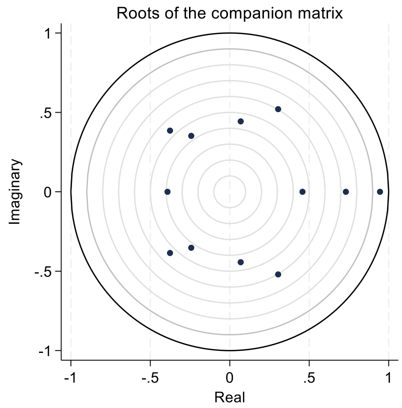

Figure 4.5. Results of Stability Test of PVARX(1) with Wheat Price.

From the figure 4.5., we can see that all of the Eigenvalues or all moduli of this PVARX(1) model are found within the unit circle which justifies the stability of this model.

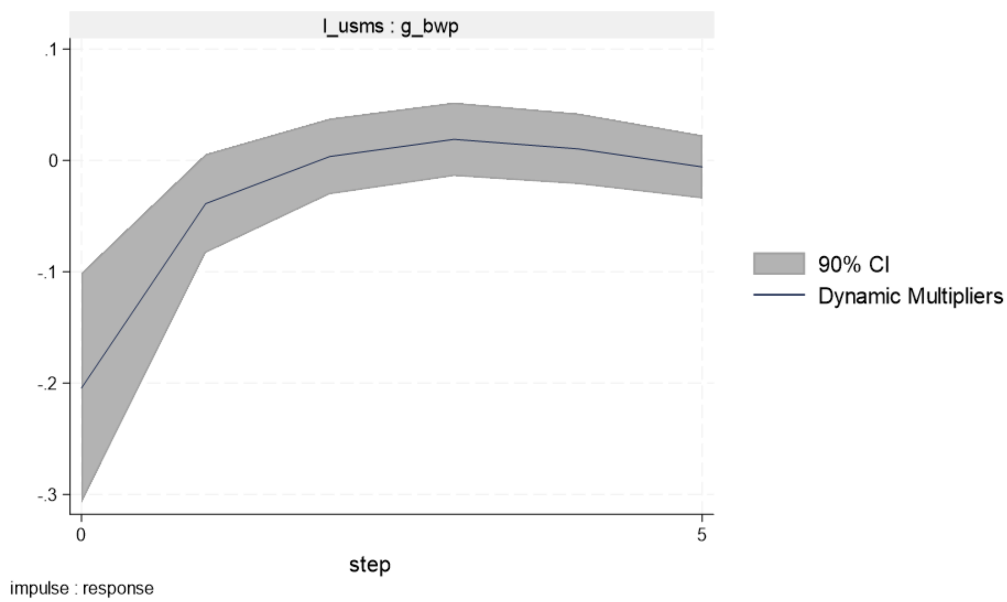

Figure 4.6. Impulse Response Function of the Growth of Wheat Price with the Dynamic Multiplier Lagged US Monetary Shocks.

Figure 4.6. represents the impulse response of wheat price with respect to a shock in the US federal fund rate in a 5-month time period. Most importantly, the wheat price of the EU shows a significant negative response until the one month with respect to one standard deviation shock in the federal fund rate, which also implies that a surprise increase in the federal fund rate leads to a decrease in the bread wheat prices of the EU and the wheat prices come back to equilibrium after this period. Analogously, an expansionary monetary shock in the US raises wheat prices in the EU.

4.4.1. Granger Causality Wald Test Results of PVARX(1) with Wheat Price

The null and alternative hypotheses of Panel VAR Granger Causality Wald test are described below.

H_0: Excluded variable does not Granger cause equation variable

Ha: Excluded variable Granger causes equation variable

Table 4.6. Granger Causality Test Results of PVARX(1) with Wheat Price.

Null Hypothesis	Chi^2	Probability	Decision
Inflation does not Granger cause Industrial Production	46.17	0.00	Bi-directional Causality
Industrial Production does not Granger cause Inflation	10.22	0.03	
Wheat Price does not Granger cause Industrial Production	7.79	0.09	Bi-directional Causality
Industrial Production does not Granger cause Wheat Price	10.01	0.04	
Wheat Price does not Granger cause Inflation	22.47	0.00	Bi-directional Causality
Inflation does not Granger cause Wheat Price	9.73	0.00	

Table 4.6. shows the Granger Causality Wald test results of the PVARX(1) model with the wheat price of the EU. From the table, we can reject the null hypothesis of this test for all 6 cases. Specifically, there are bi-directional causalities among all pairs of these variables at a 10% level of significance and lower, which suggests the eligibility of the endogeneity assumption of this model.

4.5. Comparative Discussions on Estimated Results

Considering the estimated results of our three PVARX(1) models, we can see the heterogeneous impacts of US monetary shocks on European agricultural commodity prices. These heterogeneous impacts of US monetary policy on domestic and internationally traded commodities are supported by previous literature (see, for example, Saghaian and Reed, 2014; Saghaian and Reed, 2015; and Amatov and Dorfman, 2017). Specifically, in our case, we find that monetary contraction in the US leads to a decrease in wheat and barley prices and an increase in beef prices in the EU and vice versa. Is this result economically justifiable?

To answer this question, we should take a look again at Saghaian and Reed (2014). They say expansionary monetary policy depreciates the overall value of the US dollar, which leads to an increase in its demand internationally and raises the price of internationally traded goods as commodities mostly traded in US dollars. They also mention that the movement of agricultural commodity prices depends on its nature. In particular, storable commodity prices tend to increase due to the low cost of inventories for prevailing low-interest rates in the time of monetary expansion (Frankel, 2008).

As the EU is one the largest trading regions (it had a 14.1% share of world exports and a 13.5% share of world imports in 2021, according to Eurostat[10]), the EU's commodity trading market has direct spillover from US monetary changes (see Georgiadis, 2016). According to the International Grains Council (IGC), the EU and the US are the second and third largest exporters, respectively, of the world wheat market and the first and seventh largest producers, respectively, of the world barley market. So, monetary expansion in the US induces US producers to store wheat and barley for a while to get better price (Saghaian and Reed, 2014), then the demand for EU wheat and barley tends to increase and ultimately leads to a higher price. However, beef is not a storable commodity, and the EU is mostly self-sufficient in beef (they import 8% of their consumed beef from outside and export 8-10% of their produced beef, European Parliament, 2022). Additionally, Saghaian and Reed (2014) find the heterogeneous impact on US beef prices of the Fed's first quantitative easing (2008 and 2010) and second quantitative easing (2010-2011). Glick and Leduc (2011) also find negative impacts on US domestic beef prices due to expansionary monetary policy (during the Fed's first quantitative easing).

4.6. Robustness of the Estimated Results

We check the robustness of our estimated results in a few steps. Firstly, we run three standard VARX models with aggregated EU (27 countries) growth of industrial production, inflation, and one commodity price series (from beef price, barley price, and wheat price) with one month-lagged US monetary shocks as an exogenous variable (see Appendix Table A1-3).

[10] See https://ec.europa.eu/eurostat/statistics-explained/index.php?title=USA-EU_-_international_trade_in_goods_statistics

We find similar signs of the coefficients of lagged US monetary shocks for beef price, barley price, and wheat price. Though the positive relationship between beef price and US monetary is found insignificant, the negative relationships between barley price and wheat price with the US monetary shocks are found significant in the SVARs.

Secondly, we run all of our PVARX(1) models without COVID-19 pandemic shocks (See Appendix Table A4-6), considering the time period until December 2019. Again, we find similar signs of the coefficients of lagged US monetary shocks for the beef price, barley price, and wheat price; the levels of significance are 12%, 1%, and 1%, respectively.

Thirdly, we consider the maize price of the EU for a similar PVARX(1) estimation. It is a less traded commodity (the world's 2593rd most traded product and the amount of world maize trade in 2022 is $693 million, and the EU does not have the dominant share in the world market)[11]. We do not find any significant impact of US monetary shocks on EU maize prices. This result (see Appendix Table A7) could make sense that the products, (Beef:162nd most traded product and the amount of trade is $ 29.2 billion in 2022; Wheat: 49th most traded product and the amount of trade is $ 73.3 billion in 2022; Barley: 374th most traded product and the amount of trade is $10.4 billion in 2022[12]) are internationally traded in large quantity and have significant importance among EU consumers and producers, have significant spillover for US monetary shocks.

Furthermore, some of the past literature considers the M1 US money supply as the representative of US monetary policy to study the monetary shocks and agricultural prices. So,

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[11] See https://oec.world/en/profile/hs/maize-corn-flour

[12] See for Beef https://oec.world/en/profile/hs/bovine-meat
See for Wheat https://oec.world/en/profile/hs/wheat
See for Barley https://oec.world/en/profile/hs/barley-2100300

we derive shock in the growth of M1 US money supply by following the same process of our previous shock identification, and we estimate all of our three PVARX(1) models by using the shock in the growth of M1 US money supply in lieu of the shock in shadow federal fund rate. We find that the shock in M1 US money supply growths does not have a significant impact on EU beef prices (see Appendix Table A8), but it has a positive impact on EU wheat and barley prices (see Appendix Table A9-10), which implies an expansionary monetary policy in the US raises wheat and barley prices in EU and vice versa. We also checked all of our PVARX(1) models with six lags, and we find consistent impacts of US monetary shocks on EU beef, wheat, and barley prices for the data until 2019 and 2022.

5. CONCLUSION AND POLICY RECOMMENDATIONS

The US economy plays an important role in the global financial network due to its large share in international trade and the wide acceptance of its currency (dollar) in foreign exchange transactions. Similarly, US monetary policies have spillover to the global economy through numerous channels. In fact, any shock in the US monetary policy creates uncertainties in the world market, especially in agricultural commodity prices, because of their tendency to overshoot. Hence, this study aims to identify the nexus between the shocks in the US monetary policy and the agricultural prices of the EU. For this purpose, we collect the monthly data of major three agricultural prices (Beef, Wheat, and Barley) of 21 countries from the EU. We also consider two macro variables (growth of industrial production index and inflation) of these countries to achieve the objectives of this study.

Firstly, we estimate the US monetary shocks as the residuals of a regression in which we regress the shadow federal fund rate on the US industrial production growth and inflation rate. Then, we run the IPS panel unit root tests for all concerned variables to check the stationarity and to avoid spurious results. Finally, we estimate three Panel Vector Autoregression Models with an exogenous variable (PVARX(1)) for three EU agricultural prices. The estimated results of these three PVARX(1) models justify that the shocks in the US monetary policy have a significant impact on EU agricultural prices.

Specifically, we find that a contractionary monetary policy in the US decreases domestic prices of wheat and barley in the EU and increases beef prices in the EU. We also utilize the dynamic multiplier effects on these agricultural prices. From their impulse response functions, we see that due to a shock in the US monetary policy, they overshoot heterogeneously after one month, and they go back to their equilibrium prices after two months. By applying different estimation methods and proxy variables, we ensure the robustness of our results, though past literature shows similar types of effects of US monetary policies on agricultural prices in the US and other countries. So, we can suggest that EU countries should carefully look at the movement of US monetary policy when implementing any agricultural policies in order to maintain stability in their agricultural market. Furthermore, future research can expand on these results by incorporating more agricultural prices and other US trading partners.

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APPENDIX

Table A1. Results of SVARX(1) with Aggregated Beef Price of EU.

		Dependent Variables		
		Growth of Industrial Production EU	Inflation EU	Growth of Beef Price EU
Lags of the Growth of Industrial Production EU	L1	0.0628	0.0444	-0.0250
		(0.0618)	(0.0662)	(0.0734)
	L2	-0.245***	-0.0168	-0.0931
		(0.0616)	(0.0660)	(0.0732)
	L3	-0.0311	-0.00522	-0.0208
		(0.0618)	(0.0662)	(0.0734)
	L4	-0.0360	0.173***	0.00130
		(0.0607)	(0.0650)	(0.0721)
Lags of Inflation EU	L1	0.0876	1.305***	0.0161
		(0.0577)	(0.0618)	(0.0685)
	L2	-0.0650	-0.209**	0.00470
		(0.0929)	(0.0996)	(0.110)
	L3	-0.0180	-0.0738	0.0653
		(0.0946)	(0.101)	(0.112)
	L4	-0.0114	-0.0202	-0.0816
		(0.0605)	(0.0648)	(0.0718)
Lags of the Growth of Beef Price EU	L1	0.0541	0.154***	0.552***
		(0.0513)	(0.0549)	(0.0609)
	L2	-0.0813	0.0705	0.00191
		(0.0586)	(0.0628)	(0.0696)
	L3	0.0168	-0.110*	-0.105
		(0.0595)	(0.0637)	(0.0706)
	L4	0.0192	0.0381	-0.141**
		(0.0525)	(0.0562)	(0.0623)
Lag of US monetary shocks	L1	0.112*	-0.00746	0.0520
		(0.0586)	(0.0627)	(0.0695)
Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1				

Table A2. Results of SVARX(1) with Aggregated Barley Price of EU.

		Dependent Variables		
		Growth of Industrial Production EU	Inflation EU	Growth of Barley Price EU
Lags of the Growth of Industrial Production EU	L1	0.0645	0.0621	0.131
		(0.0610)	(0.0663)	(0.107)
	L2	-0.260***	-0.00958	0.102
		(0.0612)	(0.0666)	(0.108)
	L3	-0.0398	-0.0280	0.211*
		(0.0614)	(0.0668)	(0.108)
	L4	-0.0476	0.152**	0.123
		(0.0609)	(0.0663)	(0.107)
Lags of Inflation EU	L1	0.0528	1.322***	-0.0349
		(0.0584)	(0.0635)	(0.103)
	L2	-0.0482	-0.262**	-0.0308
		(0.0956)	(0.104)	(0.168)
	L3	0.00577	-0.0538	0.0408
		(0.0969)	(0.105)	(0.171)
	L4	-0.0166	-0.00221	0.0283
		(0.0603)	(0.0655)	(0.106)
Lags of the Growth of Barley Price EU	L1	0.0440	-0.00356	0.651***
		(0.0356)	(0.0388)	(0.0627)
	L2	0.00447	0.0747	-0.159**
		(0.0425)	(0.0462)	(0.0748)
	L3	0.0211	-0.0175	0.00392
		(0.0424)	(0.0462)	(0.0747)
	L4	0.00643	0.0607	0.0684
		(0.0347)	(0.0377)	(0.0610)
Lag of US monetary shocks	L1	0.135**	-0.0193	-0.170*
		(0.0587)	(0.0639)	(0.103)
Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1				

Table A3. Results of SVARX(1) with Aggregated Wheat Price of EU.

		Dependent Variables		
		Growth of Industrial Production EU	Inflation EU	Growth of Wheat Price EU
Lags of the Growth of Industrial Production EU	L1	0.0663	0.0613	0.0554
		(0.0610)	(0.0665)	(0.112)
	L2	-0.257***	-0.00630	0.117
		(0.0611)	(0.0666)	(0.112)
	L3	-0.0373	-0.0200	0.203*
		(0.0614)	(0.0669)	(0.113)
	L4	-0.0427	0.156**	0.138
		(0.0608)	(0.0662)	(0.112)
Lags of Inflation EU	L1	0.0522	1.324***	0.00218
		(0.0581)	(0.0633)	(0.107)
	L2	-0.0446	-0.261**	-0.0941
		(0.0952)	(0.104)	(0.175)
	L3	0.000792	-0.0541	0.0185
		(0.0964)	(0.105)	(0.177)
	L4	-0.0147	-0.00630	0.0785
		(0.0600)	(0.0654)	(0.110)
Lags of the Growth of Wheat Price EU	L1	0.0420	0.00104	0.620***
		(0.0334)	(0.0364)	(0.0614)
	L2	-0.00297	0.0807*	-0.113
		(0.0395)	(0.0430)	(0.0725)
	L3	0.0310	-0.0150	-0.0306
		(0.0396)	(0.0432)	(0.0728)
	L4	0.00153	0.0315	0.0987
		(0.0331)	(0.0360)	(0.0608)
Lag of US monetary shocks	L1	0.133**	-0.0134	-0.237**
		(0.0584)	(0.0636)	(0.107)
Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1				

Table A4. Results of PVARX(1) with Beef Price (until 2019).

		Dependent Variables		
		Growth of Industrial Production	Inflation	Growth of Beef Price
Lags of the Growth of Industrial Production	L1	-0.383***	0.0697**	0.0415
		(0.0267)	(0.0309)	(0.0286)
	L2	-0.107***	0.123***	0.0205
		(0.0234)	(0.0314)	(0.0304)
	L3	0.0641***	0.0760**	0.0837***
		(0.0210)	(0.0332)	(0.0307)
	L4	0.0215	0.110***	0.0559*
		(0.0183)	(0.0273)	(0.0303)
Lags of Inflation	L1	0.0558***	1.128***	0.0459**
		(0.0116)	(0.0190)	(0.0190)
	L2	-0.0342**	-0.0852***	-0.0610**
		(0.0167)	(0.0267)	(0.0282)
	L3	0.00765	0.00390	0.0492*
		(0.0163)	(0.0260)	(0.0268)
	L4	-0.0405***	-0.0763***	-0.0149
		(0.0112)	(0.0191)	(0.0189)
Lags of the Growth of Beef Price	L1	-0.00168	0.0426***	-0.0238
		(0.00802)	(0.0134)	(0.0349)
	L2	-0.0150*	0.0278**	0.0260
		(0.00787)	(0.0135)	(0.0256)
	L3	0.00825	-0.000835	-0.0219
		(0.00804)	(0.0132)	(0.0228)
	L4	-0.00364	0.00458	-0.0397
		(0.00808)	(0.0137)	(0.0285)
Lag of US monetary shocks	L1	0.0607***	-0.103***	0.0672
		(0.0230)	(0.0356)	(0.0434)
Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1				

Table A5. Results of PVARX(1) with Wheat Price (until 2019).

		Dependent Variables		
		Growth of Industrial Production	Inflation	Growth of Wheat Price
Lags of the Growth of Industrial Production	L1	-0.401***	0.0563*	0.150***
		(0.0280)	(0.0324)	(0.0426)
	L2	-0.114***	0.0996***	0.139***
		(0.0245)	(0.0333)	(0.0509)
	L3	0.0644***	0.0499	0.135**
		(0.0219)	(0.0355)	(0.0526)
	L4	0.0153	0.0875***	0.0873*
		(0.0187)	(0.0284)	(0.0451)
Lags of Inflation	L1	0.0452***	1.116***	0.0404
		(0.0119)	(0.0193)	(0.0348)
	L2	-0.0319*	-0.0833***	-0.0458
		(0.0172)	(0.0272)	(0.0455)
	L3	0.00904	0.00771	0.00232
		(0.0167)	(0.0266)	(0.0369)
	L4	-0.0342***	-0.0683***	-0.00640
		(0.0111)	(0.0193)	(0.0270)
Lags of the Growth of Wheat Price	L1	0.0193***	0.0602***	0.296***
		(0.00691)	(0.0109)	(0.0234)
	L2	0.0195***	0.0343***	-0.0148
		(0.00720)	(0.0112)	(0.0186)
	L3	0.0181**	0.0336***	0.00417
		(0.00710)	(0.0110)	(0.0159)
	L4	0.0134*	0.0214**	0.0526***
		(0.00734)	(0.0107)	(0.0170)
Lag of US monetary shocks	L1	0.0879***	-0.0578	-0.278***
		(0.0233)	(0.0368)	(0.0569)
Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1				

Table A6. Results of PVARX(1) with Barley Price (until 2019).

		Dependent Variables		
		Growth of Industrial Production	Inflation	Growth of Barley Price
Lags of the Growth of Industrial Production	L1	-0.372***	0.0385	0.109**
		(0.0270)	(0.0325)	(0.0444)
	L2	-0.106***	0.0987***	0.122**
		(0.0237)	(0.0322)	(0.0522)
	L3	0.0167	0.0456	0.0863
		(0.0209)	(0.0340)	(0.0529)
	L4	0.0131	0.0972***	0.0896**
		(0.0182)	(0.0278)	(0.0440)
Lags of Inflation	L1	0.0387***	1.109***	0.0207
		(0.0111)	(0.0194)	(0.0298)
	L2	-0.0224	-0.0572**	-0.0156
		(0.0164)	(0.0272)	(0.0414)
	L3	0.00742	-0.00988	0.0180
		(0.0166)	(0.0263)	(0.0393)
	L4	-0.0351***	-0.0704***	-0.0325
		(0.0110)	(0.0190)	(0.0276)
Lags of the Growth of Barley Price	L1	0.0249***	0.0433***	0.261***
		(0.00638)	(0.0112)	(0.0240)
	L2	0.0144**	0.0475***	0.00612
		(0.00671)	(0.0108)	(0.0209)
	L3	0.0335***	0.0341***	0.0393**
		(0.00738)	(0.0111)	(0.0174)
	L4	0.0105	0.0269**	0.0182
		(0.00709)	(0.0117)	(0.0171)
Lag of US monetary shocks	L1	0.0796***	-0.0648*	-0.246***
		(0.0224)	(0.0356)	(0.0566)
Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1				

Table A7. Results of PVARX(1) of Maize Price.

		Dependent Variables		
		Growth of Industrial Production	Inflation	Growth of Maize Price
Lags of the Growth of Industrial Production	L1	-0.197***	-0.0659	0.0398
		(0.0577)	(0.0784)	(0.0762)
	L2	-0.205***	-0.0632	0.0355
		(0.0449)	(0.0790)	(0.0819)
	L3	-0.110***	-0.134*	0.0643
		(0.0364)	(0.0743)	(0.0729)
	L4	-0.111***	-0.0385	0.0712
		(0.0341)	(0.0722)	(0.0791)
Lags of Inflation	L1	0.0238	1.002***	0.174
		(0.0693)	(0.169)	(0.181)
	L2	-0.0453*	-0.0724	-0.114**
		(0.0232)	(0.0529)	(0.0569)
	L3	-0.0329*	-0.0109	-0.0352
		(0.0183)	(0.0400)	(0.0384)
	L4	0.00890	-0.0619**	0.00317
		(0.0128)	(0.0261)	(0.0262)
Lags of the Growth of Maize Price	L1	0.00912	-0.0273	0.278***
		(0.0167)	(0.0394)	(0.0460)
	L2	0.00711	0.0309	-0.0245
		(0.0117)	(0.0269)	(0.0301)
	L3	0.0230**	0.0206	0.00181
		(0.0101)	(0.0191)	(0.0197)
	L4	0.0149*	0.00442	-0.0154
		(0.00904)	(0.0157)	(0.0154)
Lag of US monetary shocks	L1	0.148***	0.0313	-0.0630
		(0.0455)	(0.0810)	(0.0856)
Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1				

Table A8. Results of PVARX(1) with Beef Price (Using the shocks in the growth of M1 US money supply).

		Dependent Variables		
		Growth of Industrial Production	Inflation	Growth of Beef Price
Lags of the Growth of Industrial Production	L1	-0.220***	-0.0261	0.0807**
		(0.0461)	(0.0389)	(0.0384)
	L2	-0.188***	0.000382	0.0373
		(0.0345)	(0.0515)	(0.0500)
	L3	-0.0940***	-0.0695	0.0529
		(0.0277)	(0.0472)	(0.0448)
	L4	-0.101***	0.00873	0.0516
		(0.0233)	(0.0423)	(0.0390)
Lags of Inflation	L1	0.00589	1.157***	0.209**
		(0.0384)	(0.0916)	(0.0861)
	L2	-0.0301*	-0.0889**	-0.105***
		(0.0182)	(0.0395)	(0.0335)
	L3	-0.0315*	-0.00600	0.00656
		(0.0169)	(0.0353)	(0.0274)
	L4	0.00219	-0.106***	-0.0246
		(0.0124)	(0.0229)	(0.0223)
Lags of the Growth of Beef Price	L1	0.00702	0.0484***	0.0222
		(0.0108)	(0.0172)	(0.0356)
	L2	-0.0256***	0.0359**	0.0109
		(0.00970)	(0.0157)	(0.0271)
	L3	-0.000883	0.0150	-0.00124
		(0.00872)	(0.0161)	(0.0235)
	L4	-0.00513	0.0263*	-0.0203
		(0.00929)	(0.0155)	(0.0266)
Lag of US monetary shocks	L1	0.00154***	0.00161**	0.00106
		(0.000382)	(0.000684)	(0.000771)
Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1				

Table A9. Results of PVARX(1) with Wheat Price (Using the shocks in the growth of M1 US money supply).

		Dependent Variables		
		Growth of Industrial Production	Inflation	Growth of Wheat Price
Lags of the Growth of Industrial Production	L1	-0.214***	-0.0184	0.0616
		(0.0479)	(0.0354)	(0.0417)
	L2	-0.184***	0.00263	0.151***
		(0.0348)	(0.0436)	(0.0531)
	L3	-0.0900***	-0.0796**	0.159***
		(0.0269)	(0.0406)	(0.0470)
	L4	-0.102***	-0.00243	0.143***
		(0.0222)	(0.0352)	(0.0429)
Lags of Inflation	L1	0.00732	1.141***	0.160*
		(0.0342)	(0.0759)	(0.0917)
	L2	-0.0264	-0.0620*	-0.0805*
		(0.0183)	(0.0359)	(0.0440)
	L3	-0.0388**	-0.00469	0.00733
		(0.0176)	(0.0324)	(0.0401)
	L4	0.00910	-0.112***	-0.0346
		(0.0123)	(0.0221)	(0.0276)
Lags of the Growth of Wheat Price	L1	0.0112	0.0552***	0.305***
		(0.00988)	(0.0187)	(0.0272)
	L2	0.000845	0.0357***	-0.00986
		(0.00833)	(0.0135)	(0.0187)
	L3	0.00426	0.0307**	-0.00583
		(0.00761)	(0.0123)	(0.0166)
	L4	0.00699	0.00547	0.0275
		(0.00756)	(0.0115)	(0.0176)
Lag of US monetary shocks	L1	0.00167***	0.00138**	0.00260***
		(0.000365)	(0.000588)	(0.000663)
Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1				

Table A10. Results of PVARX(1) with Barley Price (Using the shocks in the growth of M1 US money supply).

		Dependent Variables		
		Growth of Industrial Production	Inflation	Growth of Barley Price
Lags of the Growth of Industrial Production	L1	-0.198***	-0.0268	0.0743
		(0.0500)	(0.0388)	(0.0453)
	L2	-0.178***	0.0202	0.160***
		(0.0367)	(0.0502)	(0.0562)
	L3	-0.114***	-0.0645	0.125**
		(0.0276)	(0.0441)	(0.0517)
	L4	-0.0923***	0.0177	0.124***
		(0.0234)	(0.0401)	(0.0464)
Lags of Inflation	L1	-0.00567	1.169***	0.106
		(0.0372)	(0.0911)	(0.0973)
	L2	-0.0236	-0.0762*	-0.0259
		(0.0179)	(0.0400)	(0.0421)
	L3	-0.0288*	-0.0158	-0.0107
		(0.0174)	(0.0368)	(0.0392)
	L4	0.00716	-0.103***	-0.0395
		(0.0123)	(0.0235)	(0.0255)
Lags of the Growth of Barley Price	L1	0.0110	0.0350*	0.256***
		(0.00981)	(0.0205)	(0.0288)
	L2	0.00237	0.0334**	0.000834
		(0.00801)	(0.0143)	(0.0195)
	L3	0.0178**	0.0320**	0.0297*
		(0.00759)	(0.0131)	(0.0178)
	L4	0.00828	0.0252*	-0.00200
		(0.00682)	(0.0132)	(0.0168)
Lag of US monetary shocks	L1	0.00143***	0.00154**	0.00186**
		(0.000371)	(0.000624)	(0.000735)
Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1				

Figure A1. Monthly Beef prices of 21 EU Countries from Jan 2000 to Dec 2022.

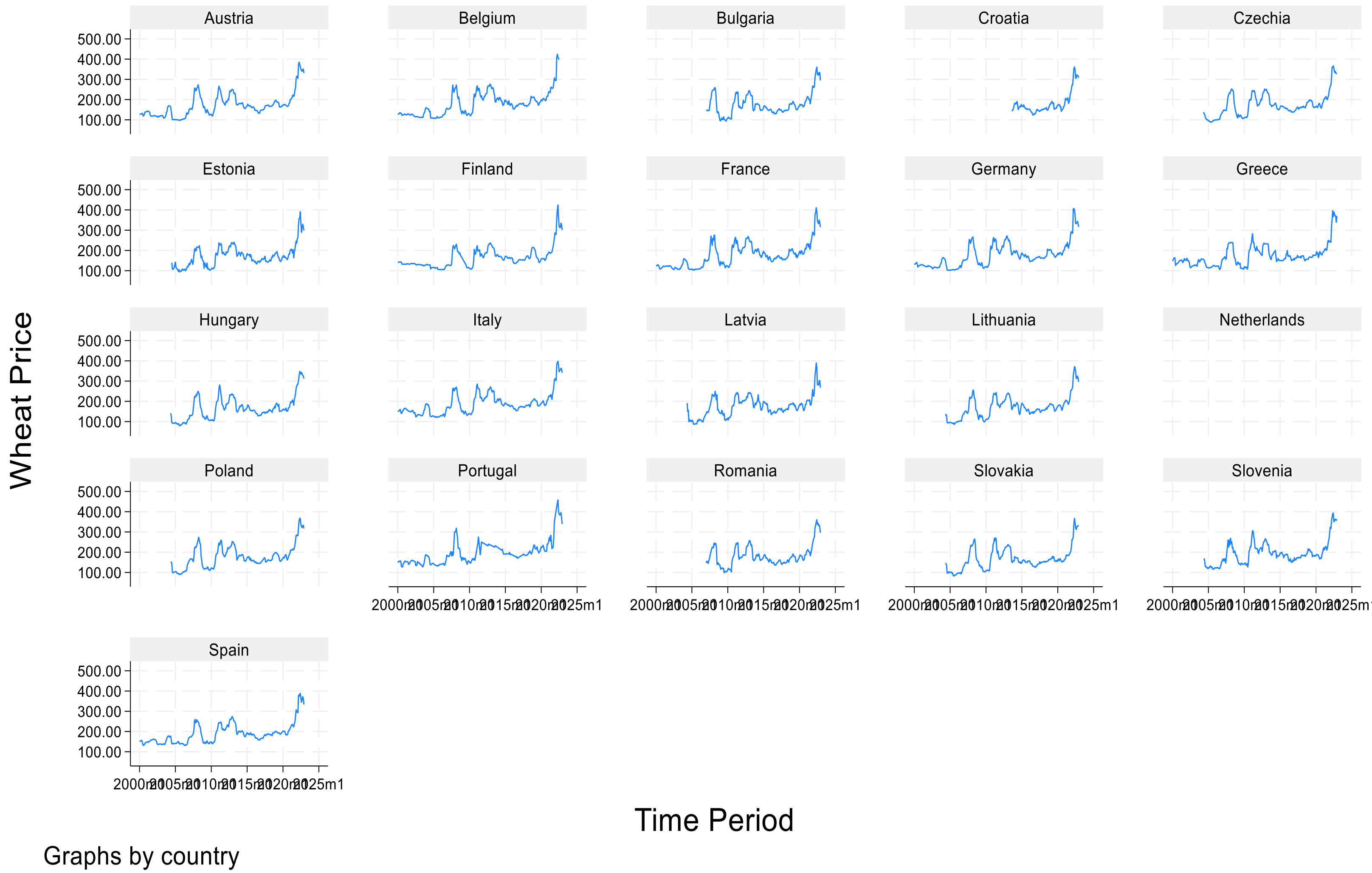

Figure A2. Monthly Wheat Prices of 20 EU Countries from Jan 2000 and Dec 2022.

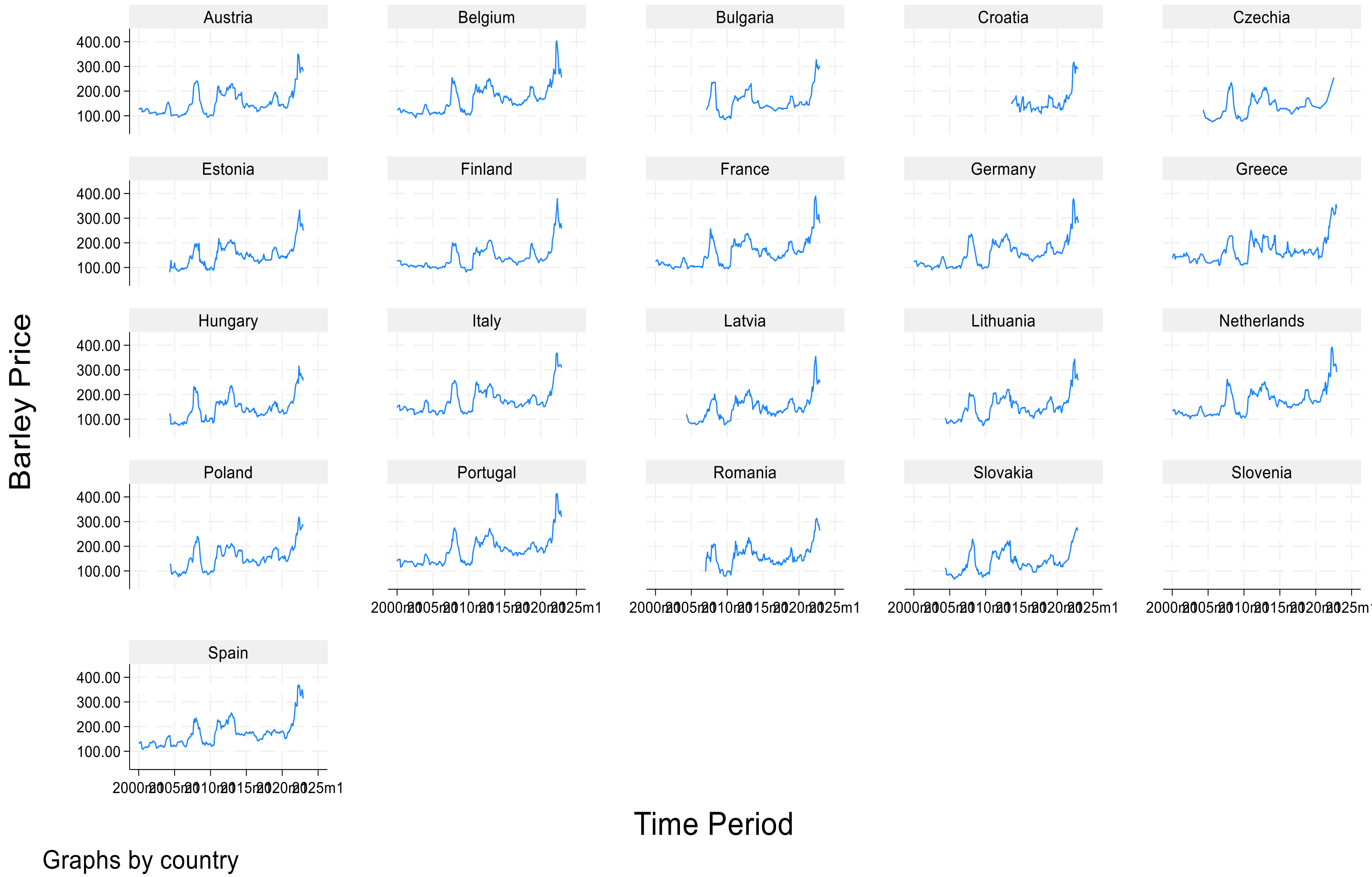

Figure A3. Monthly Barley Prices of 20 EU Countries from Jan 2000 and Dec 2022.

Figure A4. Monthly Industrial Production Index of 21 EU Countries from Jan 2000 to Dec 2022.

Figure A5. Monthly Inflation Rate of 21 EU Countries from Jan 2000 to Dec 2022.