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Oil Price Pass-Through in the EMU

An empirical study of the role of energy for oil price pass-through to inflation and inflation differentials

by

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Abstract This paper examines the relationship between oil prices and its pass-through to inflation and inflation differentials in the European Monetary Union from the first quarter of 1999 to the last quarter of 2021. By using local projections to derive impulse response functions of an oil price shock, the pass-through to the inflation level is examined focusing on the role of energy-related transmission channels. The same transmission channels are examined for pass-through of oil price inflation to inflation differentials using a Pooled OLS regression. The aim of this paper is to contribute to earlier research by giving an updated view on how exposed the European Monetary Union is to changes in oil prices. Our estimates show that the EMU is not sensitive to oil price shocks pertaining to the inflation level. As the examined transmission channels show small effects of pass-through to the inflation level, where Energy Dependency accounts for the largest effect. Moreover, the findings from examining inflation differentials show a negative linkage between oil price inflation and inflation differentials. Yet, the Transport Share of HICP is found causing a small, yet amplifying effect on inflation differentials. The linkage of the other transmission channels cannot be established for inflation differentials.

Keywords: *Inflation level, Inflation differentials, The EMU, OLS regression, Local projections, Impulse response functions, Oil price inflation, Energy*

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Introduction

The decision to form an economic and monetary union in Europe was taken under the presumption that it would instill stability and an environment promoting higher growth and employment [The European Commission, 2022c]. To achieve this, the main priority of the European Central Bank (ECB) has been to maintain low levels of inflation for the euro area. Despite having achieved this on an aggregate level, inflation differentials across member countries show high persistency. Albeit, while such differentials remain comparatively small and temporary differences in inflation levels across countries can be of a benign kind, long-lasting ones give cause for concern. In this way, the effectiveness of the European Monetary Union (EMU) can be questioned, and with cross-country heterogeneity expected to increase with the accession of more countries, understanding what causes inflation differentials in the euro area is of growing importance for curbing their development and decreasing their persistency. Hence, ensuring public acceptance of the union.

One factor, which has been of main concern in regards to the stability of the European Union (EU) is the dependency on external energy supply to secure the energy need. This is because important energy sources like oil, crude oil and petroleum products, are primarily imported from Russia [Eurostat, 2022b]. The growing tension between the euro area and Russia over the last decade, recently escalated with the Russian invasion of Ukraine, poses as a risk pertaining to the energy supply. This, because of its implication for oil and energy prices [European Parliament, 2022]. Nonetheless, this adds to the importance of understanding how oil price inflation pass-through contributes to inflation. Therefore, it is relevant to examine both the pass-through of oil prices on the level of inflation and inflation differentials. Accordingly, this paper aims to estimate the impact of oil price inflation pass-through using several transmission channels related to the EU's energy structure. In doing so, this paper shows the degree of pass-through into inflation levels and inflation differentials between 1999 to 2021 using a quarterly dataset. To fulfil the aim of this study, the primary research question for this paper is:

What is the role of energy related transmission channels pertaining to oil from an increase in oil prices for inflation and inflation differentials within the EMU?

Despite extensive empirical studies on the topic showing which factors that are most impactful for inflation, research on the effect of oil price pass-through for the EMU remains limited for this time span. Also, examining how the coinciding volatility in oil prices and the expansion of the EMU has affected inflation differentials using recent data provides renewed explanatory insight for decision makers in forming measures that minimize the susceptibility of shocks. This establishes the relevancy and importance of the empirical results in this paper as its findings pertain to an increasingly evolving area.

This paper uses a two-stage methodology to answer the research question, meaning that two separate methods are employed where one is used to examine the inflation level and another is used to examine inflation differentials. Firstly, updated empirical evidence pertaining to the inflation level will be examined using the method of local projections to derive impulse response functions. The variables of interest are the transmission channels of oil, namely the Transport Share of HICP, Total Energy Dependency, Energy Dependency on Oil, and Energy Intensity. In doing so, this paper will estimate the magnitude of pass-through with which the transmission channels of oil have for the level of inflation following an oil price shock. Secondly, a Pooled Ordinary Least Squares (OLS) regression will be used for examining the pass-through with which the transmission channels of oil have for inflation differentials following an increase in oil price inflation.

The findings in this paper suggest that the EMU area is not sensitive to oil price shocks for the level of inflation, as small linkages are found for the Transport Share of HICP, Total Energy Dependency, Energy Dependency on Oil, and Energy Intensity. The largest effect is found for Total Energy Dependency, however, despite accumulating the estimates for all transmission channels over the entire forecast horizon, the effect remains negligible in its size of pass-through to the inflation level. Thus, the results suggest that the EMU area is not sensitive to such shocks. Moreover, a negative linkage between oil price inflation and inflation differentials was found in this paper. The interpretation is that an increase in oil price inflation had a decreasing effect on inflation differentials. In contrast, the Transport Share of HICP was found causing a small, yet, positively amplifying effect on inflation differentials. However, the effect of the rest of the interacted transmission channels cannot be significantly established in this paper. This is examined further in the shorter sample periods, but none of the transmission variables showed significant linkages from 1999 to 2012. However, from 2013 to 2021 a positive interaction effect of Transport Share in the HICP basket and Total Energy Dependency is found for EMU11 - not for the EMU8. Over all, the results suggest that neither of the transmission channels have a substantial pass-through to inflation differentials. This is because the estimated effects are small in size suggesting that, while there is an amplifying effect, it does not cause a considerable effect for inflation differentials.

This paper is organised in the following way to answer the research question. Section 2 describes the energy structure within the EU. Thereafter, section 3 covers earlier empirical literature on inflation and inflation differentials focusing on the pass-through of oil prices. Further, section 4 presents the data and variables used to establish the results. In Section 5, the methodology is presented for the inflation level and inflation differentials. The results are presented and analysed in Section 6, followed by concluding remarks in Section 7.

2

Energy in the EU

This chapter aims to describe the energy structure, i.e. the energy usage, supply and distribution, within the euro area pertaining to the transmission channels of oil. This is done for two reasons: firstly, to contextualise the results in this paper. Secondly, to convey the importance of energy sources for the EU which is done by presenting statistics of energy usage, production and distribution at an aggregate level as well as at a country-specific level. Furthermore, the importance of this topic is shown by presenting many of the EU directives and policies over the last decade which have been focused towards decreasing the union's energy dependency and intensity, altogether, motivating the choice to examine the transmission channels of oil used in this paper.

2.1 Overview of EU energy statistics

Oil remains an important source of energy for the European economy, despite the long-term downward trend which has prevailed for this source of energy in recent years. A contributing factor to this downward trend is the shift towards using and producing more renewable energy, a development which continues to grow [Eurostat, 2022b]. Coincidentally, a decrease in domestic energy production followed, which explains the high dependency on energy imports of both primary energy and energy products for the EU (ibid.). The dependency rate, which shows the degree of reliance on imports in order to meet the energy need of the economy, was 58% in 2020 [Eurostat, 2022a]. The main providers of these imports were Russia and Norway, where the primary import commodities were oil and petroleum products, of which 97% was imported. Moreover, oil and petroleum products held the largest share of 35% for final energy consumption in 2020. The transport sector, which is one of the predominant users of energy, had final use of energy rates measured at 28.4% for the same year while households and the industry sector measured at 28% and 26.1%, respectively [Eurostat, 2022b].

What is more, the energy dependency rate varies across member countries. Figures 2.1 to 2.4 illustrate energy dependency rates for Malta, Cyprus and Luxembourg which all continue to have high rates of, around and above, 90%. The high dependency rates relate to limited domestic resource availability due to country size [Eurostat, 2022b]. In contrast, Estonia has experienced a downward dependency trend with a dependency rate measured at around 10% in 2020. This proves that the energy dependency rate varies substantially across member countries.

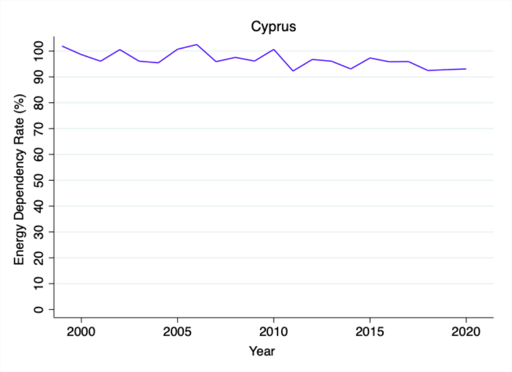

Figure 2.1: The energy dependency rate in Cyprus from 1999-2020.

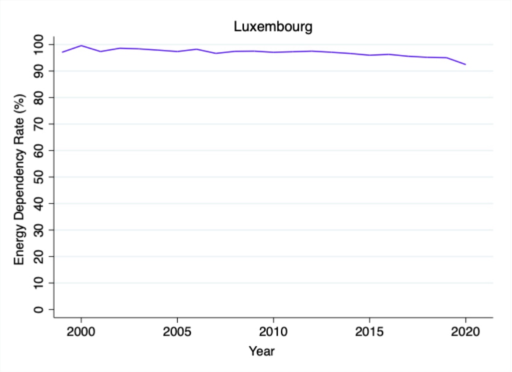

Figure 2.2: The energy dependency rate in Luxembourg from 1999-2020.

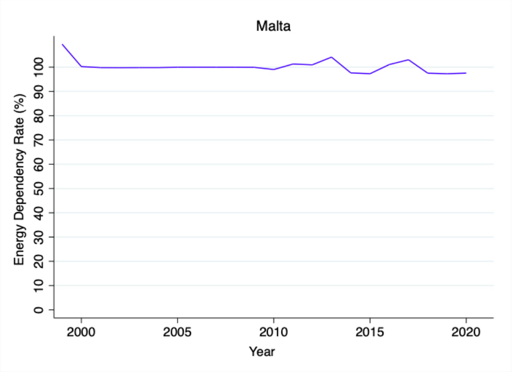

Figure 2.3: The energy dependency rate in Malta from 1999-2020.

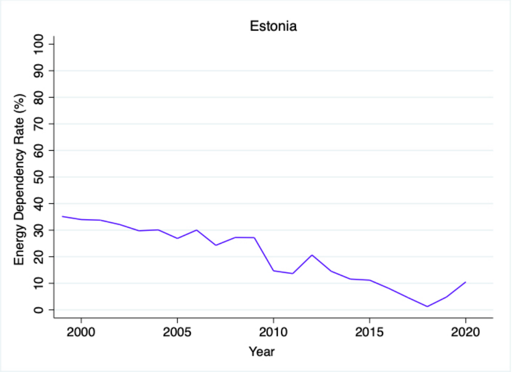

Figure 2.4: The energy dependency rate in Estonia from 1999-2020.

The trend, over the last years, is improved energy usage pertaining to the decrease in energy intensity for production. Energy intensity is an approximation of energy efficiency showing the volume of energy needed to produce one unit of Gross Domestic Product (GDP) [Eurostat, 2022b]. The reduced level of energy intensity can, among other things, be explained by a shift from industry production to a more service-based economy and a less energy-intensive industrial production for the remaining industries (ibid.) as well as a greater focus on policies to integrate the EU's energy structure. The statistics show that, while the shift toward a lower dependency on energy sources such as oil has begun, the dependency on external relations to provide energy to the union remains high. Improvements regarding energy intensity, however, reduces the concern slightly since it means that the energy is used more efficiently. Nevertheless, a general high dependency rate, low internal production of oil and petroleum products and a large share of this resource in the energy consumption basket indicates that the EMU is vulnerable to external market fluctuations among its main providers of energy, in particular to providers of oil.

2.2 Resent EU policies

The European energy structure has been one of the main subjects of discussion and policy targeting during the last decade. The Energy Efficiency Directive put forth in 2012, and the revising of this directive with the approval of the European Green Deal in 2020, are initiatives aimed at improving the energy structure. The Energy Efficiency Directive was implemented to create a more efficient use of energy for solving the issue of increased dependency on imports of energy and limited energy resources within the union [Parliament and Council of the European Union, 2012]. Further, the directive established a set of rules to accomplish the EU's efficiency targets regarding the reduction of primary and final energy consumption [The European Commission, 2022a].

The European Green Deal is, on the other hand, a set of proposals adopted by the European Commission in 2020 to reduce the net greenhouse gas emissions by at least 55% by 2030 with the adjustment of the EU's climate, energy, transport and taxation policies [The European Commission, 2021]. Hence, this policy is also aimed at reducing energy consumption and increasing energy efficiency at the EU level (ibid).

A third policy initiative, launched by the European Commission, is the Energy Union. It was formed in 2015 to promote a sustainable energy structure [The European Commission, 2022b]. The Energy Union has similar goals as the Energy Efficiency Directive and the European Green Deal, but their objective is also to integrate the internal energy market, improve energy efficiency and diversifying the sources of energy by increasing cooperation between member countries [The European Commission, 2022b].

As a concluding remark for this chapter, it is clear that the topic of energy has been prioritized for policymakers over the past decade. By aiming to reduce dependency on external powers, its importance for the economic stability of the union is suggested. Furthermore, by establishing sufficient infrastructure without technical and regulatory barriers, a greater integration among the member countries would be created in the EU. A more integrated system for energy would imply fewer differences among member countries and a greater resilience to external shocks.

3

Previous Research

In this chapter, findings of previous research related to inflation and inflation differentials will be presented. In addition to presenting empirical evidence pertaining to the pass-through of oil prices to inflation and inflation differentials, this chapter includes findings of other key factors. This is done with the aim to give a broader understanding and providing a basis for the interpretation of the results. This chapter is structured as follows: First, empirical evidence on oil price pass-through to the level of inflation will be presented in section 3.1. Followed by section 3.2, where evidence on drivers of inflation differentials is presented. Also, research on oil price pass-through for inflation differentials is provided in 3.3. Lastly, in section 3.3.1, the contribution of this paper to the literature is presented.

3.1 Empirical evidence on oil price pass-through to inflation

In Chen [2009], the linkage between oil price inflation and the inflation level was examined using an augmented Phillips curve. The result showed that inflation had become less sensitive to oil price fluctuations in the 2000s compared to the 1970s using quarterly data from 19 industrial countries: Australia, Belgium, Canada, Germany, Japan, Norway, the United Kingdom and the U.S, to mention a few. Empirical evidence accounting for this development is increased trade openness and a more active monetary policy in response to inflation [Chen, 2009]. Similarly, Herrera and Pesavento [2009] who examined the U.S economy, found that oil price shocks had a larger and more long-lasting effect on inflation during the mid-1900s. Yet another result pertaining to industrialized countries is presented in Blanchard and Galí [2007], where it is established that the impact of an oil price shock for inflation has decreased over time since the 1970s. One of the reasons behind this development, as suggested by the authors, is an increased credibility of monetary policy resulting in a decreased response of inflation expectations to an oil price shock. They further suggest that a decreased share of oil in consumption and production is another explanation for the declining pass-through of oil price shocks to inflation [Blanchard and Galí, 2007]. Thus, these findings strongly suggest that oil price inflation has had a dissipating affect on inflation for industrialized countries during the last two decades.

What is more, Chen [2009] found that oil price pass-through varies across countries and depends on the share of energy imports, i.e. energy dependency. He concludes that the larger the share of energy imports, the larger the impact of an oil price increase is. Further, the correlation of energy imports and pass-through are examined and estimated at 0.34 and 0.07 for the short- and long-run, respectively. Thus, illustrating that the dependence on imported energy is one explanation for discrepancies across countries. Adding to this, LeBlanc and Chinn [2004], who obtained estimates by adopting a Phillips curve model for the period 1990 to 2001 for countries such as the United States, United Kingdom, France, Germany, and Japan, found that an increase in oil prices of as much as 10% had an inflationary affect of about 0.1% to 0.8% in the U.S. and the EU. Thus, a modest impact. Further, Hooker [2002], who employed a Phillips curve model and using quarterly data from the second quarter of 1962 to the first quarter of 2000, established that oil price pass-through has become negligible since 1980 for the U.S. The paper also concluded that an increase in energy intensity in the U.S economy did not account for an increasing pass-through of oil prices to inflation.

Moreover, Choi et al. [2018] found a decreasing linkage between oil price inflation and inflation levels when investigating 72 advanced and developing countries. The decreasing linkage is due to increased domestic energy production, where cross-country differences in the transport share of the Consumer Price Index (CPI) basket and the share of energy subsidies of GDP result in varying pass-through of oil price inflation shocks. A country with a higher share of transport in the CPI basket is more exposed to oil price shocks than a country receiving energy subsidies since subsidies cushions the impact. The transport share in the CPI basket was found as the most robust determinant for causing varying inflation levels across countries. Thus, by accounting for oil dependency and intensity in domestic production, the analysis of the susceptibility of shocks can be furthered.

Considering the evidence presented by Chen [2009], Herrera and Pesavento [2009], Blanchard and Galí [2007], LeBlanc and Chinn [2004], Hooker [2002] and Choi et al. [2018], a strong indication of a general decreasing pass-through of oil prices to inflation is presented.

3.2 Empirical evidence on drivers of inflation differentials

Much empirical evidence on drivers of inflation differentials pertains to the exchange rate, the output gap, the fiscal stance and the price level. For instance, Beck et al. [2009] found that exchange rate movements and changes in oil prices have had significant impact on inflation differentials. Also, Honohan et al. [2003] established a linkage between a positive output gap and inflation in the euro area, in the early years of the EMU, because of its contribution to increased demand in the goods market and an increased dispersion in property prices. Thus, by implication causing inflationary pressure. Moreover, they found a negative linkage of the nominal exchange rate for inflation differentials. This is because countries in the early stages of the EMU had different trading patterns and therefore had varied exposure to external currency fluctuations. Further, Honohan et al. [2003] concluded that with time the union will shift trade patterns toward increased intra-euro area trade. Thus, shifting the impact of exchange rate shocks from consumers to producers as more imports to the euro area would be priced in euros. Thus, decreasing the impact of inflation based on consumer price indexes [Honohan et al., 2003]. Moving on, the fiscal deficit showed insignificant linkage to inflation differentials. This is because the implementation of such a policy tool is constrained by the Stability and Growth Pact. A pact aimed at sustaining long-term fiscal stability for the EU thereby minimizing domestic budget deficits affecting inflation differentials in Europe [Honohan et al., 2003].

Stavrev [2007] presented empirical evidence supporting the findings of Honohan et al. [2003], where a significant effect for the economic cycle in relation to inflation differentials was established, meaning that increased synchronization between countries implies a decrease in inflation differentials. Stavrev [2007] further suggested that the common monetary policy has contributed to business-cycle and fiscal policy synchronization, because common shocks increasingly trigger common responses. Thus, the contribution of common shocks to dispersion in inflation rates has decreased over time. Furthermore, Tasos [2021] provided empirical evidence of significant linkages between the exchange rate and the output gap for inflation differentials and insignificant estimates for fiscal stance. He also established significance for the economic cycle and inflation differentials. The same interpretation of such results follows Stavrev [2007]. In such a way, the EMU has contributed to increased efficiency and effectiveness to address common shocks. Further integration of the financial sector could do more to insure countries against shocks and increase consumption smoothing according to Stavrev [2007].

3.3 Empirical evidence on oil price pass-through for inflation differentials

Empirical evidence presented by Égert et al. [2004] for the period 1990 to 2003, found that oil price shocks contribute to inflation differentials through cross-country discrepancies in the oil dependency ratio and to the level of oil intensity in production. Where countries with higher dependency on external energy supply and more energy intensive production have greater oil price pass-through onto inflation. Thus, causing inflation differentials on an aggregate level [Égert et al., 2004]. Other empirical findings suggest the same linkage, that the impact of oil price inflation may vary depending on a country's exposure to external euro area trade and the oil intensity of production [Hofmann and Remsperger, 2005].

Further, whether or not acceding countries have contributed to increased inflation differentials in the EMU is examined. High energy dependency is found in the following countries: Lithuania, Cyprus, Latvia and the Czech Republic. Lower energy dependence is found in the Slovak Republic, Poland, Slovenia and Hungary. Oil intensity is found at equal levels or slightly below the EU average for the acceding countries, except for Slovenia, Latvia and Cyprus. Égert et al. [2004] emphasized that the lasting increase in the crude oil price partly explains the persistence of inflation differentials in the EMU. This is because the countries with the highest level of inflation are simultaneously those which depend the most on external energy supply and have the most energy-intensive production. Therefore, the focus should be placed on lowering energy dependence for Lithuania, Cyprus, Latvia and the Czech Republic as sensitivity to oil price shocks will depend on the disentanglement of oil demand either through technological progress or by shifting from industrial production to the service sector or employing other energy-saving measures [Égert et al., 2004].

As shown in chapter 2, oil dependency varies greatly across euro area countries. Consequently, as investigated by Licheron [2007], oil price inflation has asymmetric effects across countries hence causing inflation differentials. The estimation results found by Licheron [2007] showed that differences in the exposure to oil price variations played a key role in explaining inflation differentials from 1992, especially over the EMU period. However, when conducting robustness checks, a weaker linkage was found. In fact, no significance is found for oil price deviations impacting inflation differentials [Licheron, 2007]. However, Arnold and Verhoef [2004] proved that differences in oil dependency are not a major cause of inflation differentials across countries in the euro area.

3.3.1 Contribution to the literature

This paper contributes to the literature by establishing how oil price pass-through progresses in heterogeneous countries with differing energy-related characteristics - such as the transmission channels examined. By examining transmission channels which are selected because of their relation to the energy structure of the EMU, meaning its energy usage, furthers the understanding of how oil price pass-through affects this area. For instance, the variables for Total Energy Dependency and Energy Dependency on Oil, are chosen because of the decrease in domestic energy production pertaining to the euro area over this time period. In doing so, this paper examines if this has altered the pass-through of oil price fluctuations due to higher dependency on energy imports and oil imports. Further, the reason for choosing Energy Intensity relates to the efforts made by the EMU to increase energy efficiency over the last decade. Therefore, this paper evaluates the current pass-through of energy intensity and gives an update on the linkage. Moreover, the Transport Share of HICP is selected following the reasoning by Choi et al. [2018] and because it is a predominant user of oil. This sector is also a necessary part in each economy, thus it continues despite price increases thereby affecting each economy in a large scale. Furthermore, Transport Share of HICP is also used to approximate the share of oil in the HICP basket. This is not done in earlier literature for this area covering this time period and using the two-stage methodology which is employed in this paper. That is how this paper contributes to the literature.

4

Data

This chapter will present the data and variables used in this paper. A detailed description of how the dataset and the variables have been constructed and handled will be given in two separate sections. Firstly, section 4.1 describes the data. Secondly, section 4.2 describes and explains the variables.

4.1 Data description

This paper used a two-stage methodology with two separate datasets, where many of the variables have been used in both stages. The data is measured in quarterly frequency ranging from the first quarter of 1999 to the last quarter of 2021. The sample includes data from the 19 member countries of the EMU, all countries are shown in Table A.1 in Appendix A. The quarterly frequency with which we have used for our estimates, allows for more precise results pertaining to the short-term impact [Choi et al., 2018]. The lack of data availability has been dealt with by using annual or monthly frequency and manually adjusting it to fit into a quarterly dataset. This process will be further explained in section 4.2.

The dependent variable in both stages is based on the Harmonized Index of Consumer Prices (HICP). Furthermore, both regressions include global oil price inflation interacted with four different transmission channels: Transport Share of HICP, Total Energy Dependency, Energy Dependency on Oil, and Energy Intensity. The dataset pertaining to the inflation level analysis only consist of these variables, while the dataset for the analysis on inflation differentials also includes: Nominal Effective Exchange Rate (NEER), Output Gap, Fiscal Stance, and Price Level. The data is collected from various sources and are listed in Table A.2 in Appendix A. However, most of the data has been collected from Eurostat, and the International Monetary Fund (IMF).

Further, a necessary precondition for attaining accurate estimates is minimizing the occurrence of multicollinearity by, for instance, excluding variables showing such a relationship. Hence, a multicollinearity test was performed. The result is displayed in Table 4.1. It is shown that the level of multicollinearity does not exceed reasonable limits for the variables used in the various regressions performed in this paper.

Table 4.1: Test for Multicollinearity

	$\pi_{i,t}$	$\Delta NEER_{i,t-1}$	$GAP_{i,t}$	$FISC_{i,t}$	$P_{i,t-1}$	$\pi^{oil}_{i,t}$	$\delta_{i,t-1}\pi^{oil}_{i,t}$	$\rho^1_{i,t}\pi^{oil}_{i,t}$	$\rho^2_{i,t}\pi^{oil}_{i,t}$	$\rho^3_{i,t}\pi^{oil}_{i,t}$
$\pi_{i,t}$	1									
$\Delta NEER_{i,t-1}$	0.347***	1	-0.0118	0.0259	0.0123	-0.0391	-0.0432	-0.0316	-0.0352	-0.0505*
$GAP_{i,t}$	0.0692**	-0.0118	1	0.268***	0.00993	0.231***	0.232***	0.209***	0.225***	0.166***
$FISC_{i,t}$	0.0379	0.0259	0.268***	1	0.145***	-0.0223	-0.00668	0.0165	0.0423	0.0560*
$P_{i,t-1}$	0.0108	0.0123	0.00993	0.145***	1	-0.0633**	-0.0150	-0.0416	-0.0639**	-0.126***
$\pi^{oil}_{i,t}$	-0.0827***	-0.0391	0.231***	-0.0223	-0.0633**	1	0.975***	0.953***	0.999***	0.924***
$\delta_{i,t-1}\pi^{oil}_{i,t}$	-0.122***	-0.0432	0.232***	-0.00668	-0.0150	0.975***	1	0.950***	0.975***	0.861***
$\rho^1_{i,t}\pi^{oil}_{i,t}$	-0.109***	-0.0316	0.209***	0.0165	-0.0416	0.953***	0.950***	1	0.955***	0.843***
$\rho^2_{i,t}\pi^{oil}_{i,t}$	-0.106***	-0.0352	0.225***	0.0423	-0.0639**	0.999***	0.975***	0.955***	1	0.922***
$\rho^3_{i,t}\pi^{oil}_{i,t}$	-0.189***	-0.0505*	0.166***	0.0560*	-0.126***	0.924***	0.861***	0.843***	0.922***	1

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

4.2 Variable description

Inflation rate ($\pi_{i,t}$) is calculated based on the HICP and is in its original form measured with a monthly frequency. To create a quarterly frequency the average of three months is calculated per quarter. The HICP is the official measurement of consumer price inflation in the euro area and is used for monetary policy and the assessment of inflation convergence as compulsory under the Maastricht criteria for acceptance into the EMU. The index is an economic indicator that estimates changes in the price of consumer goods and services captured by households over time and is calculated following a harmonised approach. It further gives a comparable measure of inflation for the countries and the country groups for which it is produced, hence it is a reasonable measurement to use when studying inflation pertaining to the EMU.

Transport Share of HICP ($\delta_{i,t-1}$) is measured at an annual frequency and is divided by its annual rate per quarter in the dataset. The variable is measured as the transport weight in the HICP basket. According to Choi et al. [2018], the expectation of such a variable is that the larger the share of transport in the CPI (HICP) basket, the larger the expectation of inflationary effects of oil price shocks are.

Total Energy Dependency ($\rho^1_{i,t}$) is measured at an annual frequency. To fit the variable into a quarterly frequency, all four quarter for one year has the same value in similarity to the measure of Transport Share of HICP. The indicator shows the extent to which an economy relies upon imports to meet its energy need and is calculated as net imports divided by the gross available energy. Furthermore, net imports are calculated as total imports minus total exports. The measurement of energy dependency shows how volatile the European economy is to world market prices, such as global oil prices, and the risk of supply shortages, for example, due to geopolitical conflicts.

Energy Dependency on Oil ($\rho^2_{i,t}$) is measured at an annual frequency and has been manually adjusted in the same manner as the two previous variables. The indicator shows the extent to which an economy relies upon imports of oil and petroleum products to meet its energy needs. It is measured in similarity with Total Energy Dependence with the difference of this variable measuring the percent of imports of oil and petroleum products (excluding biofuel portion) in total energy consumption.

Energy Intensity ($\rho^3_{i,t}$) is measured at an annual frequency and has been manually adjusted in the same manner as the three previously mentioned variables. The variable is measured in kilograms of oil equivalent (KGOE) per thousand euros in purchasing power standards (PPS). Energy intensity is often used as an approximation of energy efficiency, and captures how much energy is used in production. The variable is of interest since if the energy need of an economy is vast in relation to the amount of domestically produced energy, it should be more volatile to changes in the world market supply of energy and, hence, the global energy prices in extension.

Global Oil Price Inflation ($\pi_{i,t}^{oil}$) is measured with a quarterly frequency and is calculated as the percentage change over the corresponding period of the previous year. The measure captures an equally weighted average of three spot prices: Dated Brent, West Texas Intermediate, and the Dubai Fateh.

When the interaction variables, consisting of the transmission channels and the global oil price inflation, are created the oil price inflation gets a country dimension and the transmission channel gets a quarterly variation.

Nominal Effective Exchange Rate (NEER) ($\Delta NEER_{i,t-1}$) is measured with a monthly frequency. To create a quarterly frequency the average of three months is calculated per quarter. NEER is an index that measures changes in the euro as a currency against a trade-weighted basket of currencies. It is produced by the European Commission and is calculated against a group of 37 trading partners with different currencies. An increase in the index implies a strengthening of the currency.

Output Gap ($GAP_{i,t}$) is determined by the difference between potential and actual gross domestic product (GDP). The potential GDP cannot directly be observed and must, therefore, be estimated. The Hodrick-Prescott (HP) filter, as one statistical method suggested by Andersson et al. [2018], has been used to obtain the potential GDP. The potential GDP is achieved by smoothing out fluctuations in actual GDP by mechanically dividing the actual GDP into a trend component and a cyclical component. The smoothing parameter is set to 1,600 which is the default and suggested for quarterly data [Hodrick and Prescott, 1997]. The GDP measure used to obtain the output gap is seasonally adjusted with a quarterly frequency.

Fiscal Stance ($FISC_{i,t}$) is measured as the actual budget position, i.e., a government surplus or deficit. It is calculated as net lending divided by net borrowing of the general government sector as a percentage of GDP. When the variable is positive a surplus exists. On the contrary, a deficit exists when it is negative. The variable is measured with a quarterly frequency.

Price level ($P_{i,t-1}$) is measured by the household consumption price level in the Penn World Tables version 10.0. The price level variable is measured with an annual frequency and has been divided by its annual rate per quarter in the dataset. Hence, all four quarters of a year show the same value.

5

Methodology

In this chapter, the models used to derive the estimates are presented as well as the statistical methods that have been used. This paper has used a two-stage methodology. Firstly, the method of local projections is used to examine the pass-through of an oil price shock to the level of inflation. Then, Pooled OLS is used to examine the pass-through of an oil price increase for inflation differentials. Both models include the transmission channels presented in the variable description in section 4.2. The chapter is structured as follows: section 5.1 covers the description of the regression model used for examining the inflation level. In section 5.1.1, a description of local projections is described. Thereafter, the regression model for inflation differentials is presented in section 5.2. In 5.2.1, the approach for the sample split is described.

5.1 Model - Inflation Level

The model and method for the inflation level follows a similar approach to the one applied by Choi et al. (2018), who employed a method of local projections originally set forth by Jordà (2005). The estimation method estimates impulse response functions (IRFs) directly from local projections - explained further in section 5.1.1.

Choi et al. [2018] reasoned that global oil prices affect headline inflation directly via the share of oil in the HICP basket and indirectly through changes in the core (non-oil) inflation. The following equation illustrates this while being specified for local projections with forecast period k:

$$\pi_{i,t+k} = {\alpha_i}^k + \vartheta^k_{i,t} + \sum_{j=1}^{l} \gamma^k_j \pi_{i,t-j} + \beta_k \delta_{i,t-1} \pi^{oil}_t + \sum_{j=1}^{k} \theta_j \delta_{i,t+j-1} \pi^{oil}_{t+j} + \epsilon^k_{i,t} \tag{5.1}$$

The hypothesis of this paper pertaining to global oil prices is that they affect the inflation level directly hinging on domestic energy dependency of external energy supply and domestic energy efficiency. Therefore, a second equation is specified for local projections with forecast period k:

$$\pi_{i,t+k} = {\alpha_i}^k + \vartheta^k_{i,t} + \sum_{j=1}^{l} \gamma^k_j \pi_{i,t-j} + \tau_k \rho^n_{i,t} \pi^{oil}_t + \sum_{j=1}^{k} \varphi_i \rho^n_{i,t+j} \pi^{oil}_{t+j} + \epsilon^k_{i,t} \tag{5.2}$$

Both equation 5.1 and 5.2 have a forecast horizon of k=0,...,8 since the effect of an oil price shock tends to dissipate after two years, eight quarters [Choi et al., 2018]. The difference between the two equations is that the first equation contains $\delta_{i,t}-_1$, which captures the Transport Share of HICP for country i lagged one period, while the second equation contains $\rho^n_{i,t}$, which is the transmission channel n for country i at time t. The transmission channels examined, for the hypotheses described above, are Total Energy Dependency (n=1), Energy Dependency on Oil (n=2), and Energy Intensity (n=3). The Transport Share of HICP is, in similarity to Choi et al. [2018] included as an approximation of oil in the HICP basket and is lagged one period since changes in global oil prices can have a direct effect on the share of transport in a country´s consumption basket. By lagging the variable, the occurrence of simultaneous affects for the interacted variable by both a change in global oil prices and a change to the share of transport in the HICP basket is avoided as a direct effect of the change in the oil price. The other transmission channels captured by $\rho^n_{i,t}$ are, however, not lagged since the channels n=1,2,3 are assumed to not be directly affected by changes in oil prices. Changes to these variables are to a larger extent brought on by policy changes and structural factors.

The inclusion of $\delta_{i,t-1}$ and $\rho^n_{i,t}$ includes the pass-through of global oil prices to the domestic inflation level which allows us to estimate the average effect of global oil prices while controlling for cross-country heterogeneity and time-fixed effects. In both equations $\pi_{i,t+k}$ represents the domestic inflation rate based on the HICP, $\pi^{oil}_{i,t}$ is the global oil price inflation, $\alpha_i{}^k$ denotes country-fixed effects, $\vartheta^k_{i,t}$ are the country-specific time trends, and γ^k_j estimates the persistence of domestic inflation. β_k estimates the impact of changes in global oil prices through the share of transport in the HICP basket on domestic inflation rate for each future period k. Similarly, τ_k measures the effect of changes in global oil prices through the three other transmission channels for each future period k. Like Choi et al. [2018], the number of lags (l) has been set to two. Both specifications include the forward leads of the interaction term of transmission channels and global oil price inflation between time 0, which is the time of the oil price shock, and the end of the forecast horizon (k). The reason for this is to correct for the bias in the impulse responses built-in to the local projection method, this will be described more in section 5.1.1.

The average effect of global oil price shocks on domestic inflation are captured by the IRFs derived by plotting the estimated $\delta_{i,t-1}$, for equation (4.1), and $\rho^n_{i,t}$, for equation (4.2), rescaled by the average of the variable capturing a transmission channel (either $\delta_{i,t-1}$ or $\rho^n_{i,t}$). Furthermore, standard errors of the estimated coefficients are used to calculate the confidence bands for the estimated IRFs, set to a 95 percent confidence interval. Choi et al. [2018] identified that the presence of a lagged dependent variable and country fixed effects may cause a bias of the estimated parameters of interest in a small sample, however, the size of the time dimension in our sample mitigates this concern.

The model is to a large extent a replication of the model used by Choi et al. [2018]. However, one of the main differences in this paper is the addition of transmission channels to the model with the aim of controlling for more cross-country heterogeneous factors that might affect how global oil prices transit to effect the level of domestic inflation. This paper covers the time period, 1999 to 2021 using quarterly data while Choi et al. [2018] covered the time period 1970 to 2015 using annual data. This paper solely examines the EMU while Choi et al. [2018] investigated 72 advanced and developing countries which do not pertain to a certain geographical area or union.

5.1.1 Method - Local Projections

In order to estimate the model pertaining to the analysis of the inflation level, this paper has employed a local projection model to obtain IRFs. An impulse response is a function of forecasts at increasingly distant horizons from a given model, usually obtained from vector autoregressions (VARs) [Jordà, 2005]. Instead, with local projections, an IRF is calculated from a separate regression for each period of interest, e.g. for each forecast horizon (ibid.). When using VAR to compute IRFs, misspecification errors are compounded with the forecast horizon, when using the local projection estimates are local to each forecast and are hence more robust to misspecifications of the unknown [Jordà, 2005]. That is, local projections uses a new set of coefficients for each forecasting horizon instead of using the same set of coefficients for the entire forecast horizon, hence avoiding the compounding of misspecification errors. However, despite local projections being more robust to model misspecifications, especially for longer forecasting horizons, the estimator is less efficient compared to analytical estimators [Teulings and Zubanov, 2014]. The loss of efficiency is nevertheless minor when compared to the VAR by Jordà [2005], implying that the flexibility of the model following the absence of dynamic restrictions renders the negatives.

Teulings and Zubanov [2014] discovered an unnoticed bias in the local projection model. Where the dependent variable in the regression includes observations that are already affected by the shock even though the corresponding shocked variable has not yet moved. As an example, consider the local projection regressions for the level of inflation and its response to an oil price shock at forecast horizon k=4, where the time frequency is measured annually. The regression is set to explain inflation at t+4 with the lags of inflation and global oil prices measured at t. Suppose that a global oil price shock occurs at t_0=6 and that the effects on inflation are observed the same year. Then the inflation levels estimated at t=6,7,8 will include the effect of the oil price shock from the onset of the shock to two years after. The problem is that the regressors only include variables observed in t-4=2,3,4, therefore the oil price shock that occurs in t_0=6 will not be captured. Instead, the effect will be captured by the fixed effects resulting in a downward bias of the estimates [Teulings and Zubanov, 2014]. However, the bias can be corrected by augmenting the local projections regression by including the forward leads of the global oil price variable, i.e. between t and t+k [Choi et al., 2018]. The described procedure has been done in the method conducted in this paper, hence, the occurrence of biased estimates have been prevented.

In conclusion, an advantage of the long forecasting horizon for this model, with k=8, is that model misspecifications are easier to avoid. Also, the inclusion of forward leads in the model prevents biased estimates. Due to these reason as well as the approach being advocated for by Choi et al. [2018] and Teulings and Zubanov [2014], the method of local projection is a suitable choice of model.

5.2 Model - Inflation Differentials

The model used for inflation differentials is an extension of the model specification used by Honohan et al. [2003]. The extension pertains to the incorporation of oil price inflation and oil price inflation interacted with the transmission channels.

The general specification representing inflation differentials, as used by Honohan et al. [2003], is shown by the following equation:

$$\pi_{it} - \pi_t^E = \beta(z_{it} - z_t^E) - \sigma(P_{i,t-1} - P_{t-1}^E) + \epsilon_{it} \tag{5.3}$$

This equation builds on an assumption made by Honohan et al. [2003] about a common long-run price level for the EMU countries. This assumption is based on a convergence club hypothesis where increasing intra-union trade and institutional linkages remove income and productivity differentials over time [Honohan et al., 2003]. Therefore the equation does not incorporate any country-specific or euro area variables capturing the long-run equilibrium price levels. The variables in the equation denote the following: π_{it} and π_t^E illustrates the national and euro area inflation rates showing that inflation differentials occur when the domestic inflation level of country i differs from the EMU average. z_{it} and z_t^E depicts the national and euro area variables capturing short-term effects on the inflation rate while $P_{i,t-1}$ represents national price levels and $P_{i,t-1}^E$ is the euro area price level.

Variables specific to the euro area in equation 5.3 can be made into a linear combination forming a time-specific dummy that is constructed in the following way:

$$\phi_t = \pi_t^E - \beta {z_t}^E - \sigma P_{t-1}^E \tag{5.4}$$

By adjusting equation 5.3 to incorporate the time dummy represented by equation 5.4, instead of the euro area variables, the following equation is obtained:

$$\pi_{i,t} = \phi_t + \beta z_{i,t} - \sigma P_{i,t-1} + \epsilon_{i,t} \tag{5.5}$$

The time dummy captures the EMU-wide common movements in inflation, which permits an explanation of inflation differentials in terms of idiosyncratic national movements in the determinants of the regression, meaning that changes in global oil prices at a national level can be analysed. Furthermore, Honohan et al. (2003) included three variables in the z_t-vector: the Nominal Effective Exchange Rate with one lag, the Impulse in the Cyclically Adjusted Fiscal Surplus as well as the Output Gap, thereby giving the following, and final, empirical specification:

$$\pi_{i,t} = \phi_t + \beta_1 \Delta NEER_{i,t-1} + \beta_2 GAP_{i,t} + \beta_3 FISC_{i,t} - \sigma P_{i,t-1} + \epsilon_{i,t} \tag{5.6}$$

where $\pi_{i,t}$ is the annual inflation rate, $\Delta NEER_{i,t-1}$ is the growth rate of the nominal effective exchange rate with one lag, $GAP_{i,t}$ is the output gap, and $FISC_{i,t}$ shows the impulse in the cyclically adjusted primary surplus. $P_{i,t-1}$ is the lagged price level. The equation illustrates how inflation differentials can be explained by factors such as trade openness captured by the variable of nominal exchange rate, the roll of price level convergence captured by the variable for the lagged price level, and policy-related factors by the cyclically adjusted primary surplus. Also, the output gap captures the economic activity in relation to potential output. Thus, it measures the degree of inflation pressure in the economy.

The model used in this thesis is an extension of the model described above to incorporate the effect of oil price inflation and how it travels through energy specific country characteristics to effect inflation differentials. The model is estimated using a Pooled OLS regression, in similarity to Honohan et al. [2003], with a quarterly data set. The extended model used in this paper is presented by the two following equations:

$$\pi_{i,t} = \phi_t + \beta_1 \Delta NEER_{i,t-1} + \beta_2 GAP_{i,t} + \beta_3 FISC_{i,t} + \beta_4 \delta_{i,t-1} \pi_t^{oil} - \sigma P_{i,t-1} + \epsilon_{i,t} \tag{5.7}$$

and

$$\pi_{i,t} = \phi_t + \beta_1 \Delta NEER_{i,t-1} + \beta_2 GAP_{i,t} + \beta_3 FISC_{i,t} + \tau \rho_{i,t}^{n} \pi_t^{oil} - \sigma P_{i,t-1} + \epsilon_{i,t} \tag{5.8}$$

In both equations, π_{it} is the measure of the HICP based inflation rate for country i at time t, and ϕ_t is the time dummy capturing the common euro-variables at time t. $\Delta NEER_{i,t-1}$ is the lagged growth rate of the nominal effective exchange rate which is generated by taking the first difference of the variable and lagging it by one period. $GAP_{i,t}$ is the output gap in country i at time t. $FISC_{i,t}$ is the fiscal stance, surplus or deficit, in country i at time t. In equation 5.7, $\delta_{i,t-1}\pi_t^{oil}$ is global oil price inflation interacted with the transmission channel capturing the Transport Share of HICP lagged one period. Equation 5.8 instead contains $\rho_{i,t}^{n}\pi_t^{oil}$ which captures the global oil price inflation interacted with the transmission channels Total Energy Dependency (n=1), Energy Dependency on Oil (n=2), and Energy Intensity (n=3). Both models have employed White-corrected clustered standard errors when regressed.

5.2.1 Model - Inflation Differentials with Sample Split

The model of inflation differentials has been run with a data set consisting of all the 19 member countries of the EMU and across the time period starting with the first quarter of 1999 to the last quarter of 2021. As an additional check, the sample was divided pertaining to time and composition of countries. This was done to examine whether the results are driven by any of these factors.

The first split, with regards to time, covers the period from 1999 to 2012. The second split ranges from 2013 to 2021. The split is done in 2012 for several reasons. The first reason is that the data of the transmission channels - Transport Share of HICP, Total Energy Dependence, Energy Dependence on Oil, and Energy Intensity - show structural breaks in the second, third and fourth quarters of 2013. Thus, by splitting the data before this, such a discrepancy affecting the data can be avoided.

Also, at the end of 2012, the European Commission launched the Energy efficiency directive, which was described in section 2.2. The split is also based on the accession of new countries to the EMU. Latvia entered the union in January 2014 and Lithuania in January 2015 [The European Central Bank, 2022]. Hence, splitting the sample in 2012 means that the period from 2013 to 2021 captures to a large extent, the time when all current member countries had entered the union.

The second split is country wise. One subsample consists of the 11 countries which first entered the EMU when it was created (EMU11), the second sample consists of the eight countries that entered the union at a later stage (EMU8). The countries included in both samples are displayed in Table A.1 in Appendix A.

The two splits have further been combined and four subsamples have been created from this: EMU8 (1999-2012), EMU8 (2013-2021), EMU11 (1999-2012), and EMU11 (2013-2021).

6

Empirical Analysis

In this chapter the results found in this paper are presented and analysed with regards to both inflation and inflation differential. The chapter is structured as follows: section 6.1 presents the results pertaining to the level of inflation. Section 6.2 describes the results pertaining to inflation differentials. Then, in section 6.2.1, the results of a sample split for inflation differentials are shown. Followed by section 6.3.1 and 6.3.2 which presents the results from specification tests of both regressions.

6.1 Result and Analysis - Inflation Level

The results from examining the inflation level are presented in Table 6.1 and Figures 6.1 to 6.4[1]. The figures display the impact and pass-through of an one percent shock in global oil prices for the domestic inflation level while controlling for cross-country heterogeneity with the interaction of transmission channels. The red vertical line in the figures represents the one-year mark ($k = 4$), and $k = 0$ denotes the onset of the shock. The IRFs indicate that all transmission channels follow similar patterns with regards to the size of their initial responses, movements and duration of pass-through following an oil price shock on the level of inflation. As displayed in figures 6.1 to 6.4, the initial response from an oil price shock yields the largest effect compared to the pass-through in later periods of the forecasting horizon.

In Table 6.1, the largest estimate of an initial interaction effect is found at 0.001% for the variable Total Energy Dependency ($\rho^1_{i,t}$). The smallest estimate is found at 0.0004% for the Transport Share of HICP ($\delta_{i,t-1}$). By way of explanation, this means that a 10% increase in oil prices initially increases the domestic inflation level by 0.01%, with an enlarged effect for countries with higher energy dependency rates. Thereby, the results in this paper shows that a higher energy dependency amplifies the initial response of an oil price shock on the level of domestic inflation. What is more, the effect of dependency on energy is estimated as larger compared to the effect of dependency solely on oil. This paper thereby establishes that dependency on energy imports plays a larger roll for the level of domestic inflation for this area compared to dependency solely on oil.

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[1] The solid line, in the figures, is the IRF while the dashed line indicates a 95% confidence band. The red reference line shows the fourth quarter to clarify the dissipating effect after this point.

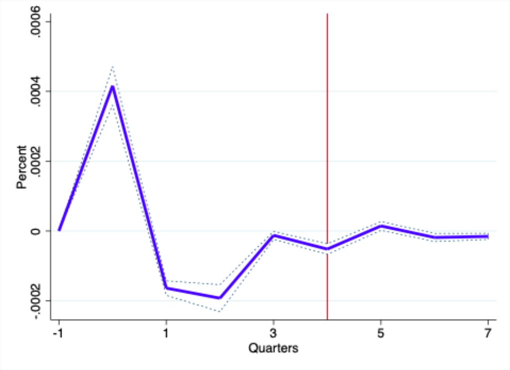

Figure 6.1: The impact of a 1% oil price shock through $\delta_{i,t-1}$ on HICP inflation.

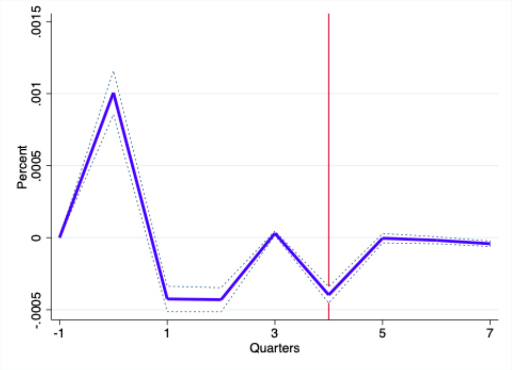

Figure 6.2: The impact of a 1% oil price shock through $\rho^1_{i,t}$ on HICP inflation.

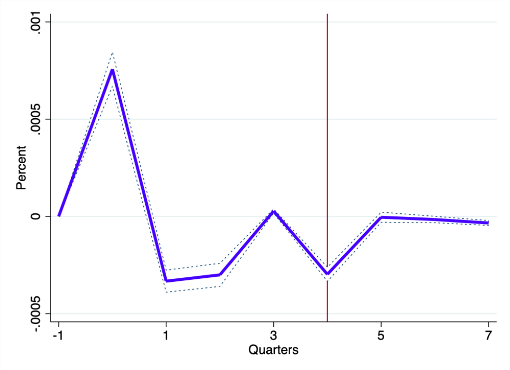

Figure 6.3: The impact of a 1% oil price shock through $\rho^2_{i,t}$ on HICP inflation.

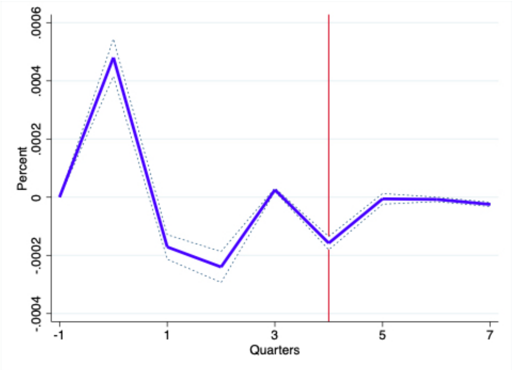

Figure 6.4: The impact of a 1% oil price shock through $\rho^3_{i,t}$ on HICP inflation.

Further, the transmission channel of Energy Intensity, ($\rho^3_{i,t}$), shows a positive initial response. An expected result since inefficient energy usage implies a larger pass-through of oil price shocks. However, when comparing these results to Total Energy Dependency it is shown that the pass-through from an oil price shock is smaller for this variable. Possibly, this result pertains to the various policies aimed at improving energy efficiency implemented by the EU during the last decade described in section 2.2. Such policies could have weakened the linkage between the variable of Energy Intensity as a transmission channel for oil prices to inflation. Yet, the results indicate that lessening the EMU:s dependency on external suppliers of energy should be prioritized over increasing energy efficiency, by decreasing energy intensity, pertaining to the stability of the level of inflation in this area.

Moreover, at the end of the first year of an oil price shock, at k=4, the effect on the level of inflation has become negative for all transmission channels, but the size of the pass-through at this stage is almost unnoticeable with a coefficient very close to zero. After one year, all transmission channels show an estimated negative effect of less than 0.01% on inflation as a response to a 10% oil price shock. At this point, the effect remains largest for countries with a higher dependency rate on energy with a negative coefficient of about 0.004% in the case of a 10% increase in oil prices. A shock of 10%, estimates a negative impact with the pass-through for the Transport Share of HICP and Energy Intensity at around 0.0005% and 0.0016%, respectively. The results show that despite the initial effect of an oil price shock on inflation being notable, it quickly diminishes to having a very slight effect after one year.

After one year, the effect of an oil price shock diminishes to negligible size. Table 6.1 shows that in the third quarter of the second year, at k=7, after the onset of a 1% shock to oil prices, all transmission channels show a negative effect of less than 0.0001% on inflation, which is a negligible effect. To contextualize this number, the size of oil price shocks often measure increases of around 50% [Choi et al., 2018]. For a shock of this size, the accumulated effect on the inflation level would be less than 0.005% for all transmission channels evaluated in this paper. This implies that neither of these transmission channels have a significantly amplifying effect of an oil price shock for the level of inflation.

The results obtained in this paper are in line with those of Chen [2009], Blanchard and Galí [2007] and Herrera and Pesavento [2009] where the pass-through of an oil price shock has dissipating effects over time. When further comparing the results in this paper to those of Chen [2009], who found that the level of inflation had become less sensitive to oil price fluctuations in the 2000s compared to the 1970s, this paper establishes a similar development. The coefficients pertaining to the examined period are smaller than those found by Chen [2009] suggesting that the impact has lessened in size. A reason for this development, as suggested by Chen [2009] and Blanchard and Galí [2007], is the inflation targeting monetary policy conducted by the ECB. Also, increased credibility of the ECB possibly decreased the response of inflation expectation to oil price shocks. Furthermore, more efficient energy usage in the EU, achieved by the shift towards a more service-based economy could be a potential cause for this development. Also, the many policy initiatives, as described in chapter 2, are plausible reasons for the declining pass-through of oil prices to inflation via transmission channels such as energy intensity and energy dependency. Adding to this analysis, is the reasoning made by Blanchard and Galí [2007] regarding a more efficient energy usage in consumption and production contributing to the decreasing pass-through of oil price shocks to the level of inflation. What is more, the results by Hooker [2002], who showed that an increase or decrease in energy intensity does not account for a substantial effect in the pass-through of oil price shocks to inflation, support our findings.

Moreover, the results suggest that a country with a higher share of transport in the HICP basket is not more exposed to oil price shocks than any other country in the EMU with regards to the small accumulated effect measured two years after the onset of a shock, as displayed in table 6.1. These results are in contrast to those of Choi et al. [2018]. However, the sample composition of countries in this paper compared to the one used by Choi et al. [2018] differs to a large extent, since the countries selected for this study all belong to an integrated area managed by the same monetary policy. Thereby, a potential cause for the differing results could be that a more synchronized response of an inflation-targeting monetary policy outweighs the effect of the transport share in the HICP basket for countries in the EMU.

To conclude this section, our findings strongly suggest that the energy-related transmission channels studied in this paper only cause a small amplifying effect of an oil price shock for the inflation level in the EMU.

Table 6.1: Impulse response estimates for the effect of an oil price shock on HICP based inflation.

	k=0	k=1	k=2	k=3	k=4	k=5	k=6	k=7	k=8
$\delta_{i,t-1}\pi^{oil}_{i,t}$	0.000416***	-0.000164***	-0.000193***	-0.0000125*	-0.0000520***	0.0000144*	-0.0000186**	-0.0000155**	-0.00000298
	(0.0000282)	(0.0000106)	(0.0000198)	(0.00000587)	(0.00000765)	(0.00000637)	(0.00000592)	(0.00000448)	(0.00000480)
$\pi_{i,t-1}$	-0.0849***	-0.146***	-0.140***	-0.524***	-0.0420***	-0.0135	-0.0232***	-0.0135***	-0.0295***
	(0.0141)	(0.0110)	(0.00820)	(0.00436)	(0.00952)	(0.00975)	(0.00374)	(0.00344)	(0.00416)
$\pi_{i,t-2}$	-0.176***	-0.135***	-0.139***	0.404***	0.0152	-0.00857	0.00581	0.00139	0.0267***
	(0.0171)	(0.00570)	(0.00711)	(0.00505)	(0.0119)	(0.00693)	(0.00420)	(0.00396)	(0.00299)
N	1667	1667	1667	1667	1648	1629	1610	1591	1572
$\rho^1_{i,t}\pi^{oil}_{i,t}$	0.00101***	-0.000425***	-0.000430***	0.0000312***	-0.000397***	-0.00000358	-0.0000180	-0.0000420***	0.000000512
	(0.0000775)	(0.0000450)	(0.0000425)	(0.00000757)	(0.0000289)	(0.0000166)	(0.0000125)	(0.00000967)	(0.0000128)
$\pi_{i,t-1}$	-0.0950***	-0.153***	-0.140***	-0.528***	0.0795***	-0.00288	-0.0231***	-0.0110**	-0.0295***
	(0.0142)	(0.0125)	(0.00762)	(0.00301)	(0.0137)	(0.0113)	(0.00348)	(0.00368)	(0.00458)
$\pi_{i,t-2}$	-0.169***	-0.129***	-0.137***	0.405***	-0.0600***	-0.0131	0.00861	-0.000177	0.0270***
	(0.0175)	(0.00727)	(0.00697)	(0.00358)	(0.0114)	(0.00845)	(0.00416)	(0.00369)	(0.00325)
N	1591	1609	1609	1609	1609	1609	1609	1609	1590
$\rho^2_{i,t}\pi^{oil}_{i,t}$	0.000757***	-0.000333***	-0.000300***	0.0000275***	-0.000298***	-0.00000427	-0.0000161	-0.0000337***	-0.00000457
	(0.0000451)	(0.0000290)	(0.0000303)	(0.00000542)	(0.0000185)	(0.0000133)	(0.00000840)	(0.00000640)	(0.00000889)
$\pi_{i,t-1}$	-0.0986***	-0.152***	-0.138***	-0.525***	0.0850***	-0.00224	-0.0235***	-0.0124**	-0.0311***
	(0.0142)	(0.0130)	(0.00763)	(0.00294)	(0.0134)	(0.0115)	(0.00395)	(0.00402)	(0.00446)
$\pi_{i,t-2}$	-0.163***	-0.128***	-0.137***	0.402***	-0.0664***	-0.0147	0.00760	-0.000537	0.0272***
	(0.0180)	(0.00735)	(0.00683)	(0.00418)	(0.0119)	(0.00838)	(0.00410)	(0.00378)	(0.00333)
N	1591	1609	1609	1609	1609	1609	1609	1609	1590
$\rho^3_{i,t}\pi^{oil}_{i,t}$	0.000480***	-0.000171***	-0.000240***	0.0000255***	-0.000158***	-0.00000571	-0.00000747	-0.0000247***	-0.000000657
	(0.0000327)	(0.0000215)	(0.0000271)	(0.00000292)	(0.0000116)	(0.00000938)	(0.00000394)	(0.00000369)	(0.00000632)
$\pi_{i,t-1}$	-0.125***	-0.167***	-0.126***	-0.502***	0.149***	0.00108	-0.0269***	-0.0134**	-0.0319***
	(0.0116)	(0.0156)	(0.00911)	(0.00560)	(0.0114)	(0.0127)	(0.00526)	(0.00466)	(0.00487)
$\pi_{i,t-2}$	-0.139***	-0.103***	-0.149***	0.390***	-0.122***	-0.0232*	0.00699	-0.00271	0.0278***
	(0.0160)	(0.0132)	(0.00736)	(0.00606)	(0.0116)	(0.0109)	(0.00449)	(0.00372)	(0.00345)
N	1591	1609	1609	1609	1609	1609	1609	1609	1590

Clustered robust standard errors are reported in parentheses.

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

6.2 Result and Analysis - Inflation Differentials

Table 6.2 shows the results pertaining to the analysis of inflation differentials. In this section, the effect of oil price inflation is studied rather than an oil price shock, which was examined in the previous section. Hence, the estimated model captures how an increase in oil price inflation effects inflation differentials in the EMU, and if any of the energy-related transmission channels have an amplifying effect on them. Each column in Table 6.2 represents one regression containing an interacted variable of a transmission channel and global oil price inflation, except for the first column which includes the non-interacted variable for global oil price inflation, ($\pi_{i,t}^{oil}$). In the first column, a negative coefficient is found for the non-interacted variable at the 0.1 % significance level. Further, aside from the fiscal stance, the nominal exchange rate, the output gap and the price level are found having linkage to inflation differentials for all regressions. Apart from the output gap, the variables show a negative linkage to the dependent variable. These results are in line with the results obtained by Honohan et al. [2003] and are therefore expected.

The second column in Table 6.2, shows the result for the interacted variable of the Transport Share of HICP and global oil price inflation ($\delta_{i,t-1}\pi_{i,t}^{oil}$), where a positive linkage is found. Albeit, the effect is virtually negligible with a coefficient estimated at 0.000137. The interpretation of this variable is that a higher share of transport in the consumption basket has a very small, yet amplifying effect of oil price inflation for inflation differentials. In addition, the rest of the interacted transmission channels covering this period cannot be significantly established in this paper. Thus, their contribution to inflation differentials cannot be conclusively proven.

This paper has established two variables with significant linkages to inflation differentials. Firstly, a negative relationship for the non-interacted variable for global oil price inflation meaning that oil price inflation causes a decrease in inflation differentials. Secondly, a very small, yet positive interaction effect of global oil price inflation and the Transport Share of HICP is found. Thus, the two variables measuring the impact of an increase in oil price inflation show opposite linkages.

However, there are underlying explanations as to why these variables show opposite linkages. Firstly, the result pertaining to the Transport Share of HICP and inflation differentials is, as expected, positive. This is explained by the fact that an increase in oil price inflation makes transport more expensive which has a pass-through at varying rates in domestic economies since they have different shares of transport in the domestic HICP basket. In turn, varying rates of pass-through causes the domestic inflation rate to differ more compared to the EMU average resulting in increased inflation differentials - however note that the estimated effect is small. This reasoning, in relation to inflation differentials, is in line with the reasoning made by Choi et al. [2018] which he made relating to the level of inflation. On an important note, the results from examining the inflation level in section 6.1, where no linkage between the Transport Share of HICP is found, do not contradict these results since we are examining an oil price shock in section 6.1. The Pooled OLS examines an increase in oil price inflation, thus not a temporary affect.

Secondly, the reason why an increase in oil price inflation has a negative effect on inflation differentials relates to the reasoning of Stavrev [2007] and Égert et al. [2004]. Both papers show results which indicates that increased synchronization of business cycles from increased intra-trade has contributed to fewer cross-country discrepancies. Thus, causing a similar response among member countries at an aggregate level following an increase in prices which, in turn, diminishes inflation differentials. Also, the efforts made by the ECB to maintain stable levels of inflation may have reduced the general effect of price increases in oil, since EMU countries deviate to a lesser extent from the EMU average because of these efforts. Accordingly, decreasing the development of inflation differentials. This follows the same reasoning made by Chen [2009] and Blanchard and Galí [2007] as previously discussed in relation to the inflation level.

Furthermore, the insignificant linkages for Total Energy Dependency, Energy Dependency on Oil and Energy Intensity are in contrast to the findings of Égert et al. [2004] and Hofmann and Remsperger [2005]. They established a significant impact for such variables. The efforts made by the EU to increase energy efficiency and create a more integrated internal energy market structure can account for why the energy-related transmission channels show no effect on inflation differentials in this paper. This follows the same reasoning made by Chen [2009] and Blanchard and Galí [2007]. Our findings are also in line with those of Arnold and Verhoef [2004] who found that oil dependency is not a major contributing factor to inflation differentials. Even more so, our findings align with those of Licheron [2007] who did not find any linkage at all. However, this result will be discussed further in section 6.2.1, when the results from the sample split is evaluated.

Table 6.2: *Pooled OLS - Inflation differentials based on HICP inflation*

	(1) hicp_inf	(2) hicp_inf	(3) hicp_inf	(4) hicp_inf	(5) hicp_inf	(6) hicp_inf
$\Delta NEER_{i,t-1}$	-33.39*	-30.22*	-33.01*	-32.23*	-31.85*	-32.09*
	(13.48)	(13.09)	(13.46)	(13.36)	(13.62)	(13.69)
$GAP_{i,t}$	17.09*	17.29*	17.40*	17.70*	17.49*	17.45*
	(6.290)	(6.410)	(6.325)	(6.586)	(6.313)	(6.303)
$FISC_{i,t}$	0.0363	0.0363	0.0351	0.0346	0.0394	0.0370
	(0.0329)	(0.0329)	(0.0331)	(0.0338)	(0.0328)	(0.0332)
$P_{i,t-1}$	-0.0186***	-0.0197***	-0.0188***	-0.0190***	-0.0194***	-0.0196***
	(0.00464)	(0.00479)	(0.00455)	(0.00469)	(0.00461)	(0.00457)
$\pi^{oil}_{i,t}$	-15.83***					
	(1.236)					
$\delta_{i,t-1}\pi^{oil}_{i,t}$		0.000137*				
		(0.0000555)				
$\rho^{1}_{i,t}\pi^{oil}_{i,t}$			-0.0000270			
			(0.000138)			
$\rho^{2}_{i,t}\pi^{oil}_{i,t}$				0.00104		
				(0.000896)		
$\rho^{3}_{i,t}\pi^{oil}_{i,t}$					-0.0000468	
					(0.0000496)	
N	1581	1581	1562	1562	1562	1562
R^2	0.880	0.881	0.881	0.882	0.881	0.881

Clustered robust standard errors are reported in parentheses.

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

6.2.1 Result and Analysis - Inflation Differentials with Sample Split

How does the results change when altering the composition of countries for smaller time periods? The split in data was made to group countries depending on their accession to the EMU, as business-cycle synchronization of member countries align over time. Each country group may therefore give somewhat different results.

Table 6.3 shows the result of the EMU8 countries for the period 1999 to 2012. Table 6.5 shows the results for EMU11 countries for the same period. Table 6.4 shows the result for EMU8 for the period 2013 to 2021. Table 6.6 shows the results for EMU11 countries for the same period. Tables 6.3 and 6.5 depict the following result: a negative relationship is found for global oil inflation for both country groups, the nominal exchange rate has negative linkage for EMU8 while no significance is found for EMU11, the output gap has positive linkage for EMU8 but no linkage is found for EMU11. Further, the fiscal stance is not significant for EMU8, but positively linked for EMU11. Lastly, the price level has no significance for EMU8, but is negatively linked for EMU11. Also, the transmission variables are not significant for this shorter time period for any of the two country groups.

The second period covering 2013 to 2021 is shown in Tables 6.4 and 6.6. The results show significance for oil price inflation for EMU8 and for EMU11 with positive coefficients. The nominal exchange rate is significant for EMU8 with a negative coefficient while no significance is found for EMU11. The output gap and fiscal stance are insignificant for both country groups. The price level is significant for EMU8 with a negative coefficient. No significance is found for EMU11. For this period we find a positive and significant interaction effect of Transport Share in the HICP basket and Total Energy Dependency for EMU11 but not for the EMU8.

Table 6.3: Pooled OLS EMU8 (1999-2012) - Inflation differentials based on HICP inflation

	(1) hicp_inf	(2) hicp_inf	(3) hicp_inf	(4) hicp_inf	(5) hicp_inf	(6) hicp_inf
$\Delta NEER_{i,t-1}$	-48.69*	-45.18*	-47.87*	-48.24*	-46.16*	-45.34
	(17.16)	(17.68)	(17.02)	(16.91)	(19.35)	(19.22)
$GAP_{i,t}$	28.77**	29.32**	28.39**	28.86**	29.09**	29.27**
	(6.799)	(7.016)	(7.062)	(7.098)	(6.879)	(6.792)
$FISC_{i,t}$	-0.0716	-0.0793	-0.0817	-0.0751	-0.0657	-0.0681
	(0.0664)	(0.0651)	(0.0607)	(0.0674)	(0.0729)	(0.0710)
$P_{i,t-1}$	-0.0348	-0.0410*	-0.0324	-0.0365*	-0.0381*	-0.0407*
	(0.0148)	(0.0163)	(0.0138)	(0.0145)	(0.0158)	(0.0158)
$\pi_{i,t}^{oil}$	-0.388***					
	(0.0350)					
$\delta_{i,t-1}\pi_{i,t}^{oil}$		0.000189				
		(0.000111)				
$\rho_{i,t}^{1}\pi_{i,t}^{oil}$			-0.000218			
			(0.000182)			
$\rho_{i,t}^{2}\pi_{i,t}^{oil}$				0.000864		
				(0.00180)		
$\rho_{i,t}^{3}\pi_{i,t}^{oil}$					-0.0000785	
					(0.000135)	
N	410	410	410	410	410	410
R^2	0.832	0.833	0.833	0.832	0.832	0.833

Clustered robust standard errors are reported in parentheses.

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

Table 6.4: Pooled OLS EMU8 (2013-2021) - Inflation differentials based on HICP inflation

	(1) hicp_inf	(2) hicp_inf	(3) hicp_inf	(4) hicp_inf	(5) hicp_inf	(6) hicp_inf
$\Delta NEER_{i,t-1}$	-45.17*	-45.18*	-42.75*	-43.83*	-43.33*	-44.18*
	(16.56)	(16.57)	(18.02)	(17.11)	(16.84)	(17.00)
$GAP_{i,t}$	-2.943	-3.420	1.509	-1.738	0.659	-2.001
	(6.270)	(5.744)	(5.058)	(6.078)	(8.349)	(6.268)
$FISC_{i,t}$	-0.0328	-0.0344	-0.0342	-0.0414	-0.0437	-0.0426
	(0.107)	(0.108)	(0.114)	(0.107)	(0.102)	(0.105)
$P_{i,t-1}$	-0.0597***	-0.0598***	-0.0619***	-0.0616***	-0.0615***	-0.0602***
	(0.0102)	(0.0106)	(0.0113)	(0.0103)	(0.00969)	(0.0108)
$\pi^{oil}_{i,t}$	0.593**					
	(0.119)					
$\delta_{i,t-1}\pi^{oil}_{i,t}$		0.000110				
		(0.0000791)				
$\rho^{1}_{i,t}\pi^{oil}_{i,t}$			-0.000269			
			(0.000156)			
$\rho^{2}_{i,t}\pi^{oil}_{i,t}$				0.000996		
				(0.000588)		
$\rho^{3}_{i,t}\pi^{oil}_{i,t}$					-0.000222	
					(0.000215)	
N	253	253	245	245	245	245
R^2	0.779	0.780	0.784	0.783	0.784	0.781

Clustered robust standard errors are reported in parentheses.

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

Table 6.5: Pooled OLS EMU11 (1999-2012) - Inflation differentials based on HICP inflation

	(1) hicp_inf	(2) hicp_inf	(3) hicp_inf	(4) hicp_inf	(5) hicp_inf	(6) hicp_inf
$\Delta NEER_{i,t-1}$	6.726	10.74	1.205	5.206	3.593	3.613
	(22.01)	(23.09)	(20.50)	(20.99)	(23.17)	(22.00)
$GAP_{i,t}$	-0.255	0.599	-0.877	-0.583	-0.0880	-0.329
	(4.989)	(5.030)	(4.118)	(5.069)	(4.660)	(4.548)
$FISC_{i,t}$	0.0975^{***}	0.0967^{***}	0.102^{***}	0.0973^{**}	0.101^{***}	0.103^{***}
	(0.0209)	(0.0198)	(0.0209)	(0.0216)	(0.0205)	(0.0202)
$P_{i,t-1}$	-0.0185	-0.0183^{*}	-0.0183^{*}	-0.0187^{*}	-0.0175	-0.0193^{*}
	(0.00846)	(0.00809)	(0.00677)	(0.00807)	(0.00807)	(0.00768)
$\pi_{i,t}^{oil}$	-1.196^{***}					
	(0.0651)					
$\delta_{i,t-1}\pi_{i,t}^{oil}$		0.000151				
		(0.000137)				
$\rho_{i,t}^{1}\pi_{i,t}^{oil}$			0.000309			
			(0.000140)			
$\rho_{i,t}^{2}\pi_{i,t}^{oil}$				0.000662		
				(0.000562)		
$\rho_{i,t}^{3}\pi_{i,t}^{oil}$					-0.0000466	
					(0.0000509)	
N	543	543	543	543	543	543
R^2	0.958	0.960	0.961	0.959	0.959	0.959

Clustered robust standard errors are reported in parentheses.

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

Table 6.6: Pooled OLS EMU11 (2013-2021) - Inflation differentials based on HICP inflation

	(1) hicp_inf	(2) hicp_inf	(3) hicp_inf	(4) hicp_inf	(5) hicp_inf	(6) hicp_inf
$\Delta NEER_{i,t-1}$	24.98	26.56	25.40	25.72	25.09	25.18
	(39.96)	(38.98)	(39.79)	(39.82)	(39.97)	(39.94)
$GAP_{i,t}$	-2.348	-2.546	-0.377	-0.782	-1.247	-1.109
	(2.654)	(2.220)	(2.654)	(2.999)	(2.841)	(2.293)
$FISC_{i,t}$	0.0397	0.0476	0.0394	0.0345	0.0402	0.0402
	(0.0527)	(0.0558)	(0.0568)	(0.0569)	(0.0558)	(0.0557)
$P_{i,t-1}$	0.00361	0.00414	0.00454	0.00481	0.00380	0.00403
	(0.00802)	(0.00843)	(0.00765)	(0.00799)	(0.00768)	(0.00786)
$\pi_{i,t}^{oil}$	0.418**					
	(0.130)					
$\delta_{i,t-1}\pi_{i,t}^{oil}$		0.000248*				
		(0.0000867)				
$\rho_{i,t}^{1}\pi_{i,t}^{oil}$			0.000286*			
			(0.000128)			
$\rho_{i,t}^{2}\pi_{i,t}^{oil}$				0.000547		
				(0.000553)		
$\rho_{i,t}^{3}\pi_{i,t}^{oil}$					-0.0000505	
					(0.0000494)	
N	349	349	338	338	338	338
R^2	0.900	0.902	0.903	0.901	0.901	0.901

Clustered robust standard errors are reported in parentheses.

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

According to the results, the relationship between oil price inflation and inflation differentials vary for the two time periods. From 1999 to 2012 a significantly negative relationship is found for both EMU8 and EMU11, while from 2013 to 2021 a significantly positive relationship is established for both groups. How come the estimates show opposite results? As argued in section 6.1 and 6.2, where the efforts to maintain stable levels of inflation may have reduced the general effect of price increases of oil, since EMU countries deviate to a lesser extent from the EMU average because of these efforts. Accordingly, decreasing the development of inflation differentials, such reasoning follows the one made by Chen [2009]. The results following the sample period from 2013 to 2021 can be explained following the same reasoning. This is because the structural changes effecting the pass-through of the transmission channels of oil prices to inflation differentials is a gradual process rather than an instant change. Also, the shift to decrease energy dependency and energy intensity within the euro area has likely moved at different rates across countries. As some countries were equipped to adapt faster to decrease their reliance on energy, while others were not. Thus, resulting in heightened inflation differentials within such a group over time. Before such efforts were made, it is possible that oil price inflation had a decreasing affect on HICP inflation since the country groups responded more similarly than after this development began. This is why a significantly positive relationship is established for both groups from 2013 to 2021 where cross-country discrepancies could be higher following this reasoning.

On another note, differing results are also given for the control variables between the sample periods pertaining to the output gap, fiscal stance and the price level. However, many economic occurrences can explain the differing results between the samples. For example, the estimates from the second sample period, 2013 to 2021, are based on a time period with lower level of inflation and a significant drop in oil prices as well as the effects linked to the aftermath of the 2008 global financial crisis. The variables in the first period, 1999 to 2012, were not exposed to such economic occurrences, hence showing varying results for some of the control variables. Furthermore, the differences in the estimates of some of the control variables can be explained by characteristics within the country groups where countries included in the EMU11 are assumed to be more homogeneous in comparison to the ones included in EMU8. Thereby it is not worrisome that the control variables have had differing impact for the two time periods and across country composition.

6.3 Specification tests

In this chapter, the results are assessed through several specification tests. This is done to ensure proper adjustments are taken to minimize anomalies hence allowing the regressions to give accurate estimates. This is done by testing for heteroskedasticity and endogeneity. In doing so, potential limitations pertaining to the results can be discussed which is a necessary precondition for a proper analysis to follow from our results.

6.3.1 Robustness Check - Inflation Level

To examine the robustness of the main results, the regressions on the level of inflation were also estimated with data of inflation based on the HICP excluding energy as the dependent variable. The results, as displayed in Table B.1 in Appendix B, show a similar tendency as the main results with regards to the significance and signs of the estimated interaction effects but with a smaller estimated coefficient for all periods. The length of pass-through is also similar to the main results with the last significant effect ending one period before the results pertaining to regressions on HICP based inflation. The response of HICP excluding energy inflation of a one percent shock to oil prices is displayed by the IRFs presented in Figures B.1, B.2, B.3 and B.4 in Appendix B. The responses shows similar movements to the ones presented in Figures 6.1, 6.2, 6.3, and 6.4 but with a more prominently dissipating effect after the fourth quarter, marked by the red line. This shows that while using an inflation measure that includes energy in the consumption basket accounts for a larger estimated effect, it does not change the significance or duration of pass-through.

Another robustness check of the main results was the sample split to examine if the sample composition drives the results over time. Therefore, the sample was divided into two groups, EMU8 and EMU11, like the ones described in section 5.2.1. Table B.2 in Appendix B show the results for EMU8 while Table B.3 in Appendix B show the results for EMU11. Both Table B.2 and B.3 show that the results based on this sample composition are very similar to the ones presented in the analysis using the main sample.

6.3.2 Robustness Check - Inflation Differentials

In [Honohan et al., 2003], the General Methods of Moments (GMM) was used to examine the estimations. However, while this method is suitable for samples with a shorter time period, it does not accurately estimate samples over longer periods such as the one in this paper. Therefore, this paper did not employ the same robustness check. Instead, other measures were taken to examine the results. Firstly, a Breusch Pagan test was conducted to examine the regressions for heteroskedasticity. The result showed that our regressions had heteroskedasticity issues, which was dealt with through using clustered standard errors in the regressions. This approach was taken due to its suitability for correcting regressions using Pooled OLS. Moving on, autocorrelation was found, which was dealt with using clustered standard errors. Next, in order to examine the data for endogeneity, a Hausman test was conducted which indicated using fixed effects in the regressions. According to Honohan et al.

(2003) it is not necessary to include fixed effects, in this instance, since permanent inflation differentials are presumed to not occur over time. For this reason Honohan et al. (2003) did not test this assumption in their paper. After conduction the test on the data pertaining to this paper, the choice to not include fixed effects was taken since matching the regression by Honohan et al. (2003) was prioritized.

7

Conclusion

Our findings suggest that the EMU countries are not sensitive to oil price shocks pertaining to the inflation level. The examined transmission channels show small effects in their pass-through to inflation levels. Transport Share of HICP, Total Energy Dependency, Energy Dependency on Oil, and Energy Intensity show the largest effect at the initial impact of an oil price shock. The largest initial effect is found for Total Energy Dependency, thereby suggesting that decreasing the dependency on external energy supply should be prioritized for this area. Still, the effect of this variable is small. In fact, when accumulating the effects for all transmission channels over the entire forecast horizon, the effect diminishes to an even more modest size with an almost negligible effect of pass-through to inflation levels. This small, yet amplifying effect can be explained by an active monetary policy in response to inflation as well as a more efficient use of energy by countries in the euro area.

Moreover, the result established from examining inflation differentials shows a negative linkage between oil price inflation and inflation differentials. This means that the results, based on data covering the period from 1999 to 2021, implies that an increase in oil price inflation had a decreasing effect on inflation differentials. The linkage is explained by an increased synchronization of business cycles followed by increased intra-euro area trade. This has contributed to fewer cross-country discrepancies. Thus, inducing similar responses among the EMU countries at an aggregate level following oil price increases, thereby diminishing inflation differentials. Also, the efforts to maintain low levels of inflation likely reduced the general effect of price increases in oil, since EMU countries deviate to a lesser extent from the EMU average because of these efforts. Accordingly, decreasing the development of inflation differentials. However, the Transport Share of HICP is found causing a small, yet amplifying effect on inflation differentials. The rest of the interacted transmission channels covering the whole period cannot be significantly established in this paper. The same result applies for the shorter sample periods examined from 1999 to 2012, where none of the transmission variables are significantly established. However, from 2013 to 2021 a positive interaction effect of Transport Share in the HICP basket and Total Energy Dependency is found for EMU11 but not for EMU8. The effects that have been significantly established are small in size suggesting that while there is an amplifying effect, it does not generate a substantial effect for inflation differentials.

In conclusion, the results of both the analysis on the effect of an oil price shock on the inflation level as well as the results pertaining to the effect of oil price inflation on inflation differentials can be accounted for by the monetary policy conducted by the ECB. An active monetary policy on inflation has decreased the pass-through of oil prices to the inflation level while a more synchronized response among countries created by a common monetary policy has led to oil price inflation decreasing inflation differentials. Furthermore, a structural shift with regards to increased energy efficiency, a more service-based economy, and an integrated energy market in the EU are potential causes for energy-related transmission channels showing low pass-through of oil prices.

7.1 Future Research

This paper has focused on the response of consumer price based inflation from an oil price shock and oil price inflation. A suggestion for future research is to examine the effect of oil prices on production based inflation to estimate the pass-through for similar transmission channels like those studied in this paper. This extension would further the analysis and give a broader understanding of how inflation is affected by an oil price shock or oil price increase.

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Appendix A

Data description

Table A.1: Description of countries included in the samples.

	Countries
EMU	Austria, Belgium, Cyprus, Estonia, Finland, France, Germany, Greece, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Portugal, Slovakia, Slovenia, and Spain.
EMU8	Cyprus, Estonia, Greece, Latvia, Lithuania, Malta, Slovenia, and Slovakia.
EMU11	Austria, Belgium, Finland, France, Germany, Ireland, Italy, Luxembourg, Netherlands, Portugal, and Spain.

Table A.2: Summary, description and source of data.

Variable	Description	Source
Inflation rate	The Harmonised Index of Consumer Prices (HICP), not seasonally adjusted, 2015 referene year	Eurostat
Transport share of HICP	The weight of transport in the HICP basket	Eurostat
Total Energy Dependencey	Measured as net imports divided by gross available energy	Eurostat
Energy dependencey on Oil	Measured as net imports divided by gross available energy for oil and petroleum products (excluding biofuel portion)	Eurostat
Energy intensity	Measured as kilograms of oil equivalent (KGOE) per thousand euros in purchasing power standards (PPS)	Eurostat
Global Oil Price Inflation	Measured as an equally weighted average of three spot prices: Dated Brent, West Texas Intermediate, and the Dubai Fateh	IMF - Primary Commodity Price System
NEER	The index is calculated against a group of 37 trading partners and for different currencies.	Eurostat
Output Gap	Gross Domestic Product, seasonally adjusted	IMF - International Financial Statistics
Fiscal Stance	Measured as net imports divided by gross available energy for oil and petroleum products (excluding biofuel portion)	The Statistical Data Warehouse of the European Central Bank
Price level	Measured as the price level of household consumption, reference year 2017	Penn World Table 10.0

Appendix B

Robustness Checks - Inflation Level

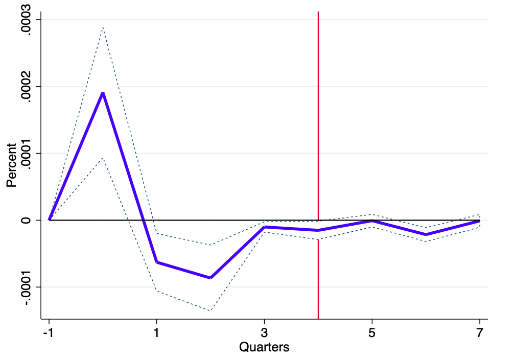

Figure B.1: The impact of a 1% oil price shocks through $\delta_{i,t-1}$ on HICP excluding energy inflation.

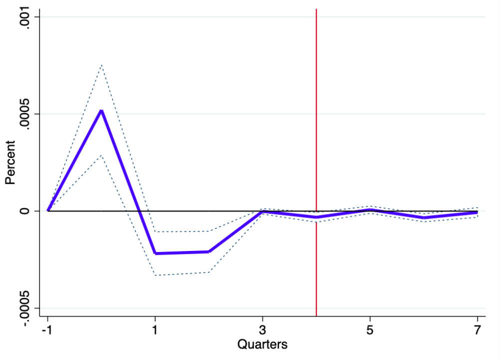

Figure B.2: The impact of a 1% oil price shocks through $\rho^1_{i,t}$ on HICP excluding energy.

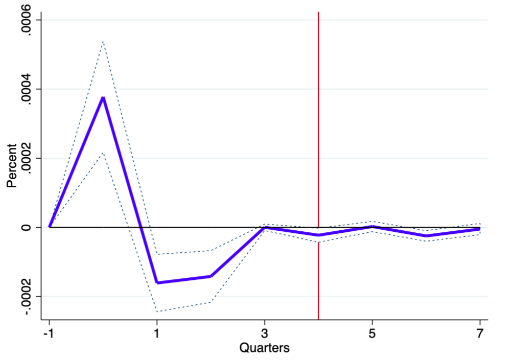

Figure B.3: The impact of a 1% oil price shocks through $\rho^2_{i,t}$ on HICP excluding energy.

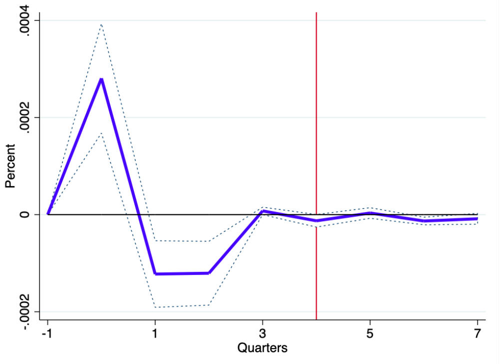

Figure B.4: The impact of a 1% oil price shocks through $\rho^3_{i,t}$ on HICP excluding energy.

Table B.1: Impulse response estimates for the effect of an oil price shock on HICP excluding energy based inflation.

	k=0	k=1	k=2	k=3	k=4	k=5	k=6	k=7	k=8
$\delta_{i,t-1}\pi^{oil}_{i,t}$	0.000191**	-0.0000628*	-0.0000865**	-0.0000101*	-0.0000151*	-0.000000635	-0.0000215***	-0.000000892	0.00000634
	(0.0000498)	(0.0000220)	(0.0000252)	(0.00000394)	(0.00000702)	(0.00000479)	(0.00000527)	(0.00000487)	(0.00000457)
$\pi_{i,t-1}$	-0.145***	-0.142***	-0.128***	-0.539***	0.0127**	0.00520	-0.0114*	-0.0175**	-0.0415***
	(0.0121)	(0.0113)	(0.00591)	(0.00352)	(0.00376)	(0.00794)	(0.00477)	(0.00459)	(0.00531)
$\pi_{i,t-2}$	-0.127***	-0.130***	-0.146***	0.425***	-0.0220***	-0.0250***	-0.0141***	-0.00642	0.0313***
	(0.00748)	(0.00285)	(0.00711)	(0.00434)	(0.00505)	(0.00405)	(0.00338)	(0.00409)	(0.00472)
N	1580	1580	1580	1580	1561	1542	1523	1504	1485
$\rho^1_{i,t}\pi^{oil}_{i,t}$	0.000521***	-0.000219**	-0.000210**	-0.00000121	-0.0000317*	0.00000721	-0.0000342**	-0.00000674	0.0000179
	(0.000119)	(0.0000572)	(0.0000540)	(0.00000718)	(0.0000129)	(0.00000952)	(0.0000105)	(0.0000127)	(0.0000120)
$\pi_{i,t-1}$	-0.155***	-0.141***	-0.126***	-0.534***	0.0129**	0.00484	-0.0115*	-0.0179**	-0.0420***
	(0.0130)	(0.0117)	(0.00582)	(0.00397)	(0.00393)	(0.00784)	(0.00485)	(0.00462)	(0.00534)
$\pi_{i,t-2}$	-0.119***	-0.129***	-0.146***	0.420***	-0.0220***	-0.0237***	-0.0134**	-0.00688	0.0315***
	(0.00814)	(0.00353)	(0.00756)	(0.00460)	(0.00498)	(0.00436)	(0.00345)	(0.00419)	(0.00478)
N	1504	1504	1504	1504	1504	1504	1504	1504	1485
$\rho^2_{i,t}\pi^{oil}_{i,t}$	0.000378***	-0.000161**	-0.000142**	0.000000176	-0.0000227*	0.00000233	-0.0000249**	-0.00000485	0.00000858
	(0.0000820)	(0.0000423)	(0.0000381)	(0.00000477)	(0.0000104)	(0.00000757)	(0.00000781)	(0.00000831)	(0.00000808)
$\pi_{i,t-1}$	-0.155***	-0.140***	-0.126***	-0.533***	0.0137**	0.00510	-0.0119*	-0.0187**	-0.0430***
	(0.0124)	(0.0120)	(0.00549)	(0.00429)	(0.00362)	(0.00774)	(0.00505)	(0.00512)	(0.00552)
$\pi_{i,t-2}$	-0.118***	-0.130***	-0.145***	0.420***	-0.0226***	-0.0245***	-0.0136***	-0.00686	0.0317***
	(0.00803)	(0.00359)	(0.00757)	(0.00504)	(0.00524)	(0.00435)	(0.00327)	(0.00422)	(0.00488)
N	1504	1504	1504	1504	1504	1504	1504	1504	1485
$\rho^3_{i,t}\pi^{oil}_{i,t}$	0.000281***	-0.000122**	-0.000121**	0.00000768	-0.0000127	0.00000339	-0.0000131**	-0.00000855	0.00000531
	(0.0000576)	(0.0000350)	(0.0000335)	(0.00000394)	(0.00000657)	(0.00000554)	(0.00000399)	(0.00000566)	(0.00000589)
$\pi_{i,t-1}\cdot$	-0.177***	-0.143***	-0.121***	-0.507***	0.0184***	0.00689	-0.0122	-0.0220**	-0.0466***
	(0.0160)	(0.0125)	(0.00812)	(0.0104)	(0.00409)	(0.00782)	(0.00656)	(0.00595)	(0.00513)
$\pi_{i,t-2}$	-0.0965***	-0.122***	-0.150***	0.404***	-0.0262***	-0.0279***	-0.0170***	-0.00838	0.0331***
	(0.00906)	(0.00935)	(0.00534)	(0.00856)	(0.00564)	(0.00515)	(0.00340)	(0.00453)	(0.00528)
N	1504	1504	1504	1504	1504	1504	1504	1504	1485

Clustered robust standard errors are reported in parentheses.

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

Table B.2: Impulse response estimates for the effect of an oil price shock on HICP based inflation (EMU8).

	k=0	k=1	k=2	k=3	k=4	k=5	k=6	k=7	k=8
$\delta_{i,t-1}\pi_{i,t}^{oil}$	0.000440***	-0.000130***	-0.000216**	-0.0000124	-0.0000742***	0.00000478	-0.0000204	-0.0000179	0.00000371
	(0.0000618)	(0.0000222)	(0.0000418)	(0.0000141)	(0.0000136)	(0.0000161)	(0.0000164)	(0.0000116)	(0.0000138)
$\pi_{i,t-1}$	-0.0658*	-0.151***	-0.145***	-0.530***	-0.0440*	-0.00177	-0.0266**	-0.0168***	-0.0343***
	(0.0262)	(0.0196)	(0.0161)	(0.00294)	(0.0176)	(0.0164)	(0.00701)	(0.00261)	(0.00588)
$\pi_{i,t-2}$	-0.195***	-0.129***	-0.127***	0.411***	0.0197	-0.0215	0.00586	0.00325	0.0327***
	(0.0318)	(0.0102)	(0.0112)	(0.00661)	(0.0213)	(0.0109)	(0.00766)	(0.00555)	(0.00335)
N	699	699	699	699	691	683	675	667	659
$\rho_{i,t}^{1}\pi_{i,t}^{oil}$	0.00107**	-0.000366*	-0.000490**	0.0000215	-0.000443**	-0.0000257	-0.00000679	-0.0000523*	0.0000121
	(0.000253)	(0.000105)	(0.000120)	(0.0000134)	(0.0000935)	(0.0000421)	(0.0000278)	(0.0000198)	(0.0000310)
$\pi_{i,t-1}$	-0.0724*	-0.159***	-0.146***	-0.530***	0.0613	0.00796	-0.0289**	-0.0144**	-0.0332**
	(0.0271)	(0.0232)	(0.0159)	(0.00497)	(0.0261)	(0.0200)	(0.00595)	(0.00398)	(0.00693)
$\pi_{i,t-2}$	-0.189***	-0.122***	-0.126***	0.408***	-0.0445	-0.0252	0.0108	0.00213	0.0323***
	(0.0340)	(0.0134)	(0.0110)	(0.00589)	(0.0237)	(0.0143)	(0.00763)	(0.00501)	(0.00403)
N	667	674	674	674	674	674	674	674	666
$\rho_{i,t}^{2}\pi_{i,t}^{oil}$	0.000831***	-0.000319**	-0.000333***	0.0000224*	-0.000336***	-0.0000245	-0.0000126	-0.0000403*	-0.000000337
	(0.0000883)	(0.0000610)	(0.0000580)	(0.00000945)	(0.0000323)	(0.0000295)	(0.0000183)	(0.0000133)	(0.0000208)
$\pi_{i,t-1}$	-0.0803*	-0.157***	-0.142***	-0.522***	0.0753*	0.00895	-0.0315**	-0.0187**	-0.0374***
	(0.0271)	(0.0245)	(0.0159)	(0.00402)	(0.0246)	(0.0205)	(0.00654)	(0.00470)	(0.00652)
$\pi_{i,t-2}$	-0.178**	-0.119***	-0.126***	0.401***	-0.0618*	-0.0300	0.00946	0.00276	0.0342***
	(0.0350)	(0.0134)	(0.0108)	(0.00682)	(0.0226)	(0.0135)	(0.00769)	(0.00528)	(0.00388)
N	667	674	674	674	674	674	674	674	666
$\rho_{i,t}^{3}\pi_{i,t}^{oil}$	0.000476***	-0.000148**	-0.000246**	0.0000259***	-0.000152***	-0.0000150	-0.00000440	-0.0000297***	-0.00000116
	(0.0000490)	(0.0000331)	(0.0000462)	(0.00000425)	(0.0000162)	(0.0000161)	(0.00000619)	(0.00000526)	(0.0000116)
$\pi_{i,t-1}$	-0.109**	-0.176***	-0.128***	-0.494***	0.147***	0.0128	-0.0370**	-0.0204**	-0.0381***
	(0.0238)	(0.0299)	(0.0189)	(0.00865)	(0.0208)	(0.0231)	(0.00831)	(0.00579)	(0.00689)
$\pi_{i,t-2}$	-0.150**	-0.0891**	-0.137***	0.386***	-0.125***	-0.0407	0.00918	-0.000149	0.0342***
	(0.0327)	(0.0237)	(0.0117)	(0.0104)	(0.0190)	(0.0181)	(0.00826)	(0.00552)	(0.00405)
N	667	674	674	674	674	674	674	674	666

Clustered robust standard errors are reported in parentheses.

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

Table B.3: Impulse response estimates for the effect of an oil price shock on HICP based inflation (EMU11).

	k=0	k=1	k=2	k=3	k=4	k=5	k=6	k=7	k=8
$\delta_{i,t-1}\pi^{oil}_{i,t}$	0.000373***	-0.000172***	-0.000164***	-0.00000753	-0.0000411***	0.0000192*	-0.0000173**	-0.0000156***	-0.00000687*
	(0.0000323)	(0.0000116)	(0.0000167)	(0.00000576)	(0.00000614)	(0.00000638)	(0.00000445)	(0.00000333)	(0.00000278
$\pi_{i,t-1}$	-0.114***	-0.135***	-0.130***	-0.516***	-0.0356***	-0.0295***	-0.0222***	-0.0125	-0.0259***
	(0.0106)	(0.00298)	(0.00577)	(0.00680)	(0.00515)	(0.00327)	(0.00315)	(0.00738)	(0.00359)
$\pi_{i,t-2}$	-0.147***	-0.145***	-0.158***	0.397***	0.00298	0.00538	0.00672	0.00114	0.0210***
	(0.0106)	(0.00256)	(0.00546)	(0.00683)	(0.00571)	(0.00411)	(0.00453)	(0.00682)	(0.00378)
N	963	963	963	963	952	941	930	919	908
$\rho^1_{i,t}\pi^{oil}_{i,t}$	0.000893***	-0.000451***	-0.000345***	0.0000440**	-0.000344***	0.0000154	-0.0000251*	-0.0000373**	-0.00000940
	(0.0000705)	(0.0000401)	(0.0000294)	(0.00000960)	(0.0000237)	(0.0000110)	(0.00000978)	(0.00000904)	(0.00000815)
$\pi_{i,t-1}$	-0.125***	-0.140***	-0.131***	-0.526***	0.0985***	-0.0206***	-0.0189***	-0.00942	-0.0254***
	(0.00926)	(0.00324)	(0.00583)	(0.00356)	(0.00983)	(0.00363)	(0.00291)	(0.00691)	(0.00439)
$\pi_{i,t-2}$	-0.141***	-0.142***	-0.154***	0.401***	-0.0728***	0.00288	0.00760	-0.000581	0.0215***
	(0.00883)	(0.00178)	(0.00534)	(0.00490)	(0.00907)	(0.00360)	(0.00453)	(0.00668)	(0.00416)
N	919	929	929	929	929	929	929	929	918
$\rho^2_{i,t}\pi^{oil}_{i,t}$	0.000666***	-0.000337***	-0.000253***	0.0000336***	-0.000256***	0.0000127	-0.0000185*	-0.0000297***	-0.00000895
	(0.0000479)	(0.0000274)	(0.0000219)	(0.00000658)	(0.0000207)	(0.00000825)	(0.00000683)	(0.00000535)	(0.00000553)
$\pi_{i,t-1}$	-0.126***	-0.141***	-0.131***	-0.526***	0.0998***	-0.0198***	-0.0179***	-0.00860	-0.0251***
	(0.00960)	(0.00334)	(0.00535)	(0.00407)	(0.00984)	(0.00352)	(0.00264)	(0.00668)	(0.00446)
$\pi_{i,t-2}$	-0.139***	-0.142***	-0.154***	0.401***	-0.0744***	0.00325	0.00724	-0.00151	0.0205***
	(0.00907)	(0.00170)	(0.00485)	(0.00499)	(0.00831)	(0.00362)	(0.00450)	(0.00648)	(0.00422)
N	919	929	929	929	929	929	929	929	918
$\rho^3_{i,t}\pi^{oil}_{i,t}$	0.000453***	-0.000192***	-0.000212***	0.0000254***	-0.000157***	0.00000655	-0.0000118*	-0.0000191***	-0.000000193
	(0.0000503)	(0.0000266)	(0.0000215)	(0.00000358)	(0.0000188)	(0.00000503)	(0.00000496)	(0.00000311)	(0.00000284)
$\pi_{i,t-1}$	-0.144***	-0.151***	-0.121***	-0.513***	0.143***	-0.0178**	-0.0182***	-0.00779	-0.0244***
	(0.0104)	(0.00422)	(0.00558)	(0.00388)	(0.00957)	(0.00419)	(0.00352)	(0.00679)	(0.00508)
$\pi_{i,t-2}$	-0.124***	-0.125***	-0.165***	0.394***	-0.113***	-0.000809	0.00640	-0.00273	0.0213**
	(0.00959)	(0.00197)	(0.00491)	(0.00562)	(0.00912)	(0.00339)	(0.00456)	(0.00650)	(0.00497)
N	919	929	929	929	929	929	929	929	918

Clustered robust standard errors are reported in parentheses.

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