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**TESIS DOCTORAL**

# El mercado del petróleo en el siglo XXI. Factores determinantes y efectos económicos

# The oil market in the 21st century. Determining factors and economic effects


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**~ Tesis por compendio ∽**

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# Resumen

El petróleo es la materia prima más comerciada a nivel internacional, siendo la evolución de su mercado un factor relevante en el desarrollo de la economía global. El objetivo de esta tesis es estudiar su evolución durante el siglo XXI, analizando tanto los factores determinantes como sus consecuencias económicas. En la primera parte de esta Tesis Doctoral estudiamos el impacto de tres tipos de shocks en la evolución del precio, tanto a largo plazo como a corto plazo. Estos shocks son: el shock económico generado por el estallido del mercado financiero en 2008; los shocks políticos provocados por las guerras de Libia, Siria y Ucrania; y el shock tecnológico generado por la introducción de la técnica *fracking* de extracción de petróleo. En la segunda parte de la Tesis Doctoral llevamos a cabo un análisis de los efectos macroeconómicos producidos por la evolución del mercado del petróleo. Por una parte, estudiamos el efecto distributivo a nivel internacional que producen las rentas del petróleo y, por otra parte, analizamos el efecto de los precios del petróleo en la inflación en los países de la zona euro, y la influencia que tiene en esta transmisión dos factores determinantes: el entorno de inflación en el que se produce las variaciones del precio y la reacción del tipo de cambio del euro respecto al dólar ante estas variaciones.

Los resultados de nuestra investigación nos permiten concluir que: la crisis financiera provocó un colapso del precio del petróleo y la introducción del *fracking* también dio lugar a precios más bajos, mientras que las distintas guerras no tuvieron un impacto directo en la evolución del precio del petróleo, sino que afectaron indirectamente al mercado, en el caso de la de Libia con una caída de la producción de la OPEP y en el de la de Ucrania provocando una acumulación de stocks. Además, aunque no afectó a la evolución del precio en el largo plazo, determinados eventos de la guerra de Ucrania relacionados con Rusia y Estados Unidos afectaron a la evolución diaria del precio del petróleo.

En cuanto a las consecuencias distributivas, los resultados muestran que el efecto redistributivo de las rentas del comercio del petróleo ha mostrado una tendencia decreciente, pasando de reducir la desigualdad a incrementarla. Respecto al efecto del precio del petróleo en la inflación en la zona euro, los resultados muestran que el entorno de inflación es determinante para la transmisión de las variaciones del precio del petróleo a la inflación, ya que el efecto de aumentos de precios es mayor en entorno de alta inflación, transmitiéndose además a la inflación subyacente. Finalmente, el tipo de cambio del euro respecto al dólar presenta una relación positiva con el precio del petróleo, generando un efecto amortiguador del impacto de las variaciones del precio del petróleo en la inflación en la zona euro, un efecto que se ha ido intensificado. Estos resultados ponen de manifiesto la necesidad de que el BCE tenga en consideración ambos factores a la hora de adoptar una respuesta ante presiones inflacionarias generadas por un incremento del precio del petróleo.

# Abstract

Oil is the most globally traded commodity, and the evolution of its market is an important factor in the evolution of the global economy. The objective of this thesis is to study its development throughout the 21st century, analysing the determining factors and their economic consequences. In the first part of the doctoral thesis, we look at the impact of three types of shocks on the evolution of oil prices in the long-term as well as in the short-term. These shocks are: the economic shock generated by the financial market collapse of 2008; the political shocks triggered by the wars in Libya, Syria, and Ukraine; and the technological shock generated by the introduction of fracking as an oil extraction technique. In the second part of the doctoral thesis, we analyse the macroeconomic effects caused by the evolution of the oil market. We study the distributive effect produced by oil rents at an international level and as well as the effect oil prices have on inflation in euro area countries, focusing on the influence of two determining factors in this transmission: the inflation environment in which the fluctuation of oil price occurs and the reaction of the euro/dollar exchange rate to those fluctuations.

The results of our research allow us to draw the following conclusions: the financial crisis caused a slump in the price of oil, and the introduction of fracking led to lower oil prices, while the various wars had no direct impact on the evolution of oil prices. Rather, they affected the oil market indirectly; in the case of the war in Libya via a drop in OPEC oil production, and in the Ukrainian war by leading to stockpiling. In addition, some events of the war in Ukraine involving Russia and the United States influenced daily changes in oil prices, although they did not affect price in the longer term.

As regards the distributional consequences, our findings show that the redistributive effect of oil trade rents has experienced a downward trend, going from reducing international inequality to increasing it. As for the transmission of oil prices to inflation in the euro area, we find that the inflationary environment is determinant for the transmission of oil price changes to inflation, since the effect of oil price increases is greater in a high inflation environment and is also transmitted to core inflation in such an environment. Finally, the euro/dollar exchange rate displays a positive relationship with the price of oil, producing a dampening effect of the impact of oil price fluctuations on the inflation rate in the euro area, an effect that has intensified over time. These findings highlight the need for the ECB to consider both factors when adopting a reaction to inflationary pressures triggered by an increase in the price of oil.

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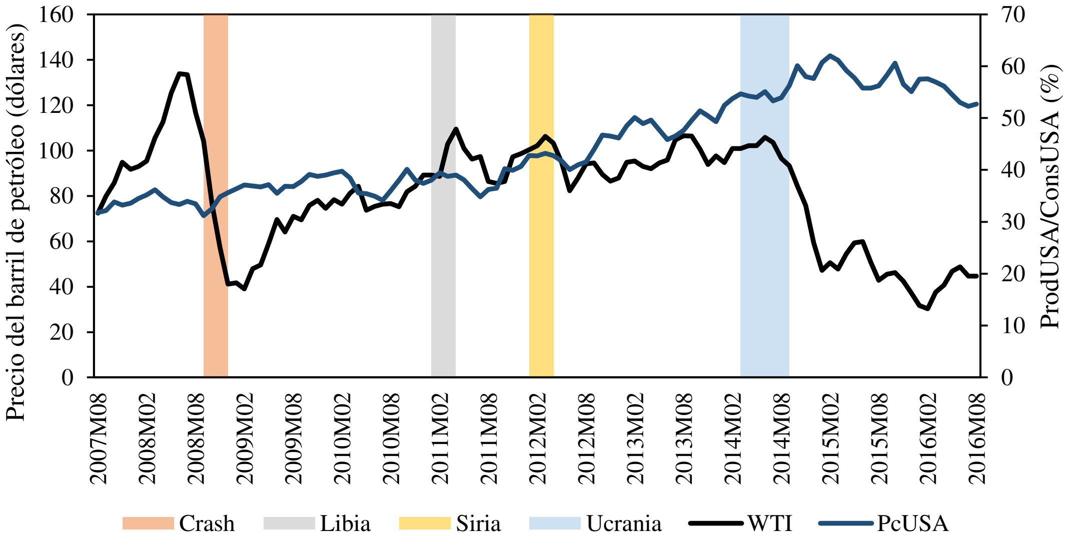
# 1. Introducción

Entre los años 2000 y 2018, las exportaciones de petróleo supusieron en torno al 7% del total de exportaciones a nivel mundial (UNCTAD, 2018). Durante el siglo XXI, y especialmente tras la Gran Recesión, el mercado de petróleo mundial se ha visto marcado por tres tipos de shocks que han determinado su evolución: - un shock de naturaleza económica y financiera, la crisis financiera de 2008 y la Gran Recesión que le sucedió; - los shocks de carácter político que representan las guerras de la primavera árabe, que afectaron a países con importantes reservas de petróleo como Libia o Siria, y la guerra civil de Ucrania, que involucró a Rusia, un país estratégico en el mercado de petróleo; - y un shock tecnológico, la aplicación de la técnica de extracción denominada como *fracking*, cuya introducción ha supuesto una revolución en el mercado del petróleo, convirtiendo a EEUU en el principal productor del mismo, reduciendo así su dependencia energética, lo que ha incrementado la competencia en el mercado de petróleo y reducido el poder de mercado de los países pertenecientes a la Organización de Países Exportadores de Petróleo (OPEP).

El shock económico experimentado en el mercado del petróleo tras la caída del mercado financiero en 2008 y la Gran Recesión supuso un impacto sobre el precio del petróleo que fue más allá del ocasionado por la caída de la demanda global de petróleo. Durante los años previos, el precio del petróleo había experimentado un importante crecimiento, causado principalmente por un aumento de la demanda global derivado de la creciente actividad económica de China y otros países emergentes (Kilian, 2009; Aastveit et al., 2015), así como por comportamientos especulativos (Kaufmann y Ullman, 2009; Juvenal y Petrella, 2015), relacionados con la financiarización de las materias primas que venía produciéndose desde el inicio del siglo XXI (Tang y Xiong, 2012). Tras el estallido de la crisis financiera, el precio del petróleo colapsó. Nos encontrábamos ante una crisis de demanda que inevitablemente tenía que tener reflejo en el precio.

Justo tras la Gran Recesión tuvieron lugar diversas guerras que también influían directa o indirectamente en el mercado de petróleo, ya fuera por la situación geoestratégica de los territorios implicados, por las reservas de petróleo ubicadas en dichos territorios, o bien por el papel relevante en el mercado del petróleo de los países involucrados. La primera de ella fue la guerra de Libia, que estalló a principios de 2011 como resultado de la primavera árabe y que afectó a territorios con grandes yacimientos de petróleo. En 2012 comenzó otra guerra civil, la de Siria, ésta con gran repercusión internacional ya que fue involucrando, además de al gobierno sirio y su oposición, a otros países como Rusia, Estados Unidos, Turquía e Irak. Durante esta guerra emergió el grupo terrorista Estado Islámico, que pasó a controlar territorios con grandes yacimientos de petróleo. Finalmente, ya en Europa, en 2014, tras las revueltas ciudadanas que desembocaron en la caída del presidente ucraniano Yanukóvich, el conflicto tomó carácter internacional cuando se produjeron los levantamientos de las regiones rusófonas del este del país, auspiciadas por Rusia, que llevaron a la declaración de independencia de Crimea y la ciudad de Sebastopol, que finalmente fueron anexadas a Rusia, y el levantamiento de las regiones de Donetsk y Lugansk. Este último dio lugar a la Guerra del Donbás. Su impacto en el mercado de petróleo no se debió a las reservas de éste de las que dispone Ucrania, que son muy reducidas, sino a la participación de Rusia, uno de los principales países productores de petróleo a nivel mundial, en el conflicto. Su intervención suscitó resistencia por parte de Estados Unidos y la Unión Europea, lo que conllevó la imposición de sanciones que afectaron a la exportación de materiales de exploración y equipos de extracción de petróleo y gas natural a Rusia, medida que impactó directamente en su capacidad de producción de petróleo y, por tanto, al conjunto del mercado de petróleo.

**Figura 1**. Evolución del precio del petróleo y la ratio Producción/Consumo de petróleo en Estados Unidos durante y tras de la Gran Recesión.




Fuente: Banco Mundial, U.S. Energy Information Administration y elaboración propia. *Notas:* la línea negra representa el precio del petróleo (en dólares). La line azul representa la ratio producción/consumo de petróleo de Estados Unidos. Las áreas sombreadas denotan el periodo durante cual ocurren los distintos eventos que afectan al mercado del petróleo.

Justo en ese periodo comenzó a manifestarse en el mercado de petróleo un shock tecnológico generado por la introducción de la técnica *fracking* de extracción de petróleo, que a la postre ha sido uno de los principales determinantes de la evolución del precio del petróleo en el periodo posterior a la Gran Recesión. Su introducción produjo importantes cambios en el mercado del petróleo. En primer lugar, Estados Unidos se convirtió en el principal productor de petróleo a nivel mundial, superando a Arabia Saudí y Rusia. Esto redujo la dependencia exterior de su consumo de combustible, lo que llevó en 2016 a levantar la prohibición de exportar petróleo, impuesta desde 1975. La reducción de la dependencia energética exterior de Estados Unidos conllevó también la pérdida de poder de mercado de los países de la OPEP, que vieron disminuida su capacidad de controlar la producción y, en consecuencia, el precio del petróleo.

La producción de petróleo vía *fracking* permite un ajuste de la producción de petróleo más rápida que las técnicas de producción convencional, por lo que algunos estudios sugieren que la elasticidad-precio de la oferta de petróleo se ha visto incrementada (Bjørnland et al., 2021; Newell y Prest, 2019). En los últimos años, el *fracking* ha generado una especie de techo al precio del petróleo, cuyas subidas se han visto frenadas por la respuesta de los productores de petróleo mediante *fracking*, dando como resultado una caída del precio.

Al estudio de como incidían estos tres factores en el precio del petróleo dedicamos la primera parte de esta Tesis Doctoral, que dio como resultado la publicación de dos artículos:

- Garzón, A. J. & Hierro, L.A. (2018). Fracking, wars and stock market crashes: the price of oil during the Great Recession. *International Journal of Energy Economics and Policy, 8(*2), 20-30.
  - Q2 SJR en Economics, Econometrics and Finance (miscellaneous) en 2018. Q1 en 2013, 2014, 2016 y 2017.
- Garzón, A. J. & Hierro, L.A. (2019). External effects of the war in Ukraine: the impact on the price of oil in the short-term. *International Journal of Energy Economics and Policy, 9*(2), 267-276.
  - Q2 SJR en Economics, Econometrics and Finance (miscellaneous) en 2018. Q1 en 2013, 2014, 2016 y 2017.

Dada la importancia del petróleo como materia prima, la evolución del mercado del petróleo tiene importantes efectos macroeconómicos sobre las economías nacionales, tanto de carácter distributivo como de estabilización. Los efectos distributivos a nivel internacional de la evolución del mercado de petróleo se derivan de su propia estructura. Así, este mercado se caracteriza por una elevada concentración de las reservas de petróleo en determinados países. En 2018, el 86,5% de las reservas probadas se encontraban concentradas en los países pertenecientes a la OPEP (BP, 2019) que, junto con Rusia y Estados Unidos, concentran la mayor parte de la producción de petróleo mundial. Debido a esta elevada concentración, el mercado de petróleo a nivel mundial se encuentra dividido entre países exportadores de petróleo, es decir, aquellos países productores que venden su producción a otros países, y países importadores de petróleo, que son aquellos países que compran petróleo a los países productores, y, por tanto, son dependientes de éstos para satisfacer sus necesidades energéticas. La división entre países exportadores e importadores conlleva importantes efectos distributivos a nivel internacional por las transferencias implícitas de renta de países importadores a exportadores.

El mercado del petróleo se caracteriza también por la generación de rentas económicas para sus productores, es decir, beneficios extraordinarios generados por el establecimiento de un precio por encima del coste de los factores de producción (Segal, 2011), que se generan por la existencia de diferencias en los costes de producción entre distintos productores respecto al productor marginal que determina el precio internacional (Bina, 1992), por la exigencia de los productores de un precio superior al coste de los factores para compensar por el coste de oportunidad de producir en el futuro dado el carácter no renovable de las materias primas (Hotelling, 1931) además de por la existencia de poder de mercado por la concentración del producto en un número reducido de productores (Golombek et al., 2018; Asker et al., 2019). Como resultado, el comercio internacional de petróleo genera transferencias implícitas de renta desde los países importadores a los países exportadores, lo que afecta a la distribución internacional de la renta. Las variaciones del precio y las variaciones en el volumen de exportaciones e importaciones determinan esas transferencias de rentas a nivel global y el efecto distributivo que las mismas producen.

Con motivo de esta Tesis Doctoral hemos realizado una aproximación a esta cuestión, que nos ha permitido cuantificar el volumen de rentas transferidas y evaluar el impacto de las mismas en la distribución de renta global. El trabajo en el que esta cuestión fue desarrollada obtuvo el *Premio José Luis Sanpedro* en el XXI Congreso Internacional de la Sociedad de Economía Mundial celebrada en la Universidad de Beira Interior, Covilhã (Portugal) en 2019 y su contenido ampliado ha sido objeto de publicación:

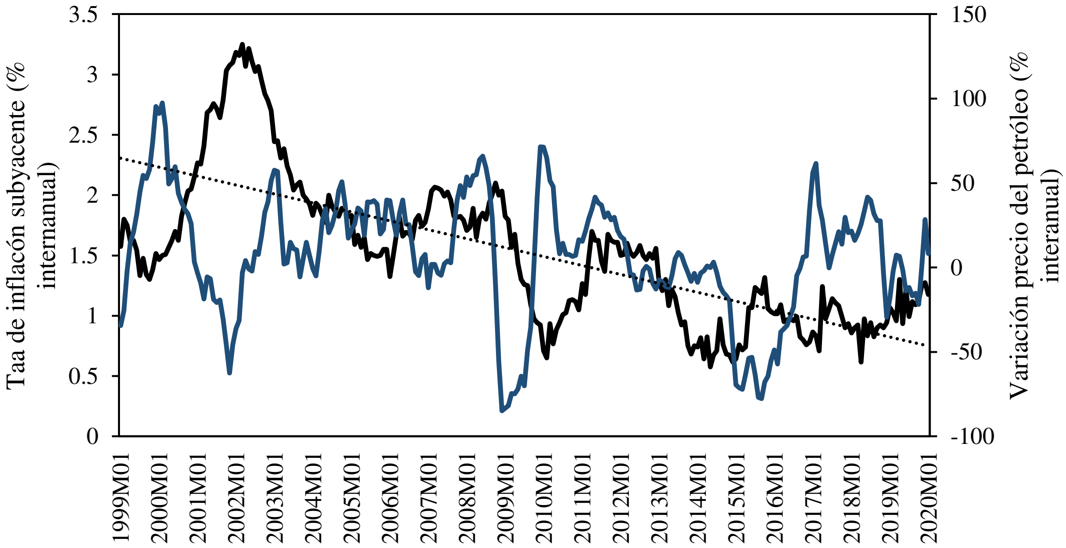
- Garzón, A.J., Hierro, L.A. & Apergis, N. (2021). Oil trade rents and international income inequality. *Revista de Economía Mundial, 58,* 203-230.
  - Q4 JCR en Economics en 2020.
  - Q2 en SJR en History. Q1 en 2016 y 2017.

El petróleo y los combustibles derivados del mismo constituyen un bien de consumo para los hogares que supone una parte importante de su cesta de consumo. Además, el petróleo es un bien intermedio para la producción de las empresas, tanto por su empleo para generar energía en los procesos industriales, como a través de su uso para el transporte y distribución de bienes. Esta condición de bien de consumo y recurso productivo hace que para los países importadores de petróleo la evolución del precio del petróleo tenga gran incidencia en las variables macroeconómicas. A la importancia del petróleo para el consumo y la producción tenemos que añadir que tanto la demanda como la oferta del mismo presentan una baja elasticidad respecto al precio. La baja elasticidad de la demanda es consecuencia de la falta de bienes sustitutivos del petróleo y sus derivados, especialmente en el corto plazo; y la de la oferta se debe a la existencia de retardos en la puesta en marcha de pozos ya existentes y en la exploración y descubrimiento de nuevos yacimientos de petróleo. La consecuencia de la baja elasticidad de demanda y oferta de petróleo es que pequeñas variaciones de las mismas dan lugar a importantes fluctuaciones en el precio del petróleo lo que amplía su influencia en la macroeconomía de los países.

La principal variable macroeconómica que se ve afectada por las fluctuaciones en el precio del petróleo es la inflación. El impacto del precio del petróleo en los precios de consumo se produce a través de distintos canales: un canal directo, que es el impacto que tiene el precio del petróleo en los precios energéticos; y un canal indirecto, que opera por medio de su impacto en los costes de producción de las empresas. A ellos hay que sumar los efectos de segunda ronda debidos a la indexación de los salarios y de las rentas del capital a la inflación pasada.

La transmisión de las variaciones del precio del petróleo a la inflación no es independiente del entorno macroeconómico en el que se produce ni del origen de las mismas (Kilian, 2008). El entorno de inflación incide en la forma en que las empresas fijan sus precios y en cómo responden ante variaciones en sus costes de producción, de manera que cuanto mayor es la inflación tendencial de la economía mayor es la transmisión de los costes a los precios por parte de las empresas (Taylor, 2000; Devereux y Yetman, 2010). En las últimas décadas, la inflación en las economías avanzadas ha experimentado una tendencia decreciente, especialmente tras la Gran Recesión. Éste es el caso de la zona euro, donde la inflación subyacente ha mostrado una tendencia decreciente desde la puesta en circulación del euro, manteniéndose tras la Gran Recesión de 2008 por debajo del objetivo de inflación del 2% a medio plazo que establece el Banco Central Europeo (ver Figura 2).

**Figura 2**. Evolución de la inflación subyacente en la zona euro y variaciones del precio del petróleo.




Fuente: Eurostat y U.S. Energy Information Administration. *Notas*: la línea negra representa la inflación subyacente media de los países de la zona euro. La línea azul representa las variaciones del precio del petróleo. La línea negra discontinua representa la tendencia temporal de la inflación subyacente.

El segundo pilar de la política monetaria del BCE, sustentado en el análisis económico de los factores determinantes de la inflación en el corto y medio plazo, incluye al precio del petróleo como uno de los elementos a tener en cuenta a la hora de determinar la política monetaria. Además de afectar a la inflación en el corto plazo debido a su impacto en los precios de los combustibles, las variaciones del precio del petróleo pueden trasladarse a la dinámica de inflación a medio plazo a través de su impacto en las expectativas futuras de inflación, pudiendo generar efectos de segunda ronda, razón por la cual las autoridades del BCE, cuyo objetivo de inflación se centra en la evolución a medio plazo, consideran el precio del petróleo como un factor relevante en su análisis económico y en las decisiones de política monetaria. No obstante, estos efectos de segunda ronda no son automáticos, sino que dependen de cómo reaccionan las expectativas de inflación futuras y de si éstas se trasladan a los precios. En este sentido, el entorno de inflación en el que se producen las variaciones del precio puede ser un determinante importante de la reacción de esas expectativas y, por tanto, de sus consecuencias inflacionarias en el medio y largo plazo.

Es por tanto una cuestión relevante analizar cómo influye el precio del petróleo en la inflación atendiendo al entorno de inflación, pues se pueden producir sobrerreacciones de la política monetaria a las variaciones inflacionarias generadas por el precio del petróleo. A esta cuestión he dedicado el artículo siguiente:

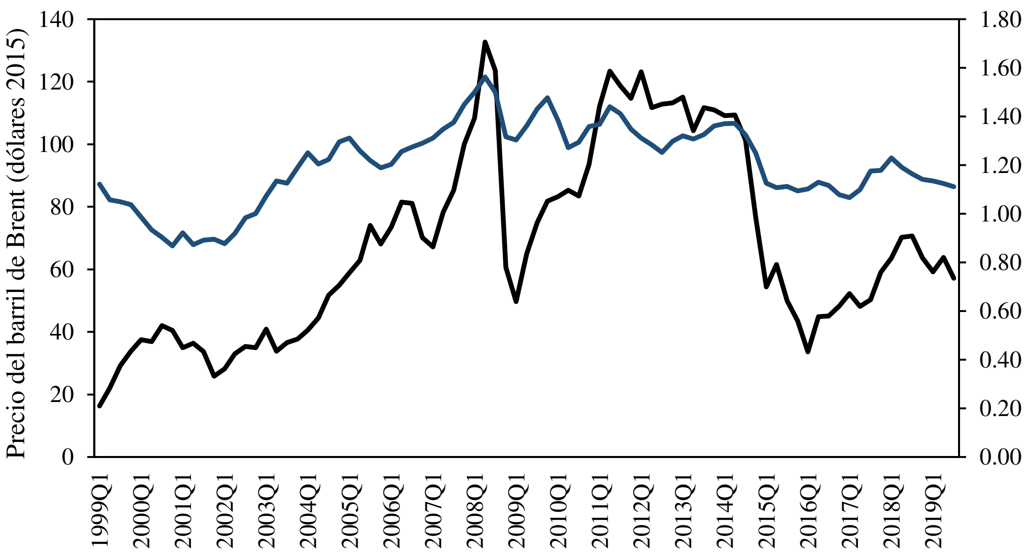
- Garzón, A.J. & Hierro, L.A. (2021). Asymmetries in the transmission of oil price shocks to inflation in the eurozone. *Economic Modelling, 105*, 105665.

- Q1 en JCR en Economics en 2020.

El mercado de petróleo internacional produce flujos monetarios internacionales que pueden alterar los tipos de cambio (para una revisión de los canales de transmisión entre el precio del petróleo y el tipo de cambio véase Beckmann et al. 2020) El comercio de petróleo a nivel internacional se factura en dólares, por lo que el tipo de cambio de cada divisa nacional respecto al dólar determina el precio final pagado en moneda nacional. Es así como el tipo de cambio se convierte en un factor determinante del efecto final de las variaciones del precio del petróleo sobre la inflación.

Centrándonos en la zona euro, la cotización del euro respecto al dólar presenta una alta correlación con la evolución del precio del petróleo en dólares, especialmente desde mediados de los 2000s, relación que no muestran otras monedas de carácter internacional como el yen japonés o la libra británica. Desde la creación del euro en 1999, la relación entre el tipo de cambio euro/dólar y el precio del petróleo han mostrado una evolución paralela, obviamente con una mayor volatilidad del precio del petróleo por los factores más arriba citados (ver Figura 3). En este periodo, incrementos del precio del petróleo están relacionados con apreciaciones del euro respecto al dólar, lo que a la postre provoca una suavización de las fluctuaciones del precio del petróleo en moneda nacional y favorece que la transmisión de las variaciones del precio del petróleo a la inflación se vea parcialmente amortiguada.

**Figura 3.** Evolución del precio del petróleo Brent y el tipo de cambio dólar/euro.




Fuente: U.S. Energy Information Administration e International Financial Statistics (IMF). *Notas*: la línea negra representa el precio del petróleo Brent. La línea azul representa el tipo de cambio dólar/euro.

A analizar la influencia de la relación entre ambas variables, dada la relevancia que hemos señalado sobre el diseño de la política monetaria, hemos dedicado el último artículo que compone esta Tesis Doctoral y que actualmente se encuentra en evaluación:

- Garzón, A.J. & Hierro, L.A. (2021). Inflation, oil prices and exchange rates. The Euro's dampening effect. En revisión en *Journal of Policy Modeling*.

- Q2 en JCR en Economics en 2020.
- Q1 en SJR en Economics and Econometrics en 2020.

Presentada como comunicación en el XXXIV Congreso Internacional de Economía Aplicada ASEPELT 2021 (Jaén, España).

En resumen, la tesis tiene como objetivo dar respuesta a dos cuestiones: en primer lugar, determinar cómo los shocks económicos, políticos y tecnológicos descritos anteriormente han afectado a la evolución del precio del petróleo durante el siglo XXI, tanto en sus fluctuaciones que ha experimentado en el corto plazo como en su tendencia a largo plazo; y, en segundo lugar, a analizar los impactos del mercado del petróleo en la distribución de la renta a nivel mundial y en la inflación. Entendemos que la misma representa un estudio amplio y novedoso del precio del petróleo que justifica su presentación como memoria de colación del grado de Doctor en el Programa de Doctorado de Ciencias Económicas, Empresariales y Sociales de la Universidad de Sevilla.

Esta memoria se estructura como sigue: el capítulo dos presenta detalladamente los objetivos de la tesis, el capítulo 3 recoge el análisis de los principales factores determinantes del precio del petróleo en el siglo XXI. El capítulo 4 presenta el estudio de los efectos macroeconómicos de la evolución del mercado del petróleo, para discutir los resultados y concluir en el capítulo 5.

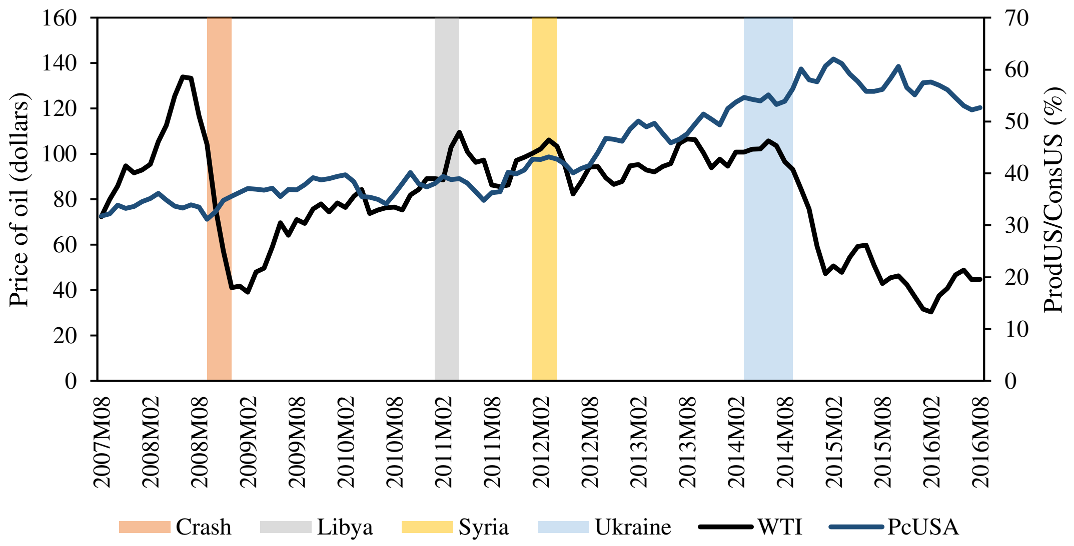
# Introduction

During the period spanning from 2000 to 2008, oil exports accounted for around 7% of total global exports (UNCTAD, 2018). During the 21st century, especially after the Great Recession, the oil market has been hit by three types of shocks that have shaped its evolution: an economic and financial shock, the 2008 financial crisis, and the Great Recession that came after it; several political shocks, caused by the wars to emerge from the Arab Spring, which affected countries with vast oil reserves such as Libya or Syria, and the civil war in Ukraine, which involved Russia, a strategic country in the oil market; and a technological shock, the development of fracking as an oil extraction technique, which heralded a revolution in the oil market, turning the United States into the main oil producer and reducing its energy dependence, which resulted in greater competition in the oil market and a reduction in the market power of OPEC (Organization of the Petroleum Exporting Countries).

The economic shock experienced in the oil market after the financial crash in 2008 and the Great Recession had an impact on the price of oil beyond the effect caused by the drop in global oil demand. During the previous years, the price of oil had been increasing, spurred by an rise in global demand due to the growing economic activity in China and other emerging economies (Kilian, 2009; Aastveit, 2015) in addition to speculative behaviour (Kaufmann and Ullman, 2009; Juvenal and Petrella, 2015) related to the financialization of commodities that has been taking place since the turn of the century (Tang and Xiong, 2012). After the outbreak of the financial crisis, the price of oil collapsed, and the world faced a demand crisis that was inevitably reflected in oil prices.

Just after the Great Recession, a number of wars broke out, affecting the oil market directly or indirectly, either because of the geo-strategic location of the territories, the oil reserves in these territories, or the key role that the countries involved played in the oil market. First, there was the Libyan war, which broke out in early 2011 as a result of the so-called Arab Spring, and which affected territories holding large oil reserves. Another civil war began in 2012, this time in Syria, and which had major international repercussions since countries such as Russia, the United States, Turkey, and Iraq, in addition to the Syrian government and the opposition, became involved. During this war, the Islamic State terrorist group emerged and gained control in areas that boasted large oil fields. Finally, in Europe in 2014, after the citizens' revolution that led to the downfall of the Ukrainian president Yanukovych, the conflict took on an international dimension with uprisings in the eastern Russian-speaking regions backed by Russia, leading to the declaration of independence of Crimea and the city of Sevastopol - the former eventually being annexed to Russia - and the uprisings of the Donetsk and Lugansk regions, with the latter giving rise to the Donbas war. Its impact on the oil market is not due to Ukraine's oil reserves, which are negligible, but to the involvement of Russia, one of the main oil-producing countries in the world, in the conflict. Its intervention triggered resistance from the United States and the European Union, which led to sanctions being imposed on Russia and affected the export of exploration materials and equipment for extracting oil and natural gas. These measures directly affected its oil production capacity and, therefore, the global oil market.

**Figure 1**. Evolution of the price of oil and the oil production/consumption ratio in the United States during and after the Great Recession.




Source: World Bank, U.S. Energy Information Administration and authors' own compilation. *Notes*: the black line denotes the price of oil (in dollars). The blue line denotes the oil production/consumption ratio in the United States. The shaded areas denote the period during which the event that affected the oil market take place.

During the same period, a technological shock took place in the oil market, caused by the development of the new oil extraction technique called fracking, and which became a key driver in the evolution of oil prices over the period preceding the Great Recession. Its introduction sparked major changes in the oil market. First, the United States became the world's leading oil producer, surpassing Saudi Arabia and Russia. This development reduced its foreign dependence on fuel consumption, which led to a lift on the ban on exporting oil in 2016, imposed in 1975. The reduction in the United States' foreign energy dependence also led to a decline in the market power of OPEC countries, who witnessed a reduction in their ability to control oil production, and therefore, the price of oil.

Oil production via fracking allows for faster oil production adjustment than conventional production techniques, increasing the price elasticity of supply, as some studies suggest (Bjørnland et al., 2021; Newell and Prest, 2019). In recent years, fracking producers have acted as the swing producer, setting a ceiling on the price of oil and stopping oil price increases through the response of oil producers via fracking and leading to a subsequent price fall.

We devote the first part of this doctoral thesis to analysing the effects of these three factors in the evolution of the price of oil, resulting in the following two articles:

- Garzón, A. J. & Hierro, L.A. (2018). Fracking, wars and stock market crashes: the price of oil during the Great Recession. *International Journal of Energy Economics and Policy, 8(*2), 20-30.
  - Q2 in SJR in Economics, Econometrics and Finance (miscellaneous) in 2018. Q1 in 2013, 2014, 2016 y 2017.

- Garzón, A. J. & Hierro, L.A. (2019). External effects of the war in Ukraine: the impact on the price of oil in the short-term. *International Journal of Energy Economics and Policy, 9*(2), 267-276.
  - Q2 in SJR in Economics, Econometrics and Finance (miscellaneous) in 2018. Q1 in 2013, 2014, 2016 y 2017.

Given the relevance of crude oil as a commodity, the evolution of the oil market has important macroeconomic effects on national economies in terms of both distribution as well as stabilization. The international distributional effect of the evolution of the oil market is generated by the latter's specific structure. It is characterized by a high concentration of reserves in just a few countries. In 2018, 86.5% of proven reserves were located in the countries belonging to the OPEC (BP, 2019), which account for most of world's oil production, together with Russia and the United States. This high concentration means that the global oil market is divided between oil-exporting countries - that is, oil producing countries who sell their production to other countries - and oil-importing countries, which are those countries who buy oil from producing countries and are therefore dependent on them to meet their energy needs. The division between exporting and importing countries triggers an important distributive effect at the international level due to the implicit transfers of rents from importing to exporting countries.

The oil market yields economic rents for producers; that is, extraordinary profits obtained by setting a price above the cost of the production factors (Segal, 2011). This is due to the existence of different production costs among producers vis-à-vis the marginal producer that determines the international price of oil (Bina, 1992) as well as to the fact that producers require a higher price than the cost of factors to compensate for the opportunity cost of producing in the future, given the exhaustibility of commodities (Hotelling, 1931) and market power caused by the concentration of oil production in a small number of producers (Golombek et al., 2018; Asker et al., 2019). As a result, the international oil trade generates implicit transfers of rents from importing to exporting countries, affecting the international distribution of income. Changes in the price of oil and the volume of oil exports and imports determine the amount of these transfers of rents at the global level and their redistributive effect.

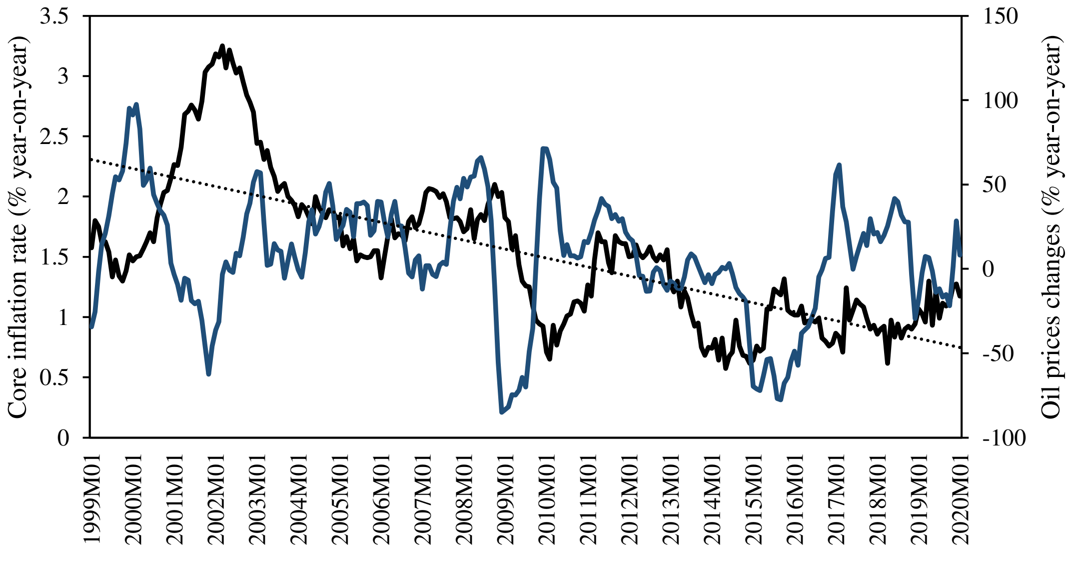
In the present doctoral thesis, we make an empirical approach to this question, quantifying the volume of rent transfers through the oil market and analysing their impact on the international distribution of income. The work that includes this analysis was awarded the Jose Luis Sampedro prize at the XXI International Congress of the World Economy Society held at the University of Beira Interior, Covilhã (Portugal) in 2019. The extended version of this work has been published in the following article:

- Garzón, A.J., Hierro, L.A. & Apergis, N. (2021). Oil trade rents and international income inequality. *Revista de Economía Mundial, 58,* 203-230.
  - Q4 in JCR in Economics in 2020.
  - Q2 in SJR in History. Q1 in 2016 and 2017.

Oil and petroleum products are consumption goods for households, and represent an important share of their consumption basket. In addition, they are also an intermediate good for firms' production, both through their use for generating energy in industrial processes and through their use for transport and the distribution of goods. This means that the evolution of the price of oil has a major impact on macroeconomic variables in oil importing countries. Another characteristic is that both demand and supply of oil have a low price elasticity. The low price elasticity of demand is due to the lack of substitute goods for oil and petroleum products, especially in the short-term. The low price elasticity of supply is due to the existence of lags in the resumption of existing wells and in the exploration and discovery of new oil reserves. The consequence of low price elasticity is that small changes in supply or demand lead to large swings in the price of oil, which amplify its impact on the macroeconomy of importing countries.

The main macroeconomic variable affected by oil price fluctuations is the inflation rate. The impact of oil prices on consumer prices occurs through different channels: a direct channel, through the impact of oil prices on energy prices; and an indirect channel, through the effect on firms' production costs. The so-called second round effects, caused by the indexation of wages and capital income to past inflation, should also be added.

**Figure 2**. Evolution of core inflation in the euro area and oil price changes.




Source: Eurostat and U.S. Energy Information Administration. *Notes*: the black line denotes the average core inflation in the euro area countries. The blue line denotes oil prices changes. The dashed black line represents the trend in euro area countries core inflation.

The transmission of oil price shocks to inflation is not independent of the macroeconomic environment in which it occurs or the source of the shock (Kilian, 2008). The inflation environment is a factor that affects the price-setting behaviour of firms and their response to changes in their production costs, such that a higher trend inflation in an economy may translate to a higher degree of pass-through of costs to consumer prices (Taylor, 2000; Devereux and Yetman, 2010). In recent decades, inflation in advanced economies has trended downward, especially after the Great Recession. This is the case of the euro area, where core inflation has shown a decreasing trend since the introduction of the euro, remaining below the 2% target set by the European Central Bank after the Great Recession (see Figure 2).

The second pillar of the ECB's monetary policy strategy, which comprises the economic analysis of the determinants of inflation in the short and medium-term, includes the price of oil as a factor to take into account when determining the implementation of monetary policy. In addition to influencing short-term fluctuation in inflation due to its impact on fuel prices, oil price shocks can also be transmitted to inflation dynamics in the medium-term through their impact on inflation expectations and by triggering second round effects, which is why the ECB, whose inflation target is focused on medium-term inflation dynamics, considers the price of oil to be a key factor in its economic analysis and monetary policy decisions. However, second round effects are not automatic, but depend on how inflation expectations react and whether they are transmitted to consumer prices. In this sense, the inflationary environment in which oil price shocks occur is an important determinant of the reaction of expectations and, therefore, their inflationary consequences in the medium and long-term.

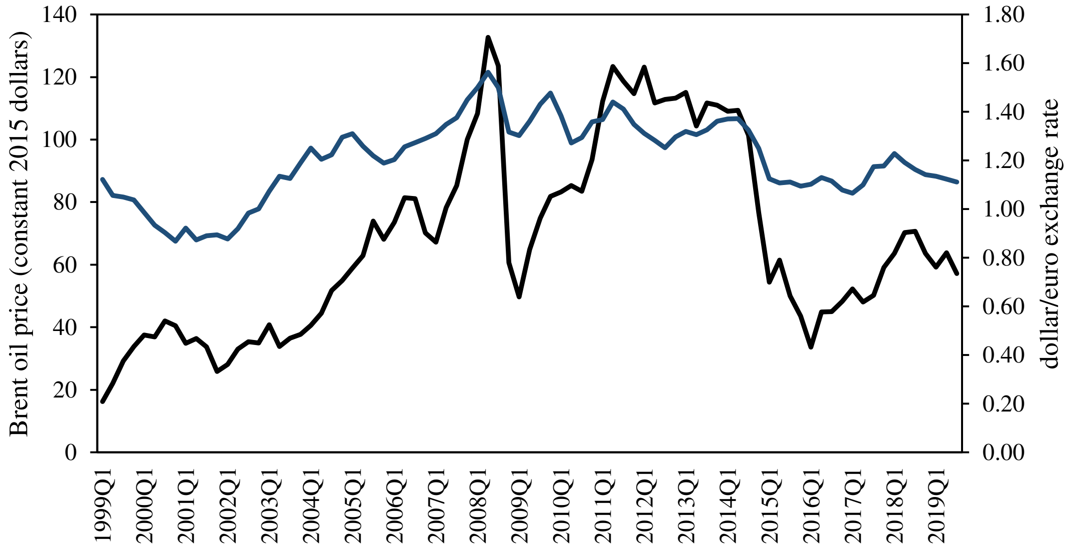
Analysing how the inflationary environment affects the impact of oil price fluctuations on inflation dynamics is therefore a relevant question, since monetary policy can overreact to inflationary pressures that arise from oil price shocks. We have devoted the following article to this question:

- Garzón, A.J. & Hierro, L.A. (2021). Asymmetries in the transmission of oil price shocks to inflation in the eurozone. *Economic Modelling, 105*, 105665.
  - Q1 in JCR in Economics in 2020.

The global oil market generates international flows that can affect exchange rates (for a review of the channel of transmission between the price of oil and the exchange rate see Beckmann et al., 2020). International oil trade is invoiced in dollars, such that the exchange rate of a national currency vis-a-vis the dollar determines the final price paid in national currency. Through this channel the exchange rate becomes a determining factor in the final effect of oil price changes on inflation.

Focusing on the euro area, the euro/dollar exchange rate shows a high correlation with the price of oil in dollars, especially after the mid-2000s, a relationship that has not been found for other international reserve currencies such as the Japanese yen or the British pound. Since the creation of the euro in 1999, the relationship between the euro/dollar exchange rate and the price of oil has shown a similar evolution, obviously with the price of oil showing a higher volatility caused by the factors mentioned above (see Figure 3). In this period, increases in the price of oil are linked to increases in the euro against the dollar, smoothing the fluctuations in the price of oil in national currency and partially cushioning their transmission to inflation.

**Figure 3.** Evolution of the price of oil (Brent) and the dollar/euro exchange rate.




Source: U.S. Energy Information Administration and IMF's International Financial Statistics. *Notes*: the black line denotes the price of oil (Brent). The blue line denotes the dollar/euro exchange rate.

Given its importance in designing monetary policy, as stated above, we have devoted the final paper of this doctoral thesis, and which is currently under review, to analysing the influence of the relationship between the two variables:

- Garzón, A.J. & Hierro, L.A. (2021). Inflation, oil prices and exchange rates. The Euro's dampening effect. Under review in *Journal of Policy Modeling*.
  - Q2 in JCR in Economics in 2020.
  - Q1 in SJR in Economics and Econometrics in 2020.
  Paper presented at the XXXIV International Congress of Applied Economics ASEPELT 2021 (Jaén, Spain).

To sum up, the thesis aims to answer two questions: firstly, to determine how the economic, political and technological shocks described above have affected the evolution of the price of oil during the 21st century, both in its short-term fluctuations and in its long-term trend; and, secondly, to analyse its impacts on international income distribution and on inflation. We understand that it represents a comprehensive and innovative study of the price of oil that justifies its presentation as a compendium of articles for the doctoral degree in the University of Seville Doctoral Program of Economic, Business and Social Sciences.

This thesis is structured as follows. Chapter 2 presents in detail the objectives of the thesis. Chapter 3 includes the analysis of the main determinants of the price of oil in the 21st century. Chapter 4 presents the study of the macroeconomic effects of the evolution of the oil market, while chapter 5 concludes.

# 2. Objetivos de la tesis

El primer objetivo de la presente Tesis Doctoral es el análisis de los principales factores determinantes de la evolución del precio del petróleo a lo largo del siglo XXI, con especial atención a su evolución tras la Gran Recesión. Con este fin, nos centramos en analizar la influencia que han ejercido los tres tipos de shocks que han marcado la evolución del mercado del petróleo durante este periodo: el shock de naturaleza financiera que supuso el estallido de la burbuja financiera y la posterior Gran Recesión; los shocks de naturaleza política, que son las guerras de Libia, Siria y Ucrania; y el shock de naturaleza tecnológica que se corresponde con la aparición y extensión del uso de la técnica *fracking* para la extracción de petróleo, especialmente en Estados Unidos, y que ha supuesto una revolución en la producción de petróleo afectando al mercado de petróleo a nivel global.

Para llevar a cabo este objetivo, se adopta una doble perspectiva: por un lado, se analiza la relación a largo plazo entre las variables fundamentales del mercado del petróleo, con objeto de determinar si los shocks anteriormente mencionados han supuesto desviaciones del equilibrio del mercado a largo plazo, y en el caso del shock tecnológico generado por la irrupción del *fracking*, si éste ha supuesto un cambio en la propia relación a largo plazo entre las variables fundamentales del mercado. Por otro lado, se adopta un enfoque a corto plazo para analizar el efecto de la guerra de Ucrania sobre la evolución diaria del precio del petróleo. Este evento, al contrario que el resto de guerras analizadas que se desarrollan en territorios con importantes reservas de petróleo, no afecta directamente a la producción de petróleo. Su incidencia en el mercado del petróleo se debe principalmente a la participación de Rusia, uno de los principales productores de petróleo a nivel global, y a la imposición de sanciones por parte de Estados Unidos y la Unión Europea sobre el sector petrolífero ruso. Las características de este evento justifican la adopción de un enfoque de análisis a corto plazo, a través del cual se estudia el impacto de las noticias del conflicto ucraniano y de las reacciones de los actores políticos involucrados en la evolución diaria del precio del petróleo.

Por medio de este análisis empírico se busca contribuir a la literatura con evidencias sobre la importancia de los tres factores analizados en la evolución experimentada por el precio del petróleo; en la influencia que ha tenido la aparición y extensión de la técnica del *fracking* en la evolución reciente del mercado del petróleo y si ha supuesto un cambio en su equilibrio a largo plazo; y si un evento como la guerra de Ucrania, que no afecta directamente a la producción de petróleo, puede afectar a la evolución a corto plazo del mercado, generando volatilidad.

El segundo objetivo de la presente Tesis Doctoral consiste en analizar las consecuencias macroeconómicas que ha generado la evolución del mercado del petróleo durante el siglo XXI. Este objetivo, a su vez, lo dividimos en dos objetivos específicos: el primero de ellos consiste en el análisis de las consecuencias distributivas de la evolución del mercado del petróleo a nivel internacional; y el segundo es el estudio de las consecuencias sobre la inflación de la evolución del mercado del petróleo en los países importadores de la zona euro. En concreto, analizamos la influencia del entorno de inflación y del tipo de cambio en la transmisión de las variaciones del precio del petróleo a la inflación.

El estudio de los efectos distributivos del comercio internacional del petróleo está justificado por el gran peso que tienen las exportaciones de petróleo en el comercio entre países, por su importancia en los ingresos de los países exportadores y por las características del propio mercado. La clara división entre países exportadores e importadores y el poder de mercado que tienen los primeros, da lugar a que el comercio internacional de petróleo genere una transferencia de rentas implícitas desde los países importadores hacia los exportadores. Por ello, es de gran relevancia determinar las transferencias que se están produciendo y los efectos que éstas tienen en la desigualdad entre países. Además, la evolución del precio del petróleo, así como los cambios en el volumen de exportaciones e importaciones de los distintos países, pueden generar variaciones en la dirección de la redistribución de rentas entre países, por lo que es importante llevar a cabo su análisis desde una perspectiva temporal.

La transmisión de las variaciones del precio del petróleo a magnitudes macroeconómicas como la inflación ha sido objeto de estudio desde los shocks del petróleo de los 1970s. Sin embargo, en la zona euro, existen dos factores que han influido en su transmisión y que no han sido estudiados hasta el momento. El primero de ellos es la tendencia decreciente de la inflación. Esta tendencia, que se ha observado en gran parte de los países desarrollados, siendo especialmente destacable en la zona euro, puede afectar a cómo se transmiten los shocks del precio del petróleo a la inflación cuando existen unas expectativas de inflación futura bajas y modificando el comportamiento de las empresas a la hora de modificar sus precios ante fluctuaciones del precio del petróleo. El segundo factor que han influido en la transmisión de las fluctuaciones del precio del petróleo en la zona euro es el tipo de cambio euro/dólar. Diversos estudios han constatado la existencia de una correlación positiva entre el precio del petróleo y el tipo de cambio euro/dólar. Puesto que el petróleo se comercia en dólares, el movimiento parejo del precio del petróleo y del tipo de cambio supone un mecanismo de amortiguación de la transmisión de las fluctuaciones del precio del petróleo a la inflación en la zona euro. Por ello, en la presente Tesis Doctoral nos proponemos analizar empíricamente cómo han influido ambos factores en la transmisión del precio del petróleo a la inflación y si su incidencia ha sido significativa.

# 3. Factores determinantes de la evolución del precio del petróleo.

## 3.1. El precio del petróleo durante la Gran Recesión.

La evolución del precio del petróleo tras la Gran Recesión ha estado condicionada por diversos factores que han marcado su devenir. Tras una continua subida en los años 2006 y 2007, asociada a una creciente demanda global (Kilian, 2009) y a un aumento de la actividad especulativa en el mercado del petróleo (Kaufmann y Ullman, 2009; Juvenal y Petrella, 2015), el precio del petróleo experimentó un colapso tras el estallido del mercado financiero en 2008, aunque para 2010 ya había recuperado su nivel previo a 2007. Entre 2010 y 2014, el precio del petróleo se mantuvo entre los 80 y 100 dólares por barril, aunque experimentando continuas fluctuaciones, coincidiendo con los estallidos de dos guerras consecuencia de la llamada primavera árabe, en Libia en 2011 y en Siria en 2012. Al final del periodo considerado, tras el inicio de la guerra en Ucrania en 2014 el precio del petróleo volvió a caer, alcanzando un valor mínimo inferior al alcanzado durante el estallido de la burbuja financiera en 2008. Esta caída se ha asociado al aumento de la producción de petróleo causado por la extensión del uso del *fracking* en Estados Unidos (Baffes et al., 2015) y a las expectativas de posteriores incrementos de la producción (Fueki et al., 2021), aunque también ha sido atribuida a una menor demanda global de petróleo (Badel y McGillicuddy, 2015; Baumeister y Kilian, 2016; Kilian, 2017) o a la respuesta acomodaticia inicial de la OPEP ante el aumento de producción de Estados Unidos (Behar y Ritz, 2017), que reaccionó aumentando la producción para mantener su cuota de mercado, en lugar de reducir su producción para estabilizar el precio.

Las crisis financieras pueden afectar al precio del petróleo más allá del efecto que provocan a través de la caída de la demanda de petróleo para la actividad económica. Por un lado, el aumento de la volatilidad del mercado financiero durante periodos de estrés financiero se transmite al precio del petróleo, aumentando también su volatilidad (Nazlioglu et al., 2015) y, por tanto, reduciendo su predictibilidad (Lahmiri, 2017). Además, la creciente financiarización de las materias primas provoca que la evolución de sus precios esté más vinculada con las fluctuaciones de los mercados financieros (Tang y Xiong, 2012). Por estas razones, en la presente Tesis Doctoral analizamos si la caída del precio del petróleo en 2008 está asociada a los propios determinantes fundamentales del mercado del petróleo, es decir, aquellos que determinan la oferta y la demanda, o si el estallido del mercado financiero provocó una mayor caída del precio.

En lo referente a las guerras que involucran a países con un importante peso en el mercado del petróleo, su efecto en el precio del petróleo puede producirse a través de dos canales: por el lado de la oferta, a través de la destrucción de pozos de petróleo o de la paralización de la producción, creando escasez en el mercado al menos a corto plazo y provocando aumentos del precio (Kilian, 2009); y por el lado de la demanda, el estallido de un conflicto bélico en un país productor de petróleo puede causar un aumento de la demanda de petróleo por motivo precaución ante la posibilidad de una posible disrupción futura de la producción (Kilian, 2009). En ambos casos, el efecto del estallido de las guerras en el precio del petróleo es su incremento. Kilian (2009) analiza el efecto de distintos eventos como la guerra de Yom Kippur, la revolución de Irán de 1979, la guerra entre Irán e Irak de 1980, la guerra del Golfo de 1990 y la guerra de Irak en 2003, concluyendo que el incremento del precio que generaron fue causado en una mayor medida por el aumento en la demanda por precaución que por caídas en la producción. Además, el estallido de las guerras puede provocar fluctuaciones de los precios no explicados por los fundamentales del mercado (Coleman, 2012) como consecuencia de la mayor volatilidad que se observa en el precio del petróleo durante estos conflictos (Zhang, 2009).

Por su parte, la introducción de la técnica de extracción de petróleo denominada *fracking* ha supuesto un importante cambio tecnológico en el mercado del petróleo. Sin embargo, su efecto sobre el precio y el mercado del petróleo ha sido objeto de discusión. Por un lado, esta técnica de producción permite la puesta en funcionamiento más rápida de los pozos de petróleo que las técnicas convencionales, lo que conlleva que la producción de petróleo sea más reactiva ante variaciones en el precio del petróleo, es decir, incrementa la elasticidad-precio de la oferta de petróleo (Newel y Prest, 2019; Bjørnland et al., 2021). Por el contrario, otros trabajos sugieren que el cambio no ha sido sustancial o no es relevante a la hora de determinar la elasticidad-precio de la producción global de petróleo (Foroni y Stracca, 2019). En cuanto a su papel en el desplome del precio del petróleo que se produjo en 2014, algunos trabajos consideran que el *fracking* fue un factor determinante porque produjo un incremento de la oferta de petróleo en el mercado (Baffes et al., 2015; Frondel y Horvath, 2019; Álvarez et al., 2020), no contrarrestado por reducciones de producción en la OPEP (Behar y Ritz, 2017), así como por las expectativas de futuros incrementos de la producción (Fueki et al., 2021). Sin embargo, otros estudios consideran que los factores de oferta jugaron un papel secundario, siendo la caída de la demanda global de petróleo la principal causa de la caída del precio del petróleo (Badel y McGillicuddy, 2015; Baumeister y Kilian, 2016; Kilian, 2017).

Asímismo, el desarrollo del *fracking* como método de producción ha convertido a Estados Unidos en el principal productor de petróleo a nivel mundial. El resultado es una reducción de la dependencia energética exterior de Estados Unidos, que es a su vez el principal consumidor de petróleo del mundo, produciendo así un importante cambio en la estructura del mercado de petróleo mundial y reduciendo el poder de mercado de los países de la OPEP. Por esta razón, en esta Tesis Doctoral analizamos el efecto de la reducción de la dependencia de petróleo de Estados Unidos en la evolución del precio del petróleo.

### 3.1.1. Metodología

*Método de estimación del modelo*

Para analizar la evolución del mercado del petróleo y el efecto de los tres factores considerados previamente, construimos un modelo en el que incluimos dos bloques de variables: un bloque de variables endógenas consideradas factores fundamentales de la evolución del mercado del petróleo a largo plazo y otro bloque de variables exógenas que representan los factores previamente citados y cuyo efecto en la evolución del mercado del petróleo queremos analizar.

El mercado del petróleo se caracteriza por la existencia de endogeneidad entre sus variables fundamentales. Variaciones en la producción o en la demanda de petróleo afectan al precio, pero, simultáneamente, estas variaciones del precio afectan a su demanda y oferta. Para solventar ese problema tradicionalmente se ha empleado la metodología de Vectores Autorregresivos (VAR) (Kilian, 2009); sin embargo, cuando las variables en niveles no son estacionarias, es decir, presentan una raíz unitaria, y están cointegradas, presentando así una relación estable a largo plazo, la estimación a través de modelos VAR no es la más adecuada, ya que obvia la existencia de esta relación a largo plazo.

Los Modelos de Vectores de Corrección de Error (VECM) son una extensión del modelo VAR que permiten recoger la relación de cointegración a largo plazo, así como las relaciones entre las variables a corto plazo. En concreto, este modelo incluye las variables no estacionarias en diferencias, añadiendo un término de corrección de error, que es el residuo de la relación a largo plazo entre las variables en niveles o relación de cointegración, y cuyo coeficiente mide la velocidad a la que se ajusta cada variable cuando se produce un desequilibrio en la relación a largo plazo. Este modelo viene expresado por la siguiente fórmula:

$$\Delta Y_t = \alpha + \sum_{i=1}^{p} \Gamma_i \Delta Y_{t-i} + \Pi Y_{t-1} + \mathrm{B} X_t + \varepsilon_t \qquad (1)$$

Donde $Y_t$ es un vector de variables endógenas, $\Gamma_i$ es un conjunto de matrices formada por los coeficientes que representan la relación a corto plazo entre las variables y $\Pi$ es una matriz que representa el término de corrección de error. Ésta es el producto de dos vectores $\Pi = \gamma\beta'$, donde $\gamma$ representa la velocidad de ajuste de las variables ante desequilibrios en la relación a largo plazo, y $\beta$ representa los coeficientes de la relación de cointegración o relación a largo plazo entre las variables endógenas. Por otra parte, $X_t$ es un vector de variables exógenas, cuya relación con las variables dependientes viene representada por la matriz de coeficientes B. Finalmente, $\varepsilon_t$ es un vector que recoge los errores.

*Variables empleadas en la estimación*

En este modelo empleamos dos bloques de variables: por un lado, un conjunto de variables endógenas, que son las determinantes de la evolución del mercado del petróleo durante todo el periodo analizado y, por otro lado, una serie de variables exógenas que son consideradas factores externos al mercado del petróleo pero que afectan a su evolución. Empleamos series de tiempo con frecuencia mensual, para el periodo que abarca desde agosto de 2007, fecha que marca el inicio de la crisis financiera que finalmente culminaría en el derrumbe del mercado financiero y la posterior crisis económica, hasta agosto de 2016, último periodo para el que existían datos disponibles de todas las variables empleadas en el momento de realizar el análisis.

La primera variable endógena del modelo es el precio del petróleo. En este trabajo, utilizamos el precio West Texas Intermediate (WTI en adelante), que es el precio del barril de petróleo de referencia en Estados Unidos. Este precio es deflactado por el Índice de Precios al Consumo (CPI) de Estados Unidos, por lo que la variable está expresada en términos reales. Además, se emplea el precio spot, es decir, el precio de adquisición física del barril, en lugar del precio de futuros, ya que éste es una mejor representación del precio de adquisición y está menos expuesto a fluctuaciones en los mercados financieros que los precios de futuros.

La siguiente variable endógena empleada es el stock de petróleo de los países de la OCDE. Esta variable representa el stock de petróleo mantenido por los países miembros de la OCDE, medido en millones de barriles y es una variable *proxy* del stock de petróleo mundial, cuyos datos no están disponibles. Esta variable ha sido usada previamente en otros trabajos (Ye et al., 2002; Kaufmann et al., 2004; Dees et al., 2007; o Coleman, 2012) y representa los movimientos entre oferta y demanda de petróleo a nivel mundial.

La tercera variable endógena incluida en el modelo es la producción de petróleo de los países de la OPEP. Tradicionalmente, se ha considerado que la OPEP ha actuado con un comportamiento monopolístico en el mercado del petróleo debido a su gran peso en la producción mundial y en el total de reservas probadas, por lo que la evolución de su producción es un factor determinante de la evolución del precio del petróleo. Esta variable ha sido empleada previamente (Kaufmann et al., 2004; Chevillon y Rifflart, 2009; o Dees et al. 2007) como determinante de la evolución del precio del petróleo. En nuestro caso, esta variable se define como la producción de petróleo del conjunto de países de la OPEP, expresada en miles de barriles por día.

La última variable endógena del modelo hace referencia a la producción de petróleo de Estados Unidos, y su función es representar la reducción de la dependencia energética de este país por el aumento de la producción de petróleo como consecuencia de la adopción de la técnica de *fracking*. El cambio tecnológico introducido en el mercado del petróleo por la adopción de esta técnica ha permitido incrementar la producción de petróleo de Estados Unidos, convirtiéndolo en el principal productor de petróleo. Esto le ha permitido reducir su dependencia de petróleo importado, reduciendo el poder de mercado del resto de países productores, especialmente de los países pertenecientes a la OPEP. Para analizar su efecto en el mercado del petróleo y en el precio del mismo, incluimos esta variable definida como la ratio entre la producción de petróleo en Estados Unidos y el consumo de petróleo de las refinerías estadounidenses. Con esta variable analizamos el efecto del *fracking* en el mercado del petróleo a través de la reducción de la demanda exterior de petróleo por parte de Estados Unidos, el principal país consumidor de petróleo.

En el modelo, todas las variables endógenas están expresadas en logaritmos, de manera que sus coeficientes expresan sus respectivas elasticidades.

En el bloque de variables exógenas, incluimos una serie de variables cualitativas que representan los diferentes factores que han afectado a la evolución del mercado del petróleo y cuyo efecto queremos estudiar. La primera de ellas representa al estallido del mercado financiero en 2008, y es una variable *dummy* que toma valor 1 en el periodo de mayor estrés financiero, que comprende desde septiembre de 2008, mes en el que el mercado financiero colapsa, hasta diciembre de 2008, cuando el G20 se reúne en Washington para decidir medidas urgentes y coordinadas para atajar la crisis económica, tomando valor 0 el resto del periodo.

El resto de variables exógenas hacen referencia a las tres grandes guerras que han tenido lugar durante el periodo que analizamos y que afectan al mercado de petróleo, bien directamente por la existencia de reservas de petróleo en el territorio en el que se producen, o indirectamente por la participación de países con gran relevancia en la producción de petróleo a nivel mundial. Estas guerras son la guerra de Libia y la guerra de Siria, que surgen de la primavera árabe, y la guerra de Ucrania.

La guerra de Libia, que comienza a principios de 2011 con un levantamiento contra el gobierno, es relevante para el mercado del petróleo, ya que ciertas regiones del país poseen importantes reservas de petróleo. De hecho, Libia es uno de los principales países productores pertenecientes a la OPEP. La variable representativa de la guerra de Libia es una variable *dummy* que toma valor 1 durante los tres primeros meses del estallido, que abarca desde febrero a abril de 2011.

La segunda guerra que surge de la primavera árabe es la guerra de Siria, que es la que adquiere una mayor repercusión internacional, involucrando a otros países, entre ellos Irak, otro de los grandes productores de petróleo. Por otra parte, durante esta guerra surge el Estado Islámico, que toma el control de territorios con importantes reservas de petróleo. Además, dada la magnitud que adquiere el conflicto, Rusia y Estados Unidos se ven involucradas en el mismo, apoyando a gobierno y oposición, respectivamente, y luchando contra el surgimiento del Estado Islámico. Para determinar su impacto en el mercado del petróleo, incluimos una variable *dummy* que toma valor 1 en los tres primeros meses desde el inicio del conflicto, periodo que abarca desde enero hasta marzo de 2012.

Finalmente, la tercera guerra cuyo impacto en el mercado del petróleo analizamos es la guerra en Ucrania. Esta guerra tiene unas características diferentes a las descritas anteriormente, pues los territorios afectados no poseen reservas de petróleo. La importancia de este conflicto para el mercado del petróleo radica en la participación de Rusia, tras la declaración de independencia de las regiones de Crimea y de la ciudad de Sebastopol que se anexaron a Rusia con posterioridad. Esta participación de Rusia desencadenó la reacción de Estados Unidos y la Unión Europea, que impusieron sanciones sobre Rusia. De especial relevancia es la imposición de sanciones sobre el sector petrolífero ruso, cuyo peso en el mercado mundial de petróleo es importante. En este caso, puesto que el conflicto tuvo una duración menor a los anteriores y el alto al fuego se puede identificar de manera precisa, optamos por incluir una variable *dummy* que toma valor 1 durante el periodo completo del conflicto, el cual abarca desde febrero hasta septiembre de 2014, cuando se firma el alto al fuego en el Protocolo de Minsk.

### 3.1.2. Resultados

Antes de estimar el modelo, es preciso comprobar si las variables son estacionarias en niveles, I(0), o estacionarias en primeras diferencias I(1), para posteriormente determinar la metodología a emplear en la estimación. Con este fin, llevamos a cabo tres pruebas de raíces unitarias: test de Dickey-Fuller aumentado (ADF), test de Phillips-Peron (PP) y test de Kwiatkowski-Phillips-Schmidt-Shin (KPSS). Los resultados, recogidos en el artículo adjunto en la sección 3.1.3 muestran que todas las variables son I(1), es decir, no son estacionarias en niveles pero lo son en primeras diferencias.

Puesto que todas las variables son integradas de primer orden, es preciso comprobar si existe una relación de cointegración a largo plazo entre ellas. Para ello, utilizamos el método de Johansen-Juselius, que emplea dos tests de contraste distintos: el test de la traza y el test del máximo autovalor. Antes de realizar dichos tests, es necesario determinar el número de retardos a incluir en la especificación VAR, puesto que el test es sensible al número de retardos incluidos. Basándonos en los criterios AIC, HQIC y FPE, seleccionamos dos retardos. Ambos tests concuerdan en la existencia de una relación de cointegración entre las variables del modelo, es decir, existe un equilibrio a largo plazo al que tienden estas variables.

Puesto que todas las variables son integradas de orden 1 y existe una relación de cointegración entre ellas, el siguiente paso es la estimación de nuestro modelo a través de un VECM, lo que nos permite estimar tanto la relación a largo plazo o de equilibrio entre las variables de interés, como sus variaciones a corto plazo. El vector de cointegración estimado es el siguiente:

$$WTI_t = 43{,}08 - 8{,}98 * StockOCDE_t - 0{,}33 * PcUSA_t + 3{,}54 * ProdOPEP_t \qquad (2)$$

La ecuación indica que un aumento del 1% del stock de petróleo de la OCDE está vinculado a una caída del precio del petróleo del 8,98%, lo que refleja una caída de la demanda de petróleo en relación a su oferta. También existe una relación negativa entre el precio WTI y la variable representativa de la producción de Estados Unidos respecto a su consumo de petróleo. Es decir, un aumento de la producción de Estados Unidos respecto a su consumo, que reduce su dependencia de petróleo y, por tanto, su demanda exterior, conlleva una caída del precio del petróleo. Por último, la relación entre la producción de petróleo de la OPEP y el precio del petróleo es positiva. Un incremento de un 1% de la producción de la OPEP va acompañada de un aumento del 3,54% del precio del petróleo. Este resultado indica que la OPEP ha adaptado su producción a la evolución del precio del petróleo a largo plazo, de forma que cuando éste ha aumentado ha incrementado la producción, y viceversa.

Las estimaciones de las relaciones a corto plazo están recogidas en la Tabla 1. En primer lugar, los términos de corrección de error (ECT) de las variables *WTI* y *StockOCDE* son negativos y significativos, lo que significa que estas variables son las que llevan a cabo el proceso de ajuste cuando se produce un desequilibrio respecto a la relación a largo plazo. No obstante, el precio del petróleo se ajusta de manera más rápida, un 20,92% por mes, mientras que el stock de petróleo muestra un ajuste lento, de alrededor de 1,33% por mes. Por el contrario, los términos de corrección de error de las variables *ProdOPEP* y *PcUSA* no son estadísticamente significativos, lo que indica que estas variables no se ajustan al equilibrio a largo plazo. Es decir, cuando existe un desequilibrio respecto a la relación a largo plazo, el ajuste se produce a través de cambios en el stock de petróleo y, especialmente, en el precio, resultado coherente con las características del mercado de petróleo, donde tanto la oferta como la demanda son inelásticas y no se ajustan en el corto plazo, recayendo este ajuste especialmente en el precio.

**Tabla 1**. Estimación de los coeficientes a corto plazo del modelo del mercado de petróleo.

| | D(WTI) | | | D(StockOCDE) | | |
|---|---|---|---|---|---|---|
| **Variable** | **Coef** | **t-stat** | **p-value** | **Coef** | **t-stat** | **p-value** |
| *D(WTI(-1))* | 0,331*** | 3,553 | 0,000 | 0,005 | 0,695 | 0,488 |
| *D(WTI(-2))* | 0,217** | 2,220 | 0,029 | 0,003 | 0,318 | 0,751 |
| *D(StockOCDE(-1))* | -0,865 | -0,768 | 0,444 | -0,221** | -2,431 | 0,017 |
| *D(StockOCDE(-2))* | 1,174 | 1,057 | 0,293 | 0,102 | 1,138 | 0,258 |
| *D(PcUSA(-1))* | 0,479** | 2,088 | 0,039 | -0,057*** | -3,072 | 0,003 |
| *D(PcUSA(-2))* | -0,061 | -0,249 | 0,804 | -0,063*** | -3,171 | 0,002 |
| *D(ProdOPEP(-1))* | -0,049 | -0,061 | 0,952 | -0,107 | -1,644 | 0,103 |
| *D(ProdOPEP(-2)* | 0,076 | 0,102 | 0,919 | -0,077 | -1,267 | 0,208 |
| *ECT(-1)* | -0,209*** | -4,187 | 0,000 | -0,013*** | -3,318 | 0,001 |
| *Crisis* | -0,191*** | -4,452 | 0,000 | -0,001 | -0,354 | 0,724 |
| *Libia* | 0,074 | 1,601 | 0,112 | -0,004 | -1,120 | 0,265 |
| *Siria* | -0,021 | -0,447 | 0,656 | 0,005 | 1,352 | 0,179 |
| *Ucrania* | 0,032 | 1,062 | 0,291 | 0,008*** | 3,178 | 0,002 |
| *C* | -0,002 | -0,262 | 0,794 | 0,001 | 1,885 | 0,062 |

| | D(PcUSA) | | | D(ProdOPEP) | | |
|---|---|---|---|---|---|---|
| **Variable** | **Coef** | **t-stat** | **p-value** | **Coef** | **t-stat** | **p-value** |
| *D(WTI(-1))* | -0,021 | -0,510 | 0,611 | 0,033*** | 3,049 | 0,003 |
| *D(WTI(-2))* | -0,076* | -1,793 | 0,076 | -0,004 | -0,388 | 0,699 |
| *D(StockOCDE(-1))* | -0,610 | -1,251 | 0,214 | -0,046 | -0,350 | 0,727 |
| *D(StockOCDE(-2))* | -0,717 | -1,489 | 0,139 | -0,187 | -1,446 | 0,151 |
| *D(PcUSA(-1))* | 0,137 | 1,377 | 0,171 | -0,052* | -1,933 | 0,056 |
| *D(PcUSA(-2))* | -0,250** | -2,337 | 0,021 | -0,086*** | -2,997 | 0,003 |
| *D(ProdOPEP(-1))* | 0,252 | 0,717 | 0,475 | -0,121 | -1,284 | 0,202 |
| *D(ProdOPEP(-2)* | -0,146 | -0,450 | 0,654 | -0,012 | -0,134 | 0,893 |
| *ECT(-1)* | -0,007 | -0,307 | 0,760 | 0,005 | 0,783 | 0,435 |
| *Crisis* | -0,001 | -0,056 | 0,956 | -0,008 | -1,573 | 0,119 |
| *Libia* | 0,005 | 0,250 | 0,803 | -0,020*** | -3,712 | 0,000 |
| *Siria* | 0,021 | 1,068 | 0,288 | 0,008 | 1,519 | 0,132 |
| *Ucrania* | 0,010 | 0,790 | 0,432 | 0,001 | 0,174 | 0,862 |
| *C* | 0,004 | 1,222 | 0,224 | 0,002** | 2,525 | 0,013 |

Fuente: elaboración propia. *Nota*:***, ** y * denotan que el coeficiente de la variable es significativo al 1%, 5% y 10% respectivamente.

Las relaciones a corto plazo entre las variables del modelo muestran que ni el stock de petróleo ni la producción de la OPEP influyen en el corto plazo sobre el precio del petróleo de forma directa. El precio se ve afectado por sus variaciones pasadas, lo que muestra la existencia de persistencia en las variaciones del precio del petróleo. También se observa una relación positiva entre variaciones en la cobertura de la demanda de petróleo de Estados Unidos y el precio del petróleo. Para explicar esta relación, es necesario tener en cuenta que existe otra relación inversa entre ambas variables, de forma que las variaciones del precio del crudo modifican en sentido contrario la tasa de cobertura *PcUSA*. Esto nos obliga a analizar la relación desde una perspectiva dinámica.

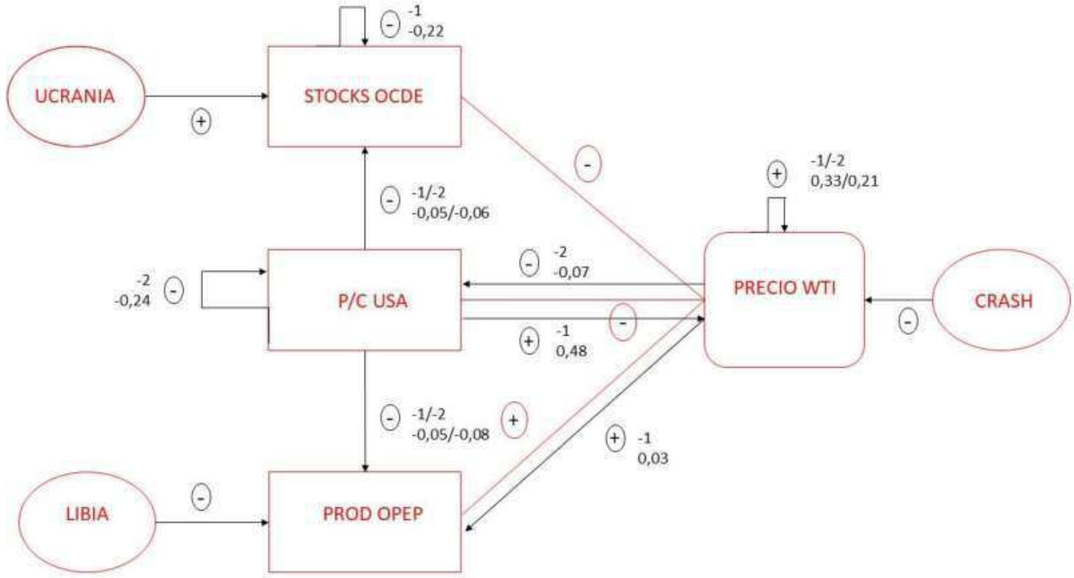
Supongamos un aumento del precio del crudo. Dicho aumento elevará rápidamente la demanda de crudo de las refinerías, dado que éstas saben que los incrementos de precio se mantendrán en los dos siguientes meses, por lo que tendrán interés en aumentar sus existencias rápidamente. Por su parte, la producción nacional de crudo también reaccionará, pero lo hará más lentamente, en tanto comprueba la persistencia de la subida de precio y ajusta su nivel de producción. El resultado es que temporalmente la subida del precio producirá una reducción de la tasa de cobertura *PcUSA*. No obstante, el proceso de acumulación de existencias por parte de las empresas de refino tiene un límite, por lo que, alcanzado el stock máximo acorde al precio, frenarán sus compras. Como además, la persistencia de la subida de precio de los meses precedentes habrá tenido efecto sobre la producción nacional, el resultado consecuente de la disminución de *PcUSA* debe ser la reducción del precio del crudo a corto plazo.

Por otra parte, la variable *PcUSA* también muestra relaciones significativas con otras variables del modelo. Por un lado, presenta una relación negativa con el stock de petróleo, lo que se traduce en que un aumento de la producción de Estados Unidos respecto a su consumo reduce el stock de petróleo, ya que se reduce la incertidumbre respecto a futuros desabastecimientos. Por otra parte, también afecta negativamente a la producción de la OPEP, ya que un aumento de la cobertura de la demanda de petróleo de Estados Unidos con petróleo nacional reduce la demanda de petróleo exterior, del que los países de la OPEP son los principales proveedores.

La variable *ProdOPEP*, por su parte, aumenta ante incrementos del precio del petróleo y, como hemos descrito anteriormente, disminuye ante aumentos de la producción de Estados Unidos. Por tanto, la producción de la OPEP se presenta como una variable endógena que reacciona ante otras variables del mercado del petróleo, mientras que sus variaciones no son determinantes de la evolución del resto de variables en el corto plazo.

Finalmente, las variables representativas de los shocks externos presentan destacables resultados. Por un lado, el estallido del mercado financiero en 2008 es el único evento que presenta un efecto directo sobre el precio el petróleo, provocando que éste cayera más de lo esperado según la evolución de las variables fundamentales en este episodio. En lo referido a las guerras, encontramos que la guerra de Siria no presenta un efecto relevante sobre el mercado del petróleo. Las guerras de Libia y Ucrania si tuvieron efecto en el mercado del petróleo, aunque no incidieron directamente en el precio. La guerra de Libia muestra un impacto negativo en la producción de la OPEP, resultado esperado dado que tal país es un miembro de esta organización y diversos pozos petrolíferos se vieron afectados. Por su parte, la guerra de Ucrania no influyó en el precio directamente pero sí sobre el stock de petróleo de la OCDE, que mostró una acumulación de crudo por encima de sus niveles esperados, lo que sugiere que este conflicto bélico incrementó la percepción de riesgo por parte del mercado, aumentando la acumulación de stocks por motivos de precaución.

**Figura 4**. Relaciones a corto plazo entre las variables obtenidas del modelo VECM.




Fuente: elaboración propia.

### 3.1.3. Artículo nº 1.

### Fracking, wars and stock market crashes. The price of oil during the Great Recession.

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# Fracking, Wars and Stock Market Crashes: The Price of Oil During the Great Recession

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**ABSTRACT**

This study analyses how oil prices have been affected by three types of events that took place during the Great Recession: The development of fracking, wars in Libya, Syria and Ukraine and the stock market crash of 2008. To do this, we employ co-integration analysis, using a vector error correction model for a period spanning August 2007 to August 2016. The principal results obtained are: Firstly, that including a variable to represent the increase in production associated to fracking in the US improves the model's long term estimation, as it embraces a new variable co-integrated in the long term; secondly, that the wars in Libya and Ukraine only influenced prices indirectly, insofar as the former sparked a reduction in Organization of Petroleum Exporting Countries production and the latter an increase in OECD oil reserves, both short term; and thirdly, that the stock market crash of 2008 led to a short- term reduction in oil prices.

**Keywords:** Great Recession, Oil Prices, Fracking, Stock Market Crash, War
**JEL Classifications:** Q4, Q43

## 1. INTRODUCTION

When observing the evolution of oil prices in the years after the financial crisis of August 2007 (Figure 1) which, following the stock market crisis of September 2008, led to the worldwide economic crisis known as the great recession, one notable feature is that oil prices experienced a sharp increase, which Kaufmann and Ullman (2009) link to market speculation prior to the stock market collapse in September 2008, and two sharp falls, with an intermediate period of stability between them, of around 90 dollars per barrel.

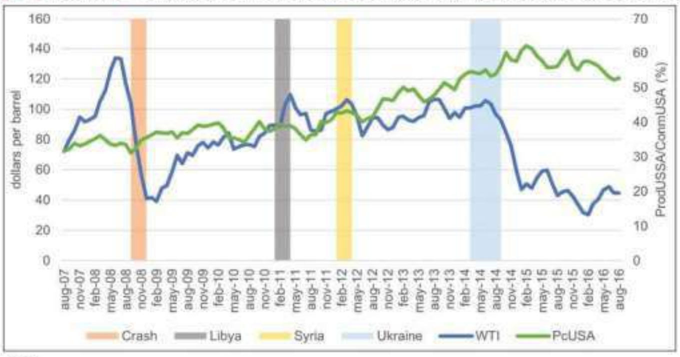
In addition to the collapse of the financial markets in September 2008 and the subsequent economic recession, there were three wars during that period which, due to the countries involved or their geostrategic situation, might have proved key to the world oil market, namely the conflicts in Libya, Syria and Ukraine.

Together with these endogenous factors, a technical-production development, namely fracking, took place during the period covered by this study. This development has had a decisive influence on oil supply and has altered the balance in the crude oil market, and has also led to the US becoming the main oil producer, overtaking Saudi Arabia.

Thus, if we superimpose the periods of instability linked to the September 2008 stock market crash and the wars in Libya, Syria and Ukraine onto the evolution of oil prices shown in Figure 1 and add a line representing oil production in the US compared to the consumption of crude oil by refineries, we see certain correspondences between the price variation and the three factors cited. Based on this, we propose studying whether there is a significant relationship between oil price and the events cited, based on the following hypotheses: Stock market crashes negatively influence prices (Lahmiri, 2017; Nazlioglu et al., 2015); wars affecting the sector spark price rises (Coleman, 2012; Kilian, 2009; Zhang et al., 2009) and fracking is a supply factor which strongly influences prices (Behar and Ritz, 2017; Fueki et al., 2016).

Few previous studies address these questions and the period considered. Some include the descriptive and non-econometric

**Figure 1:** Evolution of WTI price and US production/US refineries consumption (August 2007-August 2016)




Source: World Bank and EIA

work of Arezki and Blanchard (2014), which deals with the fall in the price of crude oil in 2014, and examines the increase in production of the Organization of Petroleum Exporting Countries (OPEC) leader, Saudi Arabia, and the financial implications of the fall in oil prices, particularly vis-à-vis the positions of oil producing countries and the economic policies which the various countries should adopt in an attempt to offset the effects of the fall; or the work of Kilian (2017), which analyses the effect of fracking and its consequences for Saudi Arabia, reduced imports from the US and the increase in refined products, also from the US. In our view, such a gap in the literature makes the present study necessary.

As regards the methodology, given the non-stationary nature of the data, we perform co-integration analysis using a vector error correction model (VECM) covering the period from August 2007 to August 2016, the final date for which data are available for all the variables.

In the econometric specification, we incorporate variables that are representative of the three factors studied. In chronological order, they are: A qualitative variable to capture the shock caused by the September 2008 stock market crash resulting from the drastic readjustment of expectations; respective qualitative variables representing the initial effects of the expectations arising from the conflicts in Syria, Libya and Ukraine (Coleman, 2012, Kilian, 2008 or Kilian and Park, 2009); and, finally, the relationship between oil production in the United States and said country's oil consumption in order to reflect the improvement brought about by fracking for the national coverage of US demand for crude oil. This latter fundamental variable is novel and has not to date been included in research, such that we focus particular attention on it.

As control variables, we use stocks in OECD countries, whose variations express the adjustment between supply and demand (Coleman, 2012; Dees et al., 2007; Fattouh 2009; Kaufmann et al., 2004; Ye et al., 2002), and OPEC production so as to capture its behaviour in the market and the capacity of OPEC countries to affect the price of crude (Chevillon and Rifflart, 2009; Dees et al., 2007; Hamilton, 2009; Kaufmann et al., 2004, Kaufmann et al., 2008).

Our principal results are as follows. With regard to the stock market crash of September 2008, the estimated model shows that it impacted oil prices significantly and very negatively; in turn, the uncertainty generated by the conflicts studied did not prove relevant to oil prices, although the civil war in Libya did obviously affect OPEC production, and the war in Ukraine led to a major increase in OECD oil reserves. Thus, both might have indirectly and negatively affected prices. Finally, the variable representing the change in the US crude market as a result of fracking is significant in the long-term equilibrium and explains part of the fall in oil prices in 2014.

The article is structured as follows: The second section includes a review of the preceding literature; the third describes the methodology employed and the sources from which the data used in the model were obtained; section four details the results to emerge; and finally, the fifth section presents the conclusions of the study.

## 2. LITERATURE REVIEW

The first aspect dealt with in the present study, namely the effect of changes in extraction technology as a result of fracking, which is still recent, has been the subject of enquiry. In this regard, the literature is divided. Certain authors argue that the substantial increase in US production of crude is one of the main reasons behind plummeting prices (Behar and Ritz, 2017). In fact, Fueki et al. (2016) consider that the first price fall in June 2014 was linked to the expected increase in production arising from fracking.

However, other authors hold that the drop in price we have witnessed has mainly been triggered by reduced demand. Kilian (2017) studies the effect of fracking on oil prices by first applying a VAR model which includes variables related to the supply of and demand for oil, and then introducing a counterfactual model in which production in the United States maintains its growth at the rate it displayed prior to the arrival of fracking. Results suggest that the effect of the increase in non-conventional production of crude by the US only contributed to the decrease in oil prices by between 5 and 10 dollars per barrel, with the remaining downturn being attributed principally to the decline in worldwide consumption of crude. Through the VAR model proposed by Kilian (2009), Badel and McGillicuddy (2015) suggest that falling prices were mainly caused by shocks on the demand side. Manescu and Nuño (2015) employ a dynamic stochastic general equilibrium model (DSGE) in which, in addition to the increase in production caused by fracking, they include the behaviour of Saudi Arabia as OPEC leader. Results suggest that increased production in the United States brought down the price by approximately four dollars, since it was anticipated by the market, and attribute the 2014 price fall mainly to increased production by other countries which are not members of the OPEC and to the fall in worldwide demand.

Researchers have also shown an interest in examining the impact of wars involving countries that play a leading role in the oil market, whether on the supply side, due to the destruction of oil fields or cuts in supply, or on the demand side, as the preventive part of the latter increased. Kilian (2009) analyses this type of shock through a VAR model spanning 1973-2005, including different events such as the Yom Kippur war and the Arab oil embargo of 1973-1974, the Iranian revolution in 1979, the Iran-Iraq war in 1980, the Gulf war in 1990 and the war in Iraq in 2003. Results show that shocks which affect supply are less important and have a shorter term effect on prices than those which influence demand. Furthermore, he suggests that the major shocks to take place during the period have mainly occurred on the demand side, and not the supply side, as has traditionally been assumed. Zhang et al. (2009) study the Gulf wars and the war in Iraq in 2003 through an Empirical Mode Decomposition (EMD) based event. Results suggest that oil price volatility increases during wars. When analysing the impact of wars, natural catastrophes and terrorist attacks for the period from 1984 until 2007, Coleman (2012) concludes that such events normally trigger price rises above the level marked by fundamental variables. However, Kilian (2014) considers that many of the price variations prompted by external shocks have an indirect impact on prices, which is not captured by models, as a result of fundamental variables also being influenced by such shocks. Whatever the case, for the purposes of our study, there are no precedents of studies which explore the effects of the most recent wars, coinciding with the Great Recession.

Thirdly, following the stock market crash of 2008 which gave rise to the economic crisis, the influence of financial markets on the oil market and its price has been widely studied. Nevertheless, most of the literature has concentrated on the relationship between interest rates, marked by monetary policy, and the price of crude. How this relationship is materialized remains open to debate. Some authors claim a negative relationship between interest rates and the price of oil, this theory being based on the assumption that a fall in interest rates stimulates the economy, boosting demand for oil and, as a result, sparking a price rise. These results appear in Akram (2009), Askari and Krichene (2010) and Novotný (2012). In contrast, other empirical studies point to a positive relationship between interest rates and the price of crude. The theory supporting this suggests that oil companies are capital intensive and, consequently, interest rates are a part of the costs they assume, such that an increase in these costs can be transferred to the price of crude. Studies such as those by Bencivenga et al. (2012), Krichene (2006) and Wang and Chueh (2013) support these findings.

Sun et al. (2017) suggest that the relationship between interest rates and oil prices is articulated in two ways: Directly, through their impact on aggregate demand, and consequently on the demand for crude, and indirectly, through the exchange rate. An increase in the interest rate gives rise to an appreciation in the dollar, thus making oil more expensive in other currencies, which negatively affects demand, triggering a price drop.

Another way to examine the relationship between financial markets and oil prices is by studying the effect of financial crises upon volatility and instability in the market price. A financial crisis sparks instability in the financial markets which may bring with it volatility in the price of crude. Such findings are reported by Nazlioglu et al. (2015), who explore how financial stress is reflected in the price of crude using a volatility test. To do this, they use the West Texas Intermediate (WTI) price of oil and Cleveland's financial stress index as variables, and conclude that after the crisis there is a relationship of transmission of volatility from financial markets towards the price of crude. Lahmiri (2017) studies the existence of chaotic behaviours in the oil market prior to and after the crisis. His results show the existence of chaotic behaviour in oil price volatility following the crisis, making it less predictable.

For their part, Kaufmann and Ullman (2009) examine the transfer of the effect of speculation in financial markets to the crude market. To do this, they use an error correction model and analyse the relationships between the various oil reference prices, and between spot and futures prices, in order to study which prices act as references for the rest, and which factors impact on price evolution. They conclude that the sharp increase in oil prices prior to the onset of the 2007-2008 financial crisis was due to a growth in demand and stable supply, and was reinforced by speculators, who took positions in light of the prospect of price rises. On the contrary, Mustapha (2012), studying the role of speculation in the determination of crude oil prices in five majors oil producing countries, suggests a positive, but weak, relationship between speculation and crude oil prices, but concludes that it is not the main driver of rising oil prices before the financial crisis.

In sum, as can be seen, there is a solid base in the literature for exploring the various factors which might have affected oil price during the Great Recession. Nevertheless, no study yet exists which examines the evolution of prices during the Great Recession as a whole, and which considers the three types of factors identified: Financial crisis, wars, and fracking.

## 3. METHODOLOGY AND DATA SOURCES

The present work aims to examine the evolution of oil prices during the Great Recession and to explore the possible impact of events such as the onset of the financial crisis in 2008, the wars which took place during that period and mass production via fracking. To do this, we use monthly data, from August 2007, which marked the start of the financial crisis that would lead to the global economic slump, until August 2016, the last month for which data are available for all the variables employed in the model.

Given that time series data are not stationary, as is common in monthly data series of this nature, it is necessary to perform co-integration analysis which determines whether those variables follow a similar evolution and lead to long-term equilibrium. To do this, we employ a VECM, which enables us to study the long-term equilibrium relationship among the variables included in the model, as well as their short term behaviour and how they restore equilibrium after deviating from it. The specification of the model is as follows:

$$\Delta Y_t = \alpha + \sum_{i=1}^{p} \Gamma_i \Delta Y_{t-1} - \Pi Y_{t-1} + \Gamma_j Dummies_t + \varepsilon_t \quad (1)$$

Where $Y_t$ is a vector of endogenous variables, which includes the price of oil, OECD oil stocks, OPEC oil production and a variable which refers to US dependence on foreign oil. In turn, $Dummies_t$ is a vector of qualitative variables which represent the eruption of the crisis in 2008, the outbreak of war in Libya and Syria and the ongoing conflict in Ukraine, and which are included as exogenous variables in the model. The equation term $\sum_{i=1}^{p} \Gamma_i \Delta Y_{t-1}$ shows the short-term relationships among the variables in the model, while the third term includes both the long-term relationship or level of equilibrium of the variables and the error correction term (ECT) reflecting the speed at which the variables are corrected to reach the level of equilibrium following a shock that diverts them from it.

The first endogenous variable is the real price of oil. Termed WTI, it is defined as the spot price of West Texas Intermediate oil, deflated by the monthly US price index (the CPI). We chose the WTI price as it allows use of a non-elaborated price index, the US inflation rate (CPI), to deflate without the need to construct a synthetic index. Although opting for this price entails losing some information, it should be pointed out that the variations and the WTI and Brent price level follow a similar trajectory.

The next endogenous variable is OECD countries' oil stocks. Defined as OCDE Stocks, it represents the oil stocks held by OECD countries in their reserves, measured in millions of barrels. This has been used in studies such as Coleman (2012), Dees et al. (2007), Kaufmann et al. (2004) and Ye et al. (2002), which employ stocks as a variable to represent the movements of supply and demand in the crude market.

Another endogenous variable in the model is oil production by the OPEC. OPEC's behaviour has been a traditional focus of study, since a certain monopolistic behaviour by this group of countries, whose oil reserves account for 73% of the world total (British Petroleum, 2016), has been suggested. Studies such as Chevillon and Rifflart (2009), Dees et al. (2007) or Kaufmann et al. (2004) have used OPEC production as a variable to determine price evolution. Our study defines this as OPECProd and represents the production of crude by OPEC in thousands of barrels per day.

The final endogenous variable we include in the model has no precedents and refers to production by the US. The technical-production breakthrough which the fracking industry has brought about in the oil market requires us to include a variable illustrating the impact that fracking has had on the oil market and on prices, through the significant increase in the amount of oil available on the market. To do this, we use the variable PcUSA, defined as the proportion between US oil production and oil consumption by refineries. The variable allows us to indirectly measure the effect of fracking through the ratio in which national production covers the demand for crude in the US. This has almost doubled in 4 years as a result of the increase in production via fracking.

All the endogenous variables included in the model are represented in logarithmic form, and thus the coefficients we obtain from the model represent the elasticities that exist among the variables studied. The values in levels of all variables are represented in Appendix.

In addition to these endogenous variables, we include a series of qualitative exogenous variables which refer to various events that took place during the period analysed and which may have affected the normal evolution of the market price of oil. First, in order to gauge the initial impact of the shock associated with the stock market crash following the collapse of Lehman Brothers, we introduce the variable Crash, a dummy variable which covers the period from September 2008, the month in which this stock market crash occurred, to December 2008, the month in which the G20 met at the Washington Summit in an effort to come up with urgent measures aimed at tackling the crisis.

In addition to the financial crisis, during the period studied there were three wars which affected countries or areas that are important to the crude market. To capture their effect, we include a dummy variable in the first three months of the conflict, following the results of Kilian and Murphy (2014), which indicate that the effect of a supply shock reaches its peak 3 months after occurring.

First, there are the two large-scale conflicts which emerged from the so-called "Arab spring," namely the Libyan civil war and the Syrian civil war. The Libyan civil war, which began in early 2011 as a result of an uprising against the government, was important due to the sizeable oilfields owned by certain regions in this country, an OPEC member. In fact, the conflict led to a military intervention of allied countries headed by NATO, aimed at overthrowing the government, bringing the war to an end and safeguarding oil reserves. To include it in the model, we use the variable Libya, a dummy variable covering February to April 2011.

Of the conflicts arising out of the Arab spring, the Syrian civil war is the one to have had the greatest repercussion since, in addition to the Syrian government and its opposition, a large number of countries have been involved, including Iraq. This war witnessed the emergence of the Islamic State, a terrorist group which took control of territories that held major oil reserves. As a result, the US and Russia have intervened in the conflict, supporting the rebels and government, respectively, and taking action against the Islamic state. To capture the impact of the shock caused by the outbreak of this conflict on oil prices, we use the variable Syria, a dummy variable which takes the value 1 for the months of January, February and March of 2012.

The third shock whose impact we study is the civil war in Ukraine. This is a war with very different characteristics to the previous ones. It began following the overthrow of the Ukraine government and gained international importance due to the uprising in the country's eastern regions which, in the case of Crimea and the city of Sebastopol, led to a declaration of their independence and subsequent annexation to Russia, and in other cases to the independence of territories. The importance this conflict had on oil prices is not due to the influence of Ukraine on this raw material, but rather to Russia's involvement in the conflict. Russia's involvement prompted strong resistance by the US and the European Union, and gave rise to sanctions because of the intervention. One particularly damaging sanction, and one which directly affects the Russian oil sector, involved imposing a ban on exporting gas or oil exploration and extraction equipment to Russia.

In this case, given that there is a ceasefire date, we opted to extend the variable to the whole period of the conflict, defining the variable Ukraine as a dummy variable which takes the value 1 for the period spanning the war in Ukraine, from its outbreak in February 2014 to September of the same year, when the ceasefire was signed in the Minsk Protocol (Table 1).

## 4. RESULTS

To study the stationarity of the series, we apply the Augmented Dickey-Fuller test, the Philip-Peron (PP) test and the Kwiatkowski–Phillips–Schmidt–Shin (KPSS) test.

In the case of the first two tests, the null hypothesis to be rejected is the existence of a unit root, while in the case of the KPSS test the

**Table 1: Summary of variables**

| Variable | Definition | Source |
|---|---|---|
| WTI | Log of WTI price deflacted by USA CPI | EIA/Federal Reserve Bank of St. Louis |
| OECDStocks | Log of OECD oil stocks | EIA |
| PcUSA | Log of proportion between the production of oil by USA and the consumption of oil by USA refineries | EIA |
| OPECProd | Log of OPEC oil production | EIA |
| Crash | Stock market crash, from September to December 2008 | Authors' compilation |
| Libya | Outbreak of Libyan war, from February to April 2011 | Authors' compilation |
| Syria | Outbreak of Syrian war, from January to March 2012 | Authors' compilation |
| Ukraine | Ukrainian civil war, from February to September 2014 | Authors' compilation |

Source: Authors' compilation. OPEC: Organization of Petroleum Exporting Countries

**Table 2: Unit root tests**

| Variable | ADF | ADF *P* value | KPSS | PP | PP P value |
|---|---|---|---|---|---|
| OECDStocks | 0.5280 | 0.9870 | 0.591287** | 0.4676 | 0.9849 |
| D (OECDStocks) | −11.90503*** | 0.0000 | 0.349224* | −11.81284*** | 0.0000 |
| PcUSA | −1.2307 | 0.6592 | 1.12125*** | −1.1637 | 0.6881 |
| D (PcUSA) | −8.849026*** | 0.0000 | 0.1350 | −9.193742*** | 0.0000 |
| OPECProd | −1.9230 | 0.3207 | 0.523599* | −2.1799 | 0.2148 |
| D (OPECProd) | −9.337299*** | 0.0000 | 0.0510 | −9.293972*** | 0.0000 |
| WTI | −1.9459 | 0.3104 | 0.450631* | −1.5100 | 0.5249 |
| D (WTI) | −6.796721*** | 0.0000 | 0.1193 | -6.662226*** | 0.0000 |

Source: Authors' compilation. *Statistical significance at the 10% level, **statistical significance at the 5% level, ***statistical significance at the 1% level. ADF: Augmented Dickey-Fuller, PP: Philip-Peron, OPEC: Organization of Petroleum Exporting Countries

**Table 3: Johansen-Juselius cointegration test (trace)**

| No. of cointegrated equations | Eigenvalue | Max-Eigen statistic | 0.05 critical value | P |
|---|---|---|---|---|
| r=0* | 0.2840 | 54.7442 | 47.8561 | 0.0098 |
| r≤1 | 0.0952 | 18.3255 | 29.7971 | 0.5421 |
| r≤2 | 0.0569 | 7.4203 | 15.4947 | 0.5293 |

Source: Authors' compilation

**Table 4: Johansen-Juselius cointegration test (maximum eigenvalue)**

| No of cointegrated equations | Eigenvalue | Trace statistic | 0.05 critical value | P |
|---|---|---|---|---|
| r=0* | 0.2840 | 36.4187 | 27.5843 | 0.0028 |
| r≤1 | 0.0952 | 10.9052 | 21.1316 | 0.6568 |
| r≤2 | 0.0569 | 6.3820 | 14.2646 | 0.5647 |

Source: Authors' compilation

null hypothesis is the existence of stationarity. The results given in Table 2 show that all the variables studied are integrated in the first order, I(1); that is to say they are not stationary at levels but present stationarity when first differences are analysed.

Since all the series are integrated at the first level, in order to study the existence of a long-term relationship we employ the Johansen-Juselius co-integration test. Before performing it, and since this test is sensitive to the number of lags of the VAR specification, we determine the number of optimum lags which, depending on different information criteria, such as the AIC, HQIC and the FPE, is 2.

We employ both the Johansen-Juselius co-integration test, based on the statistic of maximum eigenvalue and that of the trace. Tables 3 and 4 give the results for both tests, as well as the critical value at 5% and the P-values obtained. The results of the Johansen-Juselius test, based on the two statistics, concur in the existence of a long-term equilibrium among the variables studied. Given these results, an appropriate estimation technique is the VECM, which estimates on the one hand the long-term relationship of the variables, correcting the deviations from equilibrium, and on the other the impact of the variations of the variables in the short term. In our case, we estimate a VECM with two lags in first difference variables, without a deterministic trend and with a co-integration vector. The model passes the autocorrelation, heteroskedasticity and normality of residuals tests. As a result, its estimation is valid.

We obtain the following co-integration vector:

$$WTI_t = 43{,}08042 - 8{,}9827 OECDStocks_t - 0{,}3283 PcUSA_t - 3{,}5423\ OPECProd_t \quad (2)$$

In economic terms, this equation indicates that a 1% increase in the oil reserves of OECD countries would be accompanied by a fall in price of 8.98%, reflecting a decrease in the demand for crude as compared to its supply. The relationship between the PcUSA variable and the price of crude is also negative, such that an increase in US production with regard to the consumption of crude by its refineries would lead to a reduction in the country's dependence on oil and, consequently, a reduction in its demand for crude, triggering a downturn in price. In this case, the coefficient is lower, a 0.3% price drop against a 1% increase in the PcUSA variable. However, this outcome is to be

**Table 5: Short-term VECM estimation (WTI y OECDStocks)**

| | D (WTI) | | | D (OECDStocks) | | |
|---|---|---|---|---|---|---|
| | **Coefficient** | **T-stat** | **P** | **Coefficient** | **T-stat** | **P** |
| D (WTI(-1)) | 0.3313*** | 3.5531 | 0.0006 | 0.0052 | 0.6953 | 0.4883 |
| D (WTI(-2)) | 0.2173** | 2.2201 | 0.0285 | 0.0025 | 0.3178 | 0.7512 |
| D (OECDStocks(−1)) | −0.8648 | −0.7681 | 0.4441 | −0.2209** | −2.4313 | 0.0167 |
| D (OECDStocks(−2)) | 1.1739 | 1.0565 | 0.2931 | 0.1021 | 1.1380 | 0.2576 |
| D (PcUSA(−1)) | 0.4788** | 2.0877 | 0.0392 | −0.0568*** | −3.0720 | 0.0027 |
| D (PcUSA(−2)) | −0.0613 | −0.2485 | 0.8042 | −0.0630*** | −3.1707 | 0.0020 |
| D (OPECProd(−1)) | −0.0493 | −0.0609 | 0.9515 | −0.1074 | —1.6442 | 0.1030 |
| D (OPECProd(−2) | 0.0764 | 0.1017 | 0.9191 | −0.0767 | −1.2669 | 0.2079 |
| ECT(−1) | −0.2092*** | −4.1872 | 0.0000 | −0.0133*** | −3.3183 | 0.0012 |
| Crash | −0.1911*** | −4.4518 | 0.0000 | −0.0012 | −0.3544 | 0.7237 |
| Libya | 0.0740 | 1.6007 | 0.1124 | −0.0042 | −1.1201 | 0.2651 |
| Syria | −0.0207 | −0.4469 | 0.6558 | 0.0050 | 1.3515 | 0.1793 |
| Ukraine | 0.0316 | 1.0619 | 0.2907 | 0.0076*** | 3.1776 | 0.0020 |
| C | −0.0022 | −0.2616 | 0.7941 | 0.0013 | 1.8846 | 0.0622 |

Source: Authors' compilation. *Statistical significance at the 10% level, **statistical significance at the 5% level, ***statistical significance at the 1% level. VECM: Vector error correction model

**Table 6: Short-term VECM estimation (PcUSA y OPECProd)**

| | D (PcUSA) | | | D (OPECProd) | | |
|---|---|---|---|---|---|---|
| | **Coefficient** | **t-stat** | **P** | **Coefficient** | **t-stat** | **P** |
| D (WTI(−1)) | −0.0206 | −0.5101 | 0.6110 | 0.0330*** | 3.0493 | 0.0029 |
| D (WTI(−2)) | −0.0760* | −1.7931 | 0.0758 | −0.0044 | −0.3878 | 0.6989 |
| D (OECDStocks(−1)) | −0.6104 | −1.2513 | 0.2135 | −0.0457 | −0.3495 | 0.7273 |
| D (OECDStocks(−2)) | −0.7168 | −1.4890 | 0.1394 | −0.1867 | −1.4461 | 0.1510 |
| D (PcUSA(−1)) | 0.1369 | 1.3771 | 0.1713 | −0.0515* | −1.9327 | 0.0558 |
| D (PcUSA(−2)) | −0.2495** | −2.3368 | 0.0213 | −0.0858*** | −2.9973 | 0.0034 |
| D (OPECProd(−1)) | 0.2515 | 0.7173 | 0.4747 | −0.1207 | −1.2839 | 0.2019 |
| D (OPECProd(−2) | −0.1462 | −0.4495 | 0.6539 | −0.0117 | −0.1343 | 0.8934 |
| ECT(−1) | −0.0066 | −0.3068 | 0.7596 | 0.0045 | 0.7834 | 0.4351 |
| Crash | −0.0010 | −0.0557 | 0.9556 | −0.0078 | −1.5727 | 0.1187 |
| Libya | 0.0050 | 0.2503 | 0.8028 | −0.0199*** | −3.7115 | 0.0003 |
| Syria | 0.0214 | 1.0683 | 0.2878 | 0.0082 | 1.5185 | 0.1318 |
| Ukraine | 0.0102 | 0.7895 | 0.4315 | 0.0006 | 0.1738 | 0.8623 |
| C | 0.0044 | 1.2224 | 0.2242 | 0.0024** | 2.5250 | 0.0130 |

Source: Authors' compilation. *Statistical significance at the 10% level, **statistical significance at the 5% level, ***statistical significance at the 1% level. VECM: Vector error correction model expected since US production represents only a tiny fraction of worldwide crude oil production. Finally, a 1% increase in the production of crude by the OPEC would be accompanied by a 3.4% increase in the price of crude. This relationship would indicate that, during this period, OPEC adapted its production to the evolution of the market price in the long term, rather than behaving like a monopoly, as it had done in other past episodes in the oil market.

In addition, the short-term estimations of the error correction model are shown in Tables 5 and 6.

Firstly, the error correction terms ETC (−1) for WTI and OCDE Stocks are negative and significantly distinct from zero. This indicates that both variables tend to correct the disequilibria caused by a shock and contribute to long-term equilibrium restoration. In the case of price, it does so very rapidly, at a rate of 20.92% per month, while stock converges more slowly, at a rate of 1.33% per month.

However, the error correction term for the PcUSA and OPEPProd equations does not significantly differ from zero. This means that these variables do not contribute to restoring the long-term equilibrium relationship given by the co-integration equation after deviating from that equilibrium when faced with an unexpected short term shock. In economic terms, this means that when the variables deviate from the trend they share in the long term, it is price and OECD stocks which fluctuate and project the adjustment to return to equilibrium.

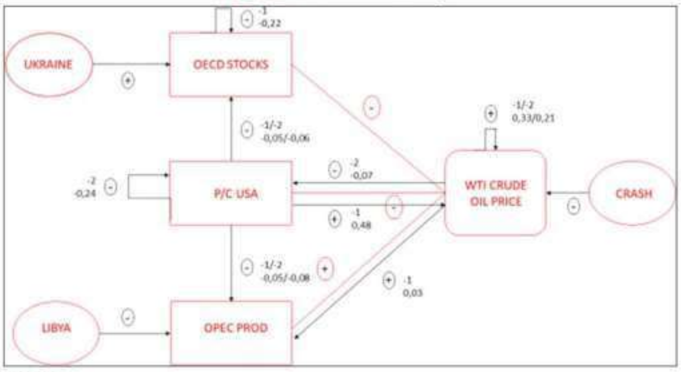
With regard to the short-term relationships between variables (Figure 2), it can be seen that neither the variation in OECD stock nor OPEC production have any impact on the evolution of the short-term price of crude. On the contrary, the model detects that the price of crude is affected, in the same direction, by variations in the price itself in the two preceding months. That is to say, the market maintains the direction of the price variation, such that a shock in the price is maintained for at least 3 months. The second variable which affects price in the short term is the PcUSA variable, such that an increase in the coverage of the demand for crude from the US with production from that country drives up the price and vice versa.

In order to explain this relation, it is necessary to take into account the existence of another inverse relationship between the two variables, such that variations in the price of crude modify the PcUSA rate of coverage in the opposite direction. This forces us to analyse the relation from a dynamic perspective.

Let us assume an upturn in the price of crude. This increase will rapidly increase demand for crude from refineries, since they know that price rises will remain in the following 2 months. They will thus be keen to rapidly increase their stocks. In turn, national crude oil production will also react, but will do so more slowly, as soon as the persistent price rise is confirmed. The result is that, temporarily, the price increase will spark a reduction in the PcUSA coverage rate. Nevertheless, refineries' ability to accumulate stocks is limited, meaning that when they reach the maximum stock in accordance with the price, they will cease purchasing. Since the persistent price increase in the preceding months will also have had an effect on national production, the subsequent result of the reduction in PcUSA must be the short term reduction in the price of crude.

According to our results, the variable PcUSA, included as an innovation in our study, proves crucial in short-term relationships with other fundamental variables. Firstly, it negatively affects OCDE Stocks, which is perfectly reasonable given that increases in the coverage of demand by national production reduce US dependence on foreign oil, thus curbing the risk of shortages and rendering the reserves of crude from the principal OECD country less necessary. Secondly, it is also reasonable to assume that it will negatively affect OPEC oil production, since if the coverage of demand is improved by national production in the US there is a reduction in demand in the international market, where the US is the principal client, forcing OPEC countries to accept a reduction in their market share. Finally, the model detects that the variable has an effect upon itself, although in this case, as in the case of the

**Figure 2:** Short-term relationships




Source: Authors' compilation

OCDE Stocks variable, the feedback is negative. That is to say, short-term changes tend to cushion preceding changes, which is perfectly consistent with the description provided above.

As the OPECProd variable responds positively in the short term to variations in the price of crude, which means that increases in production occur in times of rising prices when demand increases and vice versa, when prices fall the OPEC reduces production. Furthermore, as already stated, it varies negatively with the rate of coverage of demand in the US. In sum, the model shows that OPEC production is a variable which reacts to other variables, adjusts to circumstances, and which, in the short term, does not influence other variables.

Finally, as regards the variables representative of shocks, excluding the Syria civil war, for which no short-term influence was detected, the rest do display such an effect. The 2008 stock market crash is the only direct influence on the price of crude, which is perfectly consistent with the sharp downturn in demand sparked by the uncertainty of the early months of the crisis. For their part, the wars in Libya and Ukraine had no direct impact, but did have an indirect effect. The Libyan war impacted on OPEC production because Libya is a member of the organization. As a result, the reduction in the country's supply led to a fall in the organization's overall production until such time as supply was replaced by production from other OPEC countries. The war in Ukraine did not directly affect oil prices but meant that OECD stocks reached levels above normal figures, implying that said armed conflict increased market risk, thereby swelling precautionary stock.

## 5. DISCUSSION OF RESULTS AND CONCLUSIONS

In this study, we examine the evolution of oil prices during the Great Recession and the impact of various facts and events, such as the stock market crash of 2008, the wars in Libya, Syria and Ukraine, and fracking, taking the oil stocks held by OECD countries and OPEC production as fundamental variables in the model.

The results obtained for the long-term fundamental variables concur with those reported in other studies. Firstly, OECD oil stocks maintain a negative relationship with price, a result also to be found in Dees et al. (2007) and Ye et al. (2002). For OPEC production, there is a positive relation between this and price, indicating that during this period OPEC acted as a price taker, rather than imposing its market power, as concluded by other studies, such as those of Coleman (2012), Dees et al. (2007) or Kaufmann et al. (2004) who analyse OPEC's behaviour in previous periods.

Among the results obtained for the factors studied, prominent is the impact of the stock market crash of 2008, sparking as it did a price slump of nearly 20% greater than might otherwise be expected from market variables. From this result, it can be deduced that the uncertainty caused by the crash led to raw material prices, including oil, tumbling dramatically. Although there are no studies exploring the impact of the stock market crash on oil prices, Coleman (2012) examines the impact of the Asian financial crisis of 1998-1999, and also concludes that oil prices fell during that crisis, a notion fully consistent with our findings.

As regards the effect of the various wars that took place during the Great Recession, results from our study show that these did not have any great impact, which is consistent with the study by Kilian (2009), since they basically affected supply, and not directly but rather tangentially, except in the case of Libya.

In addition, as argued by Kilian (2014), who states that models fail to capture the influence of external shocks since the effects are brought about indirectly through changes in fundamental variables, we report these effects. The war in Ukraine had an impact on the reserves of crude by leading to greater than expected growth. Thus, taking into account that oil reserves influence prices, an indirect negative effect on prices can be deduced. The same is true of the war in Libya which, as it is an OPEC member, triggered a short-term fall in production, doubtless linked to the price of crude although, as we have seen, it is not a variable that determines the return to equilibrium, given that, as stated above, OPEC behaved as a price-taker.

Perhaps the novelest and important consequences lie in the results obtained when gauging the effect of fracking, measured indirectly through the rate of coverage of national production of US demand for crude. Examining the results of the estimation in the model, between June 2014 and February 2015 the rate of PcUSA coverage varied by 5.8%. It thus contributed with a fall of approximately four dollars per barrel, a result close to that obtained by Kilian (2017) who, through a counterfactual model, estimates a fall in oil prices of between 5 and 10 dollars per barrel. Furthermore, the reduction in US dependence on foreign crude had a negative impact on the production of OPEC countries, a result similar to that reported by Kilian (2017) for the case of Saudi Arabia. This suggests that the reduction in dependence on US crude meant less international demand for crude, thereby affecting demand for Saudi oil, and forcing the country to cut the growth of its production.

In sum, the principal events that took place during the Great Recession entailed an array of effects in different directions on oil prices, largely consistent with the expected outcomes. The model has allowed us to quantify the impact of previously unexplored facts and events. Furthermore, the study incorporates a new variable which captures the effect of fracking and which should be considered as a fundamental variable in subsequent studies.

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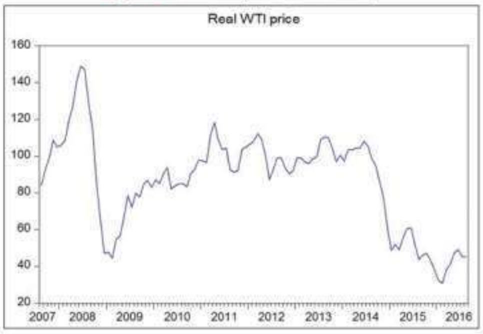
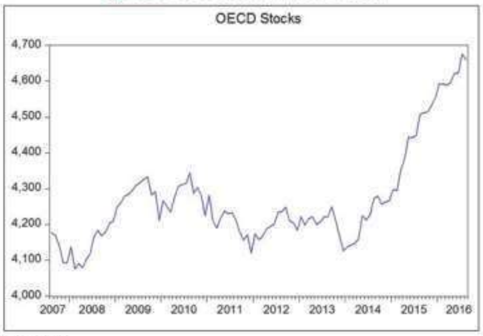
## APPENDIX

**Figure 1:** Real WTI price (dollars/barrel)



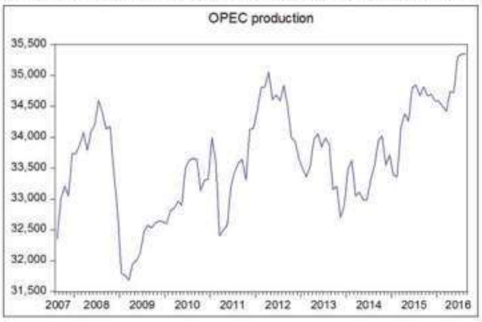

Source: World Bank

**Figure 2:** OECD stocks (millions barrels)



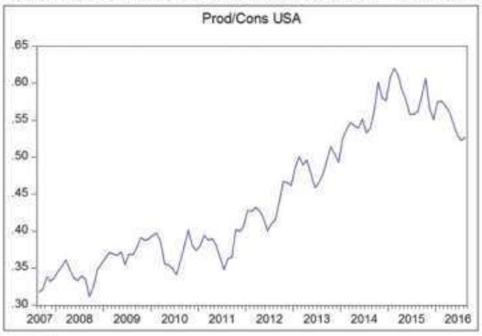

Source: US. Energy Information Administration

**Figure 3:** Organization of Petroleum Exporting Countries production (thousands barrels per day)




Source: US. Energy Information Administration

**Figure 4:** US production/US consumption (thousands barrels per day/thousands barrels per day)




Source: US. Energy Information Administration

## 3.2. La guerra de Ucrania y el precio del petróleo a corto plazo.

Los resultados obtenidos en el análisis anterior ponen de manifiesto que la guerra de Ucrania, especialmente por la participación de Rusia y la imposición de sanciones por parte de Estados Unidos y la Unión Europea sobre el sector petrolero ruso, generó una creciente incertidumbre en el mercado del petróleo, lo que se tradujo en una acumulación de reservas de petróleo por encima de lo esperado de acuerdo con los fundamentales del mercado. No obstante, los resultados anteriores muestran que el efecto de la guerra no desvió el precio del petróleo de su equilibrio a largo plazo.

En un contexto como el de la guerra de Ucrania, en un territorio donde no existen grandes reservas de petróleo y donde el vínculo entre el conflicto y el mercado del petróleo se debe a la participación de otros países con gran peso en este mercado, resulta más relevante analizar el impacto sobre el precio del petróleo a corto plazo de distintos eventos relevantes que ocurrieron durante el conflicto y que pueden afectar a la evolución diaria del precio del petróleo, aunque no supongan un efecto persistente, y por tanto, sean indetectables en modelos con una frecuencia temporal menor.

### 3.2.1. Metodología

El estudio del efecto de los eventos de la guerra de Ucrania y su impacto sobre la evolución a corto plazo del precio del petróleo requería el empleo de la metodología de estudio de eventos (*event study*), que permite aislar el efecto de determinados eventos de las variaciones normales o explicadas por la evolución de los factores fundamentales del mercado y, por lo tanto, determinar una relación causal.

Para poder analizar el impacto de los eventos relevantes de la guerra desarrollamos en primer lugar un nuevo método para seleccionar los días en los que se producen eventos relevantes para el mercado del petróleo, que posteriormente incluimos en el análisis econométrico. Seleccionar de manera no sesgada los eventos singulares relevantes durante un evento continuo, como es una guerra, supone una dificultad adicional. Los principales trabajos que emplean la metodología de estudio de eventos para el mercado del petróleo analizan los anuncios sobre las decisiones de la OPEP (Lim y Tamvakis, 2010; Loutia et al., 2016) o de la Reserva Estratégica de Petróleo de Estados Unidos (SPR) (Demirer y Kutan, 2010), cuya ventana de evento está claramente delimitada. Sin embargo, en el caso de las guerras, la delimitación y selección de eventos relevantes es más compleja y puede dar lugar a selecciones sesgadas. Ji y Guo (2015), para analizar el efecto de la guerra de Libia en el mercado del petróleo, construyen un índice de preocupación pública sobre la guerra basada en las búsquedas en Google, y seleccionan el periodo durante el cual el índice tomó unos valores mayores para analizar la variación acumulada del precio del petróleo en dicho periodo. Li et al. (2019) llevan a cabo un procedimiento similar, construyendo un índice que refleja el sentimiento del mercado a partir de noticias económicas. Estos métodos, sin embargo, no permiten delimitar eventos concretos, sino que crean una variable continua que mide la intensidad de la incertidumbre o de la expectación sobre un determinado evento.

Rigobon y Sack (2005), por su parte, analizan el efecto del riesgo generado por la guerra de Irak en distintos activos financieros y materias primas, seleccionando como eventos relevantes los días en los que las noticias sobre la guerra fueron predominantes. Sin embargo, el método de selección es arbitrario y no presenta ningún criterio explícito. Finalmente, Brune et al. (2015) emplean el número de noticias en *New York Times* con las palabras "*war"* e "*Iraq"* como variable representativa de la probabilidad de estallido de la guerra en Irak.

En esta tesis, proponemos un nuevo método de selección de eventos relevantes usando noticias sobre la guerra de Ucrania durante el conflicto, desde su estallido hasta el alto el fuego, utilizando como referencia las noticias publicadas en la prensa financiera especializada, en concreto, en *The Wall Street Journal* y *Financial Times*.

Analizamos las noticias de ambos periódicos para el periodo que abarca desde el 1 de noviembre de 2013 al 30 de septiembre de 2014, contabilizando un total de 334 días. En primer lugar, seleccionamos aquellas noticias en las que los términos "*Ukrainian war*" o "*Ukraine*" aparecen en la portada, bien en el título de la noticia o en su cuerpo. Dentro de este grupo de noticias, seleccionamos las que incluyen los términos "*Russia*" o "*Russian*", puesto que la potencial influencia de la guerra sobre el mercado de petróleo se debe a la participación de Rusia en el conflicto. Finalmente, seleccionamos los días en los que existen noticias que cumplen ambos criterios descritos previamente. Cuando dos o más días consecutivos cumplen estos criterios, seleccionamos el primer día, puesto que consideramos que el efecto de la noticia como nueva información o sorpresa pierde esa cualidad si se alarga en el tiempo.

Adicionalmente, añadimos como eventos relevantes aquellos días en los que se anuncian sanciones contra Rusia y que no cumplen los criterios previamente definidos, ya que los consideramos eventos de gran relevancia para el mercado del petróleo y de la participación de otros países en el conflicto. Por último, incluimos el día que se proclama el alto al fuego en el Protocolo de Minsk.

Para estimar el efecto de estos eventos en la evolución del precio del petróleo, empleamos la metodología de estudio de eventos, previamente empleado en estudios sobre el efecto de las decisiones de la OPEP en el precio del petróleo (Demirerr y Kutan, 2010; Lin y Tavakis, 2010; Schmidbaur y Rösch, 2012; Loutia et al., 2016). Esta metodología consiste en determinar variaciones anormales o inesperadas de la variable estudiada durante un determinado evento. La variación anormal se expresa de la siguiente forma:

$$AR_{et} = R_{et} - E(R_{et}) \quad (3)$$

siendo $AR_{et}$ la variación anormal de la variable en el periodo t, mientras que *e* representa un evento individual a estudiar. $R_{et}$ es la variación observada de la variable en el mismo periodo, y $E(R_{et})$ es la variación esperada o normal de la variable en caso de no producirse el evento. Por tanto, este método requiere, en primer lugar, determinar la ventana del evento, es decir, el periodo en el que el evento puede afectar a la variable y, por otro lado, estimar la variación esperada de la variable en ausencia del evento, para poder de esta manera determinar finalmente su variación anormal o inesperada.

Respecto a la ventana del evento, establecemos una ventana de un día, puesto que los eventos durante una guerra son generalmente dramáticos y generan reacciones rápidamente. Además, dada la existencia de numerosos eventos, seleccionar una ventana más amplia conllevaría el solapamiento de éstos, por lo que sería difícil distinguir el impacto de los distintos eventos sobre el precio del petróleo. Por último, el precio del petróleo, al igual que otros activos, está expuesto a numerosos tipos de shocks, por lo que aumentar la ventana de evento aumentaría la probabilidad de mezclar los efectos de los shocks provocados por los eventos estudiados con otros shocks de distinta naturaleza, dificultando la identificación de los primeros. No obstante, como test adicional, realizamos la estimación incluyendo una ventana de evento de dos días para analizar la existencia de una reacción retardada del mercado ante los eventos de la guerra de Ucrania.

Para estimar la evolución esperada o normal del precio del petróleo, utilizamos como variable de control el índice de precios de materias primas de Bloomberg (BCI), como *proxy* de la evolución del mercado de materias primas. Se trata de un índice sintético de 24 materias primas comercializadas a nivel internacional. La creciente financiarización de los mercados de materias primas provoca la existencia de una alta correlación entre la evolución de las distintas materias primas, entre ellas el petróleo (Tang y Xiong, 2012), especialmente en el corto plazo, de manera que la evolución de este índice nos permite estimar la evolución esperada del precio del petróleo que no está vinculada a factores específicos que afectan al mercado del petróleo, como son los eventos de la guerra de Ucrania.

Para estimar las variaciones anormales generadas por los eventos de la guerra de Ucrania, incluimos una variable *dummy* para cada evento, tomando valor 1 para el día de dicho evento y 0 el resto. Adicionalmente, realizamos el mismo test modificando la variable *dummy*, de forma que toma valor 1 el día del evento y el día posterior, de manera que podamos estimar si el efecto del evento se mantiene más allá del día en el que se produce.

Como variable dependiente, utilizamos los dos principales precios de referencia del mercado del petróleo: el West Texas Intermediate (WTI), que representa el precio del petróleo en Estados Unidos; y el Brent, que representa el precio del petróleo en Europa y es la referencia más utilizada mundialmente. Aunque ambos precios muestran una elevada correlación, durante ciertos momentos del periodo de estudio muestran fluctuaciones distintas, siendo el WTI más volátil y presentando mayores movimientos negativos, lo que sugiere el estudio de ambos precios por separados. Además, su estudio individual nos permite analizar si los efectos de los eventos tienen un impacto distinto en el mercado europeo, donde se produce la guerra, que en el mercado estadounidense, país que es el principal impulsor de las sanciones sobre Rusia. Por tanto, realizamos dos estimaciones alternativas.

La ecuación a estimar es la siguiente:

$$R_t = \alpha + \beta_1 R_{t-1} + \varphi BCI_t + \sum_j^n \mu_j Event_{jt} + \varepsilon_t \qquad (4)$$

donde $R_t$ es la variación del precio del petróleo en el día t, $R_{t-1}$ es la variación del precio en el día anterior, que se incluye para capturar la persistencia de la variable, $BCI_t$ es la variación del índice de precios de las materias primas de Bloomberg y $Event_{jt}$ es un conjunto de variables *dummy* que representa los diferentes eventos relevantes cuyo impacto en el precio del petróleo tratamos de analizar. Finalmente, en la estimación para el precio WTI incluimos una variable *dummy* de control que incluye los días 2 de enero de 2014, 22 de abril de 2014 y 2 de septiembre de 2014, en los que se observan variaciones atípicas del precio, no relacionadas con la guerra, y que pueden causar distorsiones en la estimación si no se controlan.

### 3.2.2. Resultados

Las tablas recogidas en el artículo adjunto en la sección 3.2.3 recogen los eventos seleccionados de acuerdo con los criterios establecidos en el apartado anterior. La primera tabla recoge los eventos que cumplen los criterios en ambas revistas, mientras que las otras dos tablas recogen los eventos que cumplen los criterios solo en una de las dos revistas, *The Wall Street Journal* y *Financial Times*, respectivamente.

Las Tablas 2 y 3 muestran los resultados de la estimación para el precio WTI y Brent respectivamente. Ambos precios muestran una relación negativa con sus variaciones pasadas, lo que implica que exhiben reversión a la media en el corto plazo. Además, el coeficiente del índice de precios de las materias primas de Bloomberg muestra un coeficiente positivo y significativo, confirmando que la evolución a corto plazo del precio del petróleo está vinculada al resto de materias primas.

En cuanto a los eventos relevantes, los resultados muestran que solo algunos de ellos tienen un efecto significativo en las fluctuaciones de los precios del petróleo y que, además, son distintos los eventos que afectan a cada precio de referencia.

En el caso del precio Brent, cuando incluimos los eventos con una ventana de un día, encontramos variaciones anormales en los siguientes eventos: el 3 de marzo de 2014, correspondiente con la primera amenaza de sanciones a Rusia por parte de Estados Unidos y el día 15 de abril de 2014, coincidiendo con la condena de la Unión Europea de la intervención de Rusia y con la primera sanción impuesta a oficiales de alto rango rusos. En ambos casos se produjo un incremento del precio. En el caso del precio WTI, los eventos con incidencia en el precio son: el 17 de julio de 2014, coincidiendo con las sanciones impuestas por Estados Unidos a empresas rusas; el 25 de julio de 2014, cuando la Unión Europea impone sanciones a altos cargos rusos y a empresas; y el 31 de julio de 2014, que se corresponde con la imposición de la tercera ronda de sanciones por parte de la Unión Europea y Estados Unidos. En los dos primeros eventos, se produce un aumento del precio del petróleo. No obstante, en el último, se observa una caída del precio WTI. Este resultado contraintuitivo obedece a que, el mismo día, se produjo el cierre de una refinería en Kansas debido a un incendio, lo que provocó la caída del precio como consecuencia del ajuste en la demanda provocado por el cierre. Por último, el día 5 de septiembre es el único evento que tuvo un impacto significativo en ambos precios. Este día se corresponde con la firma del alto al fuego en Minsk, provocando una caída del precio del petróleo.

En términos comparados, los eventos de la guerra de Ucrania muestran una mayor incidencia en el precio WTI, comerciado en Estados Unidos, que en el precio Brent, de referencia en los mercados europeos, lo que indica que el efecto en el precio del petróleo se produce especialmente por la noticia sobre la imposición de sanciones, donde Estados Unidos juega un peso superior a la Unión Europea, de ahí la mayor reacción en su mercado.

**Tabla 2**. Impacto de eventos relevantes de la guerra de Ucrania en el precio WTI.

| Evento 1 día | | | Evento 2 días | | |
|---|---|---|---|---|---|
| **Variable** | **Coef.** | **p-valor** | **Variable** | **Coef.** | **p-valor** |
| *WTI(-1)* | -0.157*** | 0.003 | *WTI(-1)* | -0.241*** | 0.000 |
| *Bloomberg* | 1.034*** | 0.000 | *Bloomberg* | 1.046*** | 0.000 |
| *28-feb* | -0.004 | 0.659 | - | - | - |
| *03-mar* | 0.013 | 0.156 | *03-mar* | -0.002 | 0.807 |
| *06-mar* | -0.011 | 0.223 | *06-mar* | 0.001 | 0.934 |
| *1-0-mar* | -0.007 | 0.432 | *10-mar* | -0.010 | 0.136 |
| *17-mar* | -0.002 | 0.863 | *17-mar* | 0.004 | 0.544 |
| *21-mar* | 0.003 | 0.712 | *21-mar* | 0.001 | 0.874 |
| *31-mar* | 0.000 | 0.963 | *31-mar* | -0.006 | 0.345 |
| *10-abr* | -0.005 | 0.608 | *10-abr* | 0.001 | 0.859 |
| *15-abr* | 0.001 | 0.928 | *15-abr* | -0.001 | 0.870 |
| *17-abr* | 0.001 | 0.932 | *17-abr* | 0.004 | 0.574 |
| *23-abr* | -0.008 | 0.358 | *23-abr* | -0.004 | 0.513 |
| *28-abr* | 0.002 | 0.828 | *28-abr* | -0.001 | 0.909 |
| *08-may* | -0.002 | 0.855 | *08-may* | -0.000 | 0.961 |
| *08-jul* | -0.000 | 0.975 | *08-jul* | -0.003 | 0.635 |
| *17-jul* | 0.019** | 0.038 | *17-jul* | 0.015** | 0.030 |
| *21-jul* | 0.013 | 0.143 | *21-jul* | 0.007 | 0.316 |
| *23-jul* | -0.012 | 0.187 | *23-jul* | -0.012* | 0.067 |
| *25-jul* | 0.020** | 0.031 | *25-jul* | 0.014** | 0.038 |
| *31-jul* | -0.057*** | 0.000 | *31-jul* | -0.035*** | 0.000 |
| *08-ago* | 0.006 | 0.495 | *08-ago* | 0.004 | 0.523 |
| *29-ago* | 0.013 | 0.147 | *29-ago* | 0.005 | 0.494 |
| *05-sep* | -0.016* | 0.072 | *05-sep* | -0.012* | 0.082 |
| *Control* | -0.033*** | 0.000 | *Control* | -0.035*** | 0.000 |
| | | | | | |
| *R2* | 0.4952 | | *R2* | 0.456 | |
| *R2 corregido* | 0.4333 | | *R2 corregido* | 0.392 | |
| *Jarque Bera* | 2.825 | 0.244 | *Jarque Bera* | 2.376 | 0.305 |
| *Breush-Godfrey* | 0.332 | 0.718 | *Breush-Godfrey* | 0.469 | 0.494 |
| *Breush-Pagan* | 0.460 | 0.988 | *Breush-Pagan* | 1.954*** | 0.007 |

Fuente: Elaboración propia. *Nota*:***, ** y * denotan que el coeficiente de la variable es significativo al 1%, 5% y 10% respectivamente.

Cuando incluimos los eventos con una ventana de dos días para analizar el posible retardo en la reacción del precio del petróleo a los eventos, los resultados se mantienen en línea con los anteriores. En el caso del WTI, los eventos significativos con la ventana a 1 día se mantienen, aunque el efecto sobre el precio es más reducido. Además, se añade otro evento relevante, el día 23 de julio de 2014 que coincide con el requerimiento de Estados Unidos a Rusia de retirar sus tropas de la frontera. En el caso del Brent, solo se mantiene como evento relevante el ocurrido el 15 de abril de 2014, añadiéndose otros eventos: el 20 de marzo de 2014, correspondiente a la propuesta de la Unión Europea de reducir sus importaciones de gas natural ruso; el 6 de junio de 2014, correspondiente al anuncio de la preparación del G-7 para imponer nuevas sanciones; y el 31 de julio, este último con un impacto negativo, al igual que ocurría en el caso del WTI, lo que indica que la noticia sobre el fuego en la refinería en Kansas alcanzó a este mercado con un día de retraso.

**Tabla 3.** Impacto de eventos relevantes de la guerra de Ucrania en el precio Brent.

| **Evento 1 día** | | | **Evento 2 días** | | |
|---|---|---|---|---|---|
| **Variable** | **Coef.** | **p-valor** | **Variable** | **Coef.** | **p-valor** |
| *Brent(-1)* | -0.026 | 0.682 | *Brent(-1)* | -0.075 | 0.236 |
| *Bloomberg* | 0.638*** | 0.000 | *Bloomberg* | 0.666*** | 0.000 |
| *27-feb* | -0.007 | 0.408 | *27-feb* | -0.003 | 0.660 |
| *03-mar* | 0.015* | 0.061 | *03-mar* | -0.002 | 0.693 |
| *06-mar* | -0.006 | 0.421 | *06-mar* | 0.004 | 0.492 |
| *17-mar* | -0.006 | 0.466 | *17-mar* | -0.005 | 0.378 |
| *20-mar* | 0.006 | 0.452 | *20-mar* | 0.011** | 0.047 |
| *15-abr* | 0.016** | 0.039 | *15-abr* | 0.012** | 0.039 |
| *17-abr* | -0.002 | 0.853 | *17-abr* | 0.001 | 0.802 |
| *28-abr* | -0.002 | 0.784 | *28-abr* | 0.001 | 0.884 |
| *02-may* | 0.007 | 0.410 | *02-may* | 0.004 | 0.500 |
| *08-may* | 0.002 | 0.788 | *08-may* | 0.003 | 0.558 |
| *13-may* | 0.003 | 0.685 | *13-may* | 0.007 | 0.239 |
| *06-jun* | 0.006 | 0.480 | *06-jun* | 0.009* | 0.095 |
| *14-jul* | -0.009 | 0.234 | *14-jul* | -0.003 | 0.623 |
| *17-jul* | 0.006 | 0.473 | *17-jul* | 0.006 | 0.324 |
| *21-jul* | -0.003 | 0.714 | *21-jul* | 0.004 | 0.459 |
| *25-jul* | 0.010 | 0.228 | *25-jul* | 0.005 | 0.421 |
| *31-jul* | -0.011 | 0.149 | *31-jul* | -0.011* | 0.059 |
| *06-ago* | 0.008 | 0.286 | *06-ago* | 0.006 | 0.318 |
| *13-ago* | 0.009 | 0.261 | *13-ago* | 0.001 | 0.850 |
| *22-ago* | -0.001 | 0.909 | *22-ago* | 0.002 | 0.688 |
| *26-ago* | -0.002 | 0.825 | *26-ago* | -0.001 | 0.855 |
| *03-sep* | 0.008 | 0.331 | *03-sep* | 0.007 | 0.183 |
| *05-sep* | -0.017** | 0.029 | *05-sep* | -0.007 | 0.222 |
| | | | | | |
| *R2* | 0.252 | | *R2* | 0.249 | |
| *R2 corregido* | 0.160 | | *R2 corregido* | 0.157 | |
| *Jarque Bera* | 1.405 | 0.495 | *Jarque Bera* | 0.243 | 0.886 |
| *Breush-Godfrey* | 0.380 | 0.684 | *Breush-Godfrey* | 0.788 | 0.456 |
| *Breush-Pagan* | 0.534 | 0.968 | *Breush-Pagan* | 1.611** | 0.039 |

Fuente: Elaboración propia. *Nota*:***, ** y * denotan que el coeficiente de la variable es significativo al 1%, 5% y 10% respectivamente.

El incremento de los eventos con efecto significativo en el precio Brent al incluir la ventana de 2 días indica que este precio reacciona con mayor lentitud que el WTI, cuya reacción en el día del evento es mayor. No obstante, el resultado general indica que el precio del petróleo solamente reaccionó a los eventos de la guerra de Ucrania vinculados a sanciones sobre Rusia o pronunciamientos sobre su participación en la guerra, en línea con los resultados esperados previamente.

### 3.2.3. Artículo nº 2.

### External effects of the war in Ukraine: the price of oil in the short-term.

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# External Effects of the War in Ukraine: The Impact on the Price of Oil in the Short-term

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**ABSTRACT**

This paper analyses the short-term impact of the most relevant events of the war in the Ukraine on the price of oil. In order to determine the events to be studied, we propose a methodology based on a study of the news published in two reference newspapers in the markets: The Wall Street Journal and the Financial Times. From this selection, we use an event study model to detect the significance of the events. The main results obtained are: Events that affected daily oil prices were scarce and occurred during very specific phases of the conflict; West Texas intermediate price was more affected than Brent, even though the war took place in Europe; there is no noticeable lagged effect in the events, suggesting that the market assimilated the impact of relevant events very quickly.

**Keywords:** Oil Price, War, Ukraine, Event Study
**JEL Classifications:** F51, G14, Q40

## 1. INTRODUCTION

Wars can have a number of effects on the economies of the countries involved. They can affect economic growth (Hoeffler and Reynal-Querol, 2003), the provision of production factors (Ghobarah et al., 2003; Hoeffler and Reynal-Querol, 2003; Biswas, 2000), the production structure (Mendershausen, 1940), the public budget and public debt (Collier, 1999).

Wars can also impact on the economies of third countries directly involved, causing external effects in these countries. These usually entail two types of effect: On the one hand, direct effects on third countries, usually neighbouring countries, with whom the countries affected have important relationships, and which are usually impacted by large-scale migratory flows (Ghobarah et al., 2003; Salehyan and Gleditsch, 2006; Salehyan, 2008) and substantial changes in commercial relationships (Mendershausen, 1940; Glick and Taylor, 2010; Ianchovichina and Ivanic, 2016); on the other, indirect external effects that spill over into international markets when one or more of the countries involved in the conflict is important enough to alter the equilibrium in international, financial or commodity markets, either directly or by influencing their fundamentals (Brune et al., 2015; Rigobon and Sack, 2005; Schneider and Troeger, 2006).

One of the latter effects includes the impact wars have on oil prices, when one of the countries involved is a major player in the market. These wars lead to what is known as "external shocks" in the oil market, which increase oil prices either because of a disruption in supply or because of a rise in preventive demand (Coleman, 2012; Kilian, 2009; Kilian, 2014). They also lead to greater volatility during the conflict, resulting from the uncertainty and instability that affects the market (Zhang et al., 2009).

In addition to the conflicts linked to the "Arab Spring" (Libya and Syria), recent years have also witnessed war in Europe, the civil war in Ukraine, in which Russia, one of the world's leading oil producers (BP, 2017), was involved.

The crisis in Ukraine started on 23 November 2013, when Ukrainian president Viktor Yanukovich turned his back on a trade deal with the EU and negotiated a $15 billion bailout with Russia. This led to three months of protests in the country, which culminated in the overthrow of Yanukovich on 22 February 2014. Russia considered it an illegitimate coup, refusing to recognize the new government and deploying troops in the Crimean peninsula, where a referendum for secession was held on 16 March, with secession being declared the next day followed by annexation to Russia. Hostilities began on 15 April in the eastern regions of Donetsk and Lugansk between pro-Russian armed groups and forces of the interim Ukraine government. In June 2014, the war intensified, with Russia becoming increasingly involved in the conflict. The armed confrontation continued until 5 September, when the different parties involved signed a ceasefire agreement known as the Minsk Protocol, which has remained in force until today apart from sporadic clashes.

Apart from the initial uncertainty it sparked, this war led to sanctions being imposed on Russia by western countries, led by the USA and the EU, and which was reflected in bans on weapons exports, oil extraction technology exports and access to financial markets (Davis, 2016). As for its effect on oil prices, a recent study concluded that although the war in the Ukraine had no direct effect on oil prices it did affect it through a shift in strategic reserves (Garzon and Hierro, 2018), with some countries increasing their reserves due to their concern regarding how the war might impact on the oil market.

The aim of this paper is to provide further insights into how the war in the Ukraine indirectly impacted on the price of oil by analysing the effect which the most relevant events to occur during the war had on daily oil prices. We employ an event study methodology, used in the oil market to analyse the short-term impact of OPEC announcements and decisions as well as US Strategy Petroleum Reserve announcements (Demirer and Kutan, 2010; Lin and Tamvakis, 2010; Schmidbauer and Rösch, 2012). The method is also commonly used in studies of financial markets.

The main problem we find when applying this methodology to analysing the effects of war is that wars are continuous events in which, apart from outbreak and end of the conflict, it is difficult to determine the relevant events. To solve this problem, we develop a system for identifying days when relevant events take place, by analysing news from two reference newspapers for international markets in the USA and Europe; the Wall Street Journal and the Financial Times, respectively.

The method involves selecting days on which relevant events occurred, applying two criteria: Firstly, there must be news on the front page referring to the war in the Ukraine and in which Russia, the relevant country in the oil market, is mentioned. Secondly, even if the first criterion is not met, there is news that refers to embargoes or sanctions. Furthermore, we also include the formal ceasefire, with the signing of the Minsk Protocol, although strangely enough this failed to appear on the front page of either newspaper. As a result, we obtain a total of 22 days with relevant events for the West Texas intermediate (WTI) market and 23 days for the Brent market. Having identified these particular events, we apply an event study with a market model that includes the Bloomberg commodity index, a synthetic index which shows the development of commodity markets, as an instrumental variable.

The main results we obtain are: Firstly, few events from the war in the Ukraine had an impact on daily oil prices, which is consistent with the results of Garzon and Hierro (2018); secondly, the WTI price was more affected by these events than Brent prices, despite Brent being the benchmark price in western European markets, in other words closer to where the war was being waged; and thirdly, there is no substantial lagged effect in the events studied, suggesting that the market quickly assimilated the impact of the events and that said impact did not persist even in the very short-term.

The remainder of the paper is organized as follows: Section 2 revises the existing literature. Section 3 discusses the data and methodology. Section 4 reports the estimation results and section 5 contains our conclusions.

## 2. LITERATURE REVIEW

The existing literature on the impact of wars on oil prices includes a number of works that seek to identify effects both during and after the wars, that is, in the long-term, whereas other studies aim to reflect only the effects during the course of the war. The former group includes the work of Kilian (2009), who studies the impact of war on oil prices through a vector autoregressive model, including oil price, oil production and a proxy for global real economic activity as endogenous variables. In the model, three types of shocks are analysed: Crude oil supply shocks, aggregate demand shocks and oil-specific demand shocks. The latter reflects oil price changes sparked by precautionary demand changes due to uncertainty or market concern about future supply disruption. This work looks at wars fought between 1973 and 2005 (Iranian Revolution in 1978-79; Iraq-Iran war in 1980-88; Persian Gulf War in 1990-91; civil unrest in Venezuela in 2002 and the Iraq War in 2003). Results suggest that supply shocks have smaller and transitory effects on oil prices, whereas increased demand, both aggregate and precautionary, triggers a more intense and persistent effect on oil prices over time.

The same method appears in Kilian and Murphy (2012), where sign restrictions are imposed. Kilian and Lee (2014) and Kilian and Murphy (2014) also use this method, including global and US crude oil stock, respectively, as endogenous variables, in order to pinpoint the possible role played by speculation in the episodes studied. Results from both studies are similar and confirm that the effects of wars on oil prices are more related to increased precautionary demand than to supply disruptions.

Zhang et al. (2009) employ an empirical mode decomposition based-event model to study the Persian Gulf War in 1991 and the Iraq War in 2003. This method involves decomposing the oil price time series into so-called intrinsic mode functions with different time scales, which allow a distinction to be made between short-term and long-term oscillations. Findings are similar for the two wars. Oil prices climb when the war breaks out, remain high during the course of the conflict, and then return to pre-war levels

**Table 1: Days where there is news about the Ukrainian war in the wall street journal and the financial times between 1 November 2013 and 30 September 2014**

| Sample | Wall street journal | Financial times |
|---|---|---|
| Analysed days | 334 | 334 |
| Days with news of the war on the front page | 86 | 70 |
| Days with Russian new on the front page | 55 | 47 |
| Selection | 21 | 21 |

Source: Authors' compilation

**Table 2: Descriptive statistics for the variables**

| Statistics | WTI | Brent | BCI |
|---|---|---|---|
| Mean | −0.000239 | −0.000556 | 0.000234 |
| Median | 0.00019 | −9.43E-05 | −7.93E-05 |
| Standard deviation | 0.011956 | 0.008539 | 0.00515 |
| Maximum | 0.027387 | 0.021171 | 0.016547 |
| Minimum | −0.059864 | −0.022826 | −0.014471 |
| Skewness | −0.855725 | −0.017354 | 0.053809 |
| Kurtosis | 6.484335 | 2.793891 | 3.411252 |
| Jarque-Bera | 143.7896*** | 0.416833 | 1.724276 |

Source: Authors' compilation. *Statistical significance at the 10% level, **Statistical significance at the 5% level, ***Statistical significance at the 1% level. WTI: West Texas intermediate

when it is over. Increased volatility is also in evidence during the war. Finally, by studying the residuals of the model, the authors conclude that long-term oil prices are higher than pre-war levels. The only difference lies in the intensity of the effects, since the results suggest that the Persian Gulf War had a greater impact on oil price than the Iraq War, because the Iraq War had been anticipated and discounted by the market before its outbreak.

The second group of studies includes Coleman (2012), who studies a period spanning 1984 to 2007, which encompasses the Iraq War, the Kuwait invasion, civil unrest in Venezuela and the military attack in Nigeria in 2006. Ordinary least squares (OLS) using White's heteroscedasticity-consistent standard error estimator is employed. In addition to the fundamental variables, a group of dummy variables is included which take a value of one during the course of the events mentioned above. Overall, results suggest that these events led to an increase in the price of crude oil.

Ji and Guo (2015) analyse the short-term impact of the Libyan War on the price of oil. Their aim is to identify the period during which the war impacted on prices. For this purpose, they create an index of public concern about the war, based on searches in "Google Trends." Using this index, they pinpoint the period of the Libyan war when public concern about it reached its height, namely between 20 February 2011 and 2 May 2011. For this period, they estimate the cumulative price increase. According to the results, prices rose by 10% during the period in question.

Finally, in their work into oil prices during the Great Recession, Garzon and Hierro (2018) include the effects of the wars in Libya, Syria and the Ukraine, employing a vector error correction model. For the wars in Libya and Syria, they use dummy variables which take the value one for the first 3 months. In the case of the war in the Ukraine, the dummy takes the value for the whole period, from the outbreak to the ceasefire. According to the results, none of the conflicts had a direct effect on oil prices. In the case of Libya, however, there is an indirect effect through the drop in OPEC production as a result of a disruption in Libyan oil production and, in the case of the Ukraine, increased OECD oil stocks, which might have indirectly affected changes in oil prices. These increased stocks would not have been triggered by underlying changes in fundamentals, but rather by greater uncertainty, which would have led countries to boost their reserves in order to hedge in the face of the war's possible future impact caused by Russia's involvement.

This overview highlights one of the flaws still inherent in analyses of how wars affect oil prices, namely the lack of studies that explore the immediate effects on daily changes in prices. In the case of oil prices, event studies, which are very common for other markets, remain scarce and always focus on OPEC decisions or meetings (Lin and Tavakis, 2010, Schmidbauer and Rösch, 2012), as well as announcements from the US strategy petroleum Reserve (Demirel and Kutan, 2010). The present paper aims to fill this gap.

## 3. METHODOLOGY AND DATA

In summary form, our goal is to analyse how the main events of the war in the Ukraine impacted on the daily price of crude. To do this, we adopt a two-stage approach: First, we define a method to identify a selection of standout events from an on going situation, in this case the war in the Ukraine, before then applying an event study model that allows us to pinpoint which events impacted on the price of oil and in what sense.

The key problem involved in our objective is to make an unbiased selection of days in which standout events of the war in the Ukraine occurred, in other words those which could have affected the behaviour of actors in the oil market. As noted previously, Ji and Guo (2015) employ the "Google Trends" search for the term "Libya War" to reveal public concern for the Libyan War. However, the result is a continuous index, since their aim is to identify when this war influenced oil prices, not to pinpoint the key events.

Much the same is true of the method designed by Li et al. (2017), and which seeks to transform economic news into variables that reflect market sentiment. They use news from "investing.com" to create these market sentiment indicators, which are also continuous variables, and apply them to study the extent to which they anticipate oil price changes in the oil market. Obviously, this method does not enable us to identify standout events either.

Faced with this limitation, we propose a new method to select days on which relevant events occurred in the war in the Ukraine that might have had an impact on the oil market. For this purpose, we use the news published in the press during the conflict, between the outbreak and the ceasefire. Unlike Li et al. (2017), our study focuses on a political event, a war. We therefore feel that the best references may be found in the general media, particularly newspapers seen as reference publications for the economic agents involved in financial markets: The Wall Street Journal and the Financial times.

Although the North American and European oil markets are closely linked, we felt that because the war in the Ukraine was fought on European soil there might be differences, both in terms of relevant events and their consequences. For this reason, we conducted a two-fold study such that, in order to pinpoint events that affected the WTI price, we use news from the Wall Street Journal and, in the case of Brent, news published in the Financial Times.

We study the news from both newspapers in the period spanning 1 November 2013-30 September 2014, a total of 334 days, analysing their content and selecting days where the terms "Ukrainian war" or "Ukraine" appear as front page news, either in the headline or the main body, and then, inside these groups, news that included the terms "Russia" or "Russian," given that the potential influence of this war on the oil market is related with Russian involvement in the conflict. The results from this first selection are shown in Table 1.

From this group of selected days, we removed those in which the reference to the war in the Ukraine and to Russian involvement were not mentioned in the same piece of news. Secondly, in order to avoid distortions, when there are consecutive days that meet the criteria considered a relevant event, we select the 1st day.

We add to the selected days those where, despite not fulfilling the first criterion mentioned above, sanctions against Russia were imposed, which are a relevant economic fact in themselves, since they reflect the spread of the conflict to other areas. We also add the day the ceasefire was signed, since although curiously it failed to make the front page in either of the newspapers in question, it would obviously have influenced oil prices given that it creates a new scenario. Finally, we remove from the sample those days where oil price data is not available.

The hypothesis we propose regarding the behaviour of oil price vis-à-vis the selected key events is that these should have influenced oil prices, by causing them to rise more than what are normal market variations. We employ an event study approach to test this.

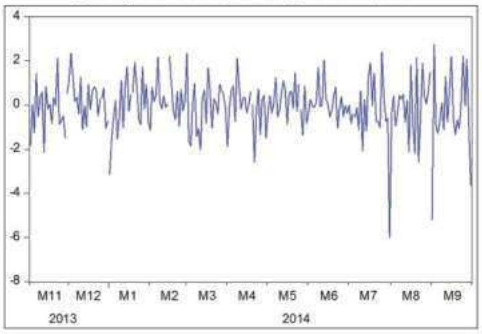
As already pointed out, this method has been employed to analyse the short-term impact of OPEC announcements and decisions concerning production and US Strategy Petroleum Reserve announcements on oil price. Lin and Tavakis (2010) estimate the abnormal returns of oil price as the differences between the real returns and the expected returns in the period considered, which in this work is deemed equal to zero. They use it to calculate the average cumulative abnormal returns in the event window, which covers ten days prior to the event and ten days after it, and then construct a test statistic to ascertain the event's significance. Schmidbaur and Rösch (2012) employ a simple regression model and a GARCH model, introducing a series of dummy variables which represent OPEC meetings, distinguishing between those which announce an increase in production quotas, a cut or no change.

In addition to OPEC decisions, Demirel and Kutan (2010) also analyse US Strategy Petroleum Reserve announcements. In order to estimate the abnormal return of oil price, they employ three different models (a market model, an ARCH model and a Fama-French model), taking the residuals as the abnormal returns in all of them. In an effort to check the significance of the events, they use a test statistic created from the average cumulative abnormal return in the event window, 20 days before and after the event. In their study, they distinguish between five types of events: OPEC announcements of an increase in production, a reduction, and no change, as well as US Strategy Petroleum Reserve announcements of increases or reductions in strategic oil reserves.

Our model is determined as follows:

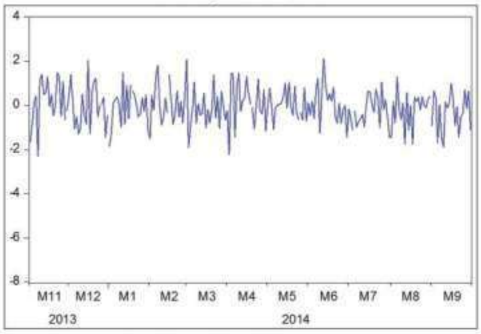
As regards the abnormal return of oil price, we defined it as follows:

**Figure 1:** West Texas intermediate price returns (%) in the period spanning November 01, 2013–September 30, 2014




Source: Energy Information Administration

**Figure 2:** Brent price returns (%) in the period spanning November 01, 2013–September 30, 2014




Source: Energy Information Administration

$$AR_{et}=R_{et}-E(R_{et}) \quad (1)$$

Where $AR_{et}$ is the abnormal return in time t, where e indicates a single event. $R_{et}$ is the normal price return in time t and $E(R_{et})$ is the expected return, assuming that the event had not taken place.

We set a 1-day event window, firstly because events in wars tend to be dramatic and therefore lead to impulsive actions, and secondly because wars are ongoing events, such that a larger than one-day event window might lead to overlaps between the different events, the effects of which might even be of a different sign. A third reason is because the oil market is exposed to numerous types of shocks, such that increasing the event window might lead us to mix the impact of the events studied with the impact of other factors, since we do not start from events that have a long-term impact on oil price. However, we also employ a two-day event window, including the event day and the day after the event, in order to check for a possible lagged effect in price related to the events studied.

In order to estimate abnormal return, we opted for a market event study approach, including, as a proxy variable, a commodity index similar to the one used in Demirel and Kutan (2010) where the Dow Jones AIG Commodity Index was applied to represent market oscillations.

To estimate the abnormal price return during the event and to test its significance, we include a dummy variable for each of the key events, as done by Schmidbauer and Rösch (2012). Each variable thus allows us to test for the existence of abnormal price returns on the day of the event. Other studies (Demirel and Kutan, 2010; Lin and Tavankis, 2010) estimate the average cumulative abnormal return in the event window, calculating a test statistic from it to analyse its significance. However, it is not possible to employ this methodology in our work due to the short length of the event window (1 day).

Finally, we include the lagged dependent variable in the equation, as is included in the Falagiarda and Reitz (2015) study of the effects of ECB announcements of non-conventional programmes on the sovereign default risk premium.

The equation to estimate is the following:

$$R_{et} = \alpha + \beta_i R_{et-1} + \varphi BCI_t + \sum_j^n \mu_j Event_t + \varepsilon_t \quad (2)$$

**Table 3: Ukrainian war selected events which meet the criteria in both newspapers**

| Date | Event description | WTI return ($) event day | WTI return ($) 2 days cumulative | Brent return ($) event day | Brent return ($) 2 days cumulative |
|---|---|---|---|---|---|
| March 03, 2014 | Senior US official threaten with implementing future economic sanctions on Russia for his interference in Ukrainian Crisis and the Crimea invasion | 2.46 | 0.76 | 2.28 | 0.19 |
| March 06, 2014 | UE political leaders discuss potential sanctions on Russia. German government oppose to implementing hard sanctions, whereas Estern's countries defend tough measures | 0.07 | 1.07 | −0.16 | 0.99 |
| March 17, 2014 | Crimea vote to secede and join Russia in a Referendum, with the support of Russia. US and the EU condemned the Referendum as illegal and set the first round of sanctions on Russian officials | −0.80 | 0.85 | −1.09 | −1.29 |
| April 15, 2014* | EU foreign ministers condemn the Russian operation in the Ukrainian borders and ask for the withdrawing of troops. They also extend the sanctions list to four new Russian officials | −0.35 | −0.34 | 1.42 | 2.03 |
| April 17, 2014 | Ukraine accused Russia of carrying out military raid in his territory. BP warns European governments of the economic consequences of imposing harder sanctions on Russia and his oil company Rosneft | 0.62 | 0.64 | 0.08 | −0.02 |
| April 28, 2014* | US and the EU extend the scope of sanctions to seven Russian officials and executives, as well as seventeen Russian firms through US visa bans and asset freezes. Among those sanctioned are Rosneft senior high executive | 0.28 | 0.71 | −0.41 | 0.36 |
| May 08, 2014 | President Putin softens harsh tone on Ukraine, calling for a delay in the independence referendum in the Eastern regions and assuring the withdrawal of Russian troops from the Ukrainian border | −0.54 | −0.74 | 0.02 | 0.09 |

Source: Authors' compilation. * Selected events according to the second criterion (news about sanctions on Russia) For the purposes of assessing the price variations, bear in mind that the average daily variation rate in absolute value for the period is 0.86 dollars for WTI and 0.72 dollars for Brent WTI: West Texas intermediate

**Table 4: Ukrainian war selected events which meet the criteria only in the wall street journal**

| Date | Event description | WTI return ($) event day | WTI return ($) 2 days cumulative |
|---|---|---|---|
| February 28, 2014 | Ukraine former president, Yanukovich, ask for protection and help to Russia government. US Secretary of State, John Kerry, ask Russia not to interfere in the conflict and to respect its border with Ukraine | 0.20 | 2.76 |
| March 10, 2014 | Russia president shows his support for Crimea secession. Crimean official, supported by Russia, claims that the region could join Russia in a month | −1.43 | −2.53 |
| March 21, 2014 | US Extend the sanctions to the inner circle of Putin. The EU meet to agree on future sanctions | 0.29 | 0.37 |
| March 31, 2014 | John Kerry, US Secretary of State and his Russian counterpart meet to address the Ukranian issue, without reaching any agreement, increasing the politica crisis. Kerry remark that Russia does not ensure the withdrawal of its troops, settled on the border with Ukraine | −0.16 | −2.04 |
| April 10, 2014 | Ukranian officials denounce the operation of Russian agents in Eastern of Ukraine. Russian government deny any interference in the Ukrainian situation. Top finance officials from the G-7 meet to consider new sanctions on Russia | −0.18 | 0.13 |
| April 23, 2014 | Joe Biden, Vice President of the US warns to withdraw his troops from Ukraine, whereas Secretary of Defence of the US officials describe a plan to send 600 soldiers to Ukraine as NATO members with the aim of controlling the Russian operations | −0.22 | 0.51 |
| July 08, 2014 | Putin ignore the requirement to send troops against Ukrainian forces by the Ukranian separatists | −0.13 | −1.26 |
| July 23, 2014 | US intelligence officials detected a surface to-air-missile launch in the separtist-controlled area in Eastern Ukraine and that there has been a growing flow of weapons from Russia to separatists over the last month | −0.78 | −1.83 |
| August 08, 2014 | Russia bans imports of a wide range of US and European foods in respond to penalties impose on Russia over the crisis in Ukraine | 0.27 | 0.75 |
| August 29, 2014 | Kiev again accuses Russia of sending troops to Eastern Ukraine to fight for the Ukrainian separatists, removing any hope of a diplomatic solution and provoking the imposition of new sanctions by US and the EU | 1.42 | −3.52 |

Source: Authors' compilation. For the purposes of assessing the price variations, bear in mind that the average daily variation rate in absolute value for the period is 0.86 dollars for WTI and 0.72 dollars for Brent. WTI: West Texas intermediate

Where $BCI_t$ is the bloomberg commodity index, a proxy variable that represents the development of commodity markets. Through this variable, we try to estimate the normal progress of oil price, since, in the short-term, its variations are mainly caused by changes in the financial and commodity markets. $R_{t-1}$ is the lagged dependent variable. $Event_t$ is a group of dummy variables with which we try to obtain abnormal oil price returns during the events studied. These variables represent the previously highlighted events, taking the value one for the day of the event (or for the day of the event and the day after in the case of a 2-day event window) and 0 for the rest of the period. In addition, in the WTI estimation, we include a dummy to control for three unusual values which appear on the following days: 2 January 2014, 22 April 2014 and 2 September 2014. These unusual values are not related to events that occurred in the war and might distort the estimation results.

All the variables employed in this work, with the exception of the dummy variables for events, are expressed in logarithm changes, since the interest of our work lay in price returns, not absolute values. The variables therefore show daily proportional changes.

As pointed out, the dependent variables of the model are the main benchmark prices in the oil market: The WTI, referred to in the model as WTI, which is the benchmark in the American oil market; and Brent, referred to in the model as Brent, which is the benchmark price in the European oil market. The data for both variables are provided by the US Energy Information Administration.

The proxy variable, BCI, takes its values from the Bloomberg Commodity Index, a synthetic index that charts the price of 24 different commodities from seven groups, including crude oil. Given that developments in financial markets in recent years have led to the financialization of commodity markets, thereby increasing the volume of investment in the commodity index, there is a greater correlation between the different commodity prices (Tang and Xiong, 2012). This allows us to employ BCI as a proxy for market movements, since it captures the returns in oil prices that are triggered by changes in the commodity market and, therefore, are not caused by specific changes in the oil market. The data is compiled from the website "investing.com."

Table 2 shows the descriptive statistics of the variables used in the model. Even though the WTI and Brent are very similar, there are some differences in their behaviour. Brent shows less variability in the period studied, reflected in a smaller standard deviation, as well as in a maximum and minimum of smaller magnitude.

Both show negative skewness, meaning that falls in oil prices prevail over increases during this period. Figures 1 and 2 show the evolution of both prices and clearly evidence that WTI displays more unsteady behaviour than Brent, and undergoes more noticeable downturns at specific moments. This makes it even more necessary to perform the estimates separately, rather than by an aggregate price index.

**Table 5: Ukrainian war selected events which meet the criteria only in the financial times**

| Date | Event description | Brent return ($) event day | Brent return ($) 2 days cumulative |
|---|---|---|---|
| February 27, 2014 | Russia put armed forces on alert in a show of military strength over the political direction of Ukraine. John Kerry, US Secretary of State warns Russia that any sign of intervention will be unacceptable for US | −0.85 | −0.41 |
| March 20, 2014 | UK urges EU to discuss a new energy security plan to reduce the dependence from Russian natural gas, increasing the imports from another sources like US or Iraq | −0.22 | 1.25 |
| May 02, 2014 | Ukraine's interim prime minister say that the country is entering its most dangerous 10 days since independence in 1991 and acusse Moscow of conspiring to promote more clashes and help pro-Russian separatists | 0.85 | 0.85 |
| May 13, 2014 | US and the EU prepare new sanctions on Russian economy and discuss a ban of exports of high-tech energy equipment if Moscow is seen to have disrupted Ukraine's presidential elections on May 25 | 0.41 | 1.50 |
| June 06, 2014 | G-7 leaders prepare to impose tougher sanctions against the Kremlin unless it halts its provocations inside Ukraine and convince pro-Russian rebels to lay down their arms | 0.78 | 2.12 |
| July 14, 2014 | Russian government accuses the Ukrainian military of killing one of its citizens in the border and warns of irreversible consequences. NATO leaders plot cyber fightback after Russian propaganda coup | −1.04 | −1.04 |
| August 06, 2014 | Russia increase the number of troops on the Eastern border of Ukraine, increasing fear of an invasion. Russia demand a humanitarian mission in Eastern Ukraine, where pro-Russian are being attacked | 1.35 | 1.20 |
| August 13, 2014 | Russian government send a humanitarian aid convoy to rebel-held city of Lugansk. Ukrainian government refuses entry to this convoy, since it's considered as an attempt to enter Ukrainian territory by Russia | 0.59 | −0.53 |
| August 22, 2014 | Oil company Rosneft loose a $2bn deal with Vitol due to sanctions imposed by the EU and US Ukraine claim to have captured two Russian troops carriers in Ukrainian territory | −0.19 | 0.21 |
| August 26, 2014 | NATO chief comment that Russian humanitarian convoy could be a guise to distract the west from a build-up of regular Russian forces in Ukraine | 0.01 | −0.09 |
| September 03, 2014 | UE diplomat considers to sanction Russia by boycotting 2018 football World Cup, among other sporting events | 0.67 | 1.00 |

Source: Authors' compilation. For the purposes of assessing the price variations, bear in mind that the average daily variation rate in absolute value for the period is 0.86 dollars for WTI and 0.72 dollars for Brent. WTI: West Texas intermediate

**Table 6: Unit root tests**

| Variable | ADF | P-value | KPSS | PP | P-value |
|---|---|---|---|---|---|
| WTI | −16.2549*** | 0.0000 | 0.2028 | −16.25788*** | 0.0000 |
| Brent | −14.9897*** | 0.0000 | 0.2579 | −14.9886*** | 0.0000 |
| BCI | −13.1209*** | 0.0000 | 0.594064** | −13.2316*** | 0.0000 |

Source: Author's compilation. *Statistical significance at the 10% level, ** Statistical significance at the 5% level, *** Statistical significance at the 1% level. ADF: Augmented Dickey-Fuller, WTI: West Texas intermediate

## 4. RESULTS

Applying the process of determining major events, as described above, the key moments selected for the war in the Ukraine are shown in Tables 3-5.

Before carrying out the model estimation, we examine the stationarity of the variables. To do this, we use the following unit root tests: Augmented Dickey-Fuller test, the Phillips-Peron test (PP) and the Kwiatkowski–Phillips–Schmidt–Shin test (KPSS). The first two tests set as the null hypothesis the existence of a unit root, whereas in the last the null hypothesis is the stationarity of the time series. Results are shown in Table 6, and all the variables are stationary, enabling us to carry out the model parameter estimation by OLS.

We perform the estimation for the daily data of the selected variables for a period spanning 1 November 2013–30 September 2014. Results for both WTI and Brent are shown in Tables 7 and 8, respectively. We observe that crude oil price shows a negative relationship with its lagged values, meaning that the price exhibits a mean reversion, where returns in the following period offset previous returns. However, this parameter is not significant for the Brent price. Furthermore, the relationship between oil price and BCI, which represents the development of the commodity market and is employed to reflect normal changes in crude oil price, is positive and significant, as expected.

As regards standout events, we notice that very few of these impacted on oil prices in the short-term and that those which did do not concur for the two benchmark prices. On the one hand, Brent, the European benchmark price, shows an abnormal return with a one-day event window on the following days: 3 March 2014, corresponding to the first threat of sanctions being imposed on Russia by the US; and 15 April 2014, which coincided with EU condemnation of Russian intervention in the Ukraine and

**Table 7: Impact of relevant events of Ukrainian war on WTI price**

| 1 day event window | | | 2 days event window | | |
|---|---|---|---|---|---|
| **Variable** | **Coeficient** | **P-value** | **Variable** | **Coeficient** | **P-value** |
| WTI(−1) | −0.156835*** | 0.0030 | WTI(−1) | −0.241283*** | 0.0000 |
| BCI | 1.03595*** | 0.0000 | BCI | 1.04575*** | 0.0000 |
| 28-February | −0.0040 | 0.6585 | - | - | - |
| 03-March | 0.0129 | 0.1559 | 03-March | −0.0016 | 0.8074 |
| 06-March | −0.0112 | 0.2228 | 06-March | 0.0006 | 0.9336 |
| 1-0-March | −0.0071 | 0.4324 | 10-March | −0.0099 | 0.1359 |
| 17-March | −0.0016 | 0.8628 | 17-March | 0.0040 | 0.5439 |
| 21-March | 0.0033 | 0.7118 | 21-March | 0.0011 | 0.8736 |
| 31-March | 0.0004 | 0.9634 | 31-March | −0.0063 | 0.3454 |
| 10-April | −0.0046 | 0.6082 | 10-April | 0.0012 | 0.8588 |
| 15-April | 0.0008 | 0.9275 | 15-April | −0.0011 | 0.8697 |
| 17-April | 0.0008 | 0.9315 | 17-April | 0.0037 | 0.5741 |
| 23-April | −0.0084 | 0.3580 | 23-April | −0.0044 | 0.5128 |
| 28-April | 0.0020 | 0.8279 | 28-April | −0.0008 | 0.9089 |
| 08-May | −0.0017 | 0.8552 | 08-May | −0.0003 | 0.9609 |
| 08-July | −0.0003 | 0.9751 | 08-July | −0.0032 | 0.6351 |
| 17-July | 0.018903** | 0.0376 | 17-July | 0.014635** | 0.0296 |
| 21-July | 0.0133 | 0.1425 | 21-July | 0.0067 | 0.3159 |
| 23-July | −0.0119 | 0.1872 | 23-July | −0.012219* | 0.0667 |
| 25-July | 0.01963** | 0.0308 | 25-July | 0.013821** | 0.0382 |
| 31-July | −0.056952*** | 0.0000 | 31-July | −0.034845*** | 0.0000 |
| 08-August | 0.0062 | 0.4954 | 08-August | 0.0042 | 0.5232 |
| 29-August | 0.0131 | 0.1465 | 29-August | 0.0050 | 0.4937 |
| 05-September | −0.016323* | 0.0720 | 05-September | −0.011626* | 0.0817 |
| Control | −0.033249*** | 0.0000 | Control | −0.034801*** | 0.0000 |
| $R^2$ | 0.4952 | | $R^2$ | 0.4559 | |
| Adjusted $R^2$ | 0.4333 | | Adjusted $R^2$ | 0.3922 | |
| Jarque Bera | 2.8251 | 0.2435 | Jarque Bera | 2.3757 | 0.3049 |
| Breush-Godfrey | 0.3316 | 0.7182 | Breush-Godfrey | 0.4687 | 0.4944 |
| Breush-Pagan | 0.4604 | 0.9880 | Breush-Pagan | 1.953629*** | 0.0068 |

Source: Author's compilation. *Statistical significance at the 10% level, **Statistical significance at the 5% level, ***Statistical significance at the 1% level, WTI: West Texas intermediate

with further sanctions being imposed on high-ranking Russian officials. Both events show an increase in oil price. In the case of the WTI price, traded in the US, the significant events are: 17 July 2014, corresponding to the sanctions imposed on Russian firms by the US; 25 July 2014, when the EU imposed further sanctions on Russian officials and firms; and 31 July 2014, corresponding to the third round of sanctions imposed on Russia by the US and the EU. In the case of the first two events, an increase in oil price is observed, whereas in the latter case the abnormal return shows a sharp fall.

Only on 05 September 2014 did the reactions of the two markets coincide. This was the day on which the ceasefire was signed in Minsk and when a price reduction occurred which the model detects as an abnormal variation for both WTI and Brent.

The estimation results show one peculiarity for 31 July 2014 when news about forthcoming sanctions, which should be followed by an increase in oil price, in fact caused it to drop. It should be borne in mind that news about the Ukraine coincided with important domestic news from the US concerning the shutdown of a major refinery in Kansas due to a fire. The plant consumed 115,000 barrels per day and its closure would have sparked an adjustment in demand and led to an understandable fall in oil price this day. It should be remembered that dummy variables in event study approaches capture the abnormal return on the day studied, but do not detect the source of this abnormality. It therefore seems reasonable to consider that the drop in oil price that day was not related to the war but to the oil refinery fire.

In comparative terms, the events caused by the war in the Ukraine had a greater effect on WTI price, quoted in the US market, than on Brent, despite the fact that the war was waged in Europe. However, in general, we are not able to assert that the war in the Ukraine had any major impact on oil prices other than at specific moments that coincided with the US and EU acting against Russia.

To test the estimates and to enable the model to reflect a possible lagged effect, we extended the event window to two days. Results are also shown in Tables 7 and 8. For the WTI price, the relevant events of the one-day event window estimation remain, although their significance and impact on price diminish. In addition, a new relevant event is added on 23 July 2014, coinciding with the US request for Russia to withdraw its troops from the border, although it is seen to have little effect and a negative impact on price. In the case of Brent, only the event which occurred on 15 April 2014 is maintained from the one-day event window estimation. However, the following days are added: 20 March 2014, corresponding to the EU proposal to reduce Russian natural gas imports; 6 June 2014, corresponding to fresh sanctions being prepared by the G-7 group; and 31 July 2014, although these latter two have little significance.

This reappears on 31 July 2014, again with a fall in oil price, which we understand to be in line with what was explained above, such

**Table 8: Impact of relevant events of Ukrainian War on Brent price**

| 1 day event window | | | 2 days event window | | |
|---|---|---|---|---|---|
| **Variable** | **Coeficient** | **P-value** | **Variable** | **Coeficient** | **P-value** |
| Brent(−1) | −0.0256 | 0.6820 | Brent(−1) | −0.0748 | 0.2360 |
| BCI | 0.6382*** | 0.0000 | BCI | 0.6655*** | 0.0000 |
| 27-February | −0.0065 | 0.4082 | 27-February | −0.0025 | 0.6599 |
| 03-March | 0.0149* | 0.0608 | 03-March | −0.0022 | 0.6932 |
| 06-March | −0.0064 | 0.4208 | 06-March | 0.0038 | 0.4916 |
| 17-March | −0.0057 | 0.4656 | 17-March | −0.0049 | 0.3782 |
| 20-March | 0.0060 | 0.4522 | 20-March | 0.0112** | 0.0470 |
| 15-April | 0.0163** | 0.0390 | 15-April | 0.0116** | 0.0394 |
| 17-April | −0.0015 | 0.8525 | 17-April | 0.0014 | 0.8017 |
| 28-April | −0.0022 | 0.7836 | 28-April | 0.0008 | 0.8843 |
| 02-May | 0.0065 | 0.4098 | 02-May | 0.0038 | 0.5003 |
| 08-May | 0.0021 | 0.7884 | 08-May | 0.0033 | 0.5575 |
| 13-May | 0.0032 | 0.6853 | 13-May | 0.0066 | 0.2391 |
| 06-June | 0.0056 | 0.4795 | 06-June | 0.0094* | 0.0946 |
| 14-July | −0.0093 | 0.2344 | 14-July | −0.0028 | 0.6227 |
| 17-July | 0.0056 | 0.4728 | 17-July | 0.0055 | 0.3238 |
| 21-July | −0.0029 | 0.7141 | 21-July | 0.0041 | 0.4589 |
| 25-July | 0.0095 | 0.2282 | 25-July | 0.0045 | 0.4209 |
| 31-July | −0.0114 | 0.1490 | 31-July | −0.0107* | 0.0587 |
| 06-August | 0.0084 | 0.2858 | 06-August | 0.0056 | 0.3175 |
| 13-August | 0.0089 | 0.2612 | 13-August | 0.0011 | 0.8503 |
| 22-August | −0.0009 | 0.9085 | 22-August | 0.0022 | 0.6877 |
| 26-August | −0.0017 | 0.8247 | 26-August | −0.0010 | 0.8551 |
| 03-September | 0.0076 | 0.3312 | 03-September | 0.0074 | 0.1827 |
| 05-September | −0.0172** | 0.0290 | 05-September | −0.0068 | 0.2216 |
| $R^2$ | 0.2517 | | $R^2$ | 0.2489 | |
| Adjusted $R^2$ | 0.1600 | | Adjusted $R^2$ | 0.1568 | |
| Jarque Bera | 1.4049 | 0.4954 | Jarque Bera | 0.2429 | 0.8856 |
| Breush-Godfrey | 0.3804 | 0.6841 | Breush-Godfrey | 0.7875 | 0.4564 |
| Breush-Pagan | 0.5337 | 0.9676 | Breush-Pagan | 1.6108** | 0.0388 |

Source: Author's compilation. *Statistical significance at the 10% level, **Statistical significance at the 5% level, ***Statistical significance at the 1% level

that the effect of the refinery fire would have hit Europe with a one-day lag. However, the increase in the number of significant events in the two-day event window for Brent might indicate that the Brent price reacts more slowly to events than the WTI.

## 5. CONCLUSIONS AND DISCUSSION

The aim of this paper is to study the impact of the war in the Ukraine on the price of oil as a result of Russia's involvement and, in particular, to go beyond previous studies and to examine the very short-term effects of certain relevant events that took place during the conflict by defining a method to pinpoint specific standout incidents from an ongoing event such as a war. We do this by analysing public news on the front page of the Wall Street Journal and the Financial Times, as well as news referring to sanctions. This allows us to isolate 33 days during which the aforementioned newspapers paid close attention to the conflict and to Russia's involvement, highlighting 22 days for the WTI market and 23 for the Brent market, 12 of which coincided. Having pinpointed the events, we employ a market model event study with a one-day and a two-day event window with a proxy variable, the Bloomberg Commodity Index, and introduce the key events through dummy variables.

As regards the results obtained, it can first be said that key events in the war had little impact on oil prices, and were generally confined to the times when Russia and the US were involved. This result is consistent with the findings of Garzon and Hierro (2018). Despite Russia's involvement, at no time did the conflict compromise the country's oil supply, and the effects were restricted to changes in market agents' expectations which, at most, affected strategic reserves, as the cited study suggests.

As for events that affected price, we see that in the European market the relevant events that had a major impact occurred in the early days of the war, while in the US the relevant events took place a few months before the ceasefire. One possible explanation for this difference is that the European market initially reacted because of its geographical proximity to the conflict and its possible spread, while the US market, distant from the warzone, would have reacted to events that were less related to the war and more linked to the US and the EU's relationship with Russia as well as sanctions imposed due to the war.

When we include the two-day event window, we see that the impact of relevant events is less in both markets. In other words, the events impact on the same day, given the general trend of the market to correct daily oscillations as evidenced by the negative sign of the coefficient of the lagged price. In relation to this issue, it should be remembered that we are dealing with highly volatile markets, exposed to many internal as well as external shocks, and which cause any fresh information to quickly exhaust the effect of the previous information, such that it is difficult to grasp what effect an event has if we extend the window.

As regards volatility, we see that the WTI price evolves in a more unstable manner than the price of Brent, evidencing that the significant impacts pinpointed were greater in the case of the WTI, even though the war took place in Europe.

In sum, the work presented allows us to explore further the external effects of the war in the Ukraine on oil prices during the 2014 conflict, with results consistent with previous works, and proposing a novel methodology to identify relevant events within an ongoing situation such as a war, and which enables us to expand the use of the event study method.

## 6. ACKNOWLEDGMENTS

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# 4. Efectos macroeconómicos de la evolución del mercado del petróleo.

## 4.1. Rentas del comercio de petróleo y la desigualdad internacional de la renta.

El mercado del petróleo se caracteriza por el poder de mercado del que disfrutan sus productores a causa de la desigual distribución física de esta materia prima a nivel global. Este poder de mercado, junto a otras características como son las diferencias de costes de producción entre diferentes productores o el carácter no renovable de la materia prima, dan lugar a la generación de rentas económicas, es decir, beneficios extraordinarios obtenidos por el establecimiento de precios superiores al coste de los factores de producción empleados para su obtención (Segal, 2011). De esta manera, cuando se comercia el petróleo, los consumidores redistribuyen rentas implícitamente a favor de los productores.

Además, el petróleo es la materia prima más comerciada a nivel mundial, suponiendo el 8,5% del total de exportaciones globales en 2017 (UNCTAD, 2018), lo que es consecuencia de que su producción está altamente concentrada en determinados países mientras que el resto de países están obligados a importar esta materia prima, siendo, por tanto, dependientes del comercio internacional. De esta forma, el comercio de petróleo entre países conlleva implícita una transferencia de rentas desde los países importadores hacia los países exportadores de petróleo, generando un efecto redistributivo que favorece a los países productores y reduce la renta de los países importadores.

Dado el elevado valor que supone el comercio internacional de petróleo, podemos considerar estas transferencias implícitas como un importante mecanismo de redistribución *ex ante* de la renta a nivel internacional. Esta redistribución se produce a través de dos vías: a través de las rentas pagadas por los países importadores y a través de las rentas obtenidas por los países exportadores. El efecto redistributivo de cada una de estas vías dependerá de la posición en que se encuentren los países que se ven beneficiados por las rentas de las exportaciones y aquellos que transfieren las rentas en el pago de las importaciones.

El objetivo de este capítulo de la presente Tesis Doctoral es determinar el efecto redistributivo de las rentas del petróleo en la distribución internacional de la renta. Con ese fin analizamos tanto la magnitud del efecto redistributivo como la dirección en la que se produce, así como su evolución en el tiempo. Además, descomponemos el efecto redistributivo entre aquel generado por las rentas obtenidas por las exportaciones y el generado por las rentas pagadas en las importaciones. Finalmente, se analiza el impacto de la redistribución por decilas de la distribución internacional de la renta, con objeto de determinar qué grupo de países, en función de sus ingresos, son los más beneficiados por esta redistribución y cuáles ven más reducidas sus rentas, además de analizar los cambios que se han producido a lo largo del periodo de manera detallada.

### 4.1.1. Metodología

*Estimación de las rentas del comercio internacional de petróleo*

La muestra que empleamos está formada por 168 países y abarca el periodo desde 1995 hasta 2016, con datos de frecuencia anual. Esta muestra representa el 95% de la población y el 99% de la producción mundiales en 1995, así como el 95% de la población y 98% de la producción en 2016. Los países incluidos están recogidos en el artículo adjunto en la sección 4.1.3.

El primer paso en el análisis empírico es la estimación de las rentas del comercio internacional de petróleo, ya que no existen estadísticas oficiales respecto a dichas rentas. Para ello, empleamos datos procedentes de dos bases de datos distintas: la base de datos *Adjusted Net Savings* del Banco Mundial, de la que empleamos los datos sobre rentas de la producción de petróleo en proporción al PIB de cada país; y la base de datos *International Energy Statistics* de la *U.S. Energy Information Administration*, de la que obtenemos datos sobre la producción total de petróleo, así como sobre sus exportaciones e importaciones por países.

Las rentas de la producción de petróleo de un determinado país representan las rentas económicas que obtiene de toda la producción de petróleo que ha llevado a cabo durante el periodo analizado. Sin embargo, no toda la producción de petróleo se comercia internacionalmente, ya que una parte de ella es consumida en el propio país. Puesto que nuestro objetivo es determinar las transferencias de rentas del comercio internacional, es preciso determinar qué proporción de esas rentas corresponden a las obtenidas de las exportaciones de petróleo. Para ello, asumimos que, dado que el precio de petróleo se determina en el mercado internacional, las rentas por barril que se obtienen de las exportaciones son iguales a las rentas por barril que se obtienen de cada barril producido, incluidos los barriles comerciados dentro del país productor. Partiendo de ese supuesto, estimamos las rentas de las exportaciones de petróleo, que llamamos $Export/PIB_{it}$, a través de la siguiente fórmula:

$$Export/PIB_{it} = \frac{\frac{\frac{RentProd}{PIB}_{it} \, x \, PIB_{it}}{Prod_{it}} \, x \, ExpPet_{it}}{PIB_{it}} \, x \, 100 \qquad (5)$$

donde $\frac{RentProd}{PIB}_{it}$ son las rentas de la producción de petróleo en proporción al PIB del país i en el año t, $PIB_{it}$ es el Producto Interior Bruto en dólares corrientes, $Prod_{it}$ es la producción de petróleo en barriles y $ExpPet_{it}$ son las exportaciones de petróleo, también en barriles. El procedimiento es el siguiente: partiendo de los datos de rentas de la producción de petróleo en relación al PIB, multiplicamos por este último para obtener el total de rentas de la producción, que posteriormente dividimos por el total de barriles producidos para obtener la renta por barril. Finalmente, multiplicamos las rentas por barril por los barriles exportados, obteniendo las rentas totales de las exportaciones de petróleo del país, que finalmente dividimos por el PIB para obtener su valor relativo en términos de PIB.

La estimación de las rentas de las importaciones es más compleja, ya que los datos de exportaciones e importaciones de petróleo no están clasificados por socios comerciales, sino en conjunto para cada país. Por tanto, para determinar las rentas pagadas por las importaciones de petróleo, tenemos que estimar un promedio global de renta por barril para cada año que analizamos. Para ello, las rentas de las exportaciones por barril de cada país, obtenidas anteriormente, se multiplican por la proporción que representan sus exportaciones respecto al total de exportaciones mundiales y la suma de todos los países para cada año nos proporciona una media ponderada de las rentas por barril de las exportaciones en dicho año, que utilizaremos para calcular la renta pagada en las importaciones. Multiplicando la renta promedio por barril por las importaciones de petróleo de cada país (en barriles), obtenemos el total de renta pagada por las importaciones de petróleo para cada año, y a continuación la dividimos por el PIB del país para obtener la variable $Import/PIB_{it}$. La fórmula empleada es la siguiente:

$$Import/PIB_{it} = \frac{\left(\sum_{i=1}^{n}\left(\frac{\frac{RentProd}{PIB}_{it} \; x \; PIB_{it}}{Prod_{it}} xW_{it}\right)\right) x \; ImpPet_{it}}{PIB_{it}} \; x \; 100 \qquad (6)$$

Donde $W_{it}$ es la proporción de exportaciones de cada país respecto al total en cada año y $ImpPet_{it}$ representa las importaciones, en barriles, del país i en el año t. Finalmente, calculamos las rentas netas, que llamaremos $Rentas/GDP_{it}$, y que representa la diferencia entre las rentas obtenidas por las exportaciones y las rentas pagadas en las importaciones, lo que nos permitirá clasificar los países entre países exportadores e importadores netos. La fórmula es la siguiente:

$$Rentas/PIB_{it} = Export/PIB_{it} - Import/PIB_{it} \qquad (7)$$

Es preciso tener en cuenta que las rentas son estimadas desde una perspectiva de la contabilidad nacional, es decir, considerando su efecto directo en la producción. No consideramos la distribución posterior de esas rentas dentro de cada país entre las diferentes partidas de las cuentas nacionales, ya que no existen datos relativos a dicha distribución y su estimación requeriría supuestos difíciles de determinar y de justificar.

Finalmente, dividimos la muestra de países entre exportadores, aquellos cuyas rentas recibidas de las exportaciones superan a las rentas pagadas en las importaciones y que, por tanto, son los beneficiarios de la redistribución implícita que genera el comercio de petróleo, e importadores, que son aquellos cuyas rentas pagadas por la importación de petróleo superan a las rentas obtenidas de las exportaciones y que, por tanto, están transfiriendo renta hacia los países exportadores. Para ello, utilizamos como variable representativa el promedio de las rentas netas de cada país durante el periodo de 1995-2016.

Con objeto de clasificar los países exportadores en función de su grado de dependencia de las rentas del petróleo, llevamos a cabo un análisis clúster. El análisis clúster nos permite agrupar los países de forma que las diferencias dentro de cada grupo se minimicen y las diferencias entre los grupos se maximicen. Para ello, tenemos que definir la medida de disimilitud que vamos a emplear. En nuestro trabajo, utilizamos la distancia euclídea, $d(i,j)$, que para dos países, i y j, se define de la siguiente forma:

$$d(i,j) = \sqrt{\sum_{k=1}^{p} (X_{ki} - X_{kj})^2} \quad (8)$$

Donde $X_{kj}$ es el valor de las observaciones k=1, 2,…,p, que en nuestro caso hacen referencia a nuestra variable $Rentas/PIB$. A continuación, utilizamos el método jerárquico aglomerativo, que comienza con un número de clústeres o grupos igual al número de observaciones y, de manera iterativa y jerárquica, va agrupando en clústeres mayores. Para agrupar los clústeres, empleamos el método de Ward (1963), que consiste en agrupar aquellos clústeres cuya suma del cuadrado de las diferencias dentro del clúster experimente el menor incremento al ser agrupados; y para determinar el número óptimo de clústeres usamos dos métodos: un método global, el método del "codo", y un método local, los índices de Duda y Hart (1973).

*Análisis del efecto redistributivo del comercio internacional de petróleo*

Una vez estimadas las rentas del comercio internacional de petróleo, el siguiente paso en el análisis empírico es estudiar su impacto en la distribución internacional de la renta. Para analizar su efecto redistributivo a nivel internacional, un aspecto determinante es el concepto de desigualdad a considerar, ya que los resultados y sus interpretaciones pueden diferir en función de éste (Bourguignon et al., 2004; Ghose, 2004). En nuestro análisis empleamos el concepto de *desigualdad internacional de la renta*, siguiendo la nomenclatura empleada en Milanovic (2005), que se define como la desigualdad entre países usando su renta media y ponderando por su población. Es decir, este concepto mide la desigualdad entre individuos a nivel mundial asignando a cada uno de ellos la renta media del país al que pertenecen.

La elección de este concepto de desigualdad, en lugar del concepto de *desigualdad interpersonal de la renta*, en la que se tiene en cuenta además las diferencias de rentas entre individuos dentro de cada país, obedece a la falta de datos sobre cómo se distribuyen las rentas del petróleo dentro de cada país. No obstante, diversos trabajos (Bourguignon y Morrison, 2002; Milanovic, 2002; Anand y Segal, 2015, Lakner y Milanovic, 2016) estiman que alrededor de dos tercios de la desigualdad interpersonal mundial está explicado por la desigualdad entre países, por lo que podemos deducir que los resultados que obtengamos sobre la distribución internacional de la renta serán relevantes también para la desigualdad interpersonal de la renta.

Un segundo aspecto determinante para nuestro análisis es el método para medir las rentas del petróleo, y por tanto el PIB, de forma que sean comparables entre distintos países. Las dos opciones disponibles son: convertirlos a dólares a tipo de cambio de mercado (TCM) o convertirlos a dólares en paridad del poder adquisitivo (PPA). Puesto que las rentas del comercio de petróleo son flujos internacionales y sus precios se determinan a nivel internacional, convertirlo a dólares constantes a tipo de cambio de mercado nos permite comparar esos flujos. Sin embargo, la desigualdad entre países se subestima al estimarse usando dólares a tipo de cambio de mercado (Dowrick y Akmal, 2005; Milanovic, 2005; Anand y Segal, 2008), ya que no tiene en cuenta las diferencias de precios entre los distintos países y, por tanto, la capacidad de consumo de un dólar es distinta entre distintos países. Por el contrario, la desigualdad estimada convirtiendo la renta a dólares en paridad del poder adquisitivo es más adecuada, ya que permite comparar la capacidad de consumo de los individuos en distintos países y, por tanto, es un mejor enfoque para medir la desigualdad. No obstante, cuando las rentas del petróleo se convierten a dólares en paridad del poder adquisitivo, el valor de un barril de petróleo varía entre países y también el valor de esas rentas. Por tanto, la redistribución deja de ser un juego de suma cero. Para solventar este asunto, llevamos a cabo el análisis empleando dos escenarios: el escenario TCM, en el que el PIB y las rentas se convierten a dólares constantes de 2010 a tipo de cambio de mercado; y el escenario PPA, donde convertimos estas variables a dólares constantes de 2011 a paridad del poder adquisitivo.

Para analizar el efecto redistributivo de las rentas del petróleo, en primer lugar, calculamos la desigualdad en la distribución internacional de la renta a través del índice de Gini, usando datos del PIB per cápita de cada país. Posteriormente, construimos un contrafactual de la distribución internacional de la renta revertiendo las transferencias de rentas implícitas en el comercio internacional del petróleo. De esta manera, al PIB per cápita de cada país se le restan las rentas per cápita obtenidas de las exportaciones y se le suman las rentas per cápita pagadas por las importaciones de petróleo. El resultado es un contrafactual de la distribución internacional de la renta bajo el supuesto de que el comercio internacional de petróleo no genera rentas.

El efecto redistributivo se calcula empleando el índice de Reynolds y Smolensky (1997) que mide el cambio en la desigualdad, medida a través del índice de Gini, y se expresa de la siguiente forma:

$$ER = G_{AR} - G_{DR} \tag{9}$$

Donde $ER$ representa al efecto redistribuivo, $G_{AR}$ es el índice de Gini de la distribución internacional de la renta antes de incluir las rentas del petróleo y $G_{DR}$ es el índice de Gini de la distribución internacional de la renta incluyendo las rentas netas del comercio del petróleo. Un aumento del índice representa un efecto redistributivo positivo, es decir, una reducción de la desigualdad.

Una vez determinado el efecto redistributivo, analizamos si éste se produce a través del incremento de rentas que obtienen los países exportadores, o por medio de la reducción en la renta de los países importadores. Para determinar el peso de cada uno de estos canales, llevamos a cabo una descomposición factorial (Shorrocks, 2013) empleando el valor de Shapley. Este procedimiento consiste en calcular el efecto parcial de las exportaciones e importaciones en el efecto redistributivo alterando el orden de secuencia, para finalmente calcular el efecto de cada canal como el promedio de los efectos parciales.

A la hora de estimar el efecto redistributivo a través de índices de concentración, como es el caso del índice de Gini, es importante tener en cuenta la posible existencia de efecto reordenación. Es decir, las trasferencias de rentas del petróleo no solo reducen las diferencias en la renta entre los distintos países, sino que pueden producir cambios de orden en la distribución de la renta. El efecto reordenación tiene un impacto negativo sobre el efecto redistributivo total. Siguiendo la metodología de Kakwani (1984), el efecto redistributivo puede descomponerse en dos elementos:

$$ER = V - R \tag{10}$$

donde $ER$ es el efecto redistributivo, como hemos calculado anteriormente, $V$ es la redistribución vertical y $R$ representa el efecto reordenación. La redistribución vertical mide la progresividad de la redistribución o la capacidad redistributiva potencial que tienen las transferencias. El efecto reordenación, por su parte, es la reducción en la redistribución potencial que se produce por el cambio de orden en la distribución generado por las rentas. Si consideramos $D_{DR}^{AR}$ como el índice de concentración de la renta final (incluyendo las rentas del petróleo) manteniendo el orden de la distribución inicial (antes de incluir las rentas del petróleo), la descomposición de Kakwani puede representarse de la siguiente forma:

$$ER = V - R = (G_{AR} - D_{DR}^{AR}) - (G_{DR} - D_{DR}^{AR}) \tag{11}$$

donde el primer término de la ecuación representa la redistribución vertical y el segundo término el efecto reordenación. Por construcción, el efecto reordenación siempre tomará valores positivos o cero, de forma que el signo negativo refleja que reduce el efecto redistributivo.

Finalmente, la estimación del efecto redistributivo a través del uso de indicadores sintéticos, como es el índice de Gini, no ofrece una descripción completa de la distribución del efecto de las rentas entre países en función de su renta. Para analizar cómo se distribuyen las rentas a lo largo de la distribución internacional de la renta, llevamos a cabo un análisis de incidencia por decilas. Para ello, calculamos la variación del PIB per cápita promedio de cada decila provocada por las rentas obtenidas y pagadas en el comercio internacional del petróleo y construimos unas curvas de incidencia no anónimas (Ravaillon y Chen, 2003; Bourguignon, 2011). Estas curvas se consideran no anónimas porque se mantienen en cada decila los países que lo formaban en la distribución de la renta antes de incluir las rentas del petróleo, a pesar de que estas rentas generen cambios de orden y saltos entre decilas. La variación del PIB per cápita por decila se calcula a través de la siguiente ecuación:

$$I(d) = \left(\left(\frac{y_{dr}(d)}{y_{ar}(d)}\right) - 1\right) x\ 100 \tag{12}$$

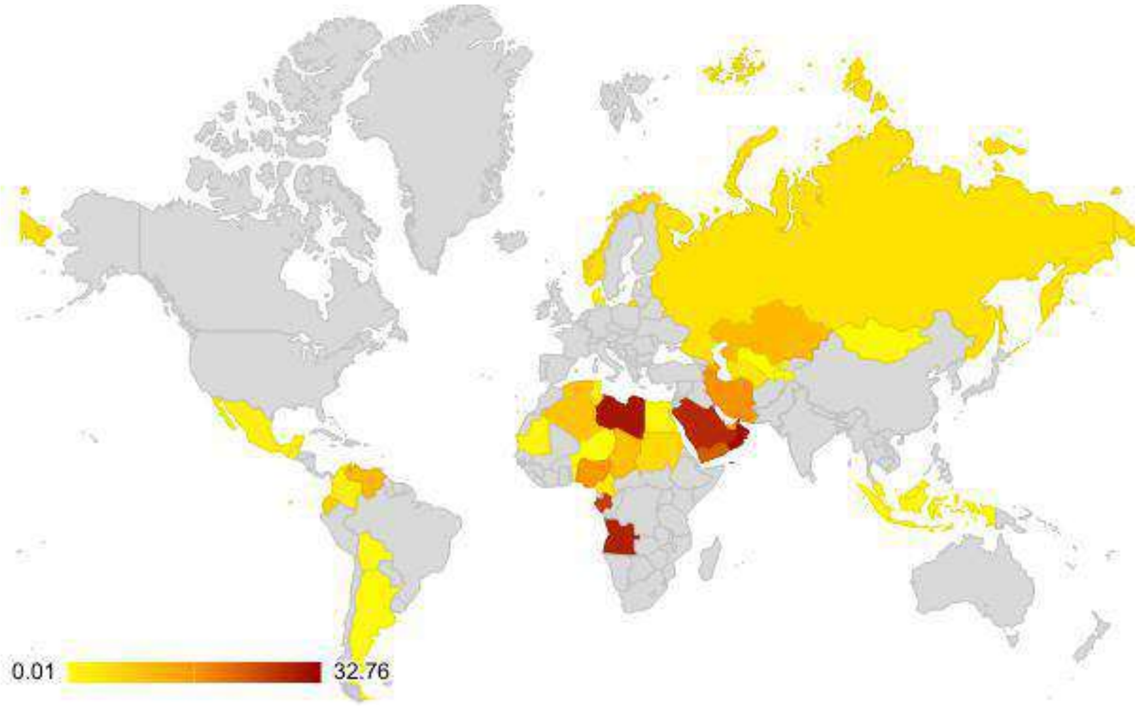
Donde $I(d)$ es la variación porcentual del PIB per cápita promedio de cada decil d=1,2,…,10, $y_{dr}(d)$ es el PIB per cápita incluyendo las rentas del petróleo y $y_{ar}(d)$ es el PIB per cápita sin incluir las rentas del petróleo.

### 4.1.2. Resultados

*<u>Estimación de las rentas del comercio internacional de petróleo</u>*

En el apéndice del artículo adjunto en la sección 4.1.3 se recoge la renta neta promedio del comercio del petróleo estimadas para cada país para el periodo 1995-2016. Los países están ordenados de mayor a menor renta neta en proporción al PIB, siendo la República del Congo la que presenta el mayor valor, con unas rentas netas del 32,76% de su PIB. El grupo de países que obtienen rentas netas positivas del comercio de petróleo, que denominamos países exportadores, está conformado por 42 países, mientras que el grupo de países importadores, es decir, aquellos cuyas rentas pagadas por las importaciones exceden las obtenidas de las exportaciones, está formado por 126 países.

**Figura 5.** Distribución global de las rentas del comercio internacional de petróleo en relación al PIB para los países exportadores.

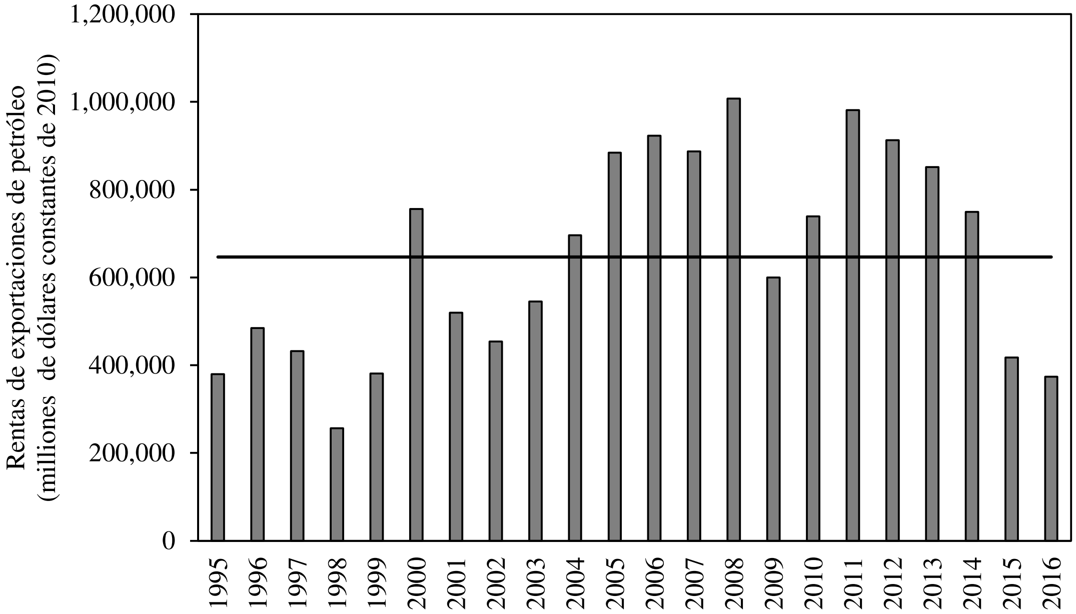



Fuente: elaboración propia. *Nota*: Solo están incluidos los países exportadores, definidos previamente.

La Figura 5 muestra la distribución geográfica de los países exportadores de petróleo, observándose que la mayoría de los países con alta dependencia de las rentas de las exportaciones se concentran principalmente en Medio Oriente y en la Costa Oeste de África Central.

Las rentas totales estimadas promedian en torno a los 647.000 millones de dólares al año, aunque su evolución presenta importantes oscilaciones, desde los 257.000 millones de dólares en 1998 a alrededor de 1.000.000 millones de dólares en 2008. La Figura 6 muestra su evolución para el periodo 1995-2016, en el que se puede observar un primer periodo ascendiente desde 1995 hasta 2008, año en que estalla la crisis económica mundial, un periodo de caída y recuperación entre 2009 y 2011 y un periodo de tendencia decreciente a partir de 2011 hasta el final de la muestra, que se hace especialmente visible en 2015-2016, tras la caída del precio del petróleo vinculada a la revolución de la producción vía *fracking*.

**Figura 6.** Evolución de las rentas de la exportación de petróleo en el periodo 1995-2016.




Fuente: elaboración propia. *Notas*: Las rentas de las exportaciones son calculadas como la suma de las rentas recibidas por las exportaciones por cada país en cada año. Las rentas están expresadas en dólares constantes de 2010. La línea negra representa el promedio anual de rentas de las exportaciones de petróleo en el periodo.

**Figura 7.** Evolución de las rentas de exportaciones e importaciones en relación al PIB (1995-2016).


Fuente: elaboración propia. *Notas*: *Renta/PIB* son calculadas como la suma de las rentas netas (rentas exportaciones-rentas importaciones) dividida por el PIB agregado de cada grupo. El grupo de países exportadores está compuesto por 42 países con una *Renta/GDP* promedio positiva, mientras que el grupo de países importadores está compuesto por 126 países con *Renta/GDP* promedio negativa o cero.

La Figura 7 muestra la evolución de las rentas netas en proporción al PIB para los países exportadores e importadores, mostrando la importancia relativa de estas rentas para ambos grupos de países. Las rentas netas pagadas por los importadores se sitúan en torno al 1,06% de su PIB, mientras que las rentas que obtienen los países exportadores suponen un promedio del 8,05% del PIB. Esto implica que las rentas del comercio del petróleo tienen un papel mucho más importante para los países exportadores que para los importadores. Es decir, el peso que tienen los beneficios obtenidos por las rentas en los países exportadores en relación a su PIB es mayor que los costes que suponen las rentas pagadas por los países importadores.

Dentro del grupo de países exportadores, dividimos a estos en función de su grado de dependencia de las rentas de las exportaciones. Para ello, llevamos a cabo un análisis clúster utilizando como variable representativa de la dependencia de las exportaciones el valor promedio en el periodo 1995-2016 de la variable *Rentas/PIB*, es decir, el porcentaje que representan las rentas netas del comercio del petróleo en el PIB del país. De acuerdo con los resultados obtenidos, definimos 4 grupos en función de su grado de dependencia de las rentas del comercio exterior de petróleo. Los países que forman cada grupo y las principales estadísticas descriptivas de cada grupo se muestran en el artículo de la sección 4.1.3 (Tabla 2). Definimos cuatro grupos: muy alta dependencia, alta dependencia, dependencia media y muy baja dependencia. El primer grupo lo componen aquellos países cuyas rentas representan alrededor de un tercio de su PIB y, por tanto, su dependencia es muy elevada. El segundo grupo, de alta dependencia de las rentas, obtiene unas rentas que ascienden a un quinto del PIB. Sin embargo, los grupos más numerosos son aquellos que tienen una dependencia media (en torno al 11% del PIB) y baja dependencia (poco más del 1% del PIB).

*Efecto redistributivo de las rentas del comercio de petróleo*

La primera cuestión planteada es determinar qué efecto redistributivo generan las rentas del comercio internacional del petróleo. Es decir, ¿reducen o incrementan la desigualdad? La respuesta a esta cuestión está recogida en la Tabla 4, que muestra el efecto redistributivo de dichas rentas tanto usando los valores a tipo de cambio de mercado como en términos de paridad de poder adquisitivo. En el primer escenario, con valores a tipo de cambio del mercado, observamos un efecto redistributivo positivo durante todo el periodo, es decir, las rentas implícitas del comercio internacional del petróleo reducen la desigualdad internacional. No obstante, este efecto redistributivo presenta una tendencia decreciente a lo largo de todo el periodo, por lo que su impacto en la desigualdad internacional se ve reducido.

En el escenario con tipos de cambio en paridad del poder adquisitivo también podemos observar una tendencia decreciente en el efecto redistributivo de las rentas del petróleo. En este caso, podemos dividir el periodo en dos sub-periodos: un primero en el que el efecto redistributivo es positivo, que acaba en el año 2000; y un segundo periodo, desde el año 2001 hasta el final de la muestra en el que el efecto redistributivo pasa a ser negativo, es decir, las rentas del petróleo contribuyen a una mayor desigualdad internacional de la renta.

**Tabla 4.** Efecto redistributivo de las rentas del comercio de petróleo (1995-2016).

| | TCM | | | | PPA | | | |
|---|---|---|---|---|---|---|---|---|
| **Año** | **$GINI_{AR}$** | **RE** | **V** | **R** | **$GINI_{AR}$** | **RE** | **V** | **R** |
| 1995 | 70.85 | 0.247 | 0.288 | -0.041 | 58.39 | 0.221 | 0.385 | -0.164 |
| 1996 | 70.72 | 0.324 | 0.420 | -0.096 | 58.02 | 0.295 | 0.483 | -0.188 |
| 1997 | 70.59 | 0.191 | 0.288 | -0.097 | 57.87 | 0.238 | 0.362 | -0.124 |
| 1998 | 70.49 | 0.114 | 0.117 | -0.003 | 57.62 | 0.011 | 0.045 | -0.034 |
| 1999 | 70.44 | 0.119 | 0.138 | -0.019 | 57.34 | -0.009 | 0.064 | -0.073 |
| 2000 | 70.55 | 0.287 | 0.571 | -0.284 | 57.48 | 0.158 | 0.463 | -0.305 |
| 2001 | 70.09 | 0.129 | 0.154 | -0.025 | 56.77 | -0.033 | 0.082 | -0.115 |
| 2002 | 69.69 | 0.077 | 0.091 | -0.014 | 56.24 | -0.099 | -0.038 | -0.061 |
| 2003 | 69.26 | 0.086 | 0.109 | -0.023 | 55.55 | -0.16 | -0.091 | -0.069 |
| 2004 | 68.90 | 0.115 | 0.137 | -0.022 | 54.85 | -0.172 | -0.072 | -0.100 |
| 2005 | 68.48 | 0.144 | 0.205 | -0.061 | 54.04 | -0.217 | -0.105 | -0.112 |
| 2006 | 67.91 | 0.123 | 0.174 | -0.051 | 53.12 | -0.265 | -0.147 | -0.118 |
| 2007 | 67.24 | 0.137 | 0.182 | -0.045 | 52.04 | -0.232 | -0.122 | -0.110 |
| 2008 | 66.62 | 0.142 | 0.215 | -0.073 | 51.14 | -0.289 | -0.156 | -0.133 |
| 2009 | 65.53 | 0.082 | 0.102 | -0.020 | 49.50 | -0.228 | -0.143 | -0.085 |
| 2010 | 65.04 | 0.132 | 0.155 | -0.023 | 48.69 | -0.226 | -0.091 | -0.135 |
| 2011 | 64.58 | 0.138 | 0.169 | -0.031 | 48.03 | -0.292 | -0.119 | -0.173 |
| 2012 | 64.05 | 0.069 | 0.118 | -0.049 | 47.33 | -0.381 | -0.199 | -0.182 |
| 2013 | 63.53 | 0.021 | 0.067 | -0.046 | 46.63 | -0.410 | -0.235 | -0.175 |
| 2014 | 63.12 | 0.021 | 0.040 | -0.019 | 46.09 | -0.363 | -0.244 | -0.119 |
| 2015 | 62.86 | 0.015 | 0.020 | -0.005 | 45.80 | -0.201 | -0.170 | -0.031 |
| 2016 | 62.40 | 0.006 | 0.009 | -0.003 | 45.41 | -0.164 | -0.142 | -0.022 |
| Promedio | 67.41 | 0.120 | 0.171 | -0.048 | 52.63 | -0.128 | -0.009 | -0.119 |

Fuente: elaboración propia.

Puesto que el impacto relativo de las rentas sobre el PIB per cápita es el mismo en ambos escenarios por construcción, esta divergencia tiene que estar explicada por saltos de los países en la distribución de la renta debido a las distintas medidas del PIB y de las rentas del comercio del petróleo. Estos cambios pueden afectar tanto a la contribución de las exportaciones e importaciones al efecto redistributivo total, como a la magnitud del efecto reordenación.

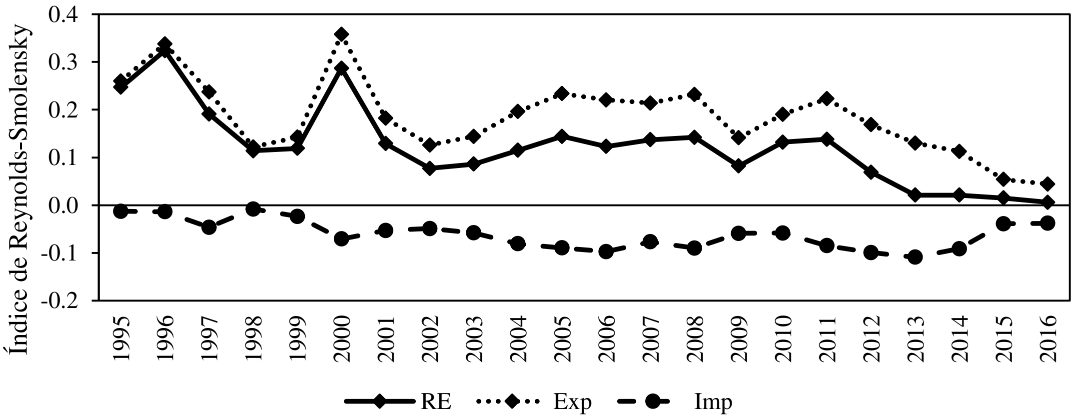
Para distinguir entre el efecto redistributivo causado por las rentas recibidas de las exportaciones y el causado por las rentas pagadas en las importaciones de crudo, llevamos a cabo la descomposición del efecto redistributivo total, cuyos resultados se encuentran representados en la Figura 8.

Como puede observarse en el panel a) de la Figura 8, en las estimaciones con tipo de cambio de mercado, el efecto redistributivo positivo es principalmente generado por el efecto redistributivo de las exportaciones, que son progresivas. El efecto de las importaciones es regresivo, es decir, incrementa la desigualdad, aunque su magnitud es reducida, por lo que el efecto redistributivo total refleja principalmente la evolución del efecto redistributivo de las exportaciones. En cuanto a su evolución, a partir del año 2000 se observa un incremento en el efecto redistributivo negativo de las importaciones, que junto a un menor efecto redistributivo positivo de las exportaciones se traduce en un menor efecto redistributivo total, aunque permanece positivo durante todo el periodo.

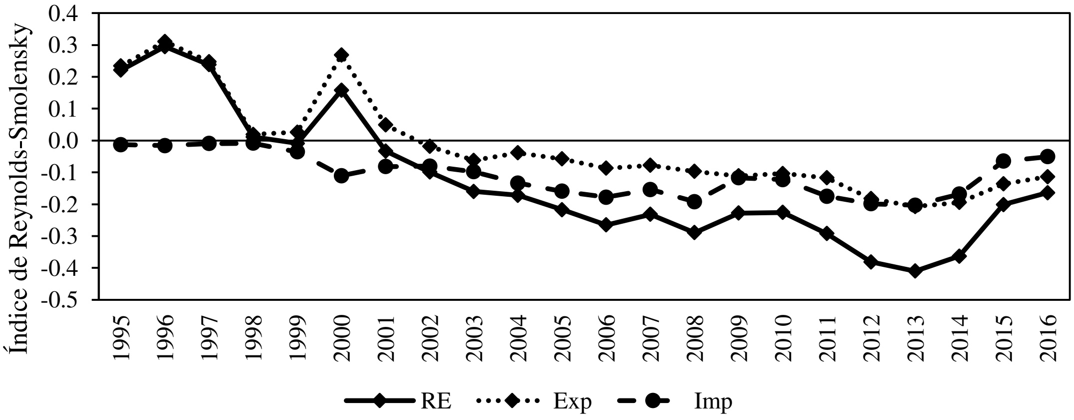
En las estimaciones con tipos en paridad del poder adquisitivo (panel b de la Figura 8), de nuevo podemos distinguir entre dos periodos. En el primero, que abarca hasta el año 2000, son las exportaciones las principales determinantes del efecto redistributivo positivo de las rentas del comercio de petróleo, siendo el efecto de las importaciones negativo pero muy reducido. Sin embargo, a partir de 2001 observamos una tendencia decreciente del efecto redistributivo de las exportaciones, que pasa a ser negativo a partir de 2002, mientras que el efecto negativo de las importaciones se incrementa, ambos contribuyendo a la tendencia negativa del efecto redistributivo total, que pasa a ser negativo en este segundo periodo.

**Figura 8**. Evolución del efecto redistributivo de exportaciones e importaciones.

a) Escenario TCM




b) Escenario PPA



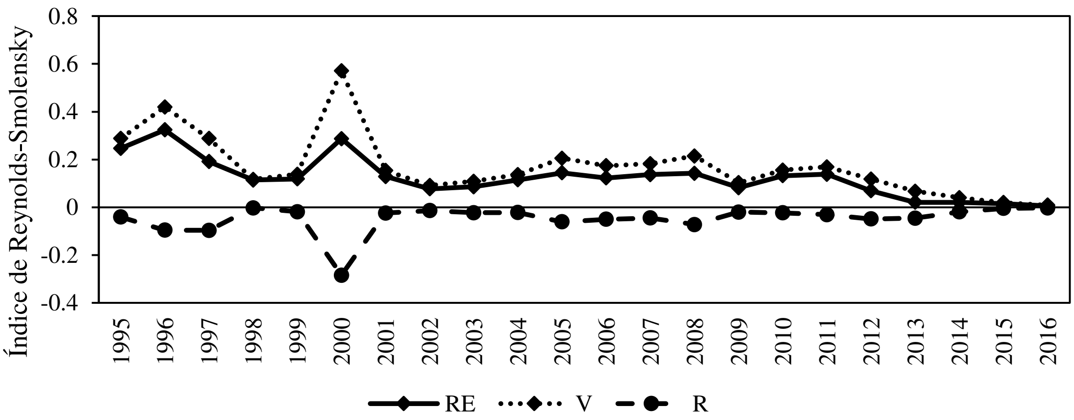

Fuente: elaboración propia. *Nota*: *RE* representa el efecto redistributivo total, *Exp* representa el efecto redistributivo de las exportaciones y *Imp* representa el efecto redistributivo de las importaciones.

Otro aspecto a tener en cuenta a la hora de estimar el efecto redistributivo de las rentas del comercio de petróleo es la reordenación, es decir, las variaciones en el ranking que experimentan los países al incluir las rentas obtenidas por las exportaciones y detraer las rentas pagadas por las importaciones de su PIB. El efecto reordenación es importante, ya que supone una reducción del efecto redistributivo respecto al potencial redistributivo de las rentas, que está representado por la redistribución vertical.

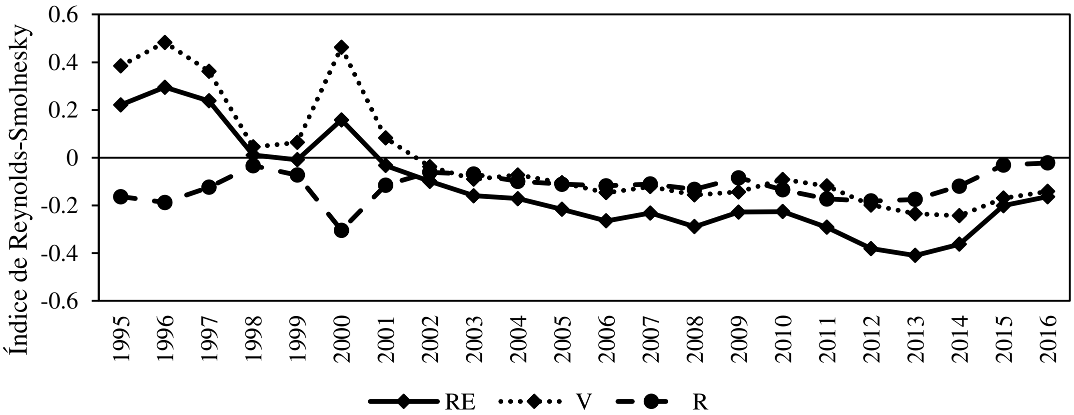
En el panel a) de la Figura 9 se muestra la descomposición del efecto redistributivo entre efecto vertical y reordenación para el escenario con tipos de cambio de mercado. En este caso, aunque existe cierto efecto reordenación, su magnitud es reducida, por lo que la redistribución potencial no se ve disminuida excesivamente por los cambios en las posiciones de los países. También se observa que su evolución refleja la evolución de la redistribución vertical, de manera que cuanto mayor es esta última, mayor es el efecto reordenación. La explicación a este fenómeno recae en que, cuando las rentas son mayores, las variaciones del PIB per cápita de los países son mayores, de manera que la posibilidad de que un país exportador supere a un importador se incrementa.

**Figura 9.** Evolución de los componentes del efecto redistributivo: redistribución vertical y reordenación.

a) Escenario TCM




b) Escenario PPA




Fuente: elaboración propia. *Notas*: *RE* representa el efecto redistributivo, *V* representa la redistribución vertical y *R* representa el efecto reordenación.

En el escenario con tipos en paridad del poder adquisitivo, el efecto reordenación muestra una evolución distinta (Panel b de la Figura 9). En primer lugar, es en promedio 2,5 veces superior al que se produce en el escenario con tipos de cambio de mercado. La menor desigualdad estimada cuando se emplean los tipos en paridad del poder adquisitivo implica que la distancia entre los países en términos de PIB per cápita es menor, por lo que la probabilidad de que unos países superen a otros es mayor, dando lugar a un mayor efecto reordenación. Hasta el año 2000, el efecto reordenación compensó casi la mitad de la redistribución potencial, reduciendo por tanto el efecto redistributivo total. Después de 2001, el efecto reordenación se une a una tendencia decreciente de la redistribución vertical, ambos contribuyendo a la caída del efecto redistributivo total, que pasa a ser negativo durante este periodo, y explica la divergencia creciente entre los dos escenarios estudiados.

Los indicadores analizados anteriormente miden el efecto redistributivo y sus principales características de una manera agregada, es decir, teniendo en cuenta la evolución de la distribución internacional de la renta medida a través del índice de Gini. Sin embargo, es importante analizar de manera más detallada el impacto de estas rentas sobre los distintos países con el fin de conocer quiénes son los beneficiados y perjudicados por la redistribución implícita en el comercio de petróleo. Para ello, calculamos el impacto de las rentas por decilas de la distribución internacional de la renta, cuyos resultados están recogidos en la Tabla 5. Por simplificación, los cálculos se hacen dividiendo la muestra en periodos de 5 años y calculando el promedio para cada periodo. El último periodo abarca únicamente los años 2015-2016.

**Tabla 5.** Impacto de las rentas del comercio internacional de petróleo en la renta promedio de cada decila.

| | **1995-1999** | | **2000-2004** | | **2005-2009** | | **2010-2014** | | **2015-2016** | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Decil** | **TCM** | **PPA** | **TCM** | **PPA** | **TCM** | **PPA** | **TCM** | **PPA** | **TCM** | **PPA** |
| 1 | 2.34 | 13.42 | -0.34 | 1.71 | 1.20 | 0.11 | 0.31 | 0.13 | 0.19 | 0.14 |
| 2 | -0.90 | 0.97 | -1.02 | -1.70 | -1.89 | 0.74 | -1.98 | 5.41 | -0.86 | 1.38 |
| 3 | 1.49 | -0.81 | -2.36 | -2.36 | -3.84 | -3.84 | -4.66 | -4.67 | -1.73 | -1.67 |
| 4 | 5.70 | 1.19 | 4.24 | 2.66 | 5.28 | 1.27 | 2.19 | -3.98 | 0.38 | -1.60 |
| 5 | -0.14 | -0.14 | -0.80 | -0.80 | -0.47 | -1.57 | 2.10 | 0.02 | 0.73 | 0.00 |
| 6 | 1.08 | -0.71 | -0.80 | -0.83 | -1.57 | -1.57 | -1.59 | -1.59 | -0.04 | 0.01 |
| 7 | 3.81 | 0.73 | 5.41 | 6.60 | 1.37 | 1.71 | -1.26 | -0.34 | -0.60 | -0.60 |
| 8 | 0.73 | 2.91 | 2.34 | 2.56 | 3.46 | 3.69 | 2.98 | 2.25 | 0.88 | 0.71 |
| 9 | 0.49 | 0.12 | 0.45 | 1.44 | 1.09 | 2.37 | 0.92 | 1.97 | 0.62 | -0.06 |
| 10 | -0.25 | 0.75 | -0.41 | -0.24 | -1.10 | -0.38 | -1.17 | -0.32 | -0.42 | 0.73 |

Fuente: elaboración propia. *Notas*: *TCM* y *PPA* representan las estimaciones usando dólares constantes de 2010 y dólares constantes de 2011 en Paridad del Poder Adquisitivo, respectivamente.

Los resultados para el escenario con tipos de cambio de mercado muestran que las rentas de las exportaciones tienen un mayor impacto relativo en las decilas bajas (1 y 4), al igual que las importaciones (decilas 2 y 3). No obstante, las decilas 6,7,8 y 9 también se benefician de estas rentas. En cuanto a su evolución, se observa un desplazamiento del efecto positivo de las rentas de las exportaciones hacia las decilas superiores, lo que reduce la capacidad redistributiva de estas rentas. Por otra parte, el impacto negativo de las rentas de las importaciones aumenta en mayor medida en las decilas bajas que en las decilas más altas, incrementando la regresividad de las importaciones. Todo esto explica la caída en el efecto redistributivo que se observa en los resultados analizados previamente de manera agregada.

En el escenario con paridad del poder adquisitivo se observa una evolución similar, aunque emergen algunas diferencias. En primer lugar, los países en las decilas 1 y 2 se benefician de las rentas de las exportaciones en todo el periodo, de manera contraria a lo que ocurre en el escenario con tipo de cambio de mercado, donde el mayor efecto positivo se produce en las decilas 4 y 5 a partir del año 2000. Esto está explicado porque India, cuyo peso es elevado por su numerosa población, se desplaza hacia arriba en la distribución al convertir su renta a dólares en paridad de poder adquisitivo, desplazando hacia las primeras decilas a determinados países exportadores de renta baja (Angola, Camerún, Rep. Congo y Yemen). En la otra cola de la distribución, el efecto negativo de las importaciones en el 10% con más rentas se reduce, incluso siendo positivo en algunos periodos. También las decilas 8 y 9 experimentan un mayor efecto positivo de las rentas, haciendo que éstas sean más regresivas. Estas variaciones se deben al desplazamiento de los países exportadores de renta alta (Arabia Saudí, Brunei, EAU, Kuwait, Rusia y Omán) al convertir su PIB per cápita en términos de paridad del poder adquisitivo. Este hecho, que es más pronunciado a partir de 2001, explica que el efecto redistributivo en este escenario pase a ser negativo y que muestre una mayor divergencia con el efecto redistributivo en el escenario con tipos de cambio del mercado.

### 4.1.3. Artículo nº 3.

## Oil trade rents and international income inequality.

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# Oil Trade Rents and International Income Inequality

## *Rentas del comercio de petróleo y la desigualdad internacional de la renta*

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Abstract

This paper investigates the role of oil rents as implicit transfers that redistribute global income through international trade channels. It involves estimating these rents, calculating the redistributive effect, exploring the role of exports and imports and the different impact depending on income per capita. The results document that (i) implicit international oil trade rents lead to a positive but declining reduction in international income inequality, although it becomes regressive after 2001 using PPP income estimates; (ii) redistribution is basically generated via exports, with imports playing a minor role; and (iii) international oil rents have a greater impact on the countries in the lowest deciles. The novelty of this work is that, for the first time, the international redistributive effect of oil rents is studied, by introducing the concept of implicit transfers in international trade, which opens up new fields of research in the area of global income inequality.

*Keywords*: Income inequality, international trade, oil rents, redistribution.

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RESUMEN

Este trabajo estudia el papel de las rentas del petróleo como transferencias implícitas que redistribuyen la renta global a través del comercio. Para ello estimamos dichas rentas, calculamos su efecto redistributivo, analizando el papel de las exportaciones y las importaciones, así como su distinto impacto en función de la renta per cápita. Los resultados muestran que (i) las rentas implícitas del comercio internacional de petróleo generan una redistribución positiva decreciente, aunque se convierte en negativa después de 2001 cuando se emplea la renta en PPA; (ii) el efecto redistributivo se genera principalmente a través de las exportaciones, mientras que las importaciones juegan un papel menor; y (iii) las rentas del comercio internacional de petróleo tiene un impacto mayor en los países que se encuentran en los deciles más bajos. La novedad de este trabajo es que, por primera vez, estudia el efecto redistributivo a nivel internacional de las rentas del petróleo, introduciendo el concepto de transferencias implícitas en el comercio internacional, abriendo nuevos campos de investigación en el área de la desigualdad global de la renta.

*Palabras claves:* desigualdad de la renta, comercio internacional, rentas del petróleo, redistribución.

*JEL Classification / Clasificación JEL:* D31, F10, Q30.

## 1. Introduction

Global income inequality has been on the decline since the 1990s (Milanovic, 2016; Bourguignon, 2017; Niño-Zarazua et al., 2017; David and Shorrocks, 2018). This trend, linked to globalization, is two-fold: on the one hand, between-country inequality has decreased as a result of greater growth rates in some developing countries whereas, in contrast, within-country inequality has increased (Milanovic, 2016; Bourguingnon, 2017). When calculating the two types of inequality, studies show that between-country inequality accounts for between 65% and 75% of global income inequality (Bourguignon and Morrison, 2002; Milanovic, 2002; Anand and Segal, 2015; Milanovic, 2016).

There are few factors that can alter the global distribution of income. Income is initially associated with production and its distribution is determined by the market, as well as by the national and international institutional mechanisms that affect it. At the national level, the initial income distribution, determined by production, can be substantially altered ex post by public sector interventions, which can generate a more equal distribution of disposable income through tax and transfer programmes (Immervoll and Richardson, 2011; Causa et al., 2017). However, at the international level, it is far more difficult to alter the initial between-country distribution of income, since there is not any redistributive mechanism as powerful as taxes and transfers (Bourguignon et al., 2009).

Among the few instruments that do redistribute international income ex post, we find two types of transfer: official development assistance and remittances from migrants. Both are reflected on national accounts and on the balance of payments and are perceptible. As regards official development assistance, Bouguignon et al. (2009) estimate a positive redistributive effect of a 0.44 percentage point change in the Gini index, concentrated on countries located in the bottom deciles of international income distribution. With regard to remittances sent by emigrants from the highest income countries to their countries of origin, there is no study that calculates their effects in terms of inequality. However, Adams and Page (2005) estimate that a 10% increase in remittances per capita reduces the share of population below the poverty line in the receiving countries by about 3.5%.

The redistributive power of both instruments is low, such that we may conclude there are few possibilities for international redistribution. However, it is possible to posit the presence of other types of mechanisms that can alter global income distribution. We refer to certain transfers that are implicit in international trade in non-reproducible goods, such as natural resources. As it is physically limited, this type of good generates a rent for its producers, since the price of the good is significantly higher than the costs of the production factors required to obtain it (Segal, 2011). When these goods are traded internationally, the commercial transaction includes an implicit transfer of rent from the importing to the exporting country, which *de facto* implies ex ante international income redistribution and that is included in the price of traded goods. Among natural resources, oil stands out for its economic importance and volume of international trade. Oil is the most traded commodity worldwide, with exports accounting for 8.3% of total world exports in 2017, worth 875,000 million dollars (UNCSTAD, 2018), and which reflects the redistributive potential of the international oil trade.

The goal of this work is to quantify the redistributive effects of oil trade and analyse its evolution, as well as which factors determine it, in the understanding that it may be triggering an important international redistribution of income. The first problem the study needs to cope with is that there are no official statistics collecting the rents transferred in the international oil trade, such that we first estimate these rents using oil production rents collected by the World Bank. We consider the period from 1995 to 2016 and estimate the rents received by oil exporters and those paid by oil importers. The analysis uses annual frequency data, including 168 countries for which data are available and which represent 95% and 98% of the world population and GDP in 2016, respectively. Estimates illustrate that exporting countries received an average of 647 billion dollars in implicit oil rents annually, accounting for 8.05% of these countries' aggregate GDP, although these numbers display a certain degree of variability over the period.

In order to analyse the redistributive effect of oil trade rents, a counterfactual of the international distribution of income is built by deducting oil rents from each country. The estimates are calculated using two income measures: exchange market rate income (in 2010 US dollars) and Purchasing Power Parity income (in 2011 PPP dollars). We then measure the redistributive effects through the difference in the Gini index before and after accounting for rents (i.e., the Reynolds-Smolensky index). In order to determine to what extent the redistributive effects are due to the improvement of oil exporters, or to the worsening of oil importers, the analysis decomposes the redistributive effects following the method applied in Hierro et al. (2012, 2014) and is based on the factor source decomposition (Shorrocks, 2013). Subsequently, using the incidence analysis by deciles, and following the proposal of Ravaillion and Chen (2003), it studies which countries are affected by redistribution; those with the highest income per capita or those with the lowest income per capita? Finally, it calculates the reranking effect in order to ascertain whether part of the redistributive power is lost by changes in the order of income distribution. To do this, it decomposes the redistributive effect following the method developed by Kakwani (1984).

The findings document that: i) the implicit rents of the oil trade lead to a reduction in international inequality when incomes are measured in US dollars, although this effect declines over the period, whereas the redistributive effect is reversed after 2001, when it is estimated in PPP terms, ii) this redistribution is mainly driven by transfers of rents to exporters, although their impact decreased after 2001 in PPP estimates, while imports play an increasing regressive role, iii) oil trade rents have a higher impact in the lowest deciles of the distribution, and iv) the loss of redistributive capacity due to the reranking effect is relatively low in exchange market rate estimates, but it increased when income was measured in PPP terms.

The contribution of this work is threefold: first, it estimates, for the first time (to the best of our knowledge), the amount of rents transferred through international oil trade. Second, it estimates the redistributive effects of international oil trade and defines in an orderly manner a process to analyse this type of effects, which allow us to explore in depth the redistributive effects of any international transfer of rents. Finally, it incorporates a new concept into the study of global income inequality, that of the implicit transfer of rents in trade, thereby, opening up a new field of research.

The rest of the paper is organized as follows: Section 2 includes the methodology used, Section 3 examines the oil trade rents estimates, while Section 4 provides the results obtained in the analysis of the redistributive effects of oil trade rents; finally, Section 5 provides conclusions and certain implications associated with the obtained results.

## 2. Methodology

### 2.1. Methodology for estimating international oil trade rents and country classification

This work employs a sample of 168 countries, spanning the period 1995 to 2016. The sample represents 95% of the world population and 99% of world production in 1995, and 95% of world population and 98% of production in 2016, respectively. The countries included in the analysis were selected based on the availability of data used in the study and are listed in the appendix. We have removed from the sample countries for which some of the variables used were not collected or for which some observations were missing. In exceptional cases, where we found a missing value in the time series, we estimated it through interpolation[1].

[1] We interpolated 7 values of the 1,870 observations of oil rents missing ithe World Bank Adjusted Net Savings database. For this purpose, we proceed as follows: we calculate the growth rate of the annual average rent per barrel and, using the latest available data for countries where missing values are found, we estimate their rents per barrel by applying the annual growth rate of rent per barrel to their previous year's rent per barrel.

Since there are no official data on international oil trade rents, the first problem to be dealt with is to estimate these rents. To this end, we rely on data published in the World Bank's *Adjusted Net Savings* database, where oil production rents as a percentage of GDP are published on an annual basis, and in the *International Energy Statistics* database by the US Energy Information Administration, which publishes data on crude oil production, as well as exports and imports of crude oil. By multiplying oil production rents by current GDP, we obtain total oil production rents in current dollars. We then divide this value by oil production in barrels. In this step, we obtain the value of rent per barrel of oil produced.

Assuming that the amount of rents per barrel of oil produced is the same for crude oil exports, we multiply the value of rents per barrel by the volume of crude oil exports, in barrels, and obtain the total value of rents originating from oil exports. Finally, dividing the latter by current GDP, we obtain the value of rents from exports relative to the size of the economy. This variable, called *Export/GDP*, responds to the following formula:

$$Export/GDP_{it} = \frac{\dfrac{\dfrac{RentProd}{GDP}_{it} \times GDP_{it}}{Prod_{it}} \times OilExp_{it}}{GDP_{it}} \times 100 \qquad (1)$$

where $\frac{RentProd}{GDP}_{it}$ represents rents from oil production as a percentage of GDP, $GDP_{it}$ represents GDP in current U.S dollars, $Prod_{it}$ is oil production expressed in barrels, and $OilExp_{it}$ is the volume of oil exports in barrels.

In the case of oil imports, the estimation is different. Since we do not have information on the origin of each country's imports, we calculate a global average amount of rent by barrel for each year. For this, we calculate the average aunt of rent per barrel weighted by each country's volume of exports with respect to total exports. The result is the average amount of rent per barrel of oil for each year worldwide, which we apply to the volume of oil imports in current dollars for each country. This value is divided by GDP. We thus obtain the variable *Import/GDP*, expressed as aercentage, and which responds to the following formula:

$$Import/GDP_{it} = \frac{\left(\sum_{i=1}^{n}\left(\dfrac{\dfrac{RentProd}{GDP}_{it} \times GDP_{it}}{Prod_{it}} x W_{it}\right)\right) x\ OilImp_{it}}{GDP_{it}} \times 100 \qquad (2)$$

where $OilImp_{it}$ is the volume of oil imports in barrels and $W_{it}$ is the relative weight of each country's oil exports with respect to total oil exports. Finally, we calculate the difference between rents obtained from exports and rents paid for imports for each country, which is also relativized with respect to GDP. This variable, called *Rent/GDP*, is expressed as a percentage and is in line with the following formula:

$$Rent/GDP_{it} = Export/GDP_{it} - Import/GDP_{it} \quad (3)$$

We should clarify that we estimate oil trade rents from a national account perspective, considering their direct impact on national production. We do not consider the subsequent distribution of those rents, which are included in different national accounting items. Studying the within-country distribution of those rents would require a country by country analysis in order to detect the mechanisms by which rents could be leaked to foreign countries in each, and would entail making strong assumptions, given the lack of data about their national distribution.

Once rents are estimated, we then divide the sample between exporting countries that receive rents from exports which are higher than those they pay for imports and which are, therefore, beneficiaries of implicit redistribution, and importing countries, that paid rents for imports which are higher than those obtained from oil exports, such that these are the countries which transfer rent to exporters.

In order to classify the results within the exporting group, the analysis uses a cluster method, which allows us to define groups so that the dissimilarity between observations within each group is as small as possible and the dissimilarity between different groups is as great as possible.

Initially, we define the measure of dissimilarity[2]. We then group countries into clusters, using the agglomerative hierarchical method which starts from a number of clusters equal to the number of observations and iteratively and hierarchically merges the clusters, such that it does not require the number of clusters to be determined. For clustering, we employ the Ward (1963) method and to determine the optimal number of clusters we used two different methods: a global method called the 'elbow method' (Thorndike, 1953) and a local method based on the Duda and Hart (1973) indexes. The definition of clusters applied to the variable *Rent/GDP* allows us to distinguish groups of countries based on their dependence on international oil trade rents.

[2] The Euclidean distance, *d(i,j)* for two countries i and j is defined as follows:

$$d(i,j) = \sqrt{\sum_{k=1}^{p} (X_{ki} - X_{kj})^2}$$

where X is the value of the observation and k = 1, 2,...,p represents the variables to be analysed, which in our case is only *Rent/GDP*.

## 2.2. Method for analysing the redistributive effect of international oil trade rents

As regards the redistributive effect of the rents estimated above, we consider it necessary to answer the following questions: do oil rents reduce global income inequality? To what extent? How much of the redistributive effect is due to the importer's loss of income and how much to exporter's profits? Is redistribution greater for countries with the lowest or the highest income per capita? And finally, is redistribution less than what would potentially occur as a result of the reranking effect? Or, put differently, is part of the redistribution lost because countries move up and down in the ranking?

### 2.2.1. Do oil rents reduce international income inequality? To what extent?

In order to analyse whether oil rents reduce global income inequality, it is important to choose the concept of inequality used, since the results may differ, as indeed may any interpretations (Bourguignon et al., 2004; Ghose, 2004). This paper uses international income inequality, following the notation of Milanovic (2005), that is, measuring inequality between countries using income per capita weighted by their population.

Given that data about national inequality and the distribution of oil rents are not available for each country in the period considered, it is not possible to analyse the impact of oil rents on global interpersonal inequality. However, taking into account that around two thirds of global interpersonal inequality is determined by inequality between countries (Bourguignon and Morrison, 2002; Milanovic, 2002; Anand and Segal, 2015, Lakner and Milanovic, 2016), we can deduce that the results obtained would prove relevant in global interpersonal inequality.

Another important issue is whether oil rents, and therefore, GDP per capita, should be measured in dollars using exchange market rates (US dollars) or PPP exchange rates. Given that oil rents are international flows, converting them into constant US dollars allows us to compare these flows, which are priced internationally. However, global inequality, measured by synthetic indexes, such as the Gini or Theil index, is overestimated when GDP is measured in US dollar terms (Dowrick and Akmal, 2005; Milanovic, 2005; Anand and Segal, 2008). In this regards, using GDP in PPP terms is a better approach to estimate the international income inequality, since it allows the comparison of welfare between individuals across different countries, taking into account the price differences between countries (Stucliffe, 2004; Milanovic, 2012). Despite the advantage of PPP in terms of welfare comparison, oil rents expressed in PPP dollars are not worth the same for every country, so the redistribution is not a zero-sum game.

To address this issue, the analysis first calculates international income inequality using the GDP per capita in constant 2010 U.S. dollars, obtained from the World Bank's *World Development Indicators* database. It then estimates a counterfactual of international income inequality without accounting for the international oil trade rents previously estimated; that is to say, rents paid in oil imports are added to GDP per capita and rents received from exports are subtracted, both in per capita terms. Alternatively, it performs the same calculations measuring GDP per capita and oil trade rents in constant 2011 PPP dollars, the former obtained from *World Development Indicators* database and the latter converted by multiplying oil trade rents by the ratio of GDP in PPP to GDP in US dollars. In the rest of the paper, we will refer to the former estimation as the *EMR scenario*, and the latter as the *PPP scenario*.

To measure the redistributive effect, the analysis employs the Reynolds and Smolensky (1997) index, which shows the change in income inequality, measured by the Gini index, and which is defined as:

$$RE = G_{BOR} - G_{AOR} \tag{4}$$

where *RE* is the redistributive effect, $G_{BOR}$ is the Gini index of income distribution, excluding oil rents, and $G_{AOR}$ is the Gini index of the final income distribution, including oil rents. A positive value of this index implies a reduction in income inequality and, therefore, yielding a positive redistribution.

### 2.2.2. How much of the redistributive effect is due to importer's loss of income and how much to exporter's profits?

In order to determine the weight of exports and imports in t redistributive effect of international oil trade rents, the analysis carries out a factorial decomposition of the redistributive effect. Following the methodology used in Hierro et al. (2012, 2014), based on Shorrocks (2013), the analysis applies a decomposition procedure employing the Shapley value, calculating the average partial effect of exports and imports rents in the redistributive effect by altering the calculation sequence. Table 1 shows the process followed.

### 2.2.3. Which countries are affected by redistribution? Those with the highest income per capita or those with the lowest?

In order to analyse how the redistributive effect is distributed, the analysis performs an incidence analysis by decile. To this end, it calculates the percentage variation of the average GDP per capita in each decile caused by oil rents and builds a non-anonymous incidence curve, following the methodology of Ravaillion and Chen (2003) and Bourguignon (2011). Income variation for each decile is given by the following equation:

TABLE 1. DECOMPOSITION OF THE REDISTRIBUTIVE EFFECT BETWEEN EXPORT AND IMPORT EFFECT

| | Sequence 1 (M+Ex) | Sequence 2 (Ex-M) | Shapley solution |
|---|---|---|---|
| Imports | $RE_{X,M}$ (I) | $RE_{X,M+Ex} - RE_{X+Ex}$ (III) | $RE_{M} = \frac{1}{2}(RE_{X,M+Ex} - RE_{X+Ex}) + \frac{1}{2}(RE_{X,M})$ (V) |
| Exports | $RE_{X,M+Ex} - RE_{X,M}$ (II) | $RE_{X+Ex}$ (IV) | $RE_{Ex} = \frac{1}{2}(RE_{X,M+Ex} - RE_{X,M}) + \frac{1}{2}(RE_{Ex})$ (VI) |
| Total | $RE_{X,M+Ex}$ (VII) | $RE_{X,M+Ex}$ (VII) | |

Source: Hierro et al. (2012) and authors' own elaboration. Notes: RE refers to the redistributive effect measure by the Reynolds-Smolenksy index. The notations X, Ex and M refers to GDP per capita before including oil rents, rents per capita received from exports and rentser capita paid in imports, respectively.

$$I(d) = \left(\left(\frac{y_{aor}(d)}{y_{bor}(d)}\right) - 1\right) x\, 100 \qquad (5)$$

where I(d) is the percentage variation of average GDP per capita for each decile $d = 1, 2, \ldots, 10$, $y_{aor}(d)$ is the average GDP per capita of each decile including oil rents, and $y_{bor}(d)$ is the average GDP per capita of each decile prior to including oil rents. This methodology allows us to analyse the relative impact of rents on countries, based on their level of income, and thus to determine how redistribution occurs. Likewise, it also allows us to analyse what happened in redistribution terms throughout the period considered.

### 2.2.4. IS THE REDISTRIBUTION WHICH OCCURS LESS THAN WHAT MIGHT OCCUR AS A RESULT OF THE RERANKING EFFECT?

Another important issue concerns the loss of the redistributive effect due to the fact that, when countries shift in the distribution ranking, there is an increase in inequality, which is known as reranking. Following the methodology proposed by Kakwani (1984), the redistributive effect can be decomposed into two components:

$$RE = V - R \qquad (6)$$

where *RE* is the total redistributive effect, *V* is vertical redistribution and *R* represents the reranking effect. Vertical redistribution measures the progressivity of redistribution or the potential redistributive effect, while reranking represents the reduction in the redistributive effect caused by changes in orders in the international distribution of income induced by redistribution itself.

We consider $D^{BOR}_{AOR}$ to be the concentration index of final income (including oil rents) maintaining the initial order (before including oil rents), we can represent the Kakwani decomposition as follows:

$$RE = V - R = (G_{BOR} - D^{BOR}_{AOR}) - (G_{AOR} - D^{BOR}_{AOR}) \qquad (7)$$

where the first term in the equation represents vertical redistribution, while the second term represents the reranking effect. By construction, reranking effect will be always positive or zero, while the minus sign in front of the reranking term reflects that it reduces the redistributive effect.

## 3. Data

### 3.1. Estimation of international oil trade rents

The average oil rents for each country is shown in the appendix. We order countries from highest to lowest rents in terms of GDP, with Republic of Congo being the country where oil trading rents represent the greatest share of GDP, 32.76%. The group of countries receiving oil rents, henceforth 'exporting countries', consists of 42 countries, and the group of countries which transfer part of their income in the form of payment of oil rents, henceforth 'importing countries', is made up of 126 countries.

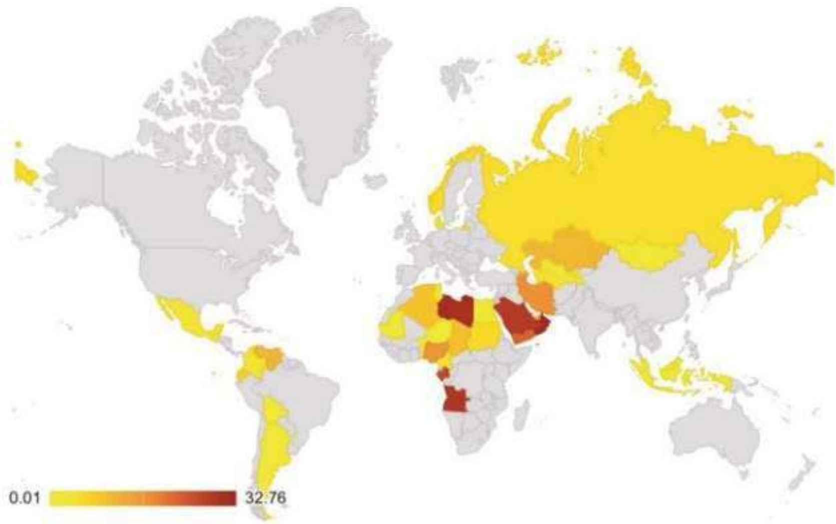
The geographical distribution of oil rents to GDP is shown in Figure 1, where it can be seen that most dependent exporters are concentrated in the areas of the Middle East and the West Coast of Central Africa.

Rents received by exporters amount to an average of 646,905 million dollars a year, although their evolution does provide evidence of a certain degree of volatility. As can be seen in Figure 2, there is a period displaying an increasing trend which stretches from 1995 to 2008, the year when the global crisis began, and another displaying a decreasing trend from 2009 to 2016.

Figure 3 shows the evolution of rents of exporting and importing countries as a percentage of their GDP. Rents paid by importers account for an average of 1.06% of their aggregate GDP, while for exporters they represent an average of 8.05%. That is, oil rents are far more relevant in economic terms for the economies of exporting countries than for the economies of importing countries, which means that exporting countries are more exposed to changes in the sector than are importing countries.

Focusing on exporting countries, we apply cluster analysis to group these countries according to their dependence on the rents from exports, using the average *Rent/GDP* for the period 1995-2016. As regards the optimal number of clusters, the Duda/Hart indexes suggests the existence of between four and five clusters. The elbow method also suggests that the optimal number of clusters is four. Therefore, we chose to define four different groups based on the average value of the variable *Rent/GDP* during the period analysed.

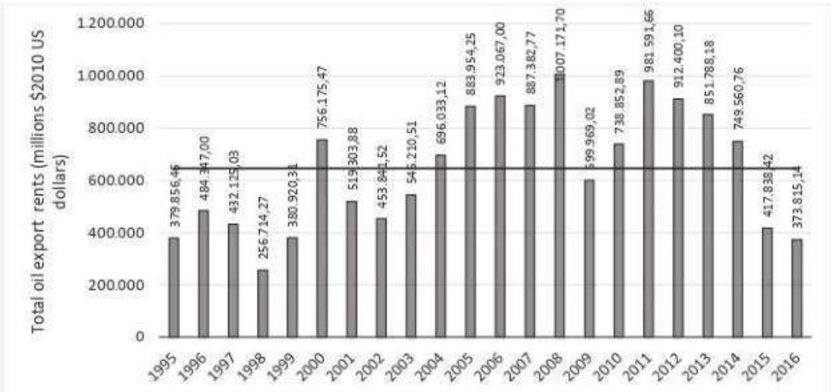
FIGURE 1. GLOBAL DISTRIBUTION OF INTERNATIONAL OIL TRADE RENTS TO GDP FOR OIL EXPORTING COUNTRIES




Source: Authors' own compilation. Note: only exporting countries, as previously defined, are included.

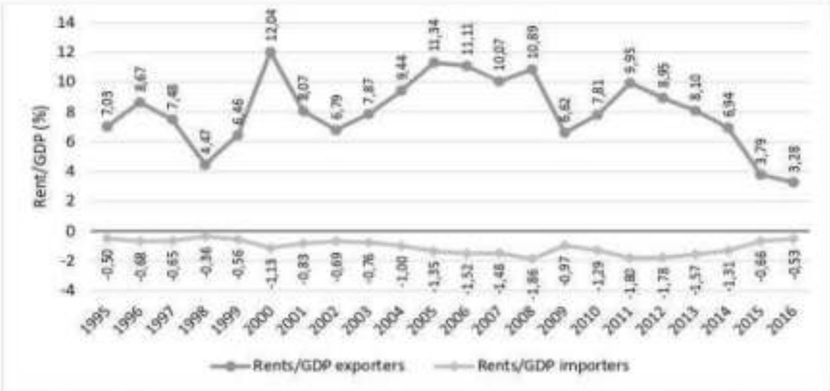
Table 2 shows the groups obtained, as well as the main statistics of each group. We classify countries into four groups: very high, high, medium, and very low dependence on oil rents based on the average value of the groups.

FIGURE 2. EVOLUTION OF OIL EXPORT RENTS IN THE PERIOD 1995-2016




Source: Authors' own compilation. Notes: Oil export rents are calculated as the sum of rents received from exports by every country in the sample. Export rents are expressed in constant 2010 US dollars. The black line represents the average oil exports rents for the whole period.

Figure 3. Evolution of exporting and importing rents to GDP (1995-2016)




Source: Authors' own compilation. Notes: rent/GDP are calculated as the sum of rents in net terms (export rents – import rents) divided by the aggregate GDP of each group. The group of exporting countries is formed by 42 countries with an average *Rent/GDP* above zero, while importing countries are the group of 126 countries with zero or a negative average *Rent/GDP*.

Table 2. Classification of exporting countries according to cluster analysis results

| Group | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| Oil trade rents dependence | Very high | High | Medium | Very low |
| Number of countries | 8 | 6 | 8 | 20 |
| Average Rent/GDP (%) | 28.82 | 17.21 | 8.11 | 1.23 |
| Std. Deviation | 3.26 | 1.48 | 2.57 | 1.08 |
| Countries | Gabon | Azerbaijan | Algeria | Argentina |
| | Oman | Nigeria | Russia | Mauritania |
| | Kuwait | Brunei | Norway | Denmark |
| | Yemen | Iran | Chad | Turkmenistan |
| | Congo | UAE | Venezuela | Belize |
| | Angola | Qatar | Kazakhstan | Egypt |
| | Saudi Arabia | | Ecuador | Guatemala |
| | Libya | | Sudan | Tunisia |
| | | | | Tajikistan |
| | | | | DRC |
| | | | | Mongolia |
| | | | | Malaysia |
| | | | | Cameroon |
| | | | | Colombia |
| | | | | Benin |
| | | | | Bolivia |
| | | | | Uzbekistan |
| | | | | Niger |
| | | | | Indonesia |
| | | | | Mexico |

Source: Authors' own compilation.

The first cluster is that of countries with a very high dependence on oil rents, which account for around a third of GDP. For the second group, dependence on oil rents is high, and accounts for around a fifth of their GDP. However, the most numerous groups are those displaying medium dependence (around 8.11% of GDP) and very low dependence (1.23% of GDP). For the latter, their economy does not depend on the rents obtained from oil exports.

With reference to dependence, it should be remembered that we are talking about dependence on oil rents from abroad, not dependence on the oil production sector, which may have a substantially greater weight in the country's economy, even if it does not produce foreign revenues.

## 4. Empirical analysis

### 4.1. Estimation and analysis of the redistributive effect of international oil trade rents

#### 4.1.1. Do oil rents reduce global income inequality? To what extent?

The answer to both questions can be found in Table 3. Columns 1 and 2 show the value of the Gini index of international distribution of income before including oil rents and the redistributive effect of this rents, respectively, when using the exchange market rate. As can be seen, international inequality is high, with an average Gini index of 67.41, although it has experienced a decline over the period. Oil rents do lead to a reduction in this inequality. The redistributive effect is positive over the whole period, such that rents implicit in the international oil trade reduce international inequality; in other words, a progressive redistribution takes places, since it makes global income more equal. Nevertheless, the size of this redistributive effect experiences a decreasing trend over the period analysed.

The scale of the redistributive effect is, on average, 0.12 points on the Gini index, reaching a maximum value of 0.32 points in 1996. The redistributive effect of Official Development Assistance (ODA), the main instrument of redistribution at the international level, is 0.44 points on the Gini index, according to the estimates by Bourguignon et al. (2009) for 2004. Therefore, taking explicitly into account that the possibilities and size of redistribution at international levels are low, the redistributive effect of oil trade rents is considerable.

Columns 5 and 6 in Table 3 show the international inequality, measured by the Gini index, and the redistributive effect when GDP per capita and oil rents are converted into PPP dollars. In these estimates, income inequality is found to be lower, given that market exchange rates undervalue the standard of livings of the poorer countries, and therefore, to overstate the international inequality (Dowrick and Akmal, 2005; Anand and Segal, 2008). As in the EMR scenario, we found a declining trend in the redistributive effect. In this

Table 3. Redistributive effect of international oil trade rents (1995-2016)

| | EMR | | | | PPP | | | |
|---|---|---|---|---|---|---|---|---|
| Year | $GINI_{BOR}$ | RE | V | R | $GINI_{BOR}$ | RE | V | R |
| 1995 | 70.85 | 0.247 | 0.288 | -0.041 | 58.39 | 0.221 | 0.385 | -0.164 |
| 1996 | 70.72 | 0.324 | 0.420 | -0.096 | 58.02 | 0.295 | 0.483 | -0.188 |
| 1997 | 70.59 | 0.191 | 0.288 | -0.097 | 57.87 | 0.238 | 0.362 | -0.124 |
| 1998 | 70.49 | 0.114 | 0.117 | -0.003 | 57.62 | 0.011 | 0.045 | -0.034 |
| 1999 | 70.44 | 0.119 | 0.138 | -0.019 | 57.34 | -0.009 | 0.064 | -0.073 |
| 2000 | 70.55 | 0.287 | 0.571 | -0.284 | 57.48 | 0.158 | 0.463 | -0.305 |
| 2001 | 70.09 | 0.129 | 0.154 | -0.025 | 56.77 | -0.033 | 0.082 | -0.115 |
| 2002 | 69.69 | 0.077 | 0.091 | -0.014 | 56.24 | -0.099 | -0.038 | -0.061 |
| 2003 | 69.26 | 0.086 | 0.109 | -0.023 | 55.55 | -0.16 | -0.091 | -0.069 |
| 2004 | 68.90 | 0.115 | 0.137 | -0.022 | 54.85 | -0.172 | -0.072 | -0.100 |
| 2005 | 68.48 | 0.144 | 0.205 | -0.061 | 54.04 | -0.217 | -0.105 | -0.112 |
| 2006 | 67.91 | 0.123 | 0.174 | -0.051 | 53.12 | -0.265 | -0.147 | -0.118 |
| 2007 | 67.24 | 0.137 | 0.182 | -0.045 | 52.04 | -0.232 | -0.122 | -0.110 |
| 2008 | 66.62 | 0.142 | 0.215 | -0.073 | 51.14 | -0.289 | -0.156 | -0.133 |
| 2009 | 65.53 | 0.082 | 0.102 | -0.020 | 49.50 | -0.228 | -0.143 | -0.085 |
| 2010 | 65.04 | 0.132 | 0.155 | -0.023 | 48.69 | -0.226 | -0.091 | -0.135 |
| 2011 | 64.58 | 0.138 | 0.169 | -0.031 | 48.03 | -0.292 | -0.119 | -0.173 |
| 2012 | 64.05 | 0.069 | 0.118 | -0.049 | 47.33 | -0.381 | -0.199 | -0.182 |
| 2013 | 63.53 | 0.021 | 0.067 | -0.046 | 46.63 | -0.41 | -0.235 | -0.175 |
| 2014 | 63.12 | 0.021 | 0.040 | -0.019 | 46.09 | -0.363 | -0.244 | -0.119 |
| 2015 | 62.86 | 0.015 | 0.020 | -0.005 | 45.80 | -0.201 | -0.170 | -0.031 |
| 2016 | 62.40 | 0.006 | 0.009 | -0.003 | 45.41 | -0.164 | -0.142 | -0.022 |
| Average | 67.41 | 0.120 | 0.171 | -0.048 | 52.63 | -0.128 | -0.009 | -0.119 |

Source: Authors' own compilation. Notes: GiniBOR represents the Gini index of the international distribution of income before including oil trade rents. RE is the redistributive effect of oil trade rents, measured by the Reynolds-Smolensky index. V and R are the Vertical and Reranking effects, estimated following equation (7). EMR and PPP represent the estimations using constant 2010 US dollars and constant 2011 PPP dollars, respectively.

case, the evolution of the redistributive effect can be divided into two different periods: a first period yielding a positive redistribution, on a similar scale to the EMR estimates, which ends in 2000; and a second period after 2001, when redistribution turns negative, implying that oil trade rents turn into being inequality-increasing.

Given that the impact in relative terms of oil trade rents in both scenarios does not differ by construction, the divergence patterns in the redistributive effect should be explained by the shifts of countries in the international distribution of income due to different income and rents measures. These changes affect both the effect of exports and imports on the total redistribution and the magnitude of reranking. These issues will be addressed in the next subsections.

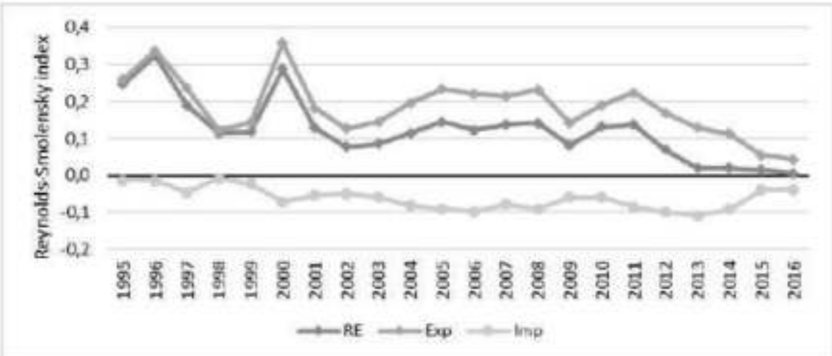
#### 4.1.2. What part of the redistributive effect is due to the loss of income from imports and what part to exporters' profits?

The redistributive effect may be caused by exporting countries' GDP per capita improvements thanks to the oil rents received and by importing countries' GDP per capita reduction due to the payment of these implicit rents. In order to know the importance and direction of each of these effects, we decompose the redistributive effect between the export and import effect (Table 4), the progression for which is shown in Figures 4a and 4b.

As can be seen in Figure 4a, in the EMR estimates, the total redistributive effect is driven by the rents received by oil exporters, which are those that operate progressively. The rents paid in imports generate a negative redistributive effect; that is, they show a regressive behaviour and do not reduce inequality, but in fact, increase it. As regards the progression over time, it can be observed that as of 2000, the negative redistributive effect of imports increases. Coupled with the loss of the redistributive effect of exports, this has led to a substantial reduction in the redistributive effect of oil rents.

In the PPP estimates (Figure 4b), exports rents are the main drivers of the positive redistributive effect until 2001. During this period, imports show a slightly regressive behaviour, but it is almost negligible. We find a downward trend in the exports redistributive effect after 2002, turning into negative

Figure 4a. Evolution of the redistributive effect of oil exports and imports (constant 2010 US dollars)




Source: Authors' own compilation. Note: RE refers to the redistributive effect Exp refers to the redistributive effect of oil export rents and Imp refers to the redistributive effect of oil import rents.

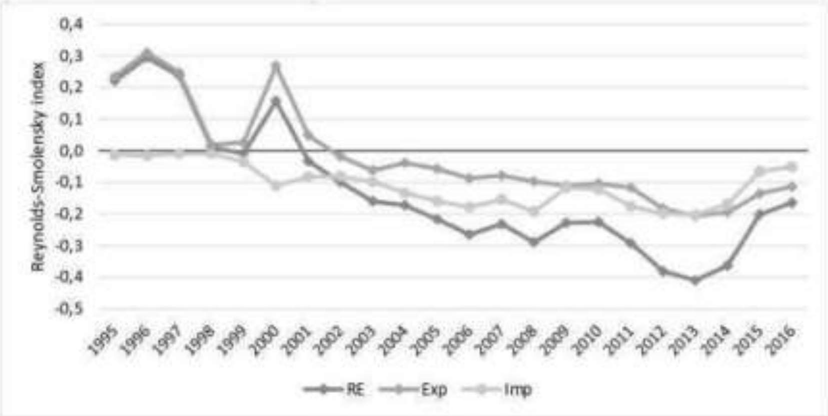
Table 4. Redistributive effect of oil exports and imports (1995-2016)

| | EMR | | | PPP | | |
|---|---|---|---|---|---|---|
| Year | RE | $RE_{Ex}$ | $RE_{Imp}$ | RE | $RE_{Ex}$ | $RE_{Imp}$ |
| 1995 | 0.247 | 0.260 | -0.013 | 0.221 | 0.234 | -0.013 |
| 1996 | 0.324 | 0.338 | -0.014 | 0.295 | 0.311 | -0.016 |
| 1997 | 0.191 | 0.237 | -0.046 | 0.238 | 0.248 | -0.010 |
| 1998 | 0.114 | 0.122 | -0.008 | 0.011 | 0.020 | -0.009 |
| 1999 | 0.119 | 0.143 | -0.023 | -0.009 | 0.027 | -0.036 |
| 2000 | 0.287 | 0.358 | -0.071 | 0.158 | 0.268 | -0.110 |
| 2001 | 0.129 | 0.182 | -0.053 | -0.033 | 0.049 | -0.082 |
| 2002 | 0.077 | 0.126 | -0.049 | -0.099 | -0.018 | -0.080 |
| 2003 | 0.086 | 0.144 | -0.058 | -0.160 | -0.062 | -0.098 |
| 2004 | 0.115 | 0.196 | -0.081 | -0.172 | -0.039 | -0.134 |
| 2005 | 0.144 | 0.233 | -0.089 | -0.217 | -0.058 | -0.159 |
| 2006 | 0.123 | 0.220 | -0.098 | -0.265 | -0.087 | -0.178 |
| 2007 | 0.137 | 0.214 | -0.077 | -0.232 | -0.078 | -0.154 |
| 2008 | 0.142 | 0.232 | -0.090 | -0.289 | -0.097 | -0.192 |
| 2009 | 0.082 | 0.141 | -0.059 | -0.228 | -0.111 | -0.117 |
| 2010 | 0.132 | 0.190 | -0.059 | -0.226 | -0.103 | -0.123 |
| 2011 | 0.138 | 0.223 | -0.085 | -0.292 | -0.117 | -0.175 |
| 2012 | 0.069 | 0.168 | -0.099 | -0.381 | -0.183 | -0.199 |
| 2013 | 0.021 | 0.130 | -0.109 | -0.410 | -0.207 | -0.203 |
| 2014 | 0.021 | 0.113 | -0.091 | -0.363 | -0.195 | -0.169 |
| 2015 | 0.015 | 0.054 | -0.039 | -0.201 | -0.136 | -0.065 |
| 2016 | 0.006 | 0.044 | -0.038 | -0.164 | -0.114 | -0.051 |
| Average | 0.124 | 0.185 | -0.061 | -0.128 | -0.020 | -0.108 |

RE is the redistributive effect of oil trade rents, measured by the Reynolds-Smolensky index. $RE_{Ex}$ and $RE_{Im}$ represent the redistributive effect of exports and imports, respectively, estimated following the methodology shown in Table 1. EMR and PPP represent the estimates using constant 2010 US dollars and constant 2011 PPP dollars, respectively.

and, thus, contributing to the negative total redistributive effect observed. Imports also show an increasing regressive effect, higher than the observed in the EMR scenario, thus, reinforcing the contribution of exports to the negative redistributive effect.

FIG 4B. EVOLUTION OF THE REDISTRIBUTIVE EFFECT OF OIL EXPORTS AND IMPORTS (CONSTANT 2011 PPP DOLLARS)




Source: Authors' own compilation. Note: RE refers to the redistributive effect Exp refers to the redistributive effect of oil export rents and Imp refers to the redistributive effect of oil import rents.

### 4.1.3. WHICH COUNTRIES ARE AFFECTED BY REDISTRIBUTION? THOSE WITH THE HIGHEST INCOME PER CAPITA OR THOSE WITH THE LOWEST?

The distribution of the redistributive effect by country can be gauged by calculating the impact of oil rents on the average GDP per capita of each decile of international income distribution, shown in Table 5. For simplicity, the impact has been calculated for an average five-year period, with the exception of the last period, which merges the years 2015 and 2016.

Table 5 shows that in the EMR estimates, oil exports initially have a greater impact on the lowest deciles (1 and 4), while oil imports have also a greater negative impact on the lowest deciles (2 and 3). Deciles 6, 7, 8 and 9 also benefit from oil rents. Table 5 also shows a shift in the impact of export rents towards the upper deciles over the period, reducing the redistributive capacity of exports, since rents have an impact on higher deciles than they did in previous periods. On the other hand, the negative effect of imports increases in the lowest deciles to a greater extent than in high income deciles, thus increasing the regressive effect of imports. These results explain the reduction in the size of the redistributive effect at the end of the period analysed, which can be seen in Figure 4a.

A similar evolution can be seen in the PPP scenario. However, important differences emerge. Firstly, countries in deciles 1 and 2 benefit from oil rents over the whole period, in contrast to the results found in the EMR scenario, where the greater impact after 2000 is found on deciles 4 and 5. This means

Table 5. Impact of international oil trade rents on average GDP per capita by decile

| | 1995-1999 | | 2000-2004 | | 2005-2009 | | 2010-2014 | | 2015-2016 | |
|---|---|---|---|---|---|---|---|---|---|---|
| Decile | EMR | PPP | EMR | PPP | EMR | PPP | EMR | PPP | EMR | PPP |
| 1 | 2.34 | 13.42 | -0.34 | 1.71 | 1.20 | 0.11 | 0.31 | 0.13 | 0.19 | 0.14 |
| 2 | -0.90 | 0.97 | -1.02 | -1.70 | -1.89 | 0.74 | -1.98 | 5.41 | -0.86 | 1.38 |
| 3 | 1.49 | -0.81 | -2.36 | -2.36 | -3.84 | -3.84 | -4.66 | -4.67 | -1.73 | -1.67 |
| 4 | 5.70 | 1.19 | 4.24 | 2.66 | 5.28 | 1.27 | 2.19 | -3.98 | 0.38 | -1.60 |
| 5 | -0.14 | -0.14 | -0.80 | -0.80 | -0.47 | -1.57 | 2.10 | 0.02 | 0.73 | 0.00 |
| 6 | 1.08 | -0.71 | -0.80 | -0.83 | -1.57 | -1.57 | -1.59 | -1.59 | -0.04 | 0.01 |
| 7 | 3.81 | 0.73 | 5.41 | 6.60 | 1.37 | 1.71 | -1.26 | -0.34 | -0.60 | -0.60 |
| 8 | 0.73 | 2.91 | 2.34 | 2.56 | 3.46 | 3.69 | 2.98 | 2.25 | 0.88 | 0.71 |
| 9 | 0.49 | 0.12 | 0.45 | 1.44 | 1.09 | 2.37 | 0.92 | 1.97 | 0.62 | -0.06 |
| 10 | -0.25 | 0.75 | -0.41 | -0.24 | -1.10 | -0.38 | -1.17 | -0.32 | -0.42 | 0.73 |

Source: Authors' own compilation. EMR and PPP represent the estimates using constant 2010 US dollars and constant 2011 PPP dollars, respectively.

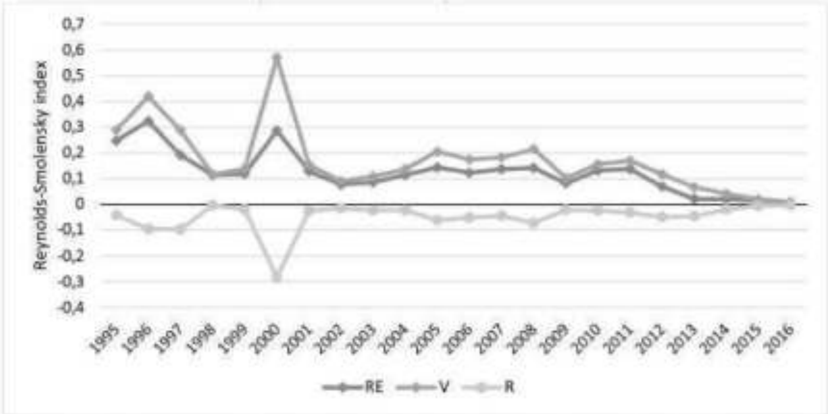
that the oil-exporting countries located in those deciles in the EMR scenario (Angola, Cameroon, Yemen, Rep. of Congo) move down in the distribution due to the increase in India's GDP per capita in PPP with respect to US dollars. On the other tail of the distribution, the negative impact of oil trade rents in decile 10 is smaller in the PPP estimates, even turning positive in periods 1995-1999 and 2015-2016. In the same line, deciles 8 and 9 experience an average higher positive impact of oil rents in this scenario, thus making the redistributive effect of oil rents more regressive. These variations are explained by shifts of high-income oil-exporting countries (i.e., Saudi Arabia, Brunei, United Arab Emirates, Kuwait, Oman, and Russia) in the international distribution when converting GDP per capita into PPP terms. These differences become more pronounced after 2001, explaining the deeper decline of the redistributive effect in the PPP scenario and the increasing divergences with respect to the estimated in the EMR scenario.

#### 4.1.4. Is redistribution less than what might occur as a result of the reranking effect?

Figure 5a and 5b displays the decomposition of the redistributive effect into vertical redistribution (potential redistribution) and reranking effect, following equation (7).

In the EMR estimates, the reranking effect exists, albeit it remains low. For this reason, vertical redistribution is slightly greater than the total redistributive effect. This implies that oil rents implicit in international trade do not lose excessive redistributive potential because of countries changing their position

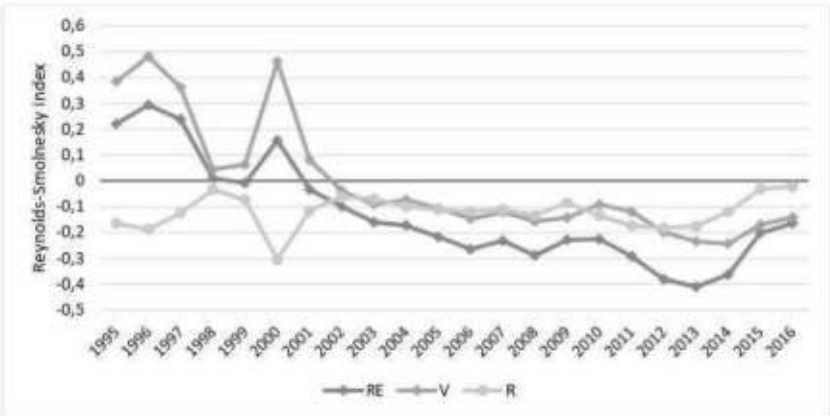
FIGURE 5A. PROGRESSION OF THE COMPONENTS OF THE REDISTRIBUTIVE EFFECT: VERTICAL AND RERANKING EFFECTS (2010 US DOLLARS)




Source: Authors' own compilation. Note: RE refers to the redistributive effect, V refers to vertical redistribution and R refers to reranking effect.

in the distribution. It is also observed that this loss of potential redistribution evolves inversely to that of vertical redistribution, such that in periods when the redistributive potential is greater (vertical effect), the loss of the redistributive effect due to reranking is also greater. This behaviour is perfectly explainable

FIGURE 5B. PROGRESSION OF THE COMPONENTS OF THE REDISTRIBUTIVE EFFECT: VERTICAL AND RERANKING EFFECTS (2011 PPP DOLLARS)




Source: Authors' own compilation. Note: RE refers to the redistributive effect, V refers to vertical redistribution and R refers to reranking effect.

since when oil rents are very high, the increased GDP per capita of exporters and the reduced GDP per capita of importers is greater, such that the former are more likely to surpass the latter in the distribution of income, and vice versa when oil rents decrease.

The potential redistributive effect and reranking follow a different evolution in the PPP scenario (Figure 5b). Firstly, the reranking effect is on average 2.5 times higher in this scenario. The smaller income inequality estimated when using PPP dollars means that GDP per capita differences between countries are smaller as well, making reranking more likely to occur. Given this, reranking offsets almost half of the positive redistributive potential of oil trade rents in the period before 2001, thus, reducing the actual redistributive effect.

The loss of redistribution caused by reranking is coupled with a declining potential redistributive effect after 2001, which could be explained by the upward movement of high-income oil-exporting countries in the top deciles of the income distribution, as shown in Table 5, generating a potential regressive impact of oil rents. The evolution of both effects (i.e., reranking and the potential redistribution) explains the negative redistribution, which takes place after 2001 and the increasing divergence in the redistributive effect between EMR and PPP estimates.

## 5. Conclusion and policy implications

Every natural resource which is physically limited incorporates an economic rent in its price associated with its scarcity. When this limited natural resource is traded internationally, the rent that it incorporates works as an implicit transfer from the importing to the exporting country, thereby, contributing to the international redistribution of income. Oil is the limited natural resource with the greatest weight in international trade. As a result, these rents implicit in its price can be one of the most powerful mechanisms for global redistribution.

This paper calculated these rents. It estimated these to involve an average implicit annual transfer of around 647 billion 2010 U.S. dollars over the period 1995-2016. On average, this accounts for 8.05% of exporting countries' GDP (42 countries), reaching a maximum of 12.04% in 2000. However, it only represents 1.06% of GDP on average for importing countries (126 countries). That is, it is a small transfer for importers, but a relatively large one for exporters, particularly for those who have been classified as extremely highly dependent countries (i.e., Congo, Angola, Libya, Kuwait, Gabon, Oman, Yemen and Saudi Arabia) and highly dependent countries (i.e., Azerbaijan, Nigeria, Brunei, Iran, United Arab Emirates and Qatar).

Once international oil trade rents were estimated, we determined their redistributive effect. A progressive redistribution was found that reduced international income inequality by an average of 0.12 points on the Gini index, with a maximum of 0.32 points in 1997, when income was measured in US dollars. This places the international redistribution of rents implicitly into international oil trade close to the official development assistance (i.e., technical development cooperation, grant equivalent of concessional lending and debt relief) whose redistributive effect was 0.44 points of the Gini index in 2004 (Bourguignon et al., 2009). However, the redistributive effect of oil trade rents became regressive after 2001 when income was measured in PPP dollars, showing a deeper downward trend than the one found in the exchange market rate estimates.

This redistributive effect revealed that most of it took place trough rents received in exports, although they lost ground after 2001 in terms of PPP estimates. Overall, oil trade rents reduced inequality by increasing the income of exporting countries, whereas their reversion in PPP estimates was caused by a shift of oil export rents gains to the upper deciles. In contrast, imports had a regressive effect. This regressive effect, which increased at the end of the period analysed, was due to the fact that oil imports had a greater relative weight in countries with a lower GDP per capita. When we analysed the impact of oil rents by levels of GDP per capita, the overall result was that the lowest deciles in international income distribution were those that experienced the greatest increases in GDP per capita as a result of oil rents, although the impact on these countries decreased at the end of the same period. A further decline in the redistributive effect of international oil rents can be expected in both scenarios, given the shift that high-income oil exporters in the international income distribution have experienced and the incorporation of the United States as an oil exporter after the shale oil revolution.

The results also documented that the redistributive potential or capacity of oil rents was affected by the reranking effect, that is, by changes in the order (the position in income distribution before and after accounting for oil rents). This loss of redistributive capacity was small in exchange market rate estimates. However, the reranking effect was 2.5 times higher when it was estimated using PPP incomes, thus, generating a bigger loss of potential redistribution.

This paper breaks new ground in the study of the redistributive effect of international oil trade on international income distribution. It estimates for the first time the oil rents transfers in the international market. In addition, it applied a set of methodologies that provide an exhaustive analysis of the effects of any international rent transfer. Finally, the main contribution is that it introduced a new concept, the implicit transfer of rent on trade, which opens up new fields of research in terms of global income inequality. Specifically, it is applicable to other natural resources traded internationally and other rents, such as those that may derive from the monopolistic or oligopolistic functioning of international markets.

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## Appendix

Table A1. Average Rent/GDP by country (1995-2016)

| Country | Rent/GDP | Rents (millions) | Country | Rent/GDP | Rents (millions) | Country | Rent/GDP | Rents (millions) |
|---|---|---|---|---|---|---|---|---|
| Rep. of Congo | 32.76 | 3,322.96 | Mauritania | 1.44 | 87.12 | Hong Kong | 0.00 | 0.00 |
| Oman | 31.69 | 15,390.12 | Malaysia | 1.17 | 2,242.90 | Iceland | 0.00 | 0.00 |
| Libya | 30.51 | 17,136.25 | Mongolia | 0.92 | 84.12 | Kiribati | 0.00 | 0.00 |
| Kuwait | 29.61 | 32,502.28 | Indonesia | 0.64 | 3,066.70 | Lao | 0.00 | 0.00 |
| Angola | 29.08 | 17,407.92 | Argentina | 0.50 | 1,609.26 | Latvia | 0.00 | 0.00 |
| Saudi Arabia | 28.33 | 136,925.15 | Bolivia | 0.39 | 73.62 | Maldives | 0.00 | 0.00 |
| Gabon | 25.98 | 3,657.91 | Guatemala | 0.30 | 119.58 | Malta | 0.00 | 0.00 |
| Yemen | 22.58 | 4,902.17 | Denmark | 0.27 | 867.95 | Mauritius | 0.00 | 0.00 |
| Brunei Darussalam | 19.23 | 2,520.48 | Uzbekistan | 0.22 | 105.38 | Mozambique | 0.00 | 0.00 |
| Qatar | 18.61 | 11,698.23 | Benin | 0.06 | 3.56 | Nepal | 0.00 | 0.00 |
| Iran | 17.09 | 62,673.23 | Tajikistan | 0.03 | 1.13 | Puerto Rico | 0.00 | 0.00 |
| United Arab Emirates | 16.83 | 44,847.49 | Niger | 0.01 | 0.57 | Rwanda | 0.00 | 0.00 |
| Nigeria | 16.31 | 37,532.76 | Lesotho | 0.00 | 0.00 | St. Kitts and Nevis | 0.00 | 0.00 |
| Azerbaijan | 15.21 | 6,085.23 | Luxembourg | 0.00 | 0.00 | St. Lucia | 0.00 | 0.00 |
| Venezuela | 11.02 | 37,898.86 | Antigua and Barbuda | 0.00 | 0.00 | St. Vincent and the Grenadines | 0.00 | 0.00 |
| Kazakhstan | 11.02 | 13,470.88 | Armenia | 0.00 | 0.00 | Samoa | 0.00 | 0.00 |
| Chad | 9.85 | 969.66 | Bhutan | 0.00 | 0.00 | Seychelles | 0.00 | 0.00 |
| Algeria | 9.63 | 14,147.03 | Burkina Faso | 0.00 | 0.00 | Sierra Leone | 0.00 | 0.00 |
| Ecuador | 7.22 | 4,608.15 | Burundi | 0.00 | 0.00 | Solomon Islands | 0.00 | 0.00 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Sudan | 5.92 | 2,598.30 | Cabo Verde | 0.00 | 0.00 | Suriname | 0.00 | 0.00 |
| Norway | 5.54 | 22,206.63 | Cambodia | 0.00 | 0.00 | Togo | 0.00 | 0.00 |
| Russia | 4.65 | 61,590.41 | Central African Republic | 0.00 | 0.00 | Tonga | 0.00 | 0.00 |
| Turkmenistan | 3.49 | 594.75 | Comoros | 0.00 | 0.00 | Uganda | 0.00 | 0.00 |
| Cameroon | 2.86 | 628.45 | Dominica | 0.00 | 0.00 | Vanuatu | 0.00 | 0.00 |
| Dem. Rep. of the Congo | 2.77 | 504.25 | Estonia | 0.00 | 0.00 | Zimbabwe | 0.00 | 0.00 |
| Colombia | 2.53 | 6,773.11 | Grenada | 0.00 | 0.00 | Fiji | 0.00 | 0.00 |
| Mexico | 2.04 | 20,365.71 | Guinea | 0.00 | 0.00 | Lebanon | 0.00 | -0.03 |
| Tunisia | 1.96 | 751.60 | Guyana | 0.00 | 0.00 | Malawi | 0.00 | -0.01 |
| Belize | 1.60 | 21.96 | Haiti | 0.00 | 0.00 | Mali | 0.00 | -0.02 |
| Egypt | 1.50 | 2,539.76 | Honduras | 0.00 | 0.00 | Moldova | 0.00 | -0.02 |
| Botswana | 0.00 | -0.04 | Bosnia and Herzegovina | -0.97 | -166.02 | Greece | -2.24 | -6,058.36 |
| Eswatini | 0.00 | -0.17 | China | -1.00 | -53,447.26 | Jamaica | -2.27 | -304.21 |
| Namibia | 0.00 | -0.51 | Japan | -1.01 | -57,006.06 | Slovakia | -2.28 | -1,726.70 |
| Kyrgyzstan | -0.04 | -1.60 | Italy | -1.08 | -22,819.16 | North Macedonia | -2.36 | -190.90 |
| Slovenia | -0.05 | -15.15 | Zambia | -1.09 | -168.04 | Ukraine | -2.40 | -2,796.52 |
| Georgia | -0.06 | 1.08 | El Salvador | -1.11 | -190.40 | Côte d'Ivoire | -2.56 | -621.58 |
| Gambia | -0.06 | -0.70 | Turkey | -1.14 | -7,613.75 | Nicaragua | -2.58 | -210.39 |
| Guinea-Bissau | -0.07 | -0.47 | Dominican Rep. | -1.17 | -499.26 | Trinidad and Tobago | -2.82 | -554.94 |
| Paraguay | -0.07 | -14.13 | Sweden | -1.22 | -5,653.99 | India | -2.93 | -44,052.59 |
| Brazil | -0.12 | -1,492.26 | Pakistan | -1.26 | -2,002.67 | Rep. of Korea | -3.29 | -33,043.33 |
| Tanzania | -0.15 | -23.22 | Czech Rep. | -1.29 | -2,399.13 | Bahamas | -3.46 | -346.59 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Ethiopia | -0.17 | -19.70 | Finland | -1.34 | -3,164.52 | Thailand | -3.96 | -11,979.47 |
| Papua New Guinea | -0.17 | -17.08 | Ghana | -1.35 | -167.92 | Bulgaria | -4.80 | -2,082.74 |
| Canada | -0.18 | -2,695.09 | Spain | -1.38 | -18,052.85 | Jordan | -5.62 | -1,164.18 |
| United Kingdom | -0.18 | -4,569.75 | Israel | -1.48 | -3,129.17 | Lithuania | -6.82 | -2,377.96 |
| Barbados | -0.22 | -10.55 | Hungary | -1.52 | -1,894.10 | Singapore | -7.87 | -15,214.70 |
| Switzerland | -0.26 | -1,401.22 | Poland | -1.53 | -6,518.40 | Bahrain | -8.56 | -1,391.41 |
| Australia | -0.27 | -2,781.42 | Sri Lanka | -1.55 | -682.98 | Belarus | -12.23 | -5,426.09 |
| Bangladesh | -0.38 | -363.11 | Kenya | -1.59 | -506.68 | | | |
| Costa Rica | -0.39 | -114.47 | Chile | -1.59 | -3,024.22 | | | |
| Madagascar | -0.42 | -30.60 | Uruguay | -1.65 | -570.81 | | | |
| Ireland | -0.43 | -877.36 | Portugal | -1.65 | -3,725.34 | | | |
| Austria | -0.61 | -2,273.22 | Romania | -1.66 | -2,395.15 | | | |
| Cyprus | -0.70 | -189.07 | Senegal | -1.77 | -251.83 | | | |
| Panama | -0.70 | -109.22 | Netherlands | -1.90 | -15,236.41 | | | |
| New Zealand | -0.74 | -1,015.30 | Philippines | -1.97 | -3,283.10 | | | |
| France | -0.85 | -21,624.18 | South Africa | -2.00 | -6,790.44 | | | |
| Germany | -0.87 | -29,045.75 | Croatia | -2.02 | -1,109.12 | | | |
| United States of America | -0.87 | -125,269.57 | Belgium | -2.11 | -9,588.85 | | | |
| Peru | -0.89 | -1,127.55 | Morocco | -2.19 | -1,701.15 | | | |

Source: Authors' own compilation. Rents are expressed in millions $2010 U.S. dollars.

# CERTIFICATE

## *Prize José Luis Sampedro*

In order to promote and disseminate the researches on world economy this certifies that **Antonio Jose Garzón Gordon** and **Luis Ángel Hierro Recio** with the paper entitled *La distribución internacional de la renta y el comercio de petróleo* won the **Prize José Luis Sampedro** of the **XXI International Congress of the Word Economy Society / Sociedad de Economía Mundial** held at the University of Beira Interior (Covilhã – Portugal) from June 12th to 14th, 2019.

The President of WES/SEM

(Julio Gaspar Sequeiros Tizón)

The Chair of the Organizing Committee

(José R. Pires Manso)

Sociedad de Economía Mundial
World Economy Society

UNIVERSIDADE BEIRA INTERIOR

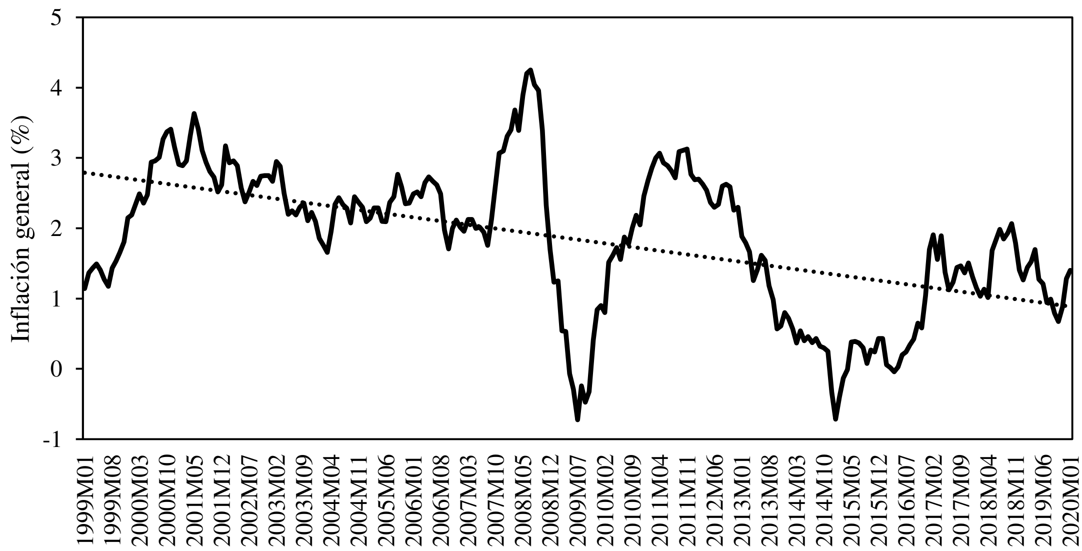
FACULDADE CIÊNCIAS SOCIAIS E HUMANAS
Departamento de Gestão e Economia

## 4.2. La transmisión de los shocks del precio del petróleo a la inflación: el papel del entorno de inflación

Las variaciones del precio del petróleo son uno de los principales factores que influyen en las variaciones de la tasa de inflación de los países importadores de petróleo, como son los pertenecientes a la zona euro (Alvarez et al., 2011), constituyendo así una importante fuente de las variaciones cíclicas de la inflación (Forbes, 2019). La transmisión de las variaciones del precio del petróleo a la inflación se produce por distintas vías: una vía directa, como consecuencia de su impacto en el precio de los combustibles y, por ello, en el componente energético de la cesta del IPC; una vía indirecta, ya que el petróleo y sus derivados son un input importante en los procesos de producción y alteran, por tanto, los costes de producción; y por último, los llamados efectos de segunda ronda, generados por la indexación de salarios y rentas del capital a la evolución del índice de precios (Peersman y Van Robays, 2009; Alvarez et al., 2011).

En las últimas décadas, y especialmente tras la Gran Recesión, los países desarrollados, entre los que destaca la zona euro, se han encontrado en un entorno de baja inflación, como muestra la Figura 9. En este contexto, es importante analizar si el entorno de inflación afecta a la transmisión de los precios del petróleo a la inflación. Algunos trabajos teóricos (Taylor, 2000; Devereux y Yetman, 2010) predicen que, en un entorno de baja inflación, los shocks de costes tienen una menor transmisión a los precios de los bienes de consumo, ya que las empresas actualizan sus precios con menor frecuencia y, además, perciben estos shocks como transitorios, por lo que la probabilidad de que transmitan esos mayores costes a sus precios son más reducidas. Existe evidencia empírica de la existencia de este tipo de no linealidad para el caso de la transmisión de las variaciones del tipo de cambio (Choudhri y Hakura, 2006; Junttila y Korhonen; 2012; Shintani et al., 2013; Cheik y Louhichi 2016; López-Villavicencio y Mignon, 2017; Cheik y Zaied, 2020); sin embargo, es escasa para el caso del precio del petróleo. Únicamente Sekine (2020) estudia esta relación para el caso de Estados Unidos, confirmando la hipótesis expuesta.

**Figura. 9**. Evolución de la inflación general en la zona euro.




Fuente: Eurostat. *Notas*: La línea negra representa la inflación media de los 12 países iniciales de la zona euro en términos interanuales. La línea discontinua muestra la tendencia lineal de la tasa de inflación.

Por otra parte, la transmisión del precio del petróleo a la inflación también puede ser asimétrica, de manera que aumentos y reducciones del precio den lugar a un efecto distinto sobre la inflación. Desde el punto de vista teórico, esta asimetría puede surgir a través de distintos canales. Por un lado, en la transmisión de las variaciones del precio del petróleo al precio de los combustibles. Existe una amplia literatura sobre el llamado "efecto cohetes y plumas", según el cual los aumentos del precio del petróleo se transmiten en mayor grado al precio de los combustibles que las caídas del mismo. Este hecho tiene varias explicaciones teóricas, entre ellas: la existencia de poder de mercado en el mercado minorista de los combustibles debido a la existencia de pocos competidores o los costes de búsqueda de precios (Borestein, 1991; Borestein et al., 1997); la propia respuesta asimétrica de los consumidores ante variaciones en el precio de la gasolina (Balke et al., 1998); o la gestión de inventarios y las técnicas contables empleadas (Balke et al., 1998). Por otra parte, el petróleo es un input en los procesos productivos y su precio afecta a los costes marginales. De esta forma, la asimetría puede surgir en la transmisión de esos costes a los precios de los bienes finales. Distintos modelos de establecimiento de precios estado-dependiente predicen que, en un entorno con inflación tendencial positiva, las variaciones positivas en los costes marginales son transmitidas en mayor grado a los precios finales que las variaciones negativas (Tsiddon, 1993; Ball y Mankiv, 1994; Devereux y Siu, 2007). Además, estos modelos suponen que la existencia de asimetría se ve afectada por el entorno de inflación, de manera que cuanto mayor sea la inflación tendencial mayor será la asimetría.

Finalmente, la asimetría puede surgir del distinto efecto de shocks positivos o negativos ejercen sobre la producción. Las causas de esta asimetría pueden encontrarse en: la rigidez en el mercado de trabajo asociada a los costes de recolocación de trabajadores de los sectores más intensos en energía, que amplifica las recesiones generadas por aumentos de los precios del petróleo (Hamilton, 1988; David y Haltiwanger, 2001); en la respuesta asimétrica de la política monetaria ante shocks positivos y negativos, puesto que desde los años 70 del siglo pasado los bancos centrales han tenido una clara tendencia a mostrar una mayor respuesta ante shocks por incrementos del precio del petróleo (Bohi, 1991; Bernanke et al., 1997); y en la incertidumbre y el estrés financiero que amplifican los efectos de los shocks positivos y amortiguan los negativos, bien por su incidencia en las decisiones futuras de inversión (Bernanke, 1983, Pindyck, 1991) o bien por el efecto en el ahorro por motivo precaución (Edelstein y Kilian, 2009). En este aspecto la mayor parte de los trabajos empíricos concluyen que los shocks por incrementos del precio del petróleo tienen un mayor efecto en la actividad económica que los shocks negativos (Mork, 1989; Bernanke et al., 1997; Balke et al., 2002; Hamilton, 2003; Jimenez-Rodriguez y Sanchez, 2005). No obstante, existen trabajos que no detectan esa asimetría (Kilian y Vigfusson, 2011 y 2013) o que solo la encuentran a nivel sectorial (Herrera et al. 2011).

La evidencia empírica sobre la existencia de asimetría en la transmisión de los precios del petróleo a la inflación es escasa y sus conclusiones son variadas. Por un lado, algunos trabajos como Balke et al. (2002) o An et al. (2014) encuentran que los shocks positivos tienen un mayor impacto en la inflación que los negativos, especialmente cuando éstos son de mayor magnitud, mientras que Lopez-Villavicencio y Pourroy (2019) señalan que, en aquellos países donde el Banco Central no lleva a cabo una estrategia de objetivo de inflación, los shocks positivos se transmiten en mayor grado a la inflación que los negativos, aunque esta asimetría desaparece en los países con objetivo de inflación. Por otra parte, para la zona euro se ha demostrado que, en periodos de incertidumbre financiera, los shocks negativos tienen una mayor transmisión y persistencia que los positivos (Evgenidis, 2018). Finalmente, Donayre y Wilmot (2016) encuentran hallan que, para el caso de Canadá, el grado en el que los shocks negativos se transmiten a la inflación es mayor que los shocks positivos, especialmente en periodos de bajo crecimiento económico.

En este marco, el objetivo de este trabajo es estudiar cómo el entorno de inflación afecta a la transmisión de los shocks del precio del petróleo a la inflación, así como analizar la existencia de asimetría en dicha transmisión y cómo ésta varía en función del entorno de inflación en el que se producen dichos shocks. Para ello, analizamos un panel de los 12 países iniciales de la zona euro para un periodo que abarca desde enero de 1999 hasta enero de 2020.

Puesto que las variaciones del precio del petróleo pueden originarse por distintos factores del mercado del petróleo y, por tanto, sus efectos macroeconómicos pueden ser distintos (Kilian y Barsky, 2004), distinguimos tres tipos de shocks: shocks de oferta de petróleo, shocks de demanda específica de petróleo y shocks de demanda agregada. Los shocks de oferta son causados por fluctuaciones exógenas en la producción de petróleo, de manera que una caída de la producción se traduce en un aumento del precio y viceversa. Por otra parte, los shocks de demanda específica de petróleo reflejan variaciones en la demanda específica de petróleo determinadas por motivos de especulación, precaución ante el riesgo de futuras caídas de la producción o cambios en las necesidades de petróleo de las empresas por cambios en sus tecnologías o modos de producción. Finalmente, los shocks de demanda agregada representan variaciones en la demanda de petróleo causadas por cambios en la actividad económica mundial.

### 4.2.1. Metodología

Para llevar a cabo nuestro trabajo, aplicamos una estrategia empírica de dos etapas, siguiendo a la propuesta por Kilian (2009) que ha sido ampliamente aplicada en el estudio de los efectos macroeconómicos de los shocks del precio del petróleo (Kilian et al., 2009; Habib et al., 2016; Lorusso y Pieroni, 2018; Jibril et al., 2020). En la primera etapa, estimamos un modelo SVAR del mercado del petróleo (Kilian, 2009) con el fin de identificar los shocks del precio del petróleo. En la segunda etapa, a través del método de proyecciones locales (Jordà, 2005), estimamos la transmisión de los shocks previamente identificados a la inflación en el panel de países de la zona euro. La selección de este modelo en lugar de estimar directamente un SVAR estado-dependiente con técnicas bayesianas se debe, en primer lugar, a la necesidad de estimar el modelo del mercado del petróleo para un periodo largo de tiempo (Kilian y Zhou, 2020), lo cual no es posible hacerlo en un SVAR en el que se incluyan las variables domésticas de la zona euro, ya que los datos están disponibles para un periodo de tiempo más corto. En segundo lugar, la correcta estimación del modelo del mercado del petróleo requiere incluir un número elevado de retardos (Hamilton y Herrera, 2004; Kilian, 2009), lo que hace necesaria también una muestra amplia para evitar la sobreparametrización.

*Identificación de los shocks del precio del petróleo*

Para identificar los shocks del precio del petróleo estimamos el modelo SVAR desarrollado por Kilian (2009) que nos permite identificar tres tipos de shocks: shocks de oferta de petróleo, shocks de demanda específica de petróleo y shocks de demanda agregada. Para ello, estimamos el siguiente modelo SVAR con tres variables:

$$A_0 Y_t = \alpha + \sum_{i=1}^{24} A_i Y_{t-i} + \varepsilon_t \tag{13}$$

Donde $Y_t$ es un vector de 3x1 de variables endógenas que son $\Delta prod_t$ que representa la variación porcentual de la producción de petróleo, $rea_t$ es el índice de actividad económica desarrollado por Kilian (2009), que representa las variaciones en la actividad económica mundial, y $rpo_t$ es el precio de adquisición de crudo por las refinerías, expresado en logaritmos. $\varepsilon_t$ es un vector de las innovaciones estructurales, que están incorreladas serialmente y entre ellas. Para obtener $\varepsilon_t$ a partir de la estimación VAR, asumimos que $A_0^{-1}$ tiene una estructura recursiva de forma que podemos recuperar las innovaciones estructurales $\varepsilon_t$ a partir de los errores de la estimación del VAR en forma reducida, $e_t$:

$$e_t = \begin{pmatrix} e_t^{\Delta prod} \\ e_t^{rea} \\ e_t^{rpo} \end{pmatrix} = \begin{pmatrix} a_{11} & 0 & 0 \\ a_{221} & a_{22} & 0 \\ a_{31} & a_{32} & a_{33} \end{pmatrix} \begin{pmatrix} \varepsilon_t^{shock\ oferta\ petróleo} \\ \varepsilon_t^{shock\ demanda\ agregada} \\ \varepsilon_t^{shock\ demanda\ específica} \end{pmatrix} \tag{14}$$

Para identificar los tres shocks estructurales empleamos una estructura recursiva basada en los siguientes supuestos:

- En primer lugar, para definir los shocks de oferta de petróleo asumimos que la producción de petróleo es inelástica en el corto plazo. Esto implica que ésta no reacciona contemporáneamente ni a variaciones en la actividad económica mundial ni al precio del barril de petróleo.

- En segundo lugar, para identificar los shocks de demanda agregada, asumimos que la actividad económica se ve afectada contemporáneamente por variaciones en la producción de petróleo, pero no por cambios en el precio. Es decir, la actividad económica solo se ve afectada con retardo por variaciones en el precio del petróleo. Por tanto, identificamos los shocks de demanda agregada como las innovaciones en el índice de actividad económica que no son explicadas por shocks de oferta de petróleo.

- Finalmente, en el caso de los shocks de demanda específica de petróleo, asumimos que el precio se ve afectado contemporáneamente tanto por cambios en la producción de petróleo como por variaciones en la actividad económica mundial. De esta forma, identificamos los shocks de demanda específica de petróleo como las innovaciones del precio del petróleo que no son explicadas por shocks de oferta de petróleo ni por shocks de demanda agregada.

Una vez identificados los shocks estructurales del mercado del petróleo $\varepsilon_t$, construimos las tres variables correspondientes a los shocks de oferta de petróleo, demanda específica de petróleo y de demanda agregada para el periodo de enero de 1999 a enero de 2020, que es el periodo de estudio que empleamos para la transmisión de los shocks del petróleo a la inflación en la zona euro.

*Estimación de la transmisión de los shocks del precio del petróleo a la inflación*

Para analizar la transmisión de los diferentes shocks estructurales del precio del petróleo a la inflación, empleamos como variables dependientes la inflación general y la inflación subyacente, alternativamente, con objeto de distinguir los efectos indirectos que generan dichos shocks. Para ello, estimamos la siguiente ecuación a través del método de proyecciones locales, similar a la empleada en otros trabajos como Sekine y Tsuruga (2018) o Caselli y Roitman (2019):

$$p_{i,t+h} - p_{i,t-1} = \alpha_{i,h} + \sum_{l=1}^{12} \mu_l^h (p_{i,t-i} - p_{i,t-1-i}) + \beta^h Shock_{a,t} + \sum_{l=0}^{12} \theta_l^h \, Control_{i,t} + \epsilon_{i,t+h} \quad (15)$$

Donde $p_{i,t}$ representa al índice de precios armonizados, en logaritmos, para el país i=1,2…12 y el periodo t=1,2,…,T. $Shock_{a,t}$ hace referencia a los tres distintos shocks previamente identificados, siendo a=1,2 y 3 en referencia a los shocks de oferta de petróleo, demanda específica de petróleo y demanda agregada, respectivamente, cuyo impacto en la inflación queremos estimar y cuyo valor es igual para cada país del panel de datos. $Control_{i,t}$ es un conjunto de variables de control, que incluye las variaciones porcentuales del índice de producción industrial y del tipo de cambio euro/dólar para cada país, incluyendo su valor contemporáneo y 12 retardos. También incluimos 12 retardos de la tasa de inflación para controlar la persistencia en la inflación (Sekine y Tsuruga, 2018). Finalmente, $\epsilon_{i,t+h}$ representa el término de error.

Para obtener la función de impulso respuesta, estimamos la ecuación para cada horizonte temporal h=0,1,…,H y obtenemos $\beta^h$ para cada horizonte, coeficiente que recoge la respuesta de la variable dependiente al shock en el periodo t. Por tanto, la función de impulso respuesta se obtiene agregando los coeficientes para todo el horizonte de estimación y es $IRF(h) = \beta^h$ para h =1, 2,...,H. En este trabajo escogemos un horizonte temporal de 24 meses. Para estimar cada ecuación, empleamos el estimador de Mínimos Cuadrados con Variable Dummy (LSDV) con la matriz de covarianzas consistente de autocorrelación y heterocedasticidad de New-West.

El método de proyecciones locales se puede extender para estimar funciones de impulso respuesta en modelos estado-dependiente. En concreto, siguiendo a Auerbach y Gorodnichenko (2012), el método de proyecciones locales se puede estimar como un modelo de transición suavizada, usando una función logística de transición entre los distintos estados. Para estimar si el entorno de inflación afecta al grado de transmisión de los shocks del petróleo a la inflación, estimamos la siguiente ecuación:

$$
\begin{aligned}
p_{i,t+h} - p_{i,t-1} = {} & \alpha_{i,h} \\
& + \left(1 - F(z_{i,t-1})\right)\left[\sum_{l=1}^{12} \mu_{H,l}^{h}\left(p_{i,t-i} - p_{i,t-1-i}\right) + \beta_H^h Shock_{a,t} + \sum_{l=0}^{12} \theta_{H,l}^{h}\, Control_{i,t}\right] \\
& + \left(F(z_{i,t-1})\right)\left[\sum_{l=1}^{12} \mu_{L,l}^{h}\left(p_{i,t-i} - p_{i,t-1-i}\right) + \beta_L^h Shock_{a,t} + \sum_{l=0}^{12} \theta_{L,l}^{h}\, Control_{i,t}\right] \\
& + \epsilon_{i,t+h}
\end{aligned} \tag{16}
$$

Donde F(.) es la función de transición que viene dada por la siguiente función logística:

$$F\left(z_{i,t-1}\right) = \frac{\exp(-\gamma z_{i,t-1})}{1+exp(-\gamma z_{i,t-1})} \quad \text{Con } \gamma > 0,$$

donde $z_{i,t-1}$ es la variable de transición. En nuestro trabajo, incluimos como variable de estado la tasa de inflación pasada estandarizada, como proponen Sekine y Tsuruga (2018). En concreto, en el modelo base empleamos la inflación subyacente, ya que representa mejor el entorno de inflación al excluir los componentes más volátiles del IPCA. Su expresión es la siguiente:

$$z_{i,t-1} = \frac{\pi_{i,t-1} - \bar{\pi}_i}{\widehat{\sigma_i}} \tag{17}$$

Siendo $\pi_{i,t-1}$ la tasa de inflación retardada del país i, $\bar{\pi}_i$ la tasa de inflación media del país durante el periodo analizado y $\widehat{\sigma_i}$ la desviación estándar de la tasa de inflación. $F\left(z_{i,t-1}\right)$ denota la probabilidad de encontrarse en el estado de baja inflación. Si $z_{i,t-1} \to \infty$, $F\left(z_{i,t-1}\right) \to 0$, por lo que la función de impulso respuesta vendrá dada por $\beta_H^h$, donde el subíndice H denota el entorno de alta inflación. Por el contrario, si $z_{i,t-1} \to -\infty$, $F\left(z_{i,t-1}\right) \to 1$, y la función de impulso respuesta estará dada por $\beta_L^h$, donde el subíndice L hace referencia al entorno de baja inflación. El parámetro $\gamma$ establece la velocidad de transición entre los dos estados. Si $\gamma = 0$, el modelo se convertiría en el modelo lineal, ya que $F\left(z_{i,t-1}\right)$ sería siempre ½. Por otra parte, si $\gamma$ es muy elevado, la transición entre estados sería inmediata, por lo que el modelo se aproximaría a un modelo de transición discreta con variable *dummy*. En este trabajo, seleccionamos $\gamma = 3$ que permite un grado intermedio de velocidad en el cambio de régimen, siguiendo a Tenreyro y Thwaites (2016). No obstante, en el siguiente apartado mostramos que los resultados obtenidos se mantienen robustos empleando otros valores de $\gamma$. La función de IR se obtiene de la siguiente forma: $IRF(h) = \left(1 - F(z_{i,t-1})\right)\beta_H^h + \left(F(z_{i,t-1})\right)\beta_L^H$. En nuestro caso, nos centramos en analizar los casos extremos cuando $F\left(z_{i,t-1}\right)$ toma valor 1 y 0, que representan las funciones de IR en entorno de baja y alta inflación, respectivamente.

Finalmente, para analizar la asimetría derivada del sentido del shock estimamos el modelo representado en la ecuación (16) sustituyendo la variable $Shock_{a,t}$ por las siguientes variables:

$$Shock_{a,t}^{+} = \begin{cases} Shock_t & si\ Shock_{a,t} > 0 \\ 0 & si\ Shock_{a,t} \leq 0 \end{cases} \quad y \quad Shock_t^{-} = \begin{cases} Shock_t & si\ Shock_{a,t} \leq 0 \\ 0 & si\ Shock_{a,t} > 0 \end{cases} \tag{18}$$

donde $Shock_{a,t}^{+}$ hace referencia a los shocks positivos, es decir, aquellos que incrementan el precio del petróleo, mientras que $Shock_{a,t}^{-}$ se refiere a los shocks negativos y que, por tanto, reducen el precio del petróleo. Introducimos ambas variables a la vez para evitar los problemas de sesgos que pueden inducir las variables truncadas. De esta forma, podemos analizar si existe asimetría en la transmisión de los distintos shocks en función de la dirección en la que se produzcan y si estas diferencias varían en función del entorno de inflación en el que se encuentre la economía.

*Robustez de los resultados*

Adicionalmente, contrastamos la robustez de los resultados obtenidos en nuestro trabajo con respecto a la siguientes dimensions: i) el método de identificación de los shocks del precio del petróleo, ii) la selección de la velocidad de transición entre regímenes, determinada por el parámetro $\gamma$, iii) a la selección de la variable de estado, $z_{i,t-1}$, utilizada para definir el entorno de inflación, y iv) al método empleado para determinar la transición entre estados o entornos de inflación.

*Identificación alternativa de los shocks del precio del petróleo*

En el modelo base identificamos los shocks del precio del petróleo a través de restricciones de exclusión con una estructura recursiva siguiendo la estrategia de identificación de Kilian (2009). Sin embargo, en la literatura sobre el mercado del petróleo está extendido el uso de restricciones de signos para identificar los distintos shocks del precio del petróleo. Para contrastar que nuestros resultados son robustos al método de identificación, llevamos a cabo la estrategia de identificación de Kilian y Murphy (2014) que distingue entre shocks de oferta de petróleo, shocks de demanda flujo de petróleo y shocks de demanda especulativa de petróleo. Para ello, los autores añaden una variable adicional al modelo de Kilian (2009) empleado en nuestro trabajo, que es la variación del stock de petróleo de la OCDE. Siguiendo a Kilian y Murphy (2014), empleamos las restricciones de signo en la respuesta contemporánea de las variables a los distintos shocks. Estas restricciones están recogidas en el artículo adjunto en la sección 4.2.3.

Además, se imponen dos restricciones adicionales. Por un lado, se establecen restricciones dinámicas en la respuesta de la producción de petróleo, la actividad económica mundial y el precio del petróleo, que mantienen el signo impuesto en la respuesta contemporánea durante 12 meses tras los shocks de oferta. Finalmente, se restringe la elasticidad-precio de la oferta de petróleo para que sea igual o menor que 0.025 en el impacto contemporáneo, mientras que la elasticidad precio de la demanda se restringe entre 0 y -0.8 (ver Kilian y Murphy, 2014).

*Velocidad de transición entre estados*

En nuestro modelo base, el valor del parámetro de velocidad de transición entre estados toma valor $\gamma = 3$, siguiendo a Tenreyro y Thwaites (2016). Para contrastar que los resultados obtenidos son robustos y no son sensibles a la selección de este parámetro, realizamos las estimaciones del modelo tomando $\gamma$ el valor 1.5 y 6, permitiendo que la velocidad de transmisión sea menor a la establecida en el modelo base, en el primer caso, y mayor en el segundo caso.

*Variable de estado*

En el modelo base empleamos como variable de estado la inflación subyacente estandarizada. La elección de la inflación subyacente obedece al hecho de que esta variable representa mejor el entorno de inflación, ya que no está expuesta a la volatilidad de los precios energéticos y de los alimentos. No obstante, otros trabajos (Sekine y Tsuruga, 2018; Cheik y Zaied, 2020; Sekine, 2020) emplean la inflación general como variable de estado. Para contrastar la robustez de los resultados, sustituimos la inflación subyacente por la inflación general.

*Determinación de la transición entre estados*

En este apartado, contrastamos la robustez de los resultados obtenidos empleando un enfoque alternativo para determinar el entorno de inflación en el que se encuentra la economía. Para ello extendemos el modelo lineal por medio de un modelo estado-dependiente con "variable de frontera" (Ahmed y Cassou, 2016; Ramey y Zubairy, 2018; Ahmed y Cassou, 2021), que viene representado por la siguiente ecuación:

$$\begin{aligned} p_{i,t+h} - p_{i,t-1} = {} & \alpha_{i,h} \\ & + D_{i,t-1}\left[\sum_{l=1}^{12} \mu_{H,l}^{h}\left(p_{i,t-i} - p_{i,t-1-i}\right) + \beta_H^h Shock_{a,t} + \sum_{l=0}^{12} \theta_{H,l}^{h}\, Control_{i,t}\right] \\ & + \left(1 - D_{i,t-1}\right)\left[\sum_{l=1}^{12} \mu_{L,l}^{h}\left(p_{i,t-i} - p_{i,t-1-i}\right) + \beta_L^h Shock_{a,t}\right. \\ & \left. + \sum_{l=0}^{12} \theta_{L,l}^{h}\, Control_{i,t}\right] + \epsilon_{i,t+h} \end{aligned} \tag{18}$$

donde $D_{i,t-1} \in \{0,1\}$ es una variable *dummy* que representa el entorno de inflación y que se define de la siguiente forma:

$$D_{i,t-1} = \begin{cases} 1 \; si \; \pi_{i,t-1} > \bar{\pi}_i \\ 0 \; si \; \pi_{i,t-1} \leq \bar{\pi}_i \end{cases} \tag{19}$$

Donde $\pi_{i,t-1}$ es la inflación subyacente pasada en el país i, y $\bar{\pi}_i$ es la tasa de inflación subyacente media a lo largo del periodo estudiado. Por tanto, la variable $D_{i,t-1}$ toma valor 1, y por tanto, indica que la economía se encuentra en un entorno de alta inflación, cuando la inflación pasada es superior a la inflación media del país, mientras que la economía se encontrará en un entorno de baja inflación cuando la tasa de inflación pasada sea inferior a la inflación media. Este método difiere del empleado en la especificación base, ya que no asume la existencia de una transición suavizada entre regímenes o entornos de inflación, sino que la transición se produce cuando la variable de estado superar el valor establecido como frontera entre estados.

*<u>Datos</u>*

Empleamos datos mensuales para el periodo que abarca desde enero de 1999 hasta enero de 2020, para un panel de los 12 países miembros iniciales de la zona euro (Austria, Bélgica, Finlandia, Francia, Alemania, Grecia, Irlanda, Italia, Luxemburgo, Países Bajos, Portugal y España). Nuestra muestra abarca desde la creación del euro hasta los últimos datos disponibles. Los datos del IPCA y del IPCA subyacente son obtenidos de Eurostat. El tipo de cambio euro/dólar es obtenido de la base de datos IFS del FMI y el índice de producción industrial se obtiene de la base de datos de la OCDE. Tanto el nivel de precios general y subyacente como la producción industrial están ajustadas estacionalmente.

Por otra parte, para la identificación de los shocks del petróleo (Kilian, 2009), usamos datos mensuales que abarcan desde enero de 1974 hasta enero de 2020. Los datos usados son la producción mundial de petróleo, el precio de adquisición del crudo por las refinerías, ambos obtenidos del US. EIA, y el índice de actividad económica elaborado por Kilian (2009). Tras obtener las tres variables representativas de los shocks estructurales, empleamos las variables obtenidas para el periodo desde enero de 1999 hasta enero 2020.

### 4.2.2. Resultados

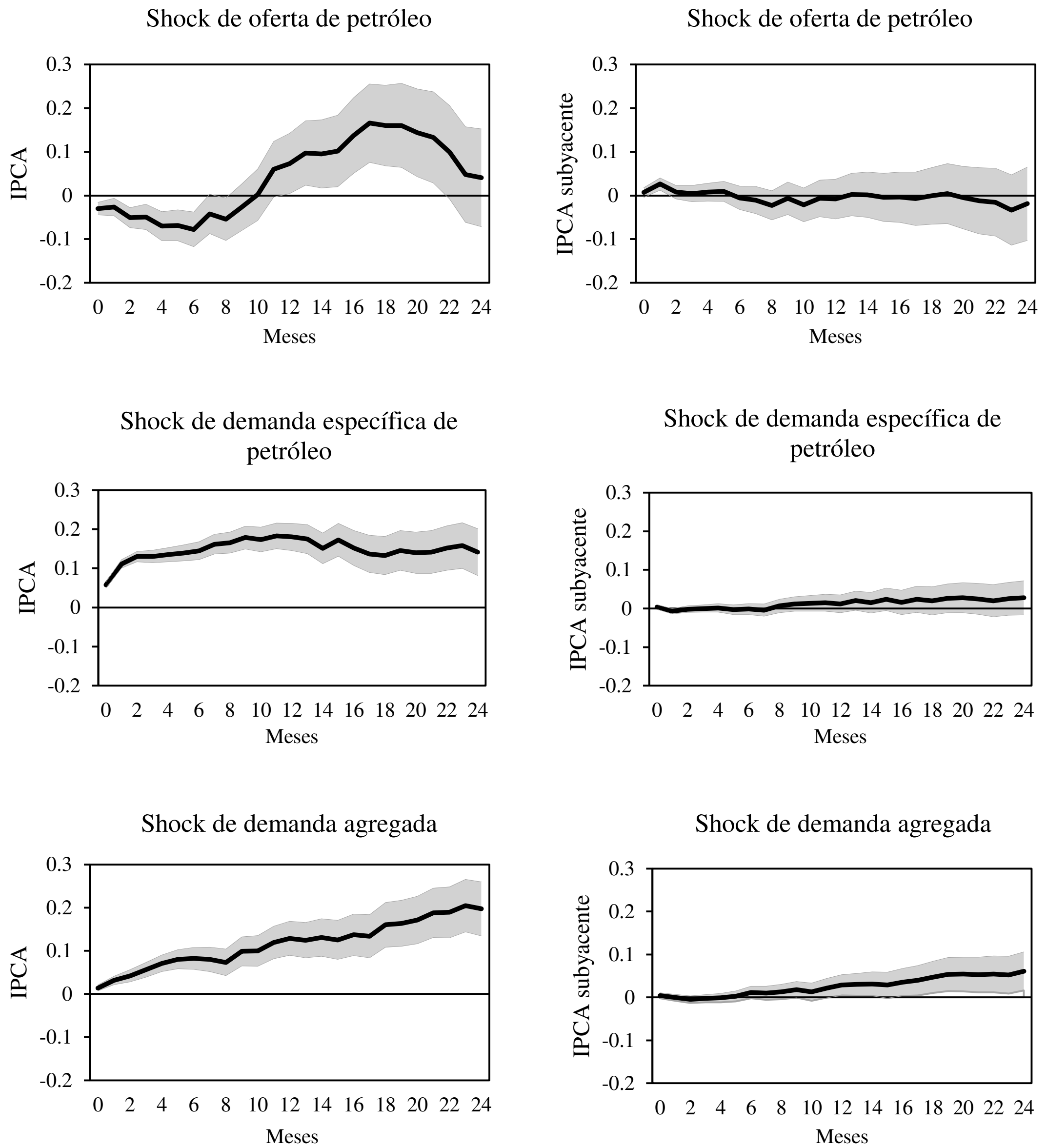
La Figura 11 presenta el efecto acumulado sobre el nivel de precios de los shocks del precio del petróleo tanto en la inflación general como subyacente para la estimación del modelo lineal. Se observa que la transmisión a la inflación de los shocks difiere en función de su origen. Para la inflación general (columna 1), los shocks de oferta de petróleo tienen una transmisión retardada a partir del sexto mes y su efecto tiende a desaparecer a largo plazo. Los shocks de demanda agregada son los que producen un mayor efecto inflacionario a largo plazo, ya que producen un aumento persistente de la inflación a lo largo de la ventana de la función de impulso respuesta. Finalmente, los shocks de demanda específica muestran un elevado impacto inicial, manteniéndose éste a largo plazo.

En cuanto a los efectos indirectos, reflejados en la transmisión de los shocks a la inflación subyacente, los resultados muestran que los shocks de demanda específica tienen escaso efecto acumulado, mientras que los de oferta es prácticamente nulo, lo que confirma que el efecto de los shocks del petróleo se produce especialmente sobre el índice general y no sobre la inflación subyacente. En el caso de los shocks de demanda agregada, su transmisión a la inflación subyacente es superior a la de los casos anteriores, ya que estos shocks son causados por aumentos en la actividad económica global que pueden afectar positivamente a la demanda de los países de la zona euro. No obstante, su transmisión es mucho más reducida que en el caso de la inflación general.

En la Figura 12 se representan las funciones de impulso respuesta de la inflación a los shocks del precio del petróleo cuando controlamos por el entorno de inflación en el que se producen dichos shocks. Los resultados muestran que el entorno de inflación en el que se producen los shocks afecta a su transmisión a la inflación. Ante shocks de oferta y, especialmente, ante shocks de demanda agregada, la respuesta de la inflación es superior en entornos de alta inflación que en entornos de baja inflación. Estos resultados están en línea con las predicciones teóricas de Taylor (2000) y Devereux y Yetman (2010).

En periodos de alta inflación, los shocks de demanda agregada muestran una mayor y más persistente transmisión a la inflación general que en entornos de baja inflación, donde el impacto es más reducido y se ve revertido al final del horizonte. Por otra parte, la respuesta de la inflación subyacente es distinta. En entornos de baja inflación, los shocks de demanda agregada se transmiten inicialmente a ésta, manteniéndose estable a partir del segundo año, mientras que, en entornos de alta inflación, la transmisión es nula en el primer año, produciéndose un efecto positivo en la inflación subyacente a partir del segundo año. No obstante, el grado de transmisión a la inflación subyacente es reducido, por lo que la evolución mostrada por la inflación general en ambos entornos es causada principalmente por la reacción de los precios energéticos.

**Figura 11**. Impulso respuesta acumulada de la tasa inflación general y de la inflación subyacente a los tres shocks estructurales del mercado de petróleo en el modelo lineal.

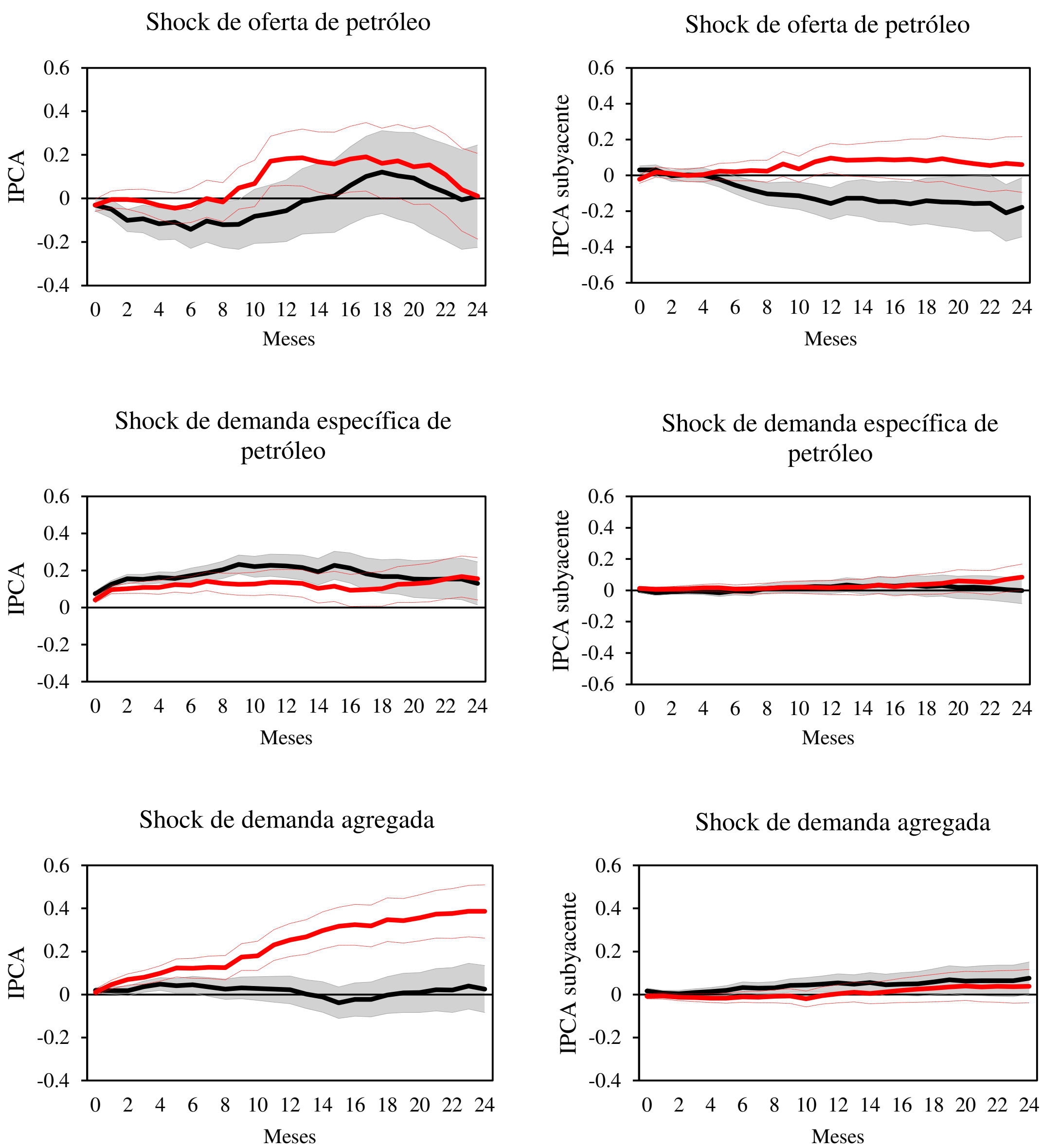



*Notas*: la figura muestra el efecto acumulado sobre la inflación general (columna 1) y subyacente (columna 2), en porcentaje, de un shock de 1 desviación estándar. El área sombreada muestra el intervalo de confianza al 90%. Los shocks de oferta están multiplicados por -1 para representar una caída de la producción.

Los shocks de oferta de petróleo también presentan una transmisión más directa a la inflación general en entornos de alta inflación, aunque las diferencias son menos pronunciadas que en el caso de los shocks de demanda agregada. En cuanto a la inflación subyacente, la transmisión es ligeramente positiva en entornos de alta inflación, mientras que, en entornos de baja inflación, tras una transmisión ligeramente positiva, se ve revertida posteriormente, pasando a ser negativo en el largo plazo.

Finalmente, los shocks de demanda específica presentan una transmisión inicialmente menor en entornos de alta inflación, aunque a largo plazo la transmisión es similar como consecuencia de una mayor persistencia en la respuesta de la inflación general en entornos de alta inflación que en entornos de baja inflación. Esta mayor persistencia es, en parte, consecuencia de una mayor transmisión de estos shocks a la inflación subyacente en entornos de alta inflación, lo que sugiere la existencia de mayores efectos indirectos.

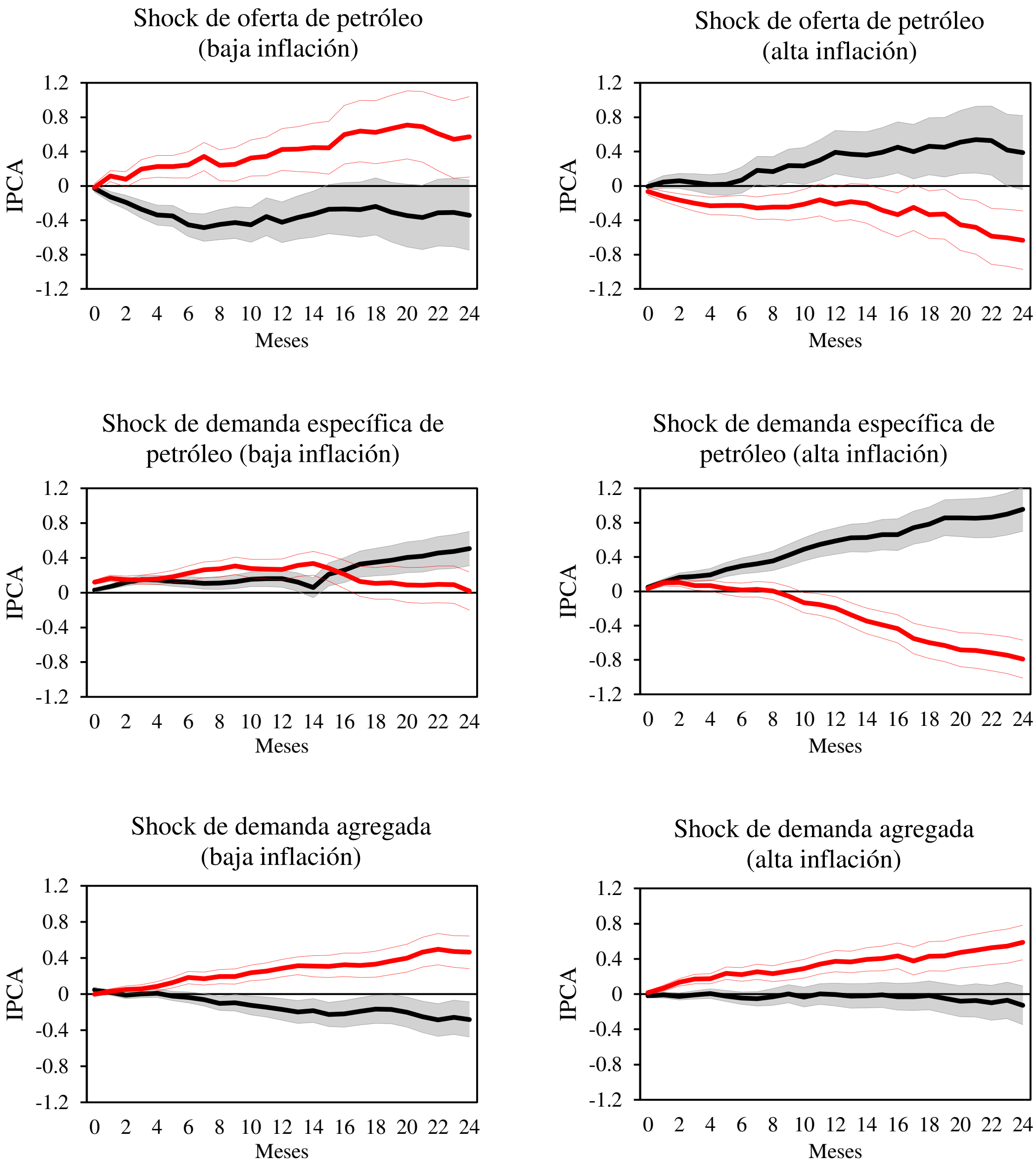
**Figura. 12.** Impulso respuesta acumulada de la tasa inflación general y subyacente a los tres shocks estructurales del mercado de petróleo en función del entorno de inflación.




*Notas*: la figura muestra el efecto acumulado sobre la inflación general (columna 1) y subyacente (columna 2), en porcentaje, de un shock de 1 desviación estándar. La línea negra representa la respuesta acumulada de la inflación a un shock en un entorno de baja inflación. La línea roja representa la respuesta acumulada de la inflación a un shock en un entorno de alta inflación. Las áreas sombreadas muestran el intervalo de confianza al 90%.

Los resultados presentados hasta ahora asumen que la respuesta de la inflación a los shocks es simétrica, es decir, no varía en función del signo del shock. Las Figuras 13 y 14 muestran la respuesta de la inflación general y subyacente, respectivamente, distinguiendo entre shocks positivos y negativos, teniendo en cuenta el entorno de inflación en el que se producen. Es decir, ampliamos el modelo anterior permitiendo la existencia de comportamientos asimétricos que pueden depender del entorno de inflación en el que tienen lugar. Estos resultados se encuentran resumidos en la Tabla 6 y 7.

**Figura 13.** Impulso respuesta acumulada de la tasa de inflación general a los tres shocks estructurales en función del entorno de inflación y la dirección del shock.




*Notas*: La columna 1 y 2 muestran la respuesta de la inflación en entornos de baja y alta inflación, respectivamente. La línea negra hace referencia al IR ante un shock positivo. La línea roja representa la IR ante un shock negativo. Los shocks negativos están multiplicados por -1 para facilitar su comparabilidad. Las áreas sombreadas muestran el intervalo de confianza al 90%.

Los resultados indican que existe asimetría en la respuesta de la inflación a los shocks del precio del petróleo y que dicha asimetría depende del entorno de inflación en el que se producen los shocks.

En el caso de los shocks de oferta de petróleo, su transmisión presenta una asimetría cuya dirección varía en función del entorno de inflación. En entornos de baja inflación, los shocks negativos generan una caída de la inflación, mientras que los shocks positivos provocan una respuesta en forma de U, con una caída inicial de la inflación, presentando un efecto positivo a partir de los seis meses, pero cuya magnitud no es suficiente para compensar la caída inicial, por lo que el efecto acumulado sobre el nivel de precios se mantiene en negativo. En entornos de alta inflación, por el contrario, son los shocks positivos los que se transmiten en mayor grado a la inflación, mientras que los shocks negativos no producen una caída del nivel de precios, sino que su efecto acumulado genera un mayor nivel de precios. Esta asimetría está en línea con la generada en los modelos teóricos de Tsiddon (1993), Ball o Mankiv (1994) o Devereux y Siu (2007) y reflejan la respuesta de la inflación subyacente, por lo que, en entornos de alta inflación, los efectos indirectos tienen un peso relativamente importante, mientras que en entornos de baja inflación la respuesta de la inflación subyacente es prácticamente nula.

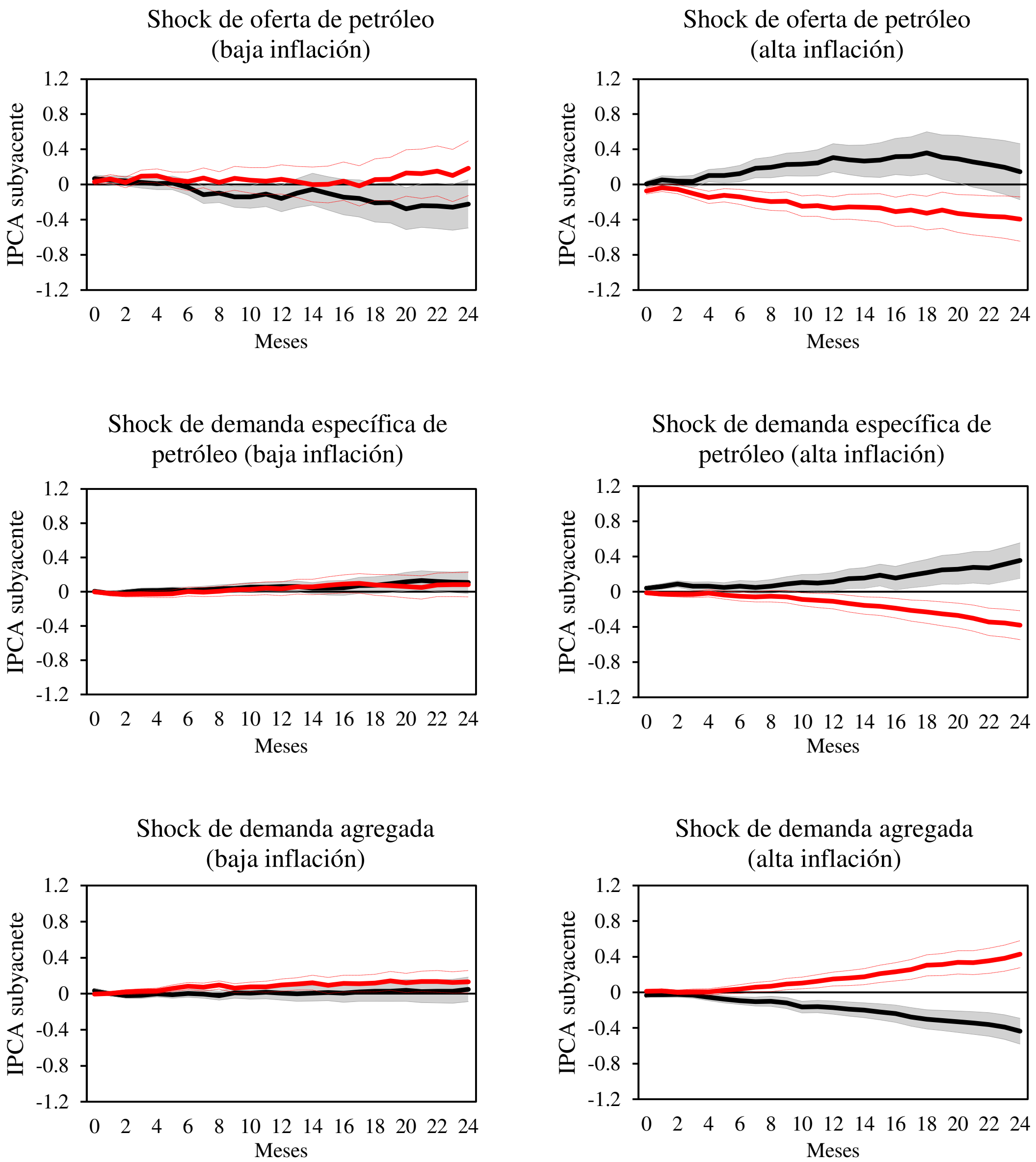
**Tabla 6**. Resumen de la transmisión de los shocks estructurales del mercado del petróleo a la inflación general.

| *Entorno* | *Signo* | *Positivo* | | | *Negativo* | | | *Diferencia por tipo de shock* | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | *Shock* | *OP* | *DE* | *DA* | *OP* | *DE* | *DA* | *OP* | *DE* | *DA* |
| *Baja inflación* | *Impacto acumulado máximo (%)* | -0,03 | 0,51 | 0,05 | 0,71 | 0,34 | 0,50 | -0,74 | 0,17 | -0,45 |
| | *Impacto acumulado 12 meses (%)* | -0,42 | 0,16 | -0,17 | 0,42 | 0,27 | 0,29 | -0,85 | -0,11 | -0,46 |
| | *Impacto acumulado 24 meses (%)* | -0,34 | 0,51 | -0,28 | 0,57 | 0,02 | 0,46 | -0,91 | 0,49 | -0,75 |
| *Alta inflación* | *Impacto acumulado máximo (%)* | 0,54 | 0,96 | 0,00 | -0,07 | 0,10 | 0,59 | 0,60 | 0,85 | -0,58 |
| | *Impacto acumulado 12 meses (%)* | 0,39 | 0,59 | 0,00 | -0,21 | -0,19 | 0,37 | 0,61 | 0,78 | -0,38 |
| | *Impacto acumulado 24 meses (%)* | 0,39 | 0,96 | -0,13 | -0,63 | -0,79 | 0,59 | 1,02 | 1,75 | -0,71 |
| *Diferencia por entorno* | *Impacto acumulado máximo (%)* | 0,57 | 0,45 | -0,04 | -0,78 | -0,23 | 0,09 | | | |
| | *Impacto acumulado 12 meses (%)* | 0,82 | 0,43 | 0,17 | -0,64 | -0,46 | 0,09 | | | |
| | *Impacto acumulado 24 meses (%)* | 0,73 | 0,45 | 0,15 | -1,20 | -0,81 | 0,12 | | | |

Fuente: Elaboración propia. *Notas:* El impacto acumulado representa el cambio en puntos porcentuales del nivel de precios general generado por los shocks. *OP* denota oferta de petróleo, *DE* denota demanda específica de petróleo y *DA* denota demanda agregada.

En el caso de los shocks de demanda específica de petróleo, los resultados también están en línea con la teoría, ya que encontramos una asimetría que es mayor en entornos de alta inflación. En entornos de baja inflación, la transmisión de ambos shocks es similar, aunque los shocks positivos presentan una mayor persistencia, mientras que los negativos se ven revertidos al final del horizonte. Por el contrario, en entornos de alta inflación la transmisión de los shocks positivos es mayor y más persistente, mientras que, ante shocks negativos, tras una caída inicial de la inflación, la transmisión se ve revertida, por lo que el impacto acumulado acaba también en un mayor nivel de precios. Finalmente, los efectos indirectos, reflejados en la inflación subyacente, son relevantes en entornos de alta inflación, especialmente ante shocks positivos, mientras que en entornos de baja inflación su transmisión es muy reducida. Estos resultados confirman la necesidad de tener en cuenta la dirección del shock al analizar su transmisión a la inflación, ya que cuando solo considerábamos el entorno de inflación, los resultados mostraban que la transmisión era mayor en un entorno de baja inflación, resultados que son rechazados cuando se distingue entre shocks positivos y negativos, demostrando que el resultado anterior era el resultado de la mayor asimetría que existe en la respuesta en entornos de alta inflación.

**Figura 14.** Impulso respuesta acumulada de la tasa de inflación subyacente a los tres shocks estructurales del mercado de petróleo en función del entorno de inflación y la dirección del shock.




*Notas*: La columna 1 y 2 muestran la respuesta de la inflación en entornos de baja y alta inflación, respectivamente. La línea negra hace referencia al IR ante un shock positivo. La línea roja representa la IR ante un shock negativo. Los shocks negativos están multiplicados por -1 para facilitar su comparabilidad. Las áreas sombreadas muestran el intervalo de confianza al 90%.

En lo que respecta a los shocks de demanda agregada, es decir, aquellos provocados por variaciones en la actividad económica mundial, observamos un patrón distinto a los shocks anteriormente descritos. Encontramos que, en ambos estados, existe una asimetría negativa, es decir, la transmisión de los shocks negativos es superior a la de los shocks positivos. De hecho, la transmisión de estos últimos es muy reducida, teniendo incluso un impacto acumulado negativo en entornos de baja inflación. En cuanto a la inflación subyacente, la transmisión de estos shocks es prácticamente nula en entornos de baja inflación, como encontramos para el resto de shocks, mientras que en entornos de alta inflación observamos que los shocks negativos producen una caída de la inflación subyacente, como es esperado, mientras que los shocks positivos, en lugar de generar un aumento de la inflación subyacente, acaban teniendo también un impacto negativo, compensando las presión inflacionista del componente energético, lo que explica la nula transmisión que se observa en la inflación general.

**Tabla 7**. Resumen de la transmisión de los shocks estructurales del mercado del petróleo a la inflación subyacente.

| *Entorno* | *Signo* | *Positivo* | | | *Negativo* | | | *Diferencia por tipo de shock* | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | *Shock* | *OP* | *DE* | *DA* | *OP* | *DE* | *DA* | *OP* | *DE* | *DA* |
| *Baja inflación* | *Impacto acumulado máximo (%)* | 0.07 | 0.13 | 0.05 | 0.18 | 0.1 | 0.14 | -0.12 | 0.03 | -0.09 |
| | *Impacto acumulado 12 meses (%)* | -0.16 | 0.06 | 0.01 | 0.06 | 0.03 | 0.1 | -0.22 | 0.03 | -0.09 |
| | *Impacto acumulado 24 meses (%)* | -0.22 | 0.11 | 0.05 | 0.18 | 0.08 | 0.13 | -0.41 | 0.02 | -0.08 |
| *Alta inflación* | *Impacto acumulado máximo (%)* | 0.36 | 0.36 | -0.02 | -0.04 | -0.01 | 0.43 | 0.4 | 0.37 | -0.45 |
| | *Impacto acumulado 12 meses (%)* | 0.31 | 0.11 | -0.17 | -0.27 | -0.11 | 0.15 | 0.57 | 0.22 | -0.32 |
| | *Impacto acumulado 24 meses (%)* | 0.15 | 0.36 | -0.44 | -0.39 | -0.38 | 0.43 | 0.54 | 0.74 | -0.86 |
| *Diferencia por entorno* | *Impacto acumulado máximo (%)* | 0.29 | 0.22 | -0.07 | -0.22 | -0.11 | 0.29 | | | |
| | *Impacto acumulado 12 meses (%)* | 0.46 | 0.05 | -0.18 | -0.33 | -0.14 | 0.05 | | | |
| | *Impacto acumulado 24 meses (%)* | 0.37 | 0.25 | -0.48 | -0.58 | -0.47 | 0.30 | | | |

Fuente: Elaboración propia. *Notas:* El impacto acumulado representa el cambio en puntos porcentuales del nivel de precios subyacente generado por los shocks. *OP* denota oferta de petróleo, *DE* denota demanda específica de petróleo y *DA* denota demanda agregada.

Estos resultados, contrarios a los obtenidos para los shocks propios del mercado del petróleo (oferta y demanda específica de petróleo), son comparables a los obtenidos por Evgenidis (2018), que encuentra que, en periodos de alto estrés financiero, los shocks negativos tienen un impacto superior que los positivos en la zona euro, y con Donayre y Wilmot (2016), que muestran que los shocks negativos tienen un mayor impacto en la inflación en periodos de bajo crecimiento económico para el caso de Canadá. Una posible explicación a la reducida transmisión de los shocks positivos de demanda agregada es que la política monetaria reacciona de forma asimétrica, de manera que ofrece una mayor reacción ante presiones inflacionistas generadas por el incremento de los precios del petróleo que ante presiones deflacionistas, lo cual quedaría reflejado en la reacción de la inflación subyacente, que presenta un impacto acumulado negativo. Otra explicación recaería en la existencia de un impacto asimétrico de las fluctuaciones de la actividad económica mundial en los países de la Eurozona, de manera que las caídas de la actividad económica producen una presión deflacionista mientras que los aumentos de la actividad económica no se transmiten a la actividad doméstica en estos países, por lo que el aumento del precio del petróleo se ve compensado por una caída de la actividad económica como consecuencia de su encarecimiento, lo que pone una presión deflacionaria sobre la inflación subyacente.

Finalmente, los resultados encontrados en este trabajo presentan alguna implicación relevante para la conducción de la política monetaria. Éstos muestran que, en entornos de baja inflación, la transmisión de los shocks del precio del petróleo a la inflación subyacente es insignificante, lo que significa que no produce efectos indirectos. Puesto que la política monetaria del BCE se centra en la dinámica de la inflación a medio plazo, representada por la evolución de la inflación subyacente, en entornos de baja inflación el *trade-off* que producen los shocks de costes entre estabilizar la inflación y estabilizar la producción se ve muy reducido. Es decir, los shocks del precio del petróleo en entornos de baja inflación solo afectan a la inflación general a través de su componente energético, sin provocar efectos indirectos o de segunda ronda que obliguen al banco central a endurecer su política monetaria para evitar una espiral inflacionaria. De esta manera, el banco central no tiene que sacrificar crecimiento económico para evitar un aumento persistente de la inflación.

A título de ejemplo, en julio de 2008, justo antes del comienzo de la crisis financiera internacional, el BCE elevó los tipos de interés en 25 puntos básicos, como reacción a una subida del precio del petróleo que se atribuía al aumento de la demanda de petróleo. La política monetaria era coherente con lo previsible según el modelo lineal, sin embargo, no hubiera sido considerada tal atendiendo a los resultados obtenidos cuando tenemos en cuenta el entorno de inflación y la dirección de los shocks. La necesidad de un análisis detallado de la transmisión de los shocks del petróleo a la inflación en función del entorno se muestra en este caso indispensable para una correcta definición de la política monetaria.

Finalmente, como indicamos en el apartado anterior, contrastamos la robustez de los resultados utilizando: una identificación alternativa de los shocks del precio del petróleo, el uso de distintas velocidades de transición entre estados, el uso de la inflación general como variable de estado o el empleo de un modelo alternativo para determinar la transición entre estados. Los resultados, que se encuentran en el apéndice del artículo adjunto en la sección 4.2.3, demuestran que las conclusiones obtenidas en nuestro modelo base se mantienen en todas las especificaciones alternativas, por lo que podemos concluir que los resultados son robustos.

### 4.2.3. Artículo nº 4.

### Asymmetries in the transmission of oil price shocks to inflation in the eurozone.

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# Asymmetries in the transmission of oil price shocks to inflation in the eurozone[☆]

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ABSTRACT

Theory predicts that the level of inflation in an economy and the trend in the prevailing inflation rate may affect how oil price shocks, through their influence on firms' expectations and price-setting behaviors, are transmitted to inflation. However, empirical evidence regarding this relationship is limited and calls for further exploration. Using data for 12 eurozone countries over the period from 1999 to 2020, we analyze how the inflation environment in which an oil price shock occurs influences its transmission. We find that the inflation environment is a determinant in the way oil supply shocks and oil-specific demand shocks are transmitted to inflation, with positive shocks displaying higher transmission in high inflation environments. Furthermore, transmission of shocks to core inflation, which represents an indirect effect, only occurs in high inflation environments. These findings highlight the need to consider the inflation environment in order to define appropriate monetary policies in response to inflationary pressures caused by oil price shocks.

## 1. Introduction

The price of oil as well as fluctuations in that price can significantly affect the evolution of a number of macroeconomic variables. The oil price shocks of the 1970s are a clear example of this (Hamilton, 1983, 1996; Mork, 1989); after those events, controlling inflation became a principal economic policy objective, particularly for monetary policy, and oil prices became a fundamental factor in analyzing economic conditions. Currently, most central banks have long-term inflation targets based on a core inflation measure that excludes an energy component. However, medium-term inflation targets are conditioned by the transmission of oil prices to consumer prices.

Oil price shocks affect inflation through two different channels as follows: directly, as fuel prices are part of the energy component of the so-called headline inflation price index and indirectly, whereby oil price shocks alter production costs and generate second-round effects on wages and incomes that are indexed to changes in consumer prices (Peersman and Van Robays, 2009; Álvarez et al., 2011). Oil price changes are one of the main factors that influence the variability of the headline inflation rate in oil-importing countries, including the United States (US) (Blanchard and Gali, 2007) and regions such as the eurozone (Álvarez et al., 2011). Analyzing how oil price shocks are transmitted to inflation is of special relevance, particularly in a context in which cyclical fluctuations in the inflation rate are mainly determined by international factors such as commodity prices (Forbes, 2019), among which oil is key.

In recent decades, inflation has trended downward in developed economies, especially after the global financial crisis, as shown in Fig. 1 for eurozone inflation. In a climate of low inflation, analyzing how cost-push shocks such as oil price shocks are transmitted to consumer prices is of major importance. Theoretically, when the inflation trend is low, the degree to which cost shocks are transmitted to inflation is lower than in a high inflationary environment for a number of reasons. In an economy with staggered price settings and monopolistic competition, cost shocks in a low inflationary environment are perceived by firms as transitory such that firms are less likely to transmit these costs through their prices (Taylor, 2000). Following this line of thought, if the frequency with which firms update their prices is endogenous to the inflation environment such that the frequency of price updates increases when the inflation trend is higher (Devereux and Yetman, 2010), the transmission of cost shocks to inflation will be greater in an environment of high-trend inflation as more firms modify their prices more frequently, passing on these higher costs through their prices.

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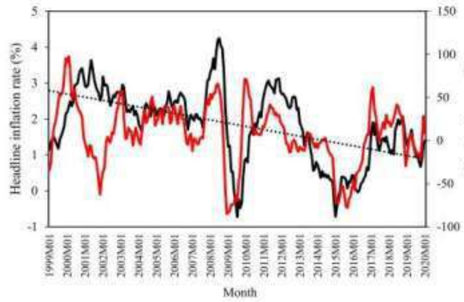


**Fig. 1.** Evolution of eurozone average headline inflation and oil price changes (1999.01–2020.01). The black line represents the average year-on-year inflation rate of the 12 original eurozone countries. The dashed line represents the linear trend of the inflation rate. The red line represents the year-on-year change of oil prices, proxied by the US imported refiner acquisition cost of crude oil. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

Another possible source of non-linearity in the transmission of oil price shocks to inflation is the existence of an asymmetry that depends on the direction of the shock; in other words, the impact of positive shocks (oil price increases) and negative shocks may differ. This asymmetric transmission may arise from different channels. One such channel is via the direct impact of oil price shocks on fuel prices, as fuels represent an important share of the basket of goods and services in the eurozone's Harmonized Index of Consumer Prices (HICP) and, therefore, directly affect headline inflation. This is the so-called "rockets and feathers" effect in the retail fuel market (Bacon, 1991) such that positive changes in the price of oil are transmitted to fuel prices to a greater degree than negative changes. This result has several theoretical explanations: the existence of market power in the retail fuel market because of its small number of competitors and/or high search costs (Borenstein, 1991; Borenstein et al., 1997); the asymmetric response of consumers to variations in fuel prices (Balke et al., 1998); or inventory management and accounting techniques used (Balke et al., 1998). Moreover, oil is an input in the production process of many firms and, hence, its price variation affects their marginal costs. In this sense, asymmetry may arise from the existence of menu costs. In an economy with positively trending inflation and monopolistic competition where firms set prices for several periods and face menu costs when changing their prices, firms adjust their prices more frequently in the face of increases in marginal costs than after decreases in those costs (Tsiddon, 1993; Ball and Mankiw, 1994). This implies that positive oil price shocks will transmit to inflation to a greater degree than negative shocks. Further, higher the inflation trend, the greater the asymmetry.

Another source of this asymmetry is the differing impact of positive and negative oil price shocks on economic activity. It has been argued that positive shocks have a greater effect on economic activity than negative shocks. This asymmetric response may be caused by one or more factors, including: (1) rigidities in the labor market associated with worker reallocation costs in the most energy-intensive sectors, which amplifies the recessionary effect generated by oil price increases (Hamilton, 1988; Davis and Haltiwanger, 2001); (2) the asymmetric response of monetary policy to positive and negative shocks given that since the 1970s, central banks have shown a clear tendency to have a greater response to positive oil shocks than negative shocks (Bohi, 1991; Bernanke et al., 1997); and (3) the uncertainty and financial stress that amplifies positive shocks and dampens negative shocks, either because of their impact on future investment decisions (Bernanke, 1983; Pindyck, 1991) or their effect on precautionary savings (Edelstein and Kilian, 2009).

As the effect of oil price shocks on inflation differs depending on the source of the shock (Barsky and Kilian, 2004), it is important to differentiate between different types of shocks. Following Kilian (2009), we distinguish three main types of shocks: (1) oil supply shocks caused by exogenous changes in oil production, whereby a decline in oil production translates to an increase in oil prices and vice versa; (2) oil-specific demand shocks, which reflect changes in oil demand caused by speculation, precautionary moves against the risk of future supply disruptions, or changes in firms' oil needs because of changes in their technologies or production processes; and (3) aggregate demand shocks, which represent changes in oil demand caused by fluctuations in global economic activity.

To the best of our knowledge, no study has comprehensively analyzed the effect of oil price shocks on inflation by jointly considering the inflation environment in which such shocks occur and the possible existence of asymmetric response. This study aims to fill this gap by examining how the inflation environment affects the transmission of oil price shocks to inflation as well as the existence of asymmetries, and how they vary depending on the inflation environment in which the shock occurs.

In this study, we analyze the transmission of oil price shocks to inflation using a panel of the 12 initial eurozone countries. We analyze the transmission of these shocks to headline inflation, which includes energy prices, as well as core inflation. This allows us to study the transmission of shocks to prices that are not directly affected by fluctuations in oil prices, thereby allowing us to distinguish indirect effects. Our methodology proceeds using a two-stage approach. In the first stage, we use an SVAR model of the oil market (Kilian, 2009) to identify the three types of shocks. In the second stage, we estimate the effect of the previously identified shocks on inflation, using local projection methods (Jorda, 2005). This method affords greater flexibility for estimating the impulse response function than is provided by traditional VAR analyses and is particularly useful for estimating nonlinear relationships and for the two-stage approach as it allows us to directly include the exogenous shocks we identify. To account for the effect of the inflation environment, we employ a smooth transition state-dependent local projection model (Auerbach and Gorodnichenko, 2012) using standardized past inflation as the state variable on which the transmission of oil price shocks depends. Further, to analyze the existence of asymmetric effects based on the direction of the shocks, we extend our state-dependent model by distinguishing between positive shocks (which increase oil prices) and negative shocks (which cause oil prices to fall) and obtain different impulse response functions for positive and negative shocks.

The main contribution of this work is that, for the first time, the influence of the current inflation environment on the transmission of oil price shocks to inflation, and on asymmetries between positive and negative shocks is jointly analyzed empirically. This allows us to identify asymmetric and conditional behaviors that should be useful in designing the European Central Bank's monetary policy with respect to its economic pillar (ECB, 2011). To date, only Sekine (2020) has studied the existence of non-linearity in the transmission of oil price changes to inflation as a function of the inflation environment. Our work extends that study in several ways. First, we distinguish the sources of oil price shocks as their transmission mechanisms to inflation differ substantially. Second, Sekine (2020) analyzes the effect using a static approach in the framework of an augmented Phillips curve, whereas we analyze the transmission of oil price shocks from a dynamic perspective by estimating impulse response functions. This allows us to obtain a more comprehensive view of the transmission at different time horizons. Finally, we also consider the presence of asymmetric responses in the transmission of oil shocks conditioned on the economy's current inflation environment.

Our main findings are that oil supply shocks as well as oil-specific demand shocks differ depending on the inflation environment in which they occur. Headline inflation shows a greater response to positive shocks in high inflation environments, while negative shocks are transmitted to a greater degree in a low inflation environment. The transmission of aggregate demand shocks depends to a greater extent on the direction of the shock such that negative shocks that reflect depressed global economic activity show a high and persistent transmission to inflation, triggering a significant deflationary effect, while positive shocks show very low transmission, especially in low inflation environments. Finally, the effect of these shocks on core inflation, which reflects indirect effects, is only significant in high inflation environments, while transmission is muted in low inflation environments. These findings imply that when determining monetary policy response to oil price shocks, it is important to consider the inflation environment in which these shocks occur as their transmission to inflation can vary considerably depending on that environment.

This study is related to three strands of literature. First, it is linked to the literature on state-dependence in the transmission of cost shocks. Although there is ample empirical evidence that the transmission of exchange rate shocks depends on the inflation environment (Choudhri and Hakura, 2006; Junttila and Korhonen, 2012; Shintani et al., 2013; Cheikh and Louhichi, 2016; López-Villavicencio and Mignon, 2017; Cheikh and Zaied, 2020), evidence on the transmission of oil price shocks is scarce. Only Sekine (2020) analyzes the influence of the inflation environment on the transmission of oil prices to inflation. Focusing on the US, he finds a higher transmission of oil price fluctuations during periods of high inflation. Nevertheless, that study takes a static perspective and does not distinguish among sources of asymmetries.

This work is also related to the literature addressing the existence of asymmetry in the effects of oil price shocks. Although there is a vast body of research on the asymmetric effect of oil price shocks on economic activity, empirical studies of the asymmetric effects of oil price shocks on inflation are scarce, and the results are not conclusive. In the US, positive shocks have been shown to have a greater effect on inflation than negative shocks (Balke et al., 2002), especially when the shocks are larger than usual (An et al., 2014). López-Villavicencio and Pourroy (2019) find that in countries where the central bank does not follow an inflation targeting strategy, positive oil price shocks also exhibit a greater degree of transmission to inflation than negative shocks, although this asymmetry does not hold in countries with inflation targeting. For the eurozone, studies have found that negative shocks have a greater degree of transmission and persistence than positive ones (Evgenidis, 2018) in periods of financial stress. Donayre and Wilmot (2016) found that in Canada, the transmission of negative shocks is higher than positive shocks, especially during periods of low economic growth.

Furthermore, our work is also related to the literature addressing the importance of the source of oil price shocks in their transmission to other variables related to the oil market and domestic variables. Studies show that the degree of transmission of oil price shocks to macroeconomic variables, including inflation, depends on whether those price shocks are caused by supply or demand shocks in the case of the US (Kilian, 2009), the United Kingdom (UK) (Lorusso and Pieroni, 2018), and the eurozone as a whole (Peersman and Van Robays, 2009; Herwartz and Plödt, 2016; Enders and Enders, 2017).

In contrast to the works cited above, our study is the first to jointly consider the influence of the inflation environment on the transmission of oil price shocks, while distinguishing shocks according to their source and sign.

The rest of this study is organized as follows: section 2 describes our methodology and dataset; section 3 presents the empirical results, and section 4 tests the robustness of our findings. In section 5, we discuss the results and their implications and then offer conclusions in section 6.

## 2. Methodology

Our methodology consists of a two-stage approach as proposed by Kilian (2009), which has been extensively used to analyze the effect of oil price shocks on different macroeconomic variables (Kilian et al., 2009; Habib et al., 2016; Lorusso and Pieroni, 2018; Jibril et al., 2020). In the first stage, we identify oil price shocks through a structural model of the global oil market, following the methodology in Kilian (2009). In the second stage, we estimate the transmission of those shocks to inflation in the eurozone using local projection methods (Jordà, 2005).

An alternative strategy would be to estimate an SVAR model of the oil market extended to include the macroeconomic variables to be studied. However, Kilian and Zhou (2020) point out that to correctly estimate a structural model of the oil market, it is necessary to use a long time series, such as one spanning from 1974 to present. When macroeconomic data are available for a shorter period of time, as is the case of the eurozone that has only been in existence since 1999, the two-stage approach is more suitable than the extended SVAR approach to correctly identify oil price shocks. Furthermore, Hamilton and Herrera (2004) and Kilian (2009) highlight the importance of including a large number of lags in the model to adequately capture the dynamics of the oil market and how oil price shocks are transmitted to the economy, which also supports our decision to use a two-stage approach, given the length of our time series data.

### 2.1. Identifying structural oil price shocks

To identify oil price shocks, we estimate an SVAR model with recursive identification as developed by Kilian (2009), which has been widely used to study the effect of oil price shocks on other macroeconomic variables (Kilian et al., 2009; Kang and Ratti, 2013; Habib et al., 2016; Enders and Enders, 2017; Kang et al., 2017; Degiannakis et al., 2018; Lorusso and Pieroni, 2018; Jibril et al., 2020).[1] Thus, we identify three types of shocks: oil supply, oil-specific demand, and aggregate demand shocks by estimating the following trivariate SVAR model:

$$A_0 Y_t = \alpha + \sum_{i=1}^{24} A_i Y_{t-i} + \varepsilon_t \tag{1}$$

where $Y_t$ is a 3x1 vector of endogenous variables, namely, $\Delta prod_t$, representing the percentage change in oil production, $rea_t$ is the real economic activity index developed by Kilian (2009) representing fluctuations in global economic activity, and $rpo_t$ is the real refiner acquisition cost of imported crude oil expressed in log form. $\varepsilon_t$ is a vector of structural innovations that are serially and mutually uncorrelated. To obtain $\varepsilon_t$ from the reduced-form errors, we assume that $A_0^{-1}$ has a recursive structure such that we can retrieve the structural innovations $\varepsilon_t$ from the VAR reduced-form errors, $e_t$:

$$e_t = \begin{pmatrix} e_t^{\Delta prod} \\ e_t^{rea} \\ e_t^{rpo} \end{pmatrix} = \begin{pmatrix} a_{11} & 0 & 0 \\ a_{21} & a_{22} & 0 \\ a_{31} & a_{32} & a_{33} \end{pmatrix} \begin{pmatrix} \varepsilon_t^{oil\ supply\ shock} \\ \varepsilon_t^{aggregate\ demand\ shock} \\ \varepsilon_t^{oil-specific\ demand\ shock} \end{pmatrix} \tag{2}$$

To identify the three structural shocks, we use a recursive structure based on the following assumptions:

- First, to identify oil supply shocks, we assume that oil production is inelastic in the short run. This implies that production does not react contemporaneously to changes in global economic activity or the price of oil.
- To identify aggregate demand shocks, we assume that global economic activity can be affected in the same month by oil production changes but not by fluctuations in oil prices. In other words, global economic activity only reacts to oil price fluctuations after a certain delay. We, therefore, identify aggregate demand shocks as innovations in the economic activity index that are not explained by oil supply shocks.

[1] An alternative option is to identify oil price shocks using an SVAR model with sign restrictions (Kilian and Murphy, 2012, 2014; Baumeister and Hamilton, 2019). In section 4, we test the robustness of the results using oil price shocks identified via sign restrictions.

- Finally, in the case of oil-specific demand shocks, we assume that oil prices react contemporaneously to both oil production changes and fluctuations in global economic activity. In this way, we identify oil-specific demand shocks as oil price innovations that are not explained by oil supply shocks and aggregate demand shocks.

After identifying these structural oil shocks $\varepsilon_t$, we construct three variables corresponding to oil supply, oil-specific demand, and aggregate demand shocks for the period from January 1999 to January 2020, which we use to study the transmission of oil shocks to inflation in the eurozone.

### 2.2. Estimation of the transmission of oil price shocks to inflation

#### 2.2.1. Linear model

To analyze the transmission of oil price shocks to inflation, we use headline inflation and, alternatively, core inflation as dependent variables in an effort to pinpoint the indirect effects generated by those shocks. We estimate the following equation using local projection methods, following other studies such as Sekine and Tsuruga (2018) and Caselli and Roitman (2019):

$$p_{i,t+h} - p_{i,t-1} = \alpha_{i,h} + \sum_{l=1}^{12} \mu_l^h (p_{i,t-l} - p_{i,t-1-l}) + \beta^h Shock_{a,t} + \sum_{l=0}^{12} \theta_l^h Control_{i,t-l} + \varepsilon_{i,t+h} \tag{3}$$

where $p_{i,t}$ represents the price index, in log form, for country $i = 1, 2, \ldots, 12$ on date $t$. $Shock_{a,t}$ refers to the three structural oil price shocks identified previously, where $a = 1, 2, 3$ refers to oil supply, oil-specific demand, and aggregate demand shocks, respectively, whose impacts on inflation we estimate. The estimates for each type of shock are the same for every country in the panel. $Control_{i,t-l}$ is a set of control variables that includes the percentage change in the industrial production index for each country and the euro/dollar exchange rate, including its contemporaneous value and its value at 12 lags. We also include 12 lags of the inflation rate to control for persistence in inflation (Sekine and Tsuruga, 2018). Finally, $\varepsilon_{i,t+h}$ represents the error term.

To obtain the impulse response function, we estimate equation (3) for each horizon $h$ and obtain $\beta^h$, a coefficient that shows the response of the dependent variable in $h$ to an exogenous shock in $t$. Therefore, the impulse response function is obtained by adding the coefficients for the entire estimation horizon, represented as $IRF(h) = \beta^h$ for $h = 1, 2, \ldots, H$. We choose a time horizon of 24 months. To estimate equation (3), we use the Least Squares Dummy Variable Estimator with the Newey West Heteroskedasticity and Autocorrelation-Consistent covariance matrix.

#### 2.2.2. Estimation of the transmission of oil price shocks based on the inflation environment

The local projection method can be extended to estimate impulse response functions in state-dependent models. Specifically, following Auerbach and Gorodnichenko (2012), the local projection method can be estimated as a smooth transition model using a logistic function as the transition between different states. To test whether the inflation environment affects the transmission of oil price shocks to inflation, we estimate the following equation:

$$\begin{aligned} p_{i,t+h} - p_{i,t-1} = {} & \alpha_{i,h} + (1 - F(z_{i,t-1})) \\ & \left[ \sum_{l=1}^{12} \mu_{H,l}^h (p_{i,t-l} - p_{i,t-1-l}) + \beta_H^h Shock_{a,t} + \sum_{l=0}^{12} \theta_{H,l}^h Control_{i,t-l} \right] \\ & + (F(z_{i,t-1})) \left[ \sum_{l=1}^{12} \mu_{L,l}^h (p_{i,t-l} - p_{i,t-1-l}) + \beta_L^h Shock_{a,t} + \sum_{l=0}^{12} \theta_{L,l}^h Control_{i,t-l} \right] + \varepsilon_{i,t+h} \end{aligned} \tag{4}$$

where F(.) is the transition function represented by the following logistic function:

$$F(z_{i,t-1}) = \frac{\exp(-\gamma z_{i,t-1})}{1 + exp(-\gamma z_{i,t-1})} \text{ with } \gamma > 0,$$

where $z_{i,t-1}$ is the transition variable. Here, we include the standardized past inflation rate as the state variable, as proposed by Sekine and Tsuruga (2018). Specifically, we use core inflation in our baseline model as we think it is a better indicator of the inflation environment, given that it excludes the most volatile components of the HICP. The state variable is represented as follows:

$$z_{i,t-1} = \frac{\pi_{i,t-1} - \overline{\pi}_i}{\widehat{\sigma}_i} \tag{5}$$

where $\pi_{i,t-1}$ is the lagged inflation rate of country $i$, $\overline{\pi}_i$ is country $i$'s average inflation rate during the period analyzed, and $\widehat{\sigma}_i$ is the standard deviation of that inflation rate. $F(z_{i,t-1})$ denotes the probability of being in a low inflation state. When $z_{i,t-1} \to \infty$, then $F(z_{i,t-1}) \to 0$, and the impulse response function would be represented by $\beta_H^h$, where the subscript $H$ denotes a high inflation environment. In contrast, when $z_{i,t-1} \to -\infty$, $F(z_{i,t-1}) \to 1$, the impulse response function is given by $\beta_L^h$ where the subscript $L$ refers to a low inflation environment. The parameter $\gamma$ sets the speed of the transition between states. If $\gamma = 0$, the model becomes the linear model as $F(z_{i,t-1})$ is always ½. On the other hand, if $\gamma$ is very high, the transition between states is immediate, and the model would approximate a discrete transition model with a threshold dummy variable. Following Tenreyro and Thwaites (2016), we select $\gamma = 3$, which allows an intermediate speed for regime transitions. However, in section 4 we show that our results hold when we use different values of $\gamma$. In general terms, the impulse response function is the weighted sum of $\beta_H^h$ and $\beta_L^h$, where the weight depends on the value of $F(z_{i,t-1})$ and is obtained as follows: $IRF(h) = (1 - F(z_{i,t-1}))\beta_H^h + (F(z_{i,t-1}))\beta_L^h$. In the extremes, a low inflation environment where $F(z_{i,t-1})$ takes the value 1, the impulse response function is given by $IRF^L(h) = \beta_L^h$ and in a high inflation environment, $F(z_{i,t-1})$ takes the value 0 such that the impulse response function is given by $IRF^H(h) = \beta_H^h$.

#### 2.2.3. Including asymmetry in the transmission of oil price shocks

To analyze the asymmetric transmission of positive and negative shocks, we extend the model represented in equation (4) by substituting the variable $Shock_{a,t}$ for the following variables:

$$Shock_{a,t}^+ = \begin{cases} Shock_t & \text{if } Shock_{a,t} > 0 \\ 0 & Shock_{a,t} \leq 0 \end{cases}, \quad Shock_t^- = \begin{cases} Shock_t & \text{if } Shock_{a,t} \leq 0 \\ 0 & \text{if } Shock_{a,t} > 0 \end{cases} \tag{6}$$

where $Shock_{a,t}^+$ refers to positive oil shocks, that is, those that trigger an increase in oil prices, and $Shock_{a,t}^-$ refers to negative shocks that reduce oil prices. We introduce both variables simultaneously to avoid any possible bias effects that might be induced by truncated variables. Using this method, we can analyze whether there is any asymmetry in the transmission of these shocks depending on their direction and whether these differences vary depending on the inflation environment for the economy at the time of the shock.

### 2.3. Data

We use monthly data for the period from January 1999 to January 2020 for a panel of the 12 initial countries of the eurozone (Austria, Belgium, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, the Netherlands, Portugal, and Spain). Our study period ranges from the creation of the euro to the latest data available. The HICP and the HICP excluding food and energy (HICPex) are obtained from Eurostat. The euro/dollar exchange rates are obtained from the International Monetary

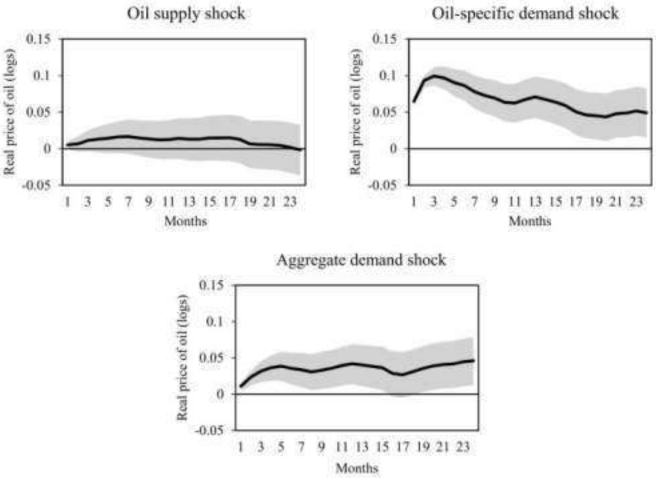


**Fig. 2.** Response of the real price of oil to one standard deviation of the three structural oil shocks. *Notes*: Oil supply shocks represent a one standard deviation decline in $\Delta prod$. Shaded areas denote 95% confidence intervals.

Fund's International Financial Statistics[2] database, and the industrial production index is obtained from the OECD database. The HICP, HICPex, and industrial production indices are seasonally adjusted (see Table A.1 in Appendix A).

To identify oil price shocks following Kilian (2009), we use monthly data from January 1974 to January 2020. The data elements are world oil production and the real refiner acquisition cost of imported crude oil, both obtained from the US Energy Information Administration, and the economic activity index developed by Kilian (2009). After obtaining the three types of structural shocks, we use these variables for the study period from January 1999 to January 2020.

## 3. Results

### 3.1. Linear model

Fig. 2 shows the response of real oil prices to the three types of shocks,[3] identified through the SVAR model defined in equation (2).

As seen in the graphs, oil prices respond differently depending on the source of the shock. Oil-specific demand shocks have a more direct impact on and a greater transmission to the price of oil, while aggregate demand shocks show a more gradual and persistent effect. Finally, of the three types of shocks, the price of oil has the lowest response to an oil supply shock, and the impact is reversed at the end of the time horizon.

Fig. 3 shows the cumulative response of headline inflation and core inflation to a one standard deviation shock in the linear model in equation (3), estimated through local projections. There is a substantial difference between the effects of these shocks on headline and core inflation. Regarding the effects on headline inflation, supply shocks show a delayed transmission after six months, reflecting a slow transmission to oil prices that tends to disappear in the long term. In contrast, aggregate demand shocks increase the demand for oil because of an increase in global economic activity and have a higher inflationary effect over the long term, triggering a persistent increase in inflation over time, with the maximum accumulated effect observed at the end of the period. These results are in line with Kilian (2009) for the US and Lorusso and Pieroni (2018) for the UK. Finally, oil-specific demand shocks show a high initial impact that persists over the time period, similar to the findings of Enders and Enders (2017) for the eurozone. Kilian (2009) and Lorusso and Pieroni (2018) found a more gradual and persistent transmission for the US and UK, respectively, similar to that observed with aggregate demand shocks.

Regarding indirect effects reflected in the transmission of shocks to core inflation, the results show that oil-specific demand shocks have little cumulative effect on core inflation; similarly, the impact of oil supply shocks is negligible, which confirms that the effect of oil price shocks takes place through headline inflation rather than core inflation. The transmission of aggregate demand shocks to core inflation is higher than the other shocks as demand shocks are caused by increases in global economic activity that could increase domestic demand in the eurozone. However, the degree of transmission is still much lower than that of headline inflation.

These results confirm that the transmission of oil price shocks to eurozone inflation differs depending on the source of the shock, in line with previous works (Peersman and Van Robays, 2009; Herwartz and Plödt, 2016; Enders and Enders, 2017).

### 3.2. Introducing the inflation environment

Fig. 4 shows the cumulative response of inflation to each type of shock in a low and a high inflation environment, using core inflation as the state variable as described in section 2.

The results show that the response of inflation to oil price shocks differs between these two states. After oil supply shocks and particularly with aggregate demand shocks, the inflation response is higher in a high inflation environment than in a low inflation environment. These results are in line with the predictions of the theoretical models in Taylor (2000) and Devereux and Yetman (2010) and with the empirical findings in Sekine (2020) for the US, although the latter does not distinguish

[2] In the case of Greece for the period from January 1999 to December 2000, we convert the drachma/dollar exchange rate to euro/dollar by multiplying the former by the fixed drachma/euro exchange rate set during the country's adoption of the euro.

[3] The three structural shocks are shown in Figure A.1. in Appendix A for the period 1999.01–2020.01.

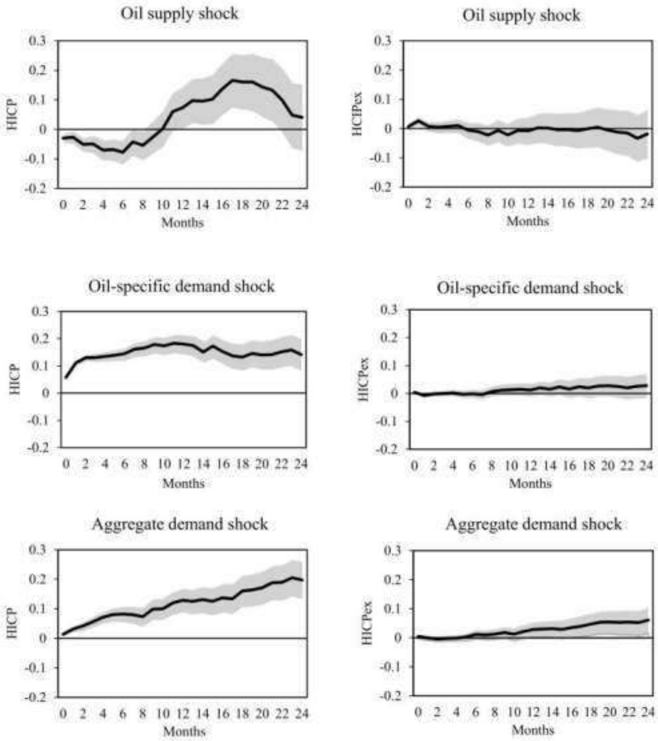


**Fig. 3.** Cumulative response of headline inflation (column 1) and core inflation (column 2) to the three structural oil shocks in the linear model. *Notes*: Figures show the cumulative effect of a one standard deviation shock to inflation. Shaded areas denote 90% confidence intervals. Supply shocks represent a decline in $\Delta prod$.

between different types of oil price shocks or estimate transmission using a dynamic approach.

During periods of high inflation, aggregate demand shocks are transmitted persistently and to a greater extent than during periods of low inflation, where the initial impact is lower and is reversed at the end of the horizon. However, the response of core inflation is different: in a low inflation environment, aggregate demand shocks are initially transmitted to core inflation and remain stable during the second year, while in a high inflation environment, transmission is close to zero during the first year and then increases in the second year. However, the degree of transmission of the shock to core inflation is low such that the evolution shown by headline inflation in both states is mainly triggered by the response of energy prices.

With respect to oil supply shocks, we also observe a more direct transmission to headline inflation in high inflationary environments, although the differences are less pronounced than in the case of aggregate demand shocks. With core inflation, transmission is slightly positive in high inflation environments, while in low inflation environments, the transmission is reversed after a slightly positive transmission in the first months, becoming negative in the longer term.

Finally, oil-specific demand shocks initially show a lower transmission in high inflation environments, although transmission is similar in the long run because of greater persistence in the inflation response in high inflation environments, compared to low inflation environments. This higher persistence is partially a consequence of a higher transmission of the shocks to core inflation in a high inflation environment, which shows the existence of higher indirect effects.

This finding, which is contrary to what theory predicts, may be the consequence of failing to account for asymmetries between positive and negative shocks such that the results may conceal the existence of a greater asymmetry in high inflationary environments, as predicted by the theoretical results in Ball and Mankiw (1994). In the next section, we empirically explore the existence of such sign asymmetries.

### *3.3. Asymmetry in the transmission of oil price shocks*

The results presented in the previous section are obtained under the assumption that the response of inflation to oil price shocks is symmetric. In this section, we relax this assumption, estimating the model in equation (4) by distinguishing between positive shocks (which increase oil prices) and negative shocks (which reduce oil prices). Results are shown in Figs. 5 and 6 and are summarized in Tables 1 and 2 for headline inflation and core inflation, respectively.

These results show the importance of distinguishing between positive and negative shocks in analyzing their transmission to inflation and the role played by the inflation environment in which they occur. For supply shocks, we find that the direction of the asymmetry changes depending on the inflation environment. In a low inflation environment, a negative shock, that is, an increase in oil production that causes oil prices to fall, triggers a drop in inflation, while a positive shock shows a U-shaped

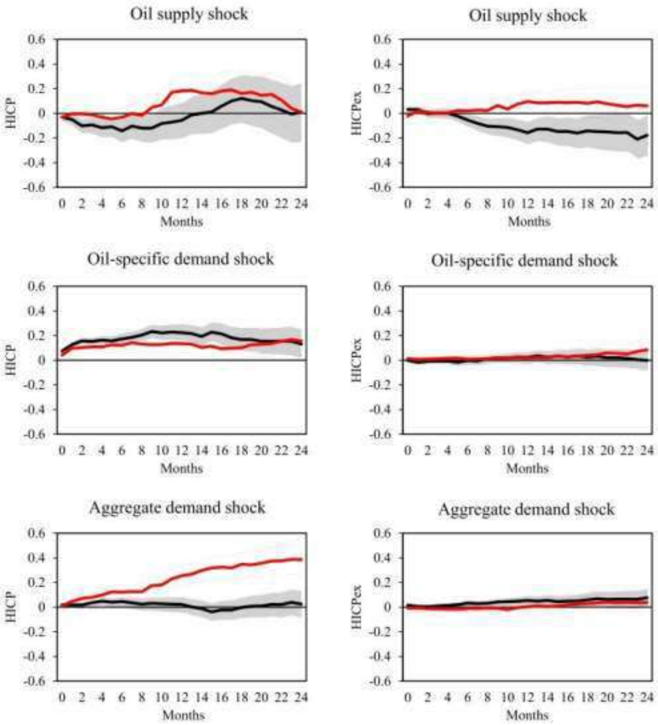


**Fig. 4.** Cumulative response of headline inflation (column 1) and core inflation (column 2) to the three structural oil shocks in the state-dependent model. *Notes*: Figures show the cumulative effect on inflation of a one standard deviation shock. The black line denotes the response of inflation in a low inflation environment. The red line denotes the response of inflation in a high inflation environment. Shaded areas denote 90% confidence intervals. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

response, with an initial drop in inflation followed by a small increase after six months, although its cumulative effect remains negative. In contrast, in high inflation environments, positive shocks have a greater impact on inflation, while negative shocks do not generate a decline in inflation but rather an increase in the long run. These results, which are in line with the asymmetry generated by the existence of positive trend inflation (Tsiddon, 1993; Ball and Mankiw, 1994), reflect the reaction of core inflation such that in high inflation environments, indirect effects play an important role in the response of inflation to the shocks. In contrast, in a low inflation environment, the response of core inflation is more muted and does not show any significant asymmetry.

For oil-specific demand shocks, the results are in line with what the theory predicts (Tsiddon, 1993; Ball and Mankiw, 1994), with asymmetry higher in a high inflation environment. In a low inflation environment, transmission of both positive and negative shocks is similar, although positive shocks are more persistent, while negative shocks revert at the end of the horizon. However, in high inflation environments, the transmission of positive shocks is higher and more persistent, while negative shocks, after an initial drop in inflation, are reversed, and the cumulative effect is a higher price level. These findings are in line with previous studies such as An et al. (2014) who found that positive shocks have a greater impact on inflation in the US than negative shocks, although comparability is limited as their study does not distinguish between the source of the shock or inflation environment in which it is generated. Finally, indirect effects are negligible in low inflation environments, while core inflation shows a similar transmission as headline inflation in high inflation environments, albeit to a lesser extent.

It is important to note that when we allow for the existence of asymmetric responses to positive and negative shocks, the counterintuitive results seen in Fig. 4 that show oil-specific demand shocks have a higher transmission in low inflation environments disappear, in line with theoretical predictions. In other words, the lower transmission of these shocks in high inflation environments shown in Fig. 4 is caused by the low transmission of negative oil-specific demand shocks, which turns negative, offsetting the higher transmission shown by positive shocks in high inflation environments. This proves the need to consider the existence of asymmetry in the response to these shocks; when the asymmetry is ignored, the results vary significantly as they average the responses of two different shocks (positive and negative shocks) whose level and rate of transmission differ.

Aggregate demand shocks show a different pattern, compared to the two other shocks as in both states, a persistent drop in inflation is seen after a negative shock, while positive shocks have a minor effect and even show a negative cumulative effect in low inflationary environments. Regarding transmission to core inflation, in an environment of low inflation, transmission is insignificant, while in high inflation environments, negative shocks trigger a significant drop in core inflation, and positive shocks also eventually produce a negative cumulative effect.

Contrary to what we observe for the other types of shocks, these results are consistent with Evgenidis (2018) who found that in periods of high financial stress, negative oil price shocks have a greater impact on inflation than positive shocks in the eurozone and Donayre and Wilmot (2016) who show that negative shocks have a greater impact on inflation than positive shocks in periods of low economic growth.

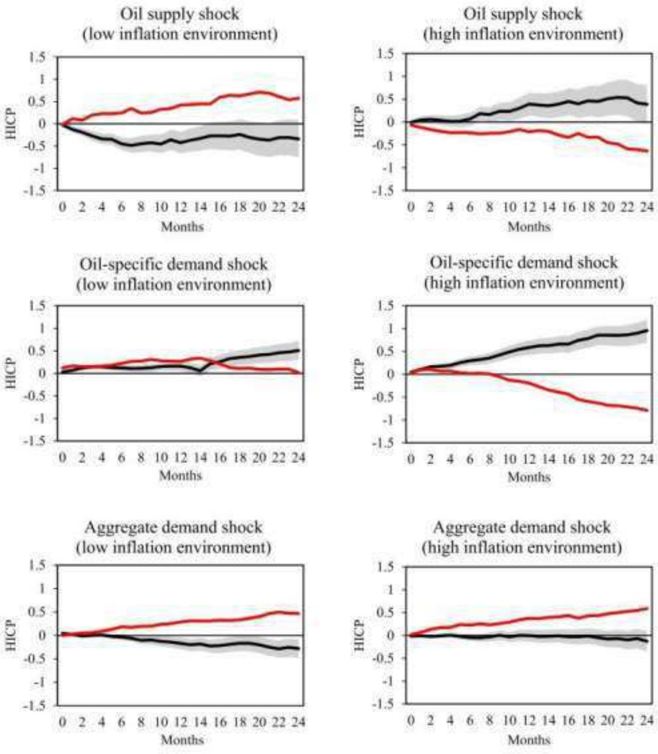


**Fig. 5.** Cumulative response of headline inflation to the three types of structural oil shocks in a low inflation environment (column 1) and in a high inflation environment (column 2). *Notes*: Figures show the cumulative effect on inflation of a one standard deviation shock. The black line denotes the response of inflation to a positive shock. The red line denotes the response of inflation to a negative shock. Shaded areas denote 90% confidence intervals. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

Further, it is important to emphasize the differences in the response of inflation to oil-specific demand shocks versus aggregate demand shocks. In a high inflation environment, negative aggregate demand shocks trigger a persistent drop in inflation, while oil-specific demand shocks, after an initial drop in inflation, cause price levels to increase such that the cumulative impact is higher inflation in the long run. One possible explanation for this is the transmission mechanisms of these shocks to the output. A negative aggregate demand shock reduces the price of oil and triggers a decline in global economic activity; this can be translated into a decline in domestic economic activity in the eurozone. On the other hand, a negative oil-specific demand shock, perhaps caused by precautionary or speculative actions, sparks the opposite response in terms of production (Kilian, 2009; Peersman and Van Robays, 2009); in other words, a lower cost of oil has a positive effect on production, so that, in an environment of high inflation, that translates into greater pressures on prices. The long-term effect is an increase in both headline and core inflation.

## 4. Robustness

In this section, we test the robustness of the results obtained thus far to the following: (i) the method used to identify exogenous oil price shocks; (ii) the choice of the speed of transition between regimes, determined by the parameter $\gamma$; (iii) the choice of the state variable $z_{i,t-1}$ used to define the inflationary environment; and (iv) the method used to define the transition between states or inflation environments.

### 4.1. *Alternative identification of oil price shocks*

In the baseline model, we identify oil price shocks using an exclusion restriction with a recursive structure, following the identification strategy in Kilian (2009). However, in studies of the oil market, oil price shocks are often identified via sign restrictions. To determine whether our results are robust to the identification method, we follow the strategy in Kilian and Murphy (2014) who distinguish between flow supply, flow demand, and speculative demand shocks. To do so, we extend the model in Kilian (2009) by adding a variable that represents changes in OECD crude oil inventories.[4] Following Kilian and Murphy (2014), we use sign restrictions in the contemporary response of the variables to these different types of shocks, as shown in Table 3.

We impose two additional restrictions. First, we include dynamic restrictions on the response of oil production, global economic activity, and the price of oil to maintain the sign imposed on the contemporary response for 12 months after a flow supply shock. Second, the impact price elasticity of oil supply is restricted to be less than or equal to 0.25, while the impact price elasticity of oil demand is restricted to be between 0 and −0.80 (see Kilian and Murphy, 2014).

[4] Since data on OECD crude oil inventories are not available, Kilian and Murphy (2014) calculated the ratio of oil and petroleum product inventories between the OECD and the US and multiplied US crude oil inventories by this ratio.

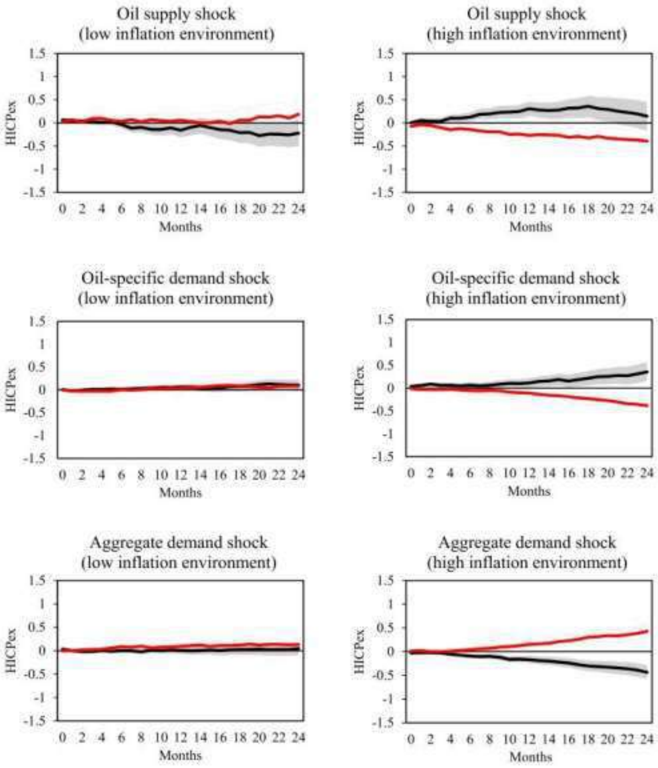


**Fig. 6.** Cumulative response of core inflation to the three types of oil shocks in a low inflation environment (column 1) and a high inflation environment (column 2). *Notes:* Figures show the cumulative effect on inflation of a one standard deviation shock. The black line denotes the response of inflation to a positive shock. The red line denotes the response of inflation to a negative shock. Shaded areas denote 90% confidence intervals. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

**Table 1**
Summary of the transmission of structural oil price shocks to headline inflation.

| State | Sign | Positive | | | Negative | | | Difference by shock | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Shock | Oil supply shock | Oil-specific demand shock | Agg. demand shock | Oil supply shock | Oil-specific demand shock | Agg. demand shock | Oil supply shock | Oil-specific demand shock | Agg. demand shock |
| Low inflation | *Max impact (%)* | −0.03 | 0.51 | 0.05 | 0.71 | 0.34 | 0.50 | −0.74 | 0.17 | −0.45 |
| | *Impact after* 12 months *(%)* | −0.42 | 0.16 | −0.17 | 0.42 | 0.27 | 0.29 | −0.85 | −0.11 | −0.46 |
| | *Impact after* 24 months *(%)* | −0.34 | 0.51 | −0.28 | 0.57 | 0.02 | 0.46 | −0.91 | 0.49 | −0.75 |
| High inflation | *Max impact (%)* | 0.54 | 0.96 | 0.00 | −0.07 | 0.10 | 0.59 | 0.60 | 0.85 | −0.58 |
| | *Impact after* 12 months *(%)* | 0.39 | 0.59 | 0.00 | −0.21 | −0.19 | 0.37 | 0.61 | 0.78 | −0.38 |
| | *Impact after* 24 months *(%)* | 0.39 | 0.96 | −0.13 | −0.63 | −0.79 | 0.59 | 1.02 | 1.75 | −0.71 |
| Difference by state | *Max impact (%)* | 0.57 | 0.45 | −0.04 | −0.78 | −0.23 | 0.09 | | | |
| | *Impact after* 12 months *(%)* | 0.82 | 0.43 | 0.17 | −0.64 | −0.46 | 0.09 | | | |
| | *Impact after* 24 months *(%)* | 0.73 | 0.45 | 0.15 | −1.20 | −0.81 | 0.12 | | | |

*Notes*: The cumulative impact represents the % change in HICP generated by a one standard deviation shock, estimated using the model in equation (4) and including the shocks as defined in equation (6).

**Table 2**
Summary of the transmission of structural oil price shocks to core inflation.

| State | Sign | Positive | | | Negative | | | Difference by shock | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Shock | Oil supply shock | Oil-specific demand shock | Agg. demand shock | Oil supply shock | Oil-specific demand shock | Agg. demand shock | Oil supply shock | Oil-specific demand shock | Agg. demand shock |
| Low inflation | *Max impact (%)* | 0.07 | 0.13 | 0.05 | 0.18 | 0.1 | 0.14 | −0.12 | 0.03 | −0.09 |
| | *Impact after* 12 months *(%)* | −0.16 | 0.06 | 0.01 | 0.06 | 0.03 | 0.1 | −0.22 | 0.03 | −0.09 |
| | *Impact after* 24 months *(%)* | −0.22 | 0.11 | 0.05 | 0.18 | 0.08 | 0.13 | −0.41 | 0.02 | −0.08 |
| High inflation | *Max impact (%)* | 0.36 | 0.36 | −0.02 | −0.04 | −0.01 | 0.43 | 0.4 | 0.37 | −0.45 |
| | *Impact after* 12 months *(%)* | 0.31 | 0.11 | −0.17 | −0.27 | −0.11 | 0.15 | 0.57 | 0.22 | −0.32 |
| | *Impact after* 24 months *(%)* | 0.15 | 0.36 | −0.44 | −0.39 | −0.38 | 0.43 | 0.54 | 0.74 | −0.86 |
| Difference by state | *Max impact (%)* | 0.29 | 0.22 | −0.07 | −0.22 | −0.11 | 0.29 | | | |
| | *Impact after* 12 months *(%)* | 0.46 | 0.05 | −0.18 | −0.33 | −0.14 | 0.05 | | | |
| | *Impact after* 24 months *(%)* | 0.37 | 0.25 | −0.48 | −0.58 | −0.47 | 0.3 | | | |

*Notes*: The cumulative impact represents the % change in the HICPex generated by a one standard deviation shock, estimated using the model in equation (4) and including the shocks as defined in equation (6).

**Table 3**
Sign restrictions on the contemporary impact responses in the SVAR model.

| | Flow supply shock | Flow demand shock | Speculative demand shock |
|---|---|---|---|
| Oil production | − | + | + |
| Real activity | − | + | − |
| Price of oil | + | + | + |
| Inventories | | | + |

*Notes*: All shocks are normalized to imply an increase in the price of oil.
Source: Kilian and Murphy (2014).

The results, shown in Appendix B, are in line with those obtained in the baseline model. Specifically, flow demand shocks are equivalent to aggregate demand shocks, while speculative demand shocks are equivalent to oil-specific demand shocks. This demonstrates that the conclusions obtained from our baseline results are robust to the method of identifying oil price shocks.

### 4.2. Speed of regime switching

In our baseline model, the parameter that determines the speed of transition between states is set to $\gamma = 3$, following Tenreyro and Thwaites (2016). To test the sensitivity of our results to the value of this parameter, we re-estimate the model in equation (4), setting $\gamma$ to 1.5 and 6 and, thereby, allowing the speed of transition to be lower and higher than in the baseline model, respectively. Results are provided in Appendix C and show that in both scenarios, the results are in line with those found in the baseline model.

### 4.3. State variable

In the baseline model, we employ standardized core inflation as the state variable. The choice of core inflation is motivated by the fact that it better represents the true inflation environment than headline inflation as it is not exposed to the volatility of energy and food prices. However, other studies (Sekine and Tsuruga, 2018; Cheikh and Zaied, 2020; Sekine, 2020) have used headline inflation as the state variable. In order to check the robustness of the model to this specification, we substitute core inflation with headline inflation as the state variable. In general, these results (shown in Appendix D) do not differ from those obtained in the baseline model, allowing us to conclude that the baseline results are robust to the choice of the state variable.

### 4.4. Definition of the transition between states

In this section, we test the robustness of our baseline findings to an alternative approach to determining the economy's current inflation environment (high or low). To do so, we extend the linear model to a threshold state-dependent model (Ahmed and Cassou, 2016, 2021; Ramey and Zubairy, 2018), represented in the following equation:

$$
\begin{aligned}
p_{i,t+h} - p_{i,t-1} &= \alpha_{i,h} \\
&+ D_{i,t-1}\left[\sum_{i=1}^{12} \mu_{H,i}^{h}(p_{i,t-i} - p_{i,t-1-i}) + \beta_H^h Shock_{a,t} + \sum_{l=0}^{12} \theta_{H,l}^{h} Control_{i,t-l}\right] \\
&+ (1 - D_{i,t-1})\left[\sum_{i=1}^{12} \mu_{L,i}^{h}(p_{i,t-i} - p_{i,t-1-i}) + \beta_L^h Shock_{a,t} + \sum_{l=0}^{12} \theta_{L,l}^{h} Control_{i,t-l}\right] \\
&+ \varepsilon_{i,t+h}
\end{aligned} \tag{7}
$$

where $D_{i,t-1} \in \{0,1\}$ is a dummy variable that represents the inflation environment and is defined as follows:

$$
D_{i,t-1} = \begin{cases} 1 & \text{if } \pi_{i,t-1} > \overline{\pi}_i \\ 0 & \text{if } \pi_{i,t-1} \leq \overline{\pi}_i \end{cases} \tag{8}
$$

where $\pi_{i,t-1}$ is the lagged core inflation of country $i$, and $\overline{\pi}_i$ is the average core inflation over the period studied. Therefore, when the lagged core inflation is higher than the country's average over the period, $D_{i,t-1}$ takes a value of 1, indicating that the economy is in a high inflation environment; when the lagged core inflation is below the country's average, the economy is in a low inflation environment, with $D_{i,t-1}$ taking a value of 0. This method differs from the approach used in equation (4) as it does not assume a smooth transition between inflation regimes or environments but rather that the transition occurs when the state variable exceeds the threshold value.

The results, displayed in Appendix E, do not show any significant differences with respect to the baseline model, confirming the robustness of our findings.

## 5. Discussion of the results

The results presented in this study show that when analyzing the effect of oil price shocks on inflation, it is essential to consider both the inflationary environment in which they occur and the sign of the shocks, as the consequences of the shocks differ depending on these factors.

When we analyze oil price shocks originating from the oil market itself, that is, oil supply and oil-specific demand shocks, the results are in line with theoretical predictions. In high inflation environments, positive shocks, that is, those that increase the price of oil, are transmitted to inflation to a greater extent than negative shocks, producing indirect effects reflected in an increase in core inflation. This relationship is consistent with the theoretical model in Taylor (2000), which argues that in an environment of higher inflation, firms have expectations of higher future inflation and greater persistence of oil price shocks and, thus, transmit these higher costs to their prices to a greater degree. Furthermore, our results show that the degree of transmission of negative price shocks is greater in low inflation environments, while in high inflation environments, that transmission is very low. This is in line with the theoretical prediction in Ball and Mankiw (1994) who show that the frequency of price increases because changes in costs grows with higher trend inflation, while the frequency of price reductions decline, leading to greater asymmetry. These results with respect to the frequency of price changes have been empirically supported at the microeconomic level for Mexico (Gagnon, 2009), Argentina (Alvarez et al., 2019), the eurozone, and the US (Dhyne et al., 2006).

Moreover, our results for aggregate demand shocks show a reaction pattern for both headline and core inflation that differs from the pattern found for the other type of shocks. In both low and high inflation environments, we find a high degree of asymmetry between positive and negative shocks. Slumps in global economic activity trigger a persistent decline in consumer prices, while increases in global economic activity have a very low level of transmission to inflation and even show a negative cumulative impact in a low inflation environment. One possible explanation for the reduced impact of positive aggregate demand shocks is a greater impact of monetary policies that respond to demand pressure in the economy, which would be reflected in the negative transmission seen in core inflation in our estimates and offset the inflationary effect of the energy component. Another possible explanation could be an asymmetric impact of global economic activity on domestic economies within the eurozone, whereby an increase in global economic activity does not necessarily result in higher domestic economic activity, whereas a downturn in global economic activity triggers a decline in domestic demand and, therefore, a drop in consumer prices in the eurozone.

Other empirical studies have found evidence of negative asymmetry, such as Evgenidis (2018) who shows that in periods of high financial stress, negative shocks have a greater deflationary effect than the inflationary effect of positive shocks in the eurozone. Donayre and Wilmot (2016) found that negative oil price shocks in Canada have a greater transmission to inflation than positive shocks, especially in periods of low economic growth. Our results imply that periods of declining global economic activity, such as the global financial crisis of 2008 or the decline in economic activity caused by the slowdown in China's economy in 2014–2015, would have triggered greater deflationary pressure than the inflationary pressures generated during periods of booming global economic activity, such as during the period from 2006 to 2007.

Another important finding is the pattern of transmission of oil price shocks to core inflation. Our results show that in a low inflation environment, the transmission is negligible for all types of shocks, while transmission is significant in high inflation environments, with an inflationary effect from shocks originating in the oil market itself. These findings are relevant for monetary policy, as in a context of low inflation such as the one the eurozone has experienced since the global financial crisis, the inflationary effects of oil price shocks are small and transitory and do not trigger the indirect effects that force a central bank to tighten monetary policies to counter inflationary pressures. These considerations should be considered by central bank authorities, especially given that the trade-off between controlling inflation or stabilizing output that oil price shocks represent is reduced in an environment of low inflation.

By way of an example, in July 2008, just prior to the start of the global financial crisis, the ECB raised interest rates by 25 basis points in reaction to a rise in the price of oil that was attributed to increased oil demand. Monetary policy was consistent with what was predictable according to a linear model. However, this policy action would not have been consistent with the results of a model that accounts for the current inflation environment and the direction of the shock. This illustrates the practical implications for pursuing a detailed analysis of the transmission of oil price shocks to inflation in determining effective monetary policy.

## 6. Conclusions

This study analyzes the transmission of oil price shocks to inflation using a state-dependent model. Distinguishing between three types of oil price shocks (oil supply, oil-specific demand, and aggregate demand shocks), the model conditions the response of inflation to the inflation environment in which shocks occur and the direction of the shocks themselves, producing a comprehensive study of the transmission of oil price shocks to inflation.

The results show that the inflation environment in which shocks take place is a key determinant when analyzing whether and how those shocks are transmitted to inflation, as it affects both the degree of transmission and the asymmetry between positive and negative shocks. The transmission of oil price shocks differs depending on the current inflation environment and on the direction of the shocks, and those differences vary among the different types of shocks. The shocks generated in the oil market itself, that is, oil supply and oil-specific demand shocks, show a greater inflationary effect in periods of high inflation, while negative shocks have a higher deflationary impact in a low inflation environment, in line with the results predicted in theoretical models (Ball and Mankiw, 1994; Taylor, 2000). However, aggregate demand shocks, that is, those caused by variations in global economic activity, show an asymmetry that holds in both states; negative shocks generate a persistent decline in inflation, whereas positive shocks are barely transmitted. This last finding implies that the deflationary risk posed by negative aggregate demand shocks is higher than the inflationary risk of positive aggregate demand shocks. This is particularly relevant in low inflation environments, where the risk of deflation is higher and monetary policy must react in order to prevent the economy from sinking into a deflationary spiral. In high inflation environments, these findings are less relevant for monetary policy as the inflationary risk of positive shocks is low, while the decline in inflation caused by negative aggregate demand shocks can offset the inflationary pressures that emerge in a high inflation environment, thus allowing a central bank to accommodate these shocks and avoid tightening its monetary policy.

Another important finding is that the transmission of oil price shocks to core inflation, which represents the indirect effects of oil price shocks, is negligible in a low inflation environment but significant in a high inflation environment. This implies that monetary policy authorities, whose inflation target focuses on the medium-term dynamics of core inflation (ECB, 2011) should not be concerned by the inflationary effect of these shocks when the macroeconomic environment is characterized by low inflation. In contrast, in a high inflation environment, the transmission of shocks, especially those originating from the oil market itself, are substantially transmitted to core inflation; in this situation, positive shocks generate inflationary pressures that the central bank must take into account when establishing its monetary policy.

The main implication of these results is that when deciding how to react to oil price shocks, a central bank must consider the current inflation environment to design an optimal monetary policy as the extent to which inflation reacts to oil price shocks depends to a great extent on the inflation setting in which the shocks occur.

Further, our results show certain counterintuitive behaviors that call for future research on their possible causes. This is especially relevant in the case of aggregate demand shocks as inflation shows little response to positive shocks, contrary to what is expected by economic theory. However, this finding highlights the importance of taking into account all the factors that interact when analyzing oil price shocks, such as the inflation environment as well as the source and direction of the shock itself.

### Credit author statement

Antonio J. Garzon: Conceptualization, Methodology, Software, Formal analysis, Writing – original draft, Visualization. Luis A. Hierro: Conceptualization, Validation, Writing – review & editing, Supervision.

### Declaration of competing interest

None.

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### Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.econmod.2021.105665.

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## 4.3. La transmisión de los shocks del precio del petróleo a la inflación: el papel del tipo de cambio.

En la transmisión de las variaciones del precio del petróleo a la inflación en los países importadores, el tipo de cambio juega también un papel relevante. El petróleo se factura y comercializa en dólares a nivel internacional; por tanto, las fluctuaciones de las cotizaciones de las divisas locales respecto al dólar generadas por variaciones en el precio del petróleo pueden influir en el grado en que se transmiten dichas variaciones a los precios de las economías domésticas. Este efecto puede producirse de manera directa, ya que las variaciones del tipo de cambio afectan al precio del barril de petróleo en moneda doméstica, que es el que finalmente pagan los países importadores; y de manera indirecta, puesto que las variaciones del tipo de cambio no solo afectan al precio del petróleo, sino al precio del resto de bienes y servicios importados. Además, existe otro efecto indirecto que se produce a través de los cambios que provoca en la composición de la demanda, en lo referido al volumen de importaciones y exportaciones del país, pudiendo afectar también al nivel de precios y a la actividad económica.

Los países que forman la zona euro presentan una elevada dependencia del petróleo y de su adquisición a terceros países. En 2018, la dependencia de los países de la zona euro, medida como el porcentaje de las importaciones netas de crudo y productos derivados respecto a su consumo total fue del 96% (Eurostat, 2019), suponiendo estas importaciones de media un 2,6% del PIB en el periodo 1999-2019. Por otra parte, los combustibles suponen, en promedio para el periodo 1999-2019, un 4,96% de la cesta de bienes y servicios que forma el IPCA, alcanzando un 9,5% de la cesta si incluimos todo el componente energético. Por tanto, la inflación en la zona euro es sensible tanto a las variaciones del precio del petróleo, que se comercializa en euros, como a las variaciones en el tipo de cambio respecto al dólar, pues éste determina el precio final de las importaciones de petróleo en moneda local.

En las últimas décadas, la evidencia ha mostrado una menor transmisión de las variaciones del precio del petróleo a la inflación, especialmente a partir de la década de los 1980s (Hooker, 2002; LeBlanc y Chinn, 2004; Clark y Terry, 2010, Herrera y Pesavento, 2009). Las principales causas del cambio en la magnitud de la transmisión que se han propuesto son: una menor intensidad en el consumo de petróleo (Blanchard y Gali, 2007; De Gregorio et al., 2007; Van de Noord y André, 2007; Choi et al., 2018), una mejora en la política monetaria (Blanchard y Gali, 2007; Chen 2009, Choi et al., 2018) o un entorno de inflación más estable (De Gregorio et al., 2007; Van de Noord y André, 2007).

No obstante, también han sido propuestas otras dos explicaciones relacionadas con el objetivo de este capítulo: una menor transmisión del tipo de cambio a la inflación (De Gregorio et al., 2007) y una apreciación del tipo de cambio de las monedas domésticas (Chen, 2009).

En efecto, existe una amplia literatura que muestra la existencia de una relación entre los tipos de cambios y el precio del petróleo. Gran parte de estos trabajos se han centrado en estudiar la relación entre el dólar, divisa en la que se comercia el petróleo y el precio del petróleo. Coudert y Mignon (2016) muestran que existe un cambio estructural en esta relación a principios de la década de los 2000s. Previamente a esta fecha, la evidencia sugiere que existe una relación positiva entre ambas variables, es decir, un incremento del precio del petróleo estaba correlacionado con una apreciación del dólar (Armano y Van Norden, 1998a; Bénassy-Quéré et al., 2007; Coudert et al., 2008). Sin embargo, los estudios más recientes, que incluyen el periodo posterior, demuestran que coinciden las subidas del precio del petróleo con depreciaciones del dólar (Beckmann y Czudaj, 2013a; McLeod y Haughton, 2018).

Analizando la relación del precio del petróleo con el tipo de cambio bilateral de cada país con respecto al dólar, la mayoría de trabajos encuentran una relación positiva entre los tipos de cambio respecto al dólar y el precio del petróleo (Aloui et al., 2013; Reboredo, 2012; Reboredo et al., 2014; Chen et al., 2016; Su et al., 2016; Yang et al., 2018) que se habría intensificado después de la Gran Recesión (Reboredo, 2012; Reboredo et al., 2014; Malik y Umar, 2019), si bien hay estudios que encuentran una relación negativa para los tipos de cambios de algunos países importadores (Lizardo y Mollick, 2010; Beckman et al., 2016). Otros trabajos muestran la existencia de respuestas asimétricas (Ahmad y Moran Hernandez, 2013; Atems et al., 2015; Beckmann et al., 2016) y no lineales (Su et al., 2016; Basher et al., 2016) del tipo de cambio ante variaciones en el precio del petróleo.

Centrándonos en el caso de la zona euro, trabajos recientes indican que existe una relación positiva entre el tipo de cambio dólar/euro y el precio del petróleo, de forma que aumentos del precio del petróleo están ligados a apreciaciones del euro respecto al dólar, si bien la causalidad de esta relación no es clara (Thalassinos y Politis, 2012; Aloui et al., 2013; Beckmann y Czudaj, 2013b; Reboredo et al., 2014; Su et al., 2016; Yang et al., 2018; Mollick y Sakaki, 2019).

La existencia de esta relación es más relevante teniendo en cuenta que la relación entre el precio del petróleo y el marco alemán, la moneda más importante en Europa antes de la introducción del euro, era negativa, de manera que aumentos del precio del petróleo estaban asociados a depreciaciones del marco (Armano y Van Norden, 1998b; Chaudhuri y Daniel, 1998; Chen y Chen, 2007). Estos resultados también se obtienen cuando se utiliza un euro sintético construido a partir de los valores ponderados de las monedas de los miembros de la moneda común antes de su implantación (Clostermann and Schnatz (2000).

El objetivo de este capítulo es llevar a cabo un análisis empírico del papel que juega el tipo de cambio euro/dólar en la transmisión de las variaciones del precio del petróleo a la inflación en la zona euro y determinar si su influencia ha variado o se ha mantenido constante a lo largo del periodo estudiado. Para ello, partiendo del marco teórico de la curva de Phillips aumentada para incluir el precio del petróleo como factor determinante de las variaciones de la inflación, estimamos el papel del tipo de cambio en su transmisión a través de dos especificaciones complementarias: convirtiendo el precio del petróleo a moneda local, de forma que las variaciones del precio incluyan las variaciones contemporáneas del tipo de cambio; y, por otro lado, incluyendo en la estimación de la curva de Phillips las variaciones del tipo de cambio para controlar su impacto en la inflación. Esto nos permite comparar los coeficientes del impacto de las variaciones del precio del petróleo en la inflación entre las distintas especificaciones, para determinar si el tipo de cambio tiene un papel significativo en dicha transmisión. Finalmente, comparamos los resultados para la zona euro con estimaciones para Japón y Reino Unido, dos economías con divisas con una elevada comercialización a nivel internacional (BIS, 2019), al igual que el euro, y que por tanto podrían experimentar una relación similar.

### 4.3.1. Metodología

En este análisis, partimos del marco teórico de una curva de Phillips aumentada, donde incluimos las variaciones del precio del petróleo:

$$\pi_t = \beta E_t \pi_{t+1} + \gamma gap_t + \theta_1(L) Poil^{\$}{}_t + \epsilon_t \tag{20}$$

donde $\pi_t$ es la tasa de inflación, $E_t \pi_{t+1}$ son las expectativas de inflación futura, $gap_t$ es la brecha de la producción, $Poil^{\$}$ es la variación del precio del precio del petróleo en dólares, (L) es un polinomio en el operador de retardos y $\epsilon_t$ el término de error (iid). Para analizar el impacto final que tienen las variaciones del precio del petróleo en los países importadores, como es el caso de los países de la Eurozona, podemos sustituir el precio del petróleo en dólares por el precio en moneda doméstica, que es el precio al que hacen frente los importadores de este bien. Por tanto, la ecuación (20) se transforma en la siguiente fórmula:

$$\pi_t = \beta E_t \pi_{t+1} + \gamma gap_t + \theta_2(L) Poil^{dom}{}_t + \epsilon_t \tag{21}$$

donde $Poil^{dom}$ representa las variaciones del precio del petróleo en moneda doméstica. Las variaciones del precio del petróleo en moneda doméstica se pueden descomponer en las variaciones del precio en dólares y las del tipo de cambio de la moneda respecto al dólar:

$$Poil^{dom}{}_t = Poil^{\$}{}_t + er_t \tag{22}$$

siendo $er_t$ la variación del tipo de cambio respecto al dólar, expresado como $er_t = moneda\ doméstica_t / dólar_t$, de forma que un aumento de $er_t$ se corresponde con una depreciación de dicha moneda con respecto al dólar. De esta forma, podemos reescribir nuestra curva de Phillips aumentada de la siguiente forma:

$$\pi_t = \beta E_t \pi_{t+1} + \gamma gap_t + \theta_2(L)(Poil^{\$}{}_t + er_t) + \epsilon_t \tag{23}$$

Donde el impacto de las variaciones del precio del petróleo en la inflación se transmite tanto por las variaciones del precio internacional del petróleo, en dólares, como por las variaciones del tipo de cambio que se producen en el mismo periodo. Si existe una relación positiva entre el precio del petróleo en dólares y el valor de la moneda respecto al dólar, de forma que un incremento de $Poil^{\$}$ se corresponde con una reducción de $e$, las variaciones de $Poil^{dom}$ se verán suavizadas. Si esta relación se mantiene, se tiene que dar la condición $\theta_2 > \theta_1$, ya que la transmisión de las variaciones del precio se ven reducidas por la apreciación de la moneda respecto al dólar.

Analizamos esta relación para el efecto del euro en la transmisión del precio del petróleo a la zona euro. Para ello, estimamos la siguiente especificación partiendo del marco de la curva de Phillips con expectativas adaptativas descrita anteriormente:

$$\pi_t = \alpha + \beta E_t\pi_{t+1} + \gamma\,(y_t - \bar{y}_t)/\bar{y}_t + \sum_{i=0}^{4} \theta_i Poil^{\$}{}_{t-i} + VAT_t + \epsilon_t \qquad (24)$$

Donde $\pi_t$ es la tasa de inflación trimestral, ajustada estacionalmente, $y_t$ es el PIB real, ajustado estacionalmente, $\bar{y}_t$ es el PIB potencial, por lo que $(y_t - \bar{y}_t)/\bar{y}_t$ representa la brecha de la producción. $Poil^{\$}$ es la variación del precio del petróleo expresado en dólares. Incluimos esta variable contemporáneamente y con cuatro retardos para calcular el impacto a largo plazo, siguiendo a otros trabajos como Leblanc y Chinn (2004) y De Gregorio et al. (2007). $VAT_t$ es una variable *dummy* que toma valor 1 para los periodos en que se produce un aumento de los tipos impositivos del Impuesto al Valor añadido (IVA). $E_t\pi_{t+1}$ representa las expectativas futuras de inflación en el periodo actual. Siguiendo a Ball y Mazumber (2011) y Coibion y Gorodnichenko (2015), calculamos las expectativas adaptativas como el promedio de la tasa de inflación de los cuatro trimestres anteriores.

Para analizar el impacto final del precio del petróleo en la inflación controlando el efecto del tipo de cambio, en primer lugar, sustituimos el precio del petróleo en dólares por el precio en moneda doméstica:

$$\pi_t = \alpha + \beta E_t\pi_{t+1} + \gamma\,(y_t - \bar{y}_t)/\bar{y}_t + \sum_{i=0}^{4} \theta_i Poil^{dom}{}_{t-i} + VAT_t + \epsilon_t \qquad (25)$$

Finalmente, estimamos una tercera especificación, en la que incluimos el precio del petróleo en dólares y añadimos las variaciones del tipo de cambio, para controlar el efecto de las variaciones del tipo de cambio que se transmiten a través de las variaciones del precio del petróleo y adicionalmente estimar la transmisión de las variaciones del tipo de cambio a la inflación. La especificación es la siguiente:

$$\pi_t = \alpha + \beta E_t\pi_{t+1} + \gamma\,(y_t - \bar{y}_t)/\bar{y}_t + \sum_{i=0}^{4} \theta_i Poil^{\$}{}_{t-i} + \sum_{i=0}^{4} \delta_i er_{t-i} + VAT_t + \epsilon_t \qquad (26)$$

$\theta_1$ y $\delta_1$ representan la transmisión a corto plazo a la inflación del precio del petróleo y del tipo de cambio, respectivamente. La transmisión a largo plazo del precio del petróleo, $\emptyset$, y del tipo de cambio, $\varphi$, viene dada por las siguientes fórmulas:

$$\emptyset = \frac{\sum_{i=0}^{4} \theta_i}{1 - \beta} \qquad (27)$$

$$\varphi = \frac{\sum_{i=0}^{4} \delta_i}{1 - \beta} \qquad (28)$$

Por último, comparamos los coeficientes de la transmisión contemporánea del precio del petróleo a la inflación entre el modelo base (24) y el modelo aumentado con el tipo de cambio (26). A través del test desarrollado por Clogg et al. (1995) contrastamos que los coeficientes son significativamente distintos. El rechazo de la hipótesis nula de igualdad de coeficientes significa que, al incluir el tipo de cambio como variable de control, el coeficiente de la transmisión de las variaciones del precio del petróleo en dólares varía sustancialmente, lo que implica que el tipo de cambio afecta a esta transmisión. El test, basado en una distribución t-student, se calcula de la siguiente manera:

$$d = \theta_0^{base} - \theta_0^{aum} \tag{29}$$

$$s(d) = \sqrt{s^2(\theta_0^{aum}) - s^2(\theta_0^{ini}) * \widehat{\sigma_{aum}^2}/\widehat{\sigma_{ini}^2}} \tag{30}$$

$$t = \frac{d}{s(d)} \tag{31}$$

donde $d$ es la diferencia en los coeficientes de la transmisión del petróleo a corto plazo entre el modelo base y el modelo aumentado, $s(d)$ es la desviación típica de $d$. Finalmente, $t$ es el estadístico empleado en el test, que sigue una distribución t-student.

Para contrastar la robustez de las estimaciones, llevamos a cabo varias modificaciones en la especificación del modelo. En primer lugar, sustituimos la brecha de la producción por la brecha de desempleo, como medida de la desviación respecto al potencial en el mercado de trabajo y de la presión sobre los precios, de forma que $gap_t = (u_t - \bar{u}_t)/\bar{u}_t$.

En segundo lugar, sustituimos las expectativas adaptativas, representadas por la tasa de inflación media de los cuatro trimestres pasados, por la tasa de inflación de los últimos cuatro trimestres de forma individual, representando la inercia de la inflación. Según Gordon (1996, 2011), la correlación entre la inflación actual y la pasada no solo depende de las expectativas de los agentes, sino que es causada por otros factores como la indexación de los salarios y rentas de capital a la inflación pasada o la divergencia temporal entre las variaciones en los precios de las materias primas o los bienes intermedios y los precios finales. La persistencia o inercia de la inflación se estima como la suma de los coeficientes individuales de las tasas de inflación pasadas, y vendría expresado de la siguiente forma:

$$\sum_{i=1}^{4} \beta_i \pi_{t-i} = \beta_1 \pi_{t-1} + \beta_2 \pi_{t-2} + \beta_3 \pi_{t-3} + \beta_4 \pi_{t-4} \tag{32}$$

Finalmente, McLeay y Tenreyro (2020) sugieren la existencia de endogeneidad causada por la simultaneidad entre la tasa de inflación y la brecha de la producción. Si la política monetaria reacciona de forma endógena, estabilizando tanto la producción como la desviación de la inflación respecto a su objetivo y su función de reacción cambia ante variaciones en la inflación inducidas por shocks de oferta, la relación estimada entre inflación y producción será infraestimada por la forma reducida de la curva de Phillips. Aunque la inclusión de variables representativas de shocks de oferta, como las variaciones del precio del petróleo, mejoran la estimación de esta relación y reducen el sesgo, adicionalmente estimamos el modelo definido inicialmente a través del estimador GMM, con objeto de identificar correctamente las variaciones exógenas de la brecha de la producción y tratar la posible existencia de endogeneidad. Para ello, siguiendo a Fitzgerald and Nicolini (2014), usamos como instrumentos los cuatro retardos de la brecha de la producción, además del resto de variables exógenas incluidas anteriormente en el modelo.

La metodología precedente es aplicada también a Japón y Reino Unido con el fin de evaluar si existen diferencias sustanciales de comportamiento del tipo de cambio en la transmisión de las variaciones de los precios del petróleo a la inflación. La selección de estos dos países se debe a que sus divisas, yen y libra, son la tercera y cuarta divisa más empleada tras dólar y euro (BIS, 2019).

_Datos_

Usamos datos trimestrales, abarcando el periodo que abarca desde el primer trimestre de 1999 al tercer trimestre de 2019. Para la tasa de inflación, $\pi_t$, empleamos la variación trimestral del índice de precios al consumo armonizado (IPCA) ajustado estacionalmente. Para calcular la brecha de la producción, $(y_t - \bar{y}_t)/\bar{y}_t$, calculamos el PIB potencial, $\bar{y}_t$, aplicando el filtro de Hodrick-Prescott al PIB real ajustado estacionalmente, $y_t$. Para calcular la brecha de la tasa de desempleo $(u_t - \bar{u}_t)/\bar{u}_t$, aplicamos igualmente el filtro de Hodrick-Prescott a la tasa de desempleo ajustada estacionalmente, $u_t$, para obtener la tasa natural de desempleo, $\bar{u}_t$. La variación del tipo de cambio, $er_t$ se define como la variación porcentual del tipo de cambio bilateral entre la moneda doméstica y el dólar, expresado en unidades de moneda doméstica por dólar. Finalmente, para el precio del petróleo en dólares, ${Poil^{\$}}_t$, empleamos el precio del barril de Brent, en dólares nominales, mientras que obtenemos el precio del petróleo en moneda doméstica, ${Poil^{dom}}_t$, multiplicando el anterior por el tipo de cambio moneda doméstica/dólar, definido previamente, ambas expresadas en variaciones porcentuales.

### 4.3.2. Resultados

La Tabla 8 muestra los coeficientes de interés para nuestro análisis, obtenidos para las tres especificaciones de la curva de Phillips estimadas a través de MCO con errores estándar robustos de heteroscedasticidad y autocorrelación a través del estimador de Newey-West. Los resultados completos están recogidos en el apéndice del artículo incluido en la sección 4.3.3.

Las columnas 1 a 3 de la Tabla 8 muestran la estimación del que llamaremos modelo base, donde se incluye en la curva de Phillips el precio del petróleo en dólares. En el caso de la zona euro, el coeficiente de las expectativas de inflación es positivo y significativo. Por otra parte, la brecha de la producción muestra una relación positiva y significativa con la tasa de inflación, acorde con la teoría de la curva de Phillips. Respecto al precio del petróleo en dólares, muestra un impacto contemporáneo significativo en la inflación, de forma que un incremento del 1% en el precio del petróleo aumenta la inflación trimestral en 0,0156 puntos porcentuales. En el largo plazo, sin embargo, un aumento del 1% en el precio del petróleo supone un incremento de 0,0317 puntos porcentuales en la inflación. En el caso de Reino Unido y Japón, el impacto a corto plazo de las variaciones del precio del petróleo a la inflación es más reducido, siendo 0,0101 y 0,0052 puntos porcentuales, respectivamente. El efecto a largo plazo es mayor en Reino Unido, mientras que en Japón es más reducido y no significativo.

Las columnas 4-6 de la tabla muestran la estimación de la ecuación (25), donde se sustituye el precio de petróleo en dólares por el precio en moneda doméstica, eliminando el impacto indirecto de la transmisión del precio del petróleo a la inflación que se produce a través de las variaciones del tipo de cambio respecto al dólar. Los resultados muestran que, en la zona euro, el precio del petróleo tiene un impacto mayor en la inflación cuando se expresa en euros. El impacto contemporáneo de un aumento del 1% es de 0,0182 puntos porcentuales, mientras que en el largo plazo es de 0,0391. Esto implica que la transmisión de los aumentos del precio internacional del petróleo (facturado en dólares) se ve amortiguada como consecuencia de la apreciación del euro respecto al dólar.

**Tabla 8.** Estimación de curva de Phillips (1991Q1-2019Q3).

| | **Modelo base** | | | **Precio en moneda doméstica** | | | **Modelo extendido** | | |
|---|---|---|---|---|---|---|---|---|---|
| | **Euro** | **UK** | **Japón** | **Euro** | **UK** | **Japón** | **Euro** | **UK** | **Japón** |
| $E_t\pi_{t+1}$ | 0.3604** | 0.5682*** | 0.3366*** | 0.5102*** | 0.5409*** | 0.3441*** | 0.5346*** | 0.5531*** | 0.3512*** |
| | (0.010) | (0.000) | (0.009) | (0.000) | (0.000) | (0.007) | (0.000) | (0.000) | (0.008) |
| $(y_t - \bar{y}_t)/\bar{y}_t$ | 0.0666*** | 0.0150 | 0.0853*** | 0.0679*** | 0.0120 | 0.0752*** | 0.0677*** | 0.0326 | 0.0633** |
| | (0.000) | (0.674) | (0.001) | (0.000) | (0.710) | (0.003) | (0.000) | (0.301) | (0.027) |
| $Poil^{\$}{}_t$ | 0.0156*** | 0.0101*** | 0.0052*** | | | | 0.0185*** | 0.0110*** | 0.0059*** |
| | (0.000) | (0.000) | (0.003) | | | | (0.000) | (0.000) | (0.001) |
| $Poil^{dom}{}_t$ | | | | 0.0182*** | 0.0115*** | 0.0056*** | | | |
| | | | | (0.000) | (0.000) | (0.002) | | | |
| $er_t$ | | | | | | | 0.0244*** | 0.0074 | 0.0028 |
| | | | | | | | (0.001) | (0.374) | (0.748) |
| $VAT$ | | 0.0078*** | 0.0210*** | | 0.0078*** | 0.0208*** | | 0.0080*** | 0.0207*** |
| | | (0.000) | (0.000) | | (0.000) | (0.000) | | (0.000) | (0.000) |
| $cons$ | 0.0024*** | 0.0020*** | -0.0002 | 0.0018*** | 0.0020 | -0.0002 | 0.0017*** | 0.0018*** | -0.0002 |
| | (0.000) | (0.001) | (0.588) | (0.000) | (0.001) | (0.509) | (0.004) | (0.002) | (0.439) |
| $\emptyset$ | 0.0317*** | 0.0411*** | 0.0137 | 0.0391*** | 0.0456 | 0.0168* | 0.0397*** | 0.0523*** | 0.0213* |
| | (0.000) | (0.001) | (0.114) | (0.000) | (0.000) | (0.092) | (0.000) | (0.000) | (0.058) |
| $\varphi$ | | | | | | | 0.0460 | 0.1048*** | 0.0357 |
| | | | | | | | (0.231) | (0.003) | (0.210) |
| R2 | 0.7646 | 0.6185 | 0.5916 | 0.8148 | 0.6201 | 0.5929 | 0.8198 | 0.6863 | 0.6072 |
| R2 corregido | 0.7410 | 0.5743 | 0.5443 | 0.7963 | 0.5761 | 0.5457 | 0.7866 | 0.6226 | 0.5274 |
| F-statistic | 32.48*** | 13.98*** | 12.50*** | 44.00*** | 14.08*** | 12.56*** | 24.65*** | 10.77*** | 7.61*** |
| | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) |
| J-B test | 0.4406 | 2.5014 | 0.3208 | 0.4727 | 0.9678 | 0.0252 | 0.6691 | 1.7556 | 0.5120 |
| | (0.802) | (0.286) | (0.852) | (0.790) | (0.616) | (0.987) | (0.716) | (0.416) | (0.774) |
| L-B B-P test | 2.3943 | 3.8240 | 1.2515 | 2.0902 | 3.3169 | 1.2182 | 2.1716 | 0.6066 | 1.3060 |
| | (0.302) | (0.148) | (0.535) | (0.352) | (0.190) | (0.544) | (0.338) | (0.738) | (0.521) |
| B-G test | 2.663 | 4.386 | 1.369 | 2.176 | 4.095 | 1.250 | 2.209 | 0.683 | 1.532 |
| | (0.264) | (0.112) | (0.504) | (0.337) | (0.129) | (0.535) | (0.331) | (0.711) | (0.465) |
| B-P test | 10.10 | 19.51*** | 10.86 | 6.07 | 15.41 | 14.06* | 13.18 | 16.78 | 16.00 |
| | (0.183) | (0.012) | (0.210) | (0.531) | (0.052) | (0.080) | (0.356) | (0.210) | (0.249) |
| ARCH test | 0.4587 | 4.2439 | 2.1932 | 0.7795 | 2.0303 | 2.1300 | 0.4640 | 2.5501 | 0.8430 |
| | (0.500) | (0.120) | (0.334) | (0.380) | (0.362) | (0.345) | (0.498) | (0.279) | (0.656) |
| $d$ | | | | | | | -0.0028*** | -0.0007 | -0.0007 |
| $t$ | | | | | | | -2.8071 | -0.4247 | -1.5279 |
| p-value | | | | | | | 0.006 | 0.672 | 0.131 |

Fuente: Elaboración propia. *Nota*: *, ** y *** denotan significatividad al 10, 5 y 1% respectivamente. P-valor en paréntesis. Errores estándar robustos corregidos de heterocedasticidad y autocorrelación a través del estimador de Newey West. $d = \theta_0^{base} - \theta_0^{aum}$ representa la diferencia entre los coeficientes de $Poil^{\$}{}_t$ en el modelo inicial y aumentado, $t = d/s(d)$ es el estadístico t-student, donde s(d) es la desviación estándar de d (ver Clogg et al., 1995).

A diferencia de lo que ocurre en la zona euro, la transmisión del precio del petróleo en moneda doméstica en Reino Unido y Japón no varía significativamente respecto a la estimación del modelo base. Es decir, no existe una relación significativa entre las variaciones del precio del petróleo y el tipo de cambio de sus monedas, de manera que sus fluctuaciones no han actuado como amortiguador de las variaciones del precio internacional del petróleo, como si ha ocurrido en el caso de la zona euro.

Para analizar esta relación más detalladamente, estimamos el modelo especificado en la ecuación (26), donde se añaden simultáneamente el tipo de cambio y el precio del petróleo en dólares. De esta forma, podemos comparar los coeficientes de las variaciones del precio del petróleo en dólares estimados en la columna 1-3 y 7-9, siendo (26) un modelo aumentado de la ecuación (24) para controlar por las variaciones del tipo de cambio y, por tanto, estimar el impacto directo del precio del petróleo en la inflación. Para la zona euro, los resultados recogidos en la columna 7-9 muestran unos coeficientes muy similares a los estimados en el modelo con precios del petróleo en moneda doméstica (columnas 4-6). El impacto contemporáneo del precio del petróleo es de 0,0185 puntos porcentuales en la tasa de inflación, con un efecto a largo plazo de 0,0397. Este coeficiente es superior al obtenido en la estimación del modelo base, cuyos valores en el corto y largo plazo eran de 0,0156 y 0,0317, respectivamente. Utilizando el test de Clogg et al. (1995) podemos concluir que las diferencias son significativas al 1%. Finalmente, las variaciones del tipo de cambio tienen un impacto significativo, de manera que una apreciación del euro del 1% (que se corresponde con una disminución de la variable $er$) reduce la tasa de inflación en 0,0244 puntos porcentuales, con un impacto a largo plazo de 0,046.

En el caso de Reino Unido y Japón, las diferencias en el coeficiente de la transmisión del petróleo a la inflación entre la estimación del modelo base y del modelo aumentado no son significativas, lo que implica que, en estos países, las variaciones del tipo de cambio no han suavizado el impacto del precio del petróleo en la inflación. Por otra parte, los resultados muestran que el tipo de cambio no tiene un impacto contemporáneo en la inflación en ninguno de los dos países, aunque en Reino Unido muestra un impacto significativo con dos cuartos de retardos, de forma que su efecto a largo plazo en la inflación es significativo.

Para contrastar la robustez de los resultados, llevamos a cabo la estimación a través de las tres especificaciones alternativas descritas en el apartado anterior. Los resultados de las estimaciones están recogidos en el apéndice del artículo adjunto en la sección 4.3.3. Tales resultados se mantienen en línea con los obtenidos en la especificación principal. La transmisión del precio del petróleo y el efecto del tipo de cambio en esta transmisión se mantienen con coeficientes muy similares, por lo que las conclusiones obtenidas no dependen de la especificación del modelo. Cuando estimamos la curva de Phillips a través de GMM, observamos una mayor relación entre la brecha de la producción y la inflación, aunque este resultado no afecta a los coeficientes de la transmisión del precio del petróleo a la inflación.

*¿Ha cambiado esta relación en el tiempo?*

Recientes trabajos han argumentado que la relación entre el precio del petróleo y el tipo de cambio respecto al dólar se ha intensificado tras la Gran Recesión (Reboredo, 2012; Reboredo et al., 2014; Malik y Umar, 2019). Además, Coudert y Mignon (2016) muestran que existe una ruptura estructural en la relación entre el precio del petróleo y el tipo de cambio del dólar que tiene lugar a mediados de la década de los 2000s, cambiando el signo de la relación. Para estudiar la posible existencia de una relación variante en el tiempo entre el tipo de cambio euro/dólar y el precio del petróleo y, por tanto, de su papel en la transmisión de las variaciones del precio del petróleo a la inflación, en esta sección estimamos el modelo base y el modelo aumentado a través del método de ventanas sucesivas (rolling window), usando una ventana de 10 años (40 trimestres) siguiendo a Marazzi et al., (2005), de manera que el número de observaciones sea suficiente para una adecuada estimación de los parámetros. Este método nos permite analizar la evolución de la transmisión del precio del petróleo a la inflación y determinar si el efecto del tipo de cambio en esta transmisión ha cambiado a lo largo del periodo estudiado.

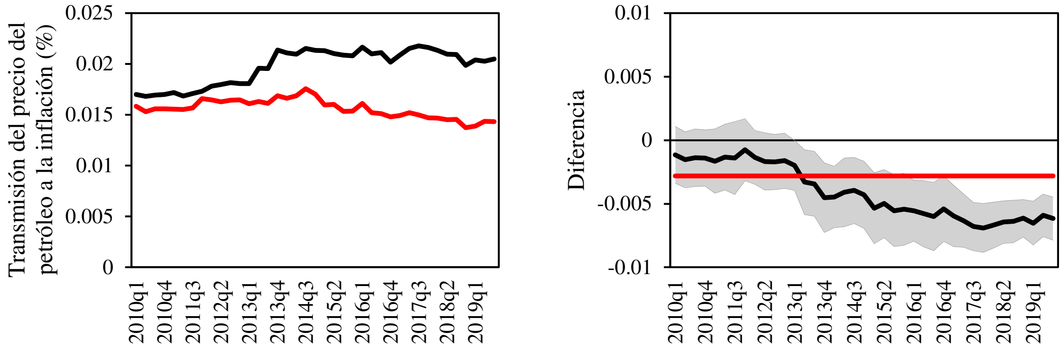
La Figura 15 presenta la evolución de la transmisión de los precios del petróleo a la inflación, tanto en el modelo base como en el modelo aumentado en el que se incorpora el efecto del tipo de cambio, así como la diferencia entre ambos, que representa el efecto indirecto del tipo de cambio en la transmisión del precio del petróleo.

En la zona euro, la Figura 15 muestra que la transmisión se ha mantenido relativamente estable a lo largo del periodo estudiado, mientras que el efecto del tipo de cambio siempre ha sido negativo, es decir, ha amortiguado el impacto directo de las fluctuaciones del precio del petróleo. Además, este efecto se ha intensificado. Al inicio del período, el efecto de las fluctuaciones del tipo de cambio sobre la transmisión del precio del petróleo es negativo, aunque no es estadísticamente significativo. Este período se corresponde con las muestras móviles que incluyen el período de principios de la década de los 2000s, cuando la relación entre el tipo de cambio euro/dólar y los precios del petróleo es negativa (Coudert y Mignon, 2016). Sin embargo, su papel como amortiguador de los shocks aumenta con el tiempo, siendo superior al efecto promedio que hemos encontrado en las estimaciones invariantes en el tiempo. El papel creciente del tipo de cambio comienza a mediados de la década de 2000, coincidiendo con la fecha en que otros trabajos marcan la ruptura estructural en la relación entre el tipo de cambio euro/dólar y los precios del petróleo (Coudert y Mignon, 2016). En la misma línea, estos resultados apoyan el hecho de que la relación entre los precios del petróleo y el tipo de cambio euro/dólar se ha intensificado tras la Gran Recesión.

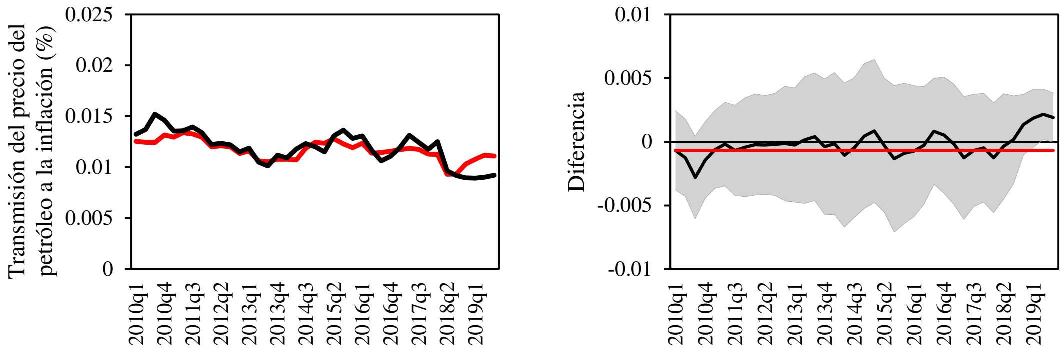
En contraste, encontramos que el papel del tipo de cambio en la transmisión de los precios del petróleo en Reino Unido y Japón no ha sido estadísticamente significativo durante todo el período. En el caso de Reino Unido, el tipo de cambio no parece haber estado relacionado con los precios del petróleo, mientras que en el caso de Japón la relación ha evolucionado en el tiempo, por lo que el tipo de cambio ha intensificado la transmisión durante algunos episodios. y lo ha amortiguado en otros períodos, aunque no es estadísticamente significativo. Por tanto, podemos considerar que el efecto amortiguador del euro ha sido una característica propia de la zona euro, y no un hecho general para el resto de países con monedas con carácter internacional.

**Figura 15.** Estimación de la transmisión del precio del petróleo a la inflación variante en el tiempo.

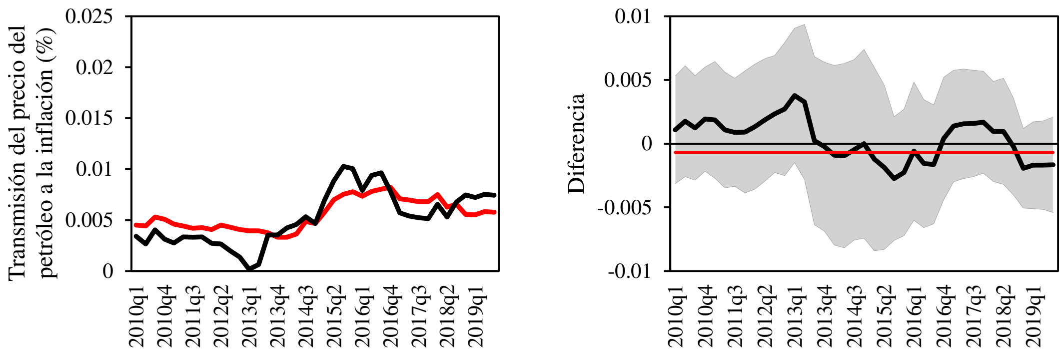
a) Zona euro




b) Reino Unido




c) Japón




*Notas*: La columna 1 muestra la evolución de la transmisión de las fluctuaciones del precio del petróleo a la inflación. La línea roja representa la transmisión del precio del petróleo en el modelo base. La línea negra representa la transmisión del precio del petróleo en el modelo aumentado. La columna 2 muestra el efecto del tipo de cambio en la transmisión del precio del petróleo a la inflación. La línea negra muestra la evolución del efecto del tipo de cambio, siendo la zona sombreada el intervalo de confianza al 95%. La línea roja muestra el efecto del tipo de cambio estimado en la regresión no variante en el tiempo.

### 4.3.3. Artículo nº 5.

### Inflation, oil prices and exchange rates. The euro's dampening effect.

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# Inflation, oil prices, and exchange rates. The Euro's dampening effect

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**Abstract**

This paper aims to analyse the relationship between the euro/dollar exchange rate and oil prices and, for the period between 1999Q1 and 2019Q3, examine what effect this relationship had on the transmission of oil price fluctuations to headline inflation in the euro area since the currency's creation. To do this, we estimate an augmented Phillips curve with backward-looking expectations, including changes in oil price, through which we study the role of the exchange rate in oil price pass-through by using different measures of oil prices. The main findings reveal a positive relationship between the euro/dollar exchange rate and oil prices, such that an increase in the price of oil is followed by an appreciation in the euro. We also find that the transmission of oil price fluctuations to headline inflation in the euro area has been partially dampened by this appreciation in the euro/dollar exchange rate. These results do not hold for other economies with internationally relevant currencies, such as Japan and the United Kingdom.

Keywords: Oil price; pass-through; inflation dynamics; exchange rate.

JEL codes: E31; F31; Q43

## 1. Introduction

Since the first oil shock in 1973, oil price pass-through into inflation has been widely studied in economics. Many studies have shown that oil price movements are transmitted to overall price levels (Brown et al., 1995; Hooker, 2002; Hamilton and Herrera, 2004). This transmission occurs directly through movements in the prices of petroleum products as well as indirectly through higher prices of industrial inputs. There are also second-round effects, such as wage increases (Peersman and Van Robays, 2009). The indirect effects include the effect caused by exchange rate fluctuations triggered by an oil price shock. Oil is internationally invoiced in dollars, such that the cost incurred by the importing country depends on the exchange rate of its currency against the dollar. In other words, oil price fluctuations can be softened or amplified depending on whether the exchange rate appreciates or depreciates against the dollar, respectively. This relationship can affect oil price transmission both directly, since exchange rate fluctuations influence the price of oil in domestic currency, and indirectly, through the impact of exchange rate fluctuations on the price of imported goods and services, which can translate to higher costs for intermediate inputs or consumer goods. Finally, it can also affect consumer prices through changes in the composition in demand, in relation to the volume of imports and exports triggered by fluctuations in the exchange rate.

In this paper, we focus on analysing the role of the exchange rate in oil price pass-through into inflation in the euro area. The euro area exhibits a high dependence on oil and its acquisition from third countries. In 2018, the external dependency of the 19 euro area countries, measured as the percentage of net imports of crude oil and petroleum products in gross available energy, reached 96% (Eurostat, 2019). The imports of crude oil and petroleum products accounted for an average of 2.26% of euro area GDP in the period 1999-2018, reaching values above 3.5% of GDP. As regards inflation, the weight of petroleum-related products in the basket of products that make up the HICP is also very high. During the period 1999-2019, the weight of fossil fuels averaged 4.96% of the basket, amounting to 9.5% when considering the weight of energy prices (Eurostat, 2019). Therefore, euro area inflation rates are sensitive to fluctuations in international oil prices, which is traded in dollars, as well as to fluctuations in the exchange rate, since this determines oil price imports in euros.

Several studies have found that oil price is positively linked to the euro/dollar exchange rate, although they do not concur vis-à-vis the direction of causality, such that increases in oil prices are accompanied by an appreciation in the euro (Thalassinos and Politis, 2012; Reboredo et al., 2014; Thurhan et al., 2014). This positive relationship between oil prices and the euro exchange rate can be seen in Figure 1, which shows the evolution of the Brent oil price, expressed in dollars, and the dollar/euro exchange rate (an increase means an appreciation of the euro against the dollar). Both variables display a similar evolution during the period studied, suggesting the existence of a relationship between them.

This singularity is even more relevant if we take into account that studies exploring the relationship between oil price and the German mark's exchange rate, the strongest legacy currency of the euro, found a negative relationship between them, such that the mark depreciated in the face of a rise in international oil prices (Armano and Van Norden, 1998a; Chaudhuri and Daniel, 1998; Chen and Chen, 2007). The same result is also found in Clostermann and Schnatz (2000), who analyse the relationship between oil prices and the exchange rate of a synthetic euro, built from the weighted values of the legacy currencies of the euro before its introduction.

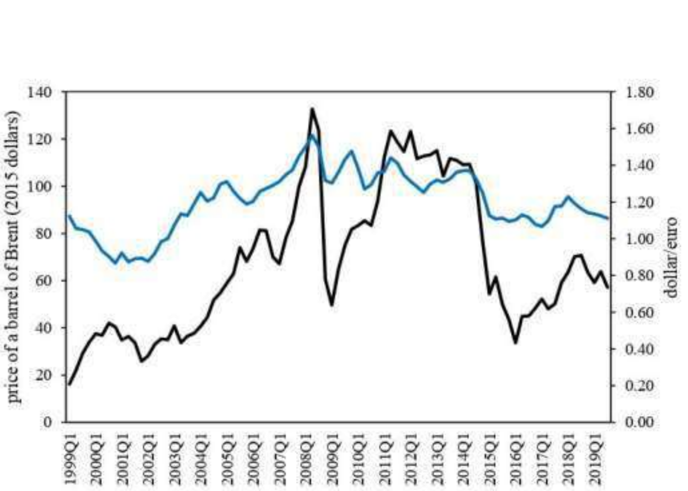


**Figure 1.** Quarterly evolution of Brent oil price (in dollars) and the dollar/euro exchange rate. Source: Energy Information Administration (EIA) and International Financial Statistics (IMF). The black line represents the price of oil. The blue line represents the dollar/euro exchange rate.

The aim of this paper is to provide empirical evidence on the role of the exchange rate in the transmission of oil prices to inflation in the euro area and to test whether the single European currency has benefited or suffered in terms of the effect on inflation since its creation. For this purpose, based on an augmented Phillips curve framework, including oil price variations, we estimate the impact of the euro/dollar exchange rate on oil-inflation pass-through using two complementary specifications: first, converting international oil prices into domestic currency, such that its fluctuations include contemporary exchange rate movements; and second, including the euro/dollar exchange rate in the augmented Phillips curve together with oil price fluctuations in dollar terms so as to control for the effects of exchange rate movements on inflation. Finally, we statistically compare the pass-through coefficients to test whether significant differences emerge when including the euro/dollar exchange rate. For comparative purposes, we also estimate the same specifications for the United Kingdom and Japan, two economies with highly internationally traded currencies (BIS, 2019) like the euro, and which therefore might have experienced a similar relationship with regard to oil prices.

The results obtained for the period spanning from 1999Q1 to 2019Q3 show that the euro and its relationship with the dollar have led to exchange rate fluctuations that have dampened oil price pass-through into the inflation rate. Thus, variations in the euro/dollar exchange rate are seen to have reduced the impact of oil prices on inflation in the euro area by around 15% during the period studied. Furthermore, this effect has been maintained throughout the period analysed, although it has intensified over time. These results contrast with those found for the United Kingdom and Japan, where no significant relationship was found to exist in terms of movements in their currency exchange rates vis-à-vis the dollar in oil price transmission to inflation.

The remainder of the work is structured as follows: section 2 provides a review of the literature on the relationship between oil prices, exchange rates and inflation; section 3 explains the methodology and data used; section 4 presents the results, while section 5 puts forward the conclusions drawn from the work and offers some discussion.

## 2. Literature review

Oil price shocks has traditionally had a significant effect on inflation (Mork, 1994; Brown et al., 1995; Hooker, 2002; Hamilton and Herrera, 2004; Cuñado and Perez de Gracia, 2005). The channels through which fluctuations in oil prices are transmitted to inflation rates are diverse (Peersman and Van Robays, 2009). One direct effect stems from the transmission of oil prices to the prices of energy products geared towards consumption, within which petroleum products have an enormous weight. The indirect channel works through production input costs. Crude oil and petroleum products are an important input for production in some industries, such that a rise in the price of these products will translate into an increase in production costs that ends up affecting the consumer prices of goods and services when companies can pass the higher costs through to prices. Finally, when oil price fluctuations substantially alter inflation rates, second-round effects may appear, which are triggered by the inflationary spiral associated with income indexation to inflation.

In the euro area, Peersman and Van Robays (2009) found that this transmission mainly occurs through second-round effects. In contrast, Enders and Enders (2017) fail to find any second-round effects in the euro area, while Alvarez et al. (2011) find that pass-through occurs mainly via the direct channel, whereas the indirect and the second-round channels have little impact.

The empirical literature has found that the oil price pass-through into inflation has decreased over the last few decades, especially after the 1980s (Hooker, 2002; LeBlanc and Chinn, 2004; Herrera and Pesavento, 2009; Clark and Terry, 2010). The main causes posited for this decline in transmission include: low oil consumption intensity (Blanchard and Gali, 2007; De Gregorio et al., 2007; Van de Noord and André, 2007; Choi et al., 2018), a reduction in wage indexation (Blanchard and Riggi, 2013), improved monetary policy (Blanchard and Gali, 2007; Chen 2009, Choi et al., 2018), or a more stable inflation environment (De Gregorio et al., 2007; Van de Noord and André, 2007).

Nevertheless, two other explanations related to the objective of our work have also been put forward: a lower transmission of exchange rate fluctuations to inflation (De Gregorio et al., 2007) and an appreciation of domestic currency exchange rates (Chen, 2009). Indeed, in addition to the aforementioned transmission channels, an additional transmission channel arises due to the fact that fluctuations in oil price may also affect inflation through its impact on the exchange rate. Oil is invoiced in dollars and may therefore affect the exchange rate of other currencies. In fact, there are multiple studies that have analysed the existence of a relationship between the dollar exchange rate and the price of oil (see Beckman et al., 2020).

Since the dollar is the denomination currency of oil prices, many studies have explored the relationship between the price of oil and the dollar's effective exchange rate. Coudert and Mignon (2016) show that a structural break in this relationship occurred in the early 2000s. Prior to this date, a positive relationship between the two variables was found; that is, an increase in oil prices was correlated with an appreciation of the dollar (Amano and Van Norden, 1998b; Bénassy-Quéré et al., 2007; Coudert et al., 2007). However, more recent studies, which include the subsequent period, have found that a depreciation of the dollar is related to a rise in oil prices (Beckmann and Czudaj, 2013a; McLeod and Haughton, 2018).

Beckmann and Czudaj (2013b) consider it more appropriate to analyse the relationship between oil prices and each country's bilateral exchange rate, since this may provide more information. When studying the relationship between bilateral exchange rates and the price of oil, the main result found is a positive relationship between exchange rates against the dollar and the price of oil (Reboredo, 2012Aloui et al., 2013; Reboredo et al., 2014; Chen et al., 2016; Su et al., 2016; Yang et al., 2018) that has intensified since the Great Recession (Reboredo, 2012; Reboredo et al., 2014; Malik and

Umar, 2019), although certain works do find a negative relationship for the exchange rates of some importing countries (Lizardo and Mollick, 2010; Beckman et al., 2016). Other studies suggest the existence of asymmetric (Ahmad and Moran Hernandez, 2013; Atems et al., 2015; Beckmann et al., 2016) and non-linear relationships (Basher et al., 2016; Su et al., 2016) between the exchange rate and oil prices. As regards the causal relationship, some studies indicate that this runs from oil prices to exchange rates (Atems et al., 2015; Basher et al., 2016), while others find the opposite relation (Becmann and Czudaj, 2013a; Jawadi et al., 2016). In the case of the euro, most of the literature (Zhang et al., 2008; Thalassinos and Politis, 2012; Aloui et al., 2013; Reboredo et al., 2014; Beckmann and Czudaj, 2013b; Su et al., 2016; Yang et al., 2018; Mollick and Sakaki, 2019) agrees that an increase in oil prices is related to a depreciation of the dollar against the euro.

On the other hand, the effect of exchange rate fluctuations on the transmission of oil prices to inflation also depends on the degree of transmission of exchange rate fluctuations to consumer prices. Exchange rate transmission to inflation has also decreased since the 1980s in advanced countries, a fact linked to greater price stability (Choudhri and Hakura, 2006; Shintani et al., 2013) resulting from a more effective monetary policy (Gagnon and Ihrig, 2004). Marazzi et al., (2005) suggest that part of the exchange rate transmission to inflation occurs through commodity prices, such that the lower pass-through observed since the 1980s, in the case of the US, is due to a lower share of imports of products that are intensive in the use of commodities. However, for euro area countries, several works show that there has been no reduction in this transmission since the introduction of the euro (Campa and Goldberg, 2005; Campa and Gonzalez, 2006; Cheikh and Rault, 2016). Finally, the recent literature suggests that the degree of transmission of exchange rate fluctuations also depends on the source triggering the exchange rate movements, such that it is low for aggregate demand shocks and higher for monetary policy shocks (Forbes et al., 2018). In euro area countries, it is monetary policy and exchange rate shocks that cause a higher transmission to import prices (Commale and Kunovac, 2017), whilst the pass-through into consumer prices is lower than it is to import prices. However, these papers do not analyse the transmission of exchange rate fluctuations caused by oil price shocks.

The literature review highlights the lack of empirical studies exploring the role of the exchange rate in the transmission of oil prices to inflation in the euro area and whether the single European currency might have proved beneficial or harmful in terms of the effects on inflation for member countries.

## 3. Methodology and data

### 3.1. Methodology

We base our empirical work on an augmented Philips curve, where oil price fluctuations are included:

$$\pi_t = \beta E_t \pi_{t+1} + \gamma gap_t + \theta_1(L) Poil^{\$}_t + \epsilon_t \tag{1}$$

where $\pi_t$ represents the inflation rate, $E_t \pi_{t+1}$ represents expectations of future inflation, $gap_t$ is a measure of the slack in the economy, $Poil_t^{\$}$ represents oil price variations in dollars, (L) is the polynomial lag operator, and $\epsilon_t$ is the error term (iid). To empirically analyse the final effect of oil price fluctuations on importing countries, as is the case of the euro area, we replace the price of oil in dollars with the price of oil in domestic currency, which is the price finally borne by oil importers. Equation (1) is thus transformed into the following formula:

$$\pi_t = \beta E_t \pi_{t+1} + \gamma gap_t + \theta_2(L) Poil^{dom}_t + \epsilon_t \tag{2}$$

where $Poil_t^{dom}$ represents oil price fluctuations in domestic currency. Changes in the price of oil in domestic currency can be separated into fluctuations in the price of oil in dollars and fluctuations in the currency exchange rate against the dollar:

$$Poil^{dom}_t = Poil^{\$}_t + er_t \tag{3}$$

$er_t$ being the variation of the exchange rate against the dollar, expressed as $er_t = \Delta\%(domestic\ currency_t /\ dollar_t)$, such that an increase in $er_t$ corresponds to a depreciation of the currency against the dollar. In this way, we can rewrite our augmented Phillips curve as follows:

$$\pi_t = \beta E_t \pi_{t+1} + \gamma gap_t + \theta(L)(Poil^{\$}_{\ t} + er_t) + \epsilon_t \tag{4}$$

The impact of oil price movements on inflation thus occurs both through fluctuations in the international price of oil, in dollars, as well as through fluctuations in the exchange rate that occur at the same time. If a positive relationship between the price of oil in dollars and the currency exchange rate against the dollar exists, such that an increase in $Poil^{\$}$ is followed by a decrease in $er_t$, fluctuations in $Poil_t^{dom}$ would be softened. If this relationship holds, then $\theta_2 > \theta_1$, since the transmission of oil price movements is reduced by the appreciation of the currency against the dollar.

In this paper, we study this relationship for the role played by the euro in the transmission of oil prices to inflation in the euro area. To analyse this relationship, we estimate the following specification, based on the Phillips curve framework with backward-looking expectations, as described above:

$$\pi_t = \alpha + \beta E_t \pi_{t+1} + \gamma (y_t - \bar{y}_t)/\bar{y}_t + \sum_{i=0}^{4} \theta_i Poil^{\$}_{\ t-i} + VAT_t + \epsilon_t \tag{5}$$

where $\pi_t$ is the quarterly inflation rate, seasonally adjusted, $y_t$ is real GDP, seasonally adjusted, and $\bar{y}_t$ is potential GDP, such that $(y_t - \bar{y}_t)/\bar{y}_t$ represents the output gap. $Poil^{\$}_{\ t}$ is the percentage change in the price of oil, expressed in dollars. We include this variable with four lags so that we can estimate the long-run pass-through, following other works such as Lablanc and Chinn (2004) and De Gregorio et al. (2007). $VAT_t$ is a dummy variable which takes the value 1 for periods when value added tax (VAT) are raised. $E_t\pi_{t+1}$ represents the expected future inflation in the current period. Following Ball and Mazumber (2011) and Coibion and Gorodnichenko (2015), we calculate the backward-looking expectations as the average inflation rate for the past four quarters.

To analyse the final impact of oil prices on inflation, controlling for the impact of the exchange rate, we first substitute the price of oil in dollars for the price in domestic currency:

$$\pi_t = \alpha + \beta E_t \pi_{t+1} + \gamma (y_t - \bar{y}_t)/\bar{y}_t + \sum_{i=0}^{4} \theta_i Poil^{dom}_{\ t-i} + VAT_t + \epsilon_t \tag{6}$$

Finally, we estimate a third specification, in which we include the price of oil in dollars and add the exchange rate fluctuations in order to control for the impact of exchange rate fluctuations transmitted through oil price fluctuations and, additionally, estimate the exchange rate pass-through into inflation. The specification is as follows:

$$\pi_t = \alpha + \beta E_t \pi_{t+1} + \gamma (y_t - \bar{y}_t)/\bar{y}_t + \sum_{i=0}^{4} \theta_i Poil^{\$}_{\ t-i} + \sum_{i=0}^{4} \delta_i er_{t-i} + VAT_t + \epsilon_t \tag{7}$$

$\theta_1$ and $\delta_1$ represent short-run oil prices and exchange rate pass-through into inflation, respectively. The long-run pass-through of oil prices, $\emptyset$, and exchange rate, $\varphi$, to inflation are calculated as follows:

$$\emptyset = \frac{\sum_{i=0}^{4} \theta_i}{1 - \beta} \tag{8}$$

$$\varphi = \frac{\sum_{i=0}^{4} \delta_i}{1 - \beta} \tag{9}$$

Finally, we compare the coefficients of the contemporary transmission of oil price to inflation between the baseline model (5) and the augmented model with the exchange rate (7). Using the test developed by Clogg et al. (1995), we test whether the coefficients are statistically different. The rejection of the null hypothesis of equality of the coefficients means that when the exchange rate is included as a control variable the coefficients of the transmission of oil prices in dollars change substantially, implying that the exchange rate affects this transmission. The test, based on the t-student distribution, is calculated as follows:

$$d = \theta_0^{base} - \theta_0^{aum} \tag{10}$$

$$s(d) = \sqrt{s^2(\theta_0^{aum}) - s^2(\theta_0^{ini}) + \widehat{\sigma_{aum}^2}/\widehat{\sigma_{ini}^2}} \tag{11}$$

$$t = \frac{d}{s(d)} \tag{12}$$

where $d$ is the difference between the short-run pass-through of oil prices between the baseline model and the augmented model, $s(d)$ is the standard deviation of $d$. Finally, $t$ is the statistic used in the test, which follows a t-student distribution.

To test the robustness of the results, we made some modifications to the model specification. First, we replace the output gap with the unemployment gap, as a measure of the slack in the labour market and price pressure $gap_t = (u_t - \bar{u}_t)/\bar{u}_t$, where $u_t$ is the unemployment rate and $\bar{u}_t$ is the natural rate of unemployment.

Secondly, we replace the backward-looking expectations, represented by the average inflation rate of the past four quarters, by the inflation rate of the past four quarters individually, which better represents the inertia of inflation. According to Gordon (1997, 2011), the correlation between current and past inflation depends not only on agents' expectations, but is caused by other factors such as the indexation of wages and incomes to past inflation or temporal divergence between fluctuations in the prices of commodities or intermediate goods and consumer prices. Inflation persistence or inertia is estimated as the sum of the four individual coefficients of past inflation rates, and it would be expressed as follows:

$$\sum_{i=1}^{4} \beta_i \pi_{t-i} = \beta_1 \pi_{t-1} + \beta_2 \pi_{t-2} + \beta_3 \pi_{t-3} + \beta_4 \pi_{t-4} \tag{13}$$

Finally, McLeay and Tenreyro (2020) suggest the presence of endogeneity caused by the simultaneity, which arise between the inflation rate and the output gap measures. If monetary policy reacts endogenously, stabilizing both the output gap and the deviation of inflation from its target, and its targeting rule reacts to changes in the inflation rate induced by cost-push shocks, the estimated relationship between inflation and the output gap will be underestimated by the reduced-form Phillips curve. Even though the inclusion of variables capturing cost-push shocks, such as fluctuations in oil prices, improves the estimation of this relationship and reduces the implicit bias, we additionally estimate the initial model trough the GMM estimator, in order to correctly identified the exogenous changes of the output gap and address the presence of endogeneity. Following Fitzgerald and Nicolini (2014), we use four lags of the output gap as instruments, as well as the rest of exogenous variables previously included in the model.

The preceding methodology is also applied to Japan and the United Kingdom in order to assess whether there are substantial differences in behaviour in the transmission of oil prices to inflation. We select these two countries because their currencies, the yen and the pound, are the third and fourth most traded currencies in the world, after the dollar and the euro (BIS, 2019).

### 3.2. Data

In this work, we use quarterly data, spanning a period from 1999Q1 to 2019Q3. For the inflation rate $\pi_t$, the quarterly variation of the seasonally adjusted Harmonized Consumer Price Index (HICP) is used. To calculate the output gap, $(y_t - \bar{y}_t)/\bar{y}_t$, we calculate the potential GDP $\bar{y}$ applying the Hodrick-Prescott filter to the seasonally adjusted real GDP, $\bar{y}$. For the unemployment gap, $(u_t - \bar{u}_t)/\bar{u}_t$, we also apply the Hodrick-Prescott filter to the seasonally adjusted unemployment rate, $u_t$, to obtain the natural rate of unemployment $\bar{u}_t$. The variation in the exchange rate, $er_t$ is defined as the percentage variation of the bilateral currency exchange rate against the dollar, expressed in unit of domestic currency per dollar. Finally, for the price of oil in dollars, $Poil^{\$}{}_t$ we use the dollar price of a barrel of Brent oil, in nominal dollars, while we obtain the price of oil in domestic currency, $Poil^{dom}{}_t$ by multiplying the latter by the already defined domestic currency/dollar exchange rate. Both variables are expressed in percentage variations. Table 1 shows the definition of each variable and its source.

**Table 1**. Model variables, definition and sources.

| Variables | Definition | Sources |
|---|---|---|
| $\pi$ | Variation of the Harmonized Consumer Price Index (in logs) (index 100 = 2015) | ECB, OECD |
| $y$ | GDP in constant euros, seasonally adjusted (Index 100 = 2015) | Eurostat, OECD |
| $\bar{y}$ | Potential GDP, calculated by applying the Hodrick-Prescott filter to real GDP, seasonally adjusted. | Eurostat, OECD and authors' own compilation |
| $u$ | Unemployment rate, seasonally adjusted: percentage of unemployed in the active population. | Eurostat, OECD |
| $\bar{u}$ | Natural rate of unemployment, calculated by applying the Hodrick-Prescott filter to the unemployment rate, seasonally adjusted. | Eurostat, OECD, authors' own compilation |
| $Poil^{\$}$ | Variation in Brent oil price (in logs) expressed in current US dollars. | EIA |
| $Poil^{dom}$ | Variation in Brent oil price (in logs) expressed in current euros, calculated according to the current euro/dollar exchange rate. | EIA and IMF (IFS) |
| $er$ | Variation in the euro/dollar exchange rate (in logs) expressed in domestic currency per dollar | IMF (IFS) |
| $VAT$ | Dummy variable, which takes the value 1 in the period where VAT rates increase, and 0 otherwise. | OECD |

Source: authors' own compilation

## 4. Results

Table 2 shows the estimates of the augmented Phillips curve specified in equations (5), (6) and (7), estimated through OLS with HAC robust standard errors using the Newey-West estimator.

Columns 1 to 3 in Table 2 show the estimate of equation (5), which we call the baseline model, where the price of oil in dollars is included in the Phillips curve. In the case of the euro area, the coefficient of inflation expectations is found to be positive and significant. In addition, the output gap shows a positive and significant relationship with the inflation rate, in line with the Phillips curve theory. A 1% increase in the output gap pushes up the inflation rate by 0.07 percentage points.

**Table 2**. Estimates of the augmented Phillips curve with the output gap (1999Q1-2019Q3)

| | Baseline model | | | Oil prices in domestic currency | | | Augmented model | | |
|---|---|---|---|---|---|---|---|---|---|
| | Euro area | UK | Japan | Euro area | UK | Japan | Euro area | UK | Japan |
| $E_t\pi_{t+1}$ | 0.3604** (0.010) | 0.5682*** (0.000) | 0.3366*** (0.009) | 0.5102*** (0.000) | 0.5409*** (0.000) | 0.3441*** (0.007) | 0.5346*** (0.000) | 0.5531*** (0.000) | 0.3512*** (0.008) |
| $(y_t - \bar{y}_t)/\bar{y}_t$ | 0.0666*** (0.000) | 0.0150 (0.674) | 0.0853*** (0.001) | 0.0679*** (0.000) | 0.0120 (0.710) | 0.0752*** (0.003) | 0.0677*** (0.000) | 0.0326 (0.301) | 0.0633** (0.027) |
| $Poil^{\$}_t$ | 0.0156*** (0.000) | 0.0101*** (0.000) | 0.0052*** (0.003) | | | | 0.0185*** (0.000) | 0.0110*** (0.000) | 0.0059*** (0.001) |
| $Poil^{\$}_{t-1}$ | 0.0012 (0.460) | 0.0067*** (0.000) | 0.0045** (0.029) | | | | 0.0014 (0.336) | 0.0070*** (0.000) | 0.0059*** (0.007) |
| $Poil^{\$}_{t-2}$ | 0.0014 (0.182) | 0.0011 (0.471) | 0.0009 (0.671) | | | | 0.0001 (0.911) | 0.0035 (0.133) | 0.0019 (0.355) |
| $Poil^{\$}_{t-3}$ | 0.0027** (0.016) | 0.0032* (0.077) | -0.0011 (0.637) | | | | 0.0006 (0.673) | 0.0050*** (0.006) | -0.0005 (0.832) |
| $Poil^{\$}_{t-4}$ | -0.0008 (0.601) | -0.0038*** (0.004) | -0.0003 (0.854) | | | | -0.0021 (0.228) | -0.0032 (0.163) | 0.0005 (0.763) |
| $Poil^{dom}_t$ | | | | 0.0182*** (0.000) | 0.0115*** (0.000) | 0.0056*** (0.002) | | | |
| $Poil^{dom}_{t-1}$ | | | | 0.0015 (0.336) | 0.0077*** (0.000) | 0.0047** (0.021) | | | |
| $Poil^{dom}_{t-2}$ | | | | 0.0006 (0.572) | 0.0020 (0.294) | 0.0015 (0.430) | | | |
| $Poil^{dom}_{t-3}$ | | | | 0.0010 (0.343) | 0.0033 (0.138) | -0.0003 (0.882) | | | |
| $Poil^{dom}_{t-4}$ | | | | -0.0021* (0.072) | -0.0036* (0.065) | -0.0004 (0.826) | | | |
| $er_t$ | | | | | | | 0.0244*** (0.001) | 0.0074 (0.374) | 0.0028 (0.748) |
| $er_{t-1}$ | | | | | | | -0.0017 (0.787) | -0.0039 (0.638) | 0.0045 (0.693) |
| $er_{t-2}$ | | | | | | | 0.0016 (0.712) | 0.0236*** (0.006) | 0.0056 (0.596) |
| $er_{t-3}$ | | | | | | | -0.0027 (0.563) | 0.0070 (0.387) | 0.0107 (0.250) |
| $er_{t-4}$ | | | | | | | -0.0002 (0.967) | 0.0127 (0.111) | -0.0005 (0.939) |
| $VAT$ | | 0.0078*** (0.000) | 0.0210*** (0.000) | | 0.0078*** (0.000) | 0.0208*** (0.000) | | 0.0080*** (0.000) | 0.0207*** (0.000) |
| $cons$ | 0.0024*** (0.000) | 0.0020*** (0.001) | -0.0002 (0.588) | 0.0018*** (0.000) | 0.0020 (0.001) | -0.0002 (0.509) | 0.0017*** (0.004) | 0.0018*** (0.002) | -0.0002 (0.439) |
| $\emptyset$ | 0.0317*** (0.000) | 0.0411*** (0.001) | 0.0137 (0.114) | 0.0391*** (0.000) | 0.0456 (0.000) | 0.0168* (0.092) | 0.0397*** (0.000) | 0.0523*** (0.000) | 0.0213* (0.058) |
| $\varphi$ | | | | | | | 0.0460 (0.231) | 0.1048*** (0.003) | 0.0357 (0.210) |
| R2 | 0.7646 | 0.6185 | 0.5916 | 0.8148 | 0.6201 | 0.5929 | 0.8198 | 0.6863 | 0.6072 |
| Adjusted R2 | 0.7410 | 0.5743 | 0.5443 | 0.7963 | 0.5761 | 0.5457 | 0.7866 | 0.6226 | 0.5274 |
| F-statistic | 32.4766*** (0.000) | 13.9849*** (0.000) | 12.4953*** (0.000) | 43.9970*** (0.000) | 14.0811*** (0.000) | 12.5593*** (0.000) | 24.6454*** (0.000) | 10.7695*** (0.000) | 7.6105*** (0.000) |
| $d$ | | | | | | | -0.0028*** | -0.0007 | -0.0007 |
| $t$ | | | | | | | -2.8071 | -0.4247 | -1.5279 |
| p-value | | | | | | | 0.006 | 0.672 | 0.131 |

Source: authors' own compilation. Note: *, ** , and *** denote statistical significance at the 10%, 5%, and 1% level, respectively, p-values in parenthesis. HAC robust standard errors through the Newey-West estimator. $d = \theta_0^{base} - \theta_0^{aum}$ represents the difference between the coefficients of $Poil^{\$}_t$ in the baseline model and the augmented model, $t = d/s(d)$ is the t-student statistic and $s(d)$ is the standard deviation of $d$ (see Clogg et al., 1995).

As regards oil price in dollars, a significant contemporary effect on inflation is seen to exist, such that a 1% increase in the price of oil increases the quarterly inflation rate by 0.0156 percentage points. In the long run, however, a 1% increase in the price of oil triggers an increase of 0.0317 percentage in prices. In the case of the United Kingdom and Japan, the short-run pass-through is lower, being 0.0101 and 0.0052 percentage points, respectively. The long-run pass-through is higher in the United Kingdom, whereas in Japan it is lower and not significant.

Columns 4-6 in Table 2 show the estimate of equation (6), where the price of oil in dollars is replaced by the price of oil in domestic currency. In this way, the indirect effect of the oil price pass-through into inflation that takes place through exchange rate fluctuations against the dollar is eliminated. The results show that, in the case of the euro area, the persistence of inflation, measured by the backward-looking expectations coefficient, is higher than in the baseline model. With regard to the relation between the output gap and inflation, the coefficient remains positive and significant, with a value similar to that estimated in column 1. On the other hand, the price of oil has a greater impact on the inflation rate when expressed in euros. The short-run transmission of a 1% increase is 0.0182 percentage points, while the long-run pass-through is 0.0391. This implies that the transmission of increases in the international price of oil (invoiced in dollars) is dampened as a result of the appreciation of the euro against the dollar.

Unlike what happens in the euro area, the transmission of oil prices in domestic currency in the United Kingdom and Japan does not differ significantly with respect to that estimated in the baseline model. In other words, there is no significant relationship between oil price fluctuations and the exchange rate of its currencies, such that its fluctuations have not softened the fluctuations in international oil prices, as has occurred in the case of the euro area.

To analyse this relationship in more detail, we estimate the model specified in equation (7), where the exchange rate and the price of oil are included simultaneously. This allows us to compare the coefficients of the pass-through estimated in columns 1-3 and 7-9, being (7) an augmented model of equation (5) to control for variations in the exchange rate, and therefore, estimate the direct effect of oil price on inflation. For the euro area, the results shown in columns 7-9 in Table 2 evidence a coefficient that is very similar to those found in the model using oil prices in domestic currency (columns 4-6). Inflation expectations have a very similar effect, with a coefficient of 0.53. The output gap also shows a coefficient similar to the two previous estimates, supporting the positive relationship expected by the theory. The variations in oil prices, expressed in dollars, show a coefficient similar to the one obtained in specification (6) using domestic currency. The short-run pass-through is 0.0185 percentage points in the inflation rate, reaching a long-run pass-through of 0.0397. This coefficient is higher than that found in the baseline model, whose short-run and long-run pass-through are 0.0156 and 0.0317, respectively. In order to determine whether these differences are statistically significant, we performed the test developed by Clogg et al. (1995) which tests whether the coefficient of a variable varies significantly when adding additional variables to the estimate. This test is calculated for the contemporary effect of oil prices on inflation, and the results allow us to reject the null hypothesis of coefficient equality at a 1% level. Finally, fluctuations in the exchange rate also have a significant impact on inflation, such that a 1% appreciation of the euro against the dollar (which corresponds to a decrease in $er_t$) reduces the inflation rate by 0.0244 percentage points, with a long-run impact of 0.046.

In the case of the United Kingdom and Japan, the differences in the contemporary pass-through coefficients between the baseline and augmented model are found to be non-significant, which means that the variations in the exchange rate have not softened the impact of oil prices on inflation in these countries. The results also show that the exchange rate does not have a contemporary impact on inflation in either of the two countries, although in the United Kingdom it does evidence a significant impact after two quarters, such that it has a major long-run effect on inflation.

### 4.1. Alternative specifications

To test the robustness of the results, we estimate three alternative specifications. We first replace the output gap by the unemployment gap as a measure of slack in the labour market. Second, we use an additional specification where backward-looking expectations are replaced by inflation inertia. For this, we include the inflation rates of the past four quarters individually in the Phillips curve, as shown in equation (13), such that the persistence or inertia of inflation is measured as the sum of the coefficients of past inflation. Finally, in order to take into account the possible existence of endogeneity in the Phillips curve due to the relationship between inflation and the output gap, we estimate the Phillips curve specified above through the GMM estimator.

The results of the alternative estimates are in line with those found in the benchmark specification. Oil price pass-through as well as the effect of exchange rate fluctuations in this transmission shows very similar coefficients, allowing us to conclude that our findings do not depend on the specification of the model.

### 4.2. Has the relationship varied over time?

It has been argued that the oil price-exchange rate relationship has intensified since the onset of the Great Recession (Reboredo, 2012; Reboredo et al., 2014; Malik and Umar, 2019). Furthermore, Coudert and Mignon (2016) found a structural break in the relationship between the US dollar and oil prices in the mid-2000s, which later turned negative. In this section, we examine whether the role of the exchange rate in oil price pass-through into inflation has changed during the period under analysis. For this purpose, we estimate rolling regressions of specifications (5) and (7), using a ten-year window (40 quarters), following Marazzi et al. (2005), such that the number of observations is enough to adequately estimate the parameters of our model. The rolling window approach allows us to analyse the evolution of oil price pass-through and the indirect effect of the exchange rate over the period. Figure 2 shows the time-varying oil price pass-through into inflation estimated in the baseline model (equation 5), and in the augmented model (equation 7) in which we control for the effect of exchange rate fluctuations, as well as the evolution of $d$: in other words, the difference in oil price pass-through between the baseline and the augmented model, as described in section 4, which represents the effect of the exchange rate on the transmission of oil price fluctuations to inflation.

The results displayed in figure 2 show that, for the euro area, oil price pass-through remained fairly stable over the whole sample, while the role of the exchange rate in the transmission of oil prices to inflation has always been negative: in other words, it has reduced the pass-through, although its effect has intensified over time. At the beginning of the period, the effect of exchange rate fluctuations on oil price pass-through is not statistically significant. This period corresponds to the rolling samples which include the period 2000-2003, when the relationship between the euro/dollar exchange rate and oil prices was found to be negative in previous works. However, its effect increases over time, and is higher than the average effect we found in the time-invariant estimates. The increasing role of the exchange rate commences around the mid-2000s, coinciding with the date when other works set the structural break in the relationship between the euro/dollar exchange rate and oil prices (Coudert and Mignon, 2016). In the same vein, these results support the fact that the correlation between oil prices and the euro/dollar exchange rate has intensified since the Great Recession. In contrast, we find that the role played by the exchange rate in the transmission of oil prices in the United Kingdom and Japan was not statistically significant over the whole period. In the case of the United Kingdom, the exchange rate does not seem to have been related to oil prices, whereas in the case of Japan, the relationship has evolved over time, such that the exchange rate intensified the pass-through in certain episodes and softened it in other periods, although it is not statistically significant.

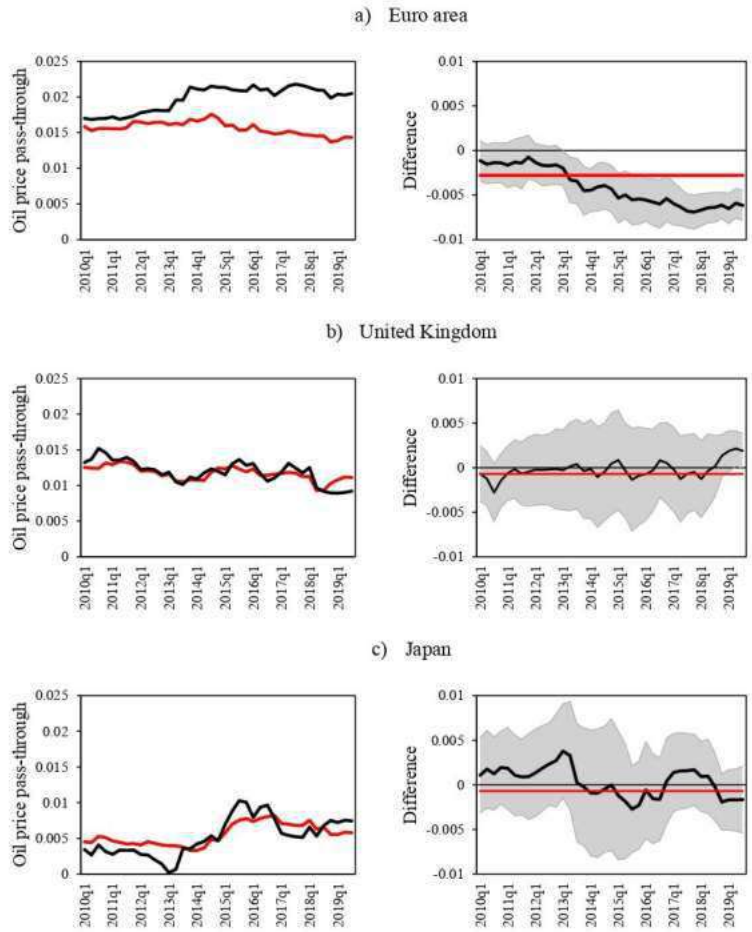


**Figure 2**. Ten year rolling-window estimates of contemporaneous oil price pass-through to inflation in the baseline and in the augmented model. Column 1 shows the time varying oil price pass-through. The red line represents the time varying pass-through in the baseline model. The black line represents pass-through in the augmented model. Column 2 shows the differences in the time varying pass-through. The black line represents the time-varying differences in pass-through. The shaded areas represent the 95% confidence bands for the time-varying differences in pass-through. The red line represents the average difference in the time-invariant pass-through estimated in section 4. The date on the x-axis represents the end of the rolling sample.

## 5. Conclusions and discussion

Although oil price pass-through into inflation has fallen in recent decades, understanding its underlying mechanisms proves crucial to monetary authorities when carrying out monetary policy and vis-à-vis understanding price response in the face of this kind of shock. The existence of a relationship between the euro/dollar exchange rate and oil prices adds special interest when evaluating the direct effect of oil prices on inflation in the euro area. This work focuses on exploring the role played by fluctuations in the bilateral exchange rate of the euro against the dollar in the transmission of oil prices to inflation in the euro area.

We analyse the transmission of changes in oil prices in headline inflation and the indirect effect of the euro/dollar exchange rate in the euro area for the period between 1999Q1 and 2019Q3 by estimating an augmented Phillips curve. Furthermore, we estimate the same model for Japan and the United Kingdom so as to compare the effect of the euro to that of other highly relevant international currencies. Results show that, during the period studied, the transmission of oil prices in the euro area is significantly higher after controlling for the impact of the exchange rate. In other words, the euro/dollar exchange rate has a negative indirect effect on inflation. This implies that an increase in the price of oil in dollars is followed by an appreciation of the euro against the dollar, which makes the barrel of oil cheaper in the domestic currency.

As a consequence, fluctuations in the euro/dollar exchange rate partially dampen the impact of changes in the dollar price of oil on inflation. According to our estimates, the exchange rate reduces dollar oil price pass-through into inflation by about 15% in the euro area. Chen (2009) suggests that the appreciation of domestic currencies against the dollar may have contributed to a lower oil price pass-through. However, this dampening effect is found neither in the Japanese yen nor in the British pound. Therefore, the dampening effect of the exchange rate on the transmission of oil prices appears as a singularity shown by the euro, and not as a general relationship between the main international currencies and the dollar.

Furthermore, our findings show that the euro's dampening effect has intensified throughout the period. This can be explained by the fact that the positive relationship between the oil prices and the euro/dollar exchange rate appears from the mid-2000s onwards (Bénassy-Quéré et al., 2007; Coudert and Mignon, 2016). Previously, the relationship between the euro/dollar exchange rate (expressed as the weighted average of the legacy currencies of the euro) and the price of oil was found to be negative; that is, an increase in the price of oil was followed by a depreciation in said exchange rate (Clostermann and Schnatz, 2000; Bénassy-Quéré et al., 2007). One possible explanation for this break is the emergence of the euro as an international currency, such that a share of the financial and trade flows of the oil-exporting countries shifted towards assets and goods denominated in euros, giving rise to a positive relationship between oil revenues and the euro/dollar exchange rate.

The relationship between the price of oil and the euro/dollar exchange rate lessens the inflationary risk of an oil price shock, which is of major importance given that the euro area is a net importer of this commodity. However, the pass-through of oil to headline inflation is still important, since a 10% increase in the price of oil in dollars triggers an increase of around 0.16 percentage points in the quarterly inflation rate, which in annualized terms means an increase of 0.81 percentage points. In the long-run, this shock produces an increase in the price level of around 1.33% in annualized terms.

Moreover, the positive relationship between the price of oil and the euro/dollar exchange rate, in addition to reducing oil price pass-through by softening the fluctuations in domestic currency, affects the price of other imported goods that are invoiced in dollars, further reducing the inflationary effect of a rise in oil prices. According to our estimates, a 1% appreciation in the euro/dollar has a negative impact of 0.1 percentage points in the quarterly inflation rate in annualized terms. In this way, the appreciation of the euro that follows a rise in the price of oil reduces the price of imports and, therefore, has a negative effect on the inflation rate.

In sum, the euro has acted as a buffer against the impact of oil prices on inflation in the euro area, since its appreciation has reduced the oil bill in domestic currency. This may have implications for monetary policy, since the price of oil, as well as the exchange rate, are relevant variables for economic analysis in Pillar II of the ECB's monetary policy (ECB, 2011). First, it has reduced the reaction required in the face of an oil shock, since the fluctuations in the exchange rate allow the inflation rate to partially stabilize. On the other hand, monetary policy authorities should be cautious in their reactions to increases in inflation caused by oil prices, since a rise in interest rates designed to reduce inflationary pressure may lead to a higher appreciation of the euro and, therefore, trigger a reaction that is greater than the one desired, reducing the inflation rate below the objective of monetary policy and generating higher price volatility.

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## Appendix A

**Table A1**. Estimates of the augmented Phillips curve with the unemployment gap (1999Q1-2019Q3)

| | Baseline model | | | Oil prices in domestic currency | | | Augmented model | | |
|---|---|---|---|---|---|---|---|---|---|
| | **Euro area** | **UK** | **Japan** | **Euro area** | **UK** | **Japan** | **Euro area** | **UK** | **Japan** |
| $E_t\pi_{t+1}$ | 0.3640** | 0.5901*** | 0.3387** | 0.5231*** | 0.5418*** | 0.3680** | 0.5393*** | 0.5853*** | 0.3795** |
| | (0.015) | (0.000) | (0.024) | (0.000) | (0.001) | (0.013) | (0.000) | (0.000) | (0.013) |
| $(u_t - \bar{u}_t)/\bar{u}_t$ | -0.0120*** | -0.0032 | -0.0095** | -0.0119*** | -0.0011 | -0.0068* | -0.0116*** | -0.0056 | -0.0048 |
| | (0.000) | (0.698) | (0.035) | (0.000) | (0.881) | (0.098) | (0.000) | (0.440) | (0.300) |
| $Poil^{\$}_t$ | 0.0161*** | 0.0103*** | 0.0061*** | | | | 0.0188*** | 0.0112*** | 0.0072*** |
| | (0.000) | (0.000) | (0.009) | | | | (0.000) | (0.000) | (0.000) |
| $Poil^{\$}_{t-1}$ | 0.0020 | 0.0068*** | 0.0063** | | | | 0.0021 | 0.0071*** | 0.0077*** |
| | (0.309) | (0.000) | (0.019) | | | | (0.189) | (0.000) | (0.002) |
| $Poil^{\$}_{t-2}$ | 0.0021* | 0.0011 | 0.0015 | | | | 0.0009 | 0.0035 | 0.0031 |
| | (0.098) | (0.476) | (0.498) | | | | (0.526) | (0.127) | (0.120) |
| $Poil^{\$}_{t-3}$ | 0.0030*** | 0.0032* | -0.0004 | | | | 0.0011 | 0.0052*** | 0.0005 |
| | (0.006) | (0.066) | (0.876) | | | | (0.433) | (0.003) | (0.851) |
| $Poil^{\$}_{t-4}$ | -0.0005 | -0.0038*** | 0.0005 | | | | -0.0017 | -0.0032 | 0.0013 |
| | (0.737) | (0.006) | (0.794) | | | | (0.329) | (0.166) | (0.481) |
| $Poil^{dom}_t$ | | | | 0.0187*** | 0.0115*** | 0.0067*** | | | |
| | | | | (0.000) | (0.000) | (0.004) | | | |
| $Poil^{dom}_{t-1}$ | | | | 0.0023 | 0.0078*** | 0.0068*** | | | |
| | | | | (0.203) | (0.000) | (0.004) | | | |
| $Poil^{dom}_{t-2}$ | | | | 0.0013 | 0.0021 | 0.0026 | | | |
| | | | | (0.317) | (0.278) | (0.199) | | | |
| $Poil^{dom}_{t-3}$ | | | | 0.0014 | 0.0034 | 0.0007 | | | |
| | | | | (0.236) | (0.122) | (0.767) | | | |
| $Poil^{dom}_{t-4}$ | | | | -0.0020 | -0.0036* | 0.0005 | | | |
| | | | | (0.125) | (0.076) | (0.797) | | | |
| $er_t$ | | | | | | | 0.0240*** | 0.0060 | 0.0026 |
| | | | | | | | (0.000) | (0.496) | (0.765) |
| $er_{t-1}$ | | | | | | | -0.0022 | -0.0039 | 0.0097 |
| | | | | | | | (0.718) | (0.651) | (0.382) |
| $er_{t-2}$ | | | | | | | 0.0023 | 0.0227*** | 0.0094 |
| | | | | | | | (0.585) | (0.008) | (0.388) |
| $er_{t-3}$ | | | | | | | -0.0018 | 0.0074 | 0.0147* |
| | | | | | | | (0.709) | (0.356) | (0.087) |
| $er_{t-4}$ | | | | | | | 0.0008 | 0.0120 | 0.0019 |
| | | | | | | | (0.878) | (0.122) | (0.773) |
| $VAT$ | | 0.0076*** | 0.0203*** | | 0.0078*** | 0.0201*** | | 0.0078*** | 0.0199*** |
| | | (0.000) | (0.000) | | (0.000) | (0.000) | | (0.000) | (0.000) |
| $cons$ | 0.0023*** | 0.0019** | -0.0002 | 0.0017*** | 0.0020** | -0.0003 | 0.0017*** | 0.0016** | -0.0003 |
| | (0.000) | (0.019) | (0.525) | (0.002) | (0.011) | (0.396) | (0.008) | (0.032) | (0.336) |
| $\emptyset$ | 0.0356*** | 0.0428** | 0.0212* | 0.0456*** | 0.0464*** | 0.0273** | 0.0461*** | 0.0574*** | 0.0319** |
| | (0.000) | (0.017) | (0.060) | (0.000) | (0.005) | (0.038) | (0.000) | (0.006) | (0.020) |
| $\varphi$ | | | | | | | 0.0500 | 0.1066** | 0.0618** |
| | | | | | | | (0.190) | (0.018) | (0.035) |
| R2 | 0.7515 | 0.6188 | 0.5398 | 0.7992 | 0.619 | 0.5562 | 0.8040 | 0.6837 | 0.5845 |
| Adjusted R2 | 0.7267 | 0.5746 | 0.4865 | 0.7792 | 0.5748 | 0.5047 | 0.7678 | 0.6195 | 0.5002 |
| F-statistic | 30.2495*** | 13.9994*** | 10.1175*** | 39.8092*** | 14.0120*** | 10.8077*** | 22.2166*** | 10.6423*** | 6.9269*** |
| | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) |
| $d$ | | | | | | | -0.0027*** | -0.0006 | -0.0011 |
| $t$ | | | | | | | -2.9699 | -0.3726 | -1.3848 |
| p-value | | | | | | | 0.004 | 0.711 | 0.171 |

Source: authors' own compilation. Note: see Table 2.

**Table A2**. Estimates of the augmented Phillips curve with the inertia of inflation (1999Q1-2019Q3)

| | **Baseline model** | | | **Oil prices in domestic currency** | | | **Augmented model** | | |
|---|---|---|---|---|---|---|---|---|---|
| | **Euro area** | **UK** | **Japan** | **Euro area** | **UK** | **Japan** | **Euro area** | **UK** | **Japan** |
| $\pi_{t-1}$ | 0.2904*** | 0.4235*** | 0.0915 | 0.3093*** | 0.4229*** | 0.0947 | 0.3130*** | 0.3842*** | 0.0635 |
| | (0.004) | (0.000) | (0.324) | (0.003) | (0.000) | (0.288) | (0.007) | (0.000) | (0.499) |
| $\pi_{t-2}$ | -0.0181 | 0.1340 | 0.0511 | 0.0136 | 0.0672 | 0.0489 | 0.0165 | 0.1102 | 0.0462 |
| | (0.868) | (0.335) | (0.537) | (0.894) | (0.614) | (0.596) | (0.885) | (0.444) | (0.608) |
| $\pi_{t-3}$ | 0.1027 | 0.0885 | 0.2296** | 0.1224 | 0.0674 | 0.2339** | 0.1417 | 0.1287 | 0.2616*** |
| | (0.452) | (0.419) | (0.014) | (0.438) | (0.533) | (0.013) | (0.406) | (0.220) | (0.004) |
| $\pi_{t-4}$ | 0.0395 | -0.0342 | -0.0076 | 0.0996 | 0.0336 | -0.0020 | 0.0919 | -0.0333 | 0.0254 |
| | (0.708) | (0.747) | (0.951) | (0.367) | (0.765) | (0.986) | (0.474) | (0.735) | (0.838) |
| $(y_t - \bar{y}_t)/\bar{y}_t$ | 0.0584*** | 0.0107 | 0.0820*** | 0.0609*** | 0.0069 | 0.0717*** | 0.0599*** | 0.0244 | 0.0576** |
| | (0.000) | (0.729) | (0.001) | (0.000) | (0.802) | (0.004) | (0.001) | (0.379) | (0.039) |
| $Poil^{\$}_{t}$ | 0.0159*** | 0.0112*** | 0.0055*** | | | | 0.0184*** | 0.0118*** | 0.0064*** |
| | (0.000) | (0.000) | (0.005) | | | | (0.000) | (0.000) | (0.002) |
| $Poil^{\$}_{t-1}$ | -0.0020 | 0.0038** | 0.0048* | | | | -0.0019 | 0.0043** | 0.0071*** |
| | (0.319) | (0.044) | (0.058) | | | | (0.484) | (0.044) | (0.008) |
| $Poil^{\$}_{t-2}$ | 0.0026 | -0.0015 | 0.0011 | | | | 0.0015 | 0.0015 | 0.0026 |
| | (0.167) | (0.502) | (0.646) | | | | (0.468) | (0.622) | (0.330) |
| $Poil^{\$}_{t-3}$ | 0.0021 | 0.0025 | -0.0019 | | | | 0.0004 | 0.0042* | -0.0008 |
| | (0.349) | (0.280) | (0.436) | | | | (0.900) | (0.059) | (0.775) |
| $Poil^{\$}_{t-4}$ | -0.0006 | -0.0030** | -0.0005 | | | | -0.0017 | -0.0032 | 0.0002 |
| | (0.771) | (0.047) | (0.774) | | | | (0.474) | (0.121) | (0.914) |
| $Poil^{dom}_{t}$ | | | | 0.0182*** | 0.0124*** | 0.0059*** | | | |
| | | | | (0.000) | (0.000) | (0.003) | | | |
| $Poil^{dom}_{t-1}$ | | | | -0.0018 | 0.0041** | 0.0050** | | | |
| | | | | (0.410) | (0.044) | (0.041) | | | |
| $Poil^{dom}_{t-2}$ | | | | 0.0019 | -0.0002 | 0.0018 | | | |
| | | | | (0.316) | (0.948) | (0.386) | | | |
| $Poil^{dom}_{t-3}$ | | | | 0.0009 | 0.0033 | -0.0011 | | | |
| | | | | (0.731) | (0.196) | (0.655) | | | |
| $Poil^{dom}_{t-4}$ | | | | -0.0020 | -0.0032* | -0.0006 | | | |
| | | | | (0.284) | (0.095) | (0.719) | | | |
| $er_t$ | | | | | | | 0.0237*** | 0.0062 | 0.0038 |
| | | | | | | | (0.002) | (0.442) | (0.671) |
| $er_{t-1}$ | | | | | | | -0.0062 | -0.0049 | 0.0033 |
| | | | | | | | (0.429) | (0.608) | (0.781) |
| $er_{t-2}$ | | | | | | | 0.0040 | 0.0236*** | 0.0099 |
| | | | | | | | (0.470) | (0.007) | (0.361) |
| $er_{t-3}$ | | | | | | | -0.0032 | 0.0066 | 0.0094 |
| | | | | | | | (0.581) | (0.363) | (0.370) |
| $er_{t-4}$ | | | | | | | 0.0006 | 0.0066 | 0.0005 |
| | | | | | | | (0.925) | (0.390) | (0.946) |
| *dummyVAT* | | 0.0077*** | 0.0202*** | | 0.0074*** | 0.0200*** | | 0.0083*** | 0.0198*** |
| | | (0.000) | (0.000) | | (0.000) | (0.000) | | (0.000) | (0.000) |
| *cons* | 0.0022*** | 0.0018*** | -0.0002 | 0.0017*** | 0.0018*** | -0.0002 | 0.0016*** | 0.0017*** | -0.0002 |
| | (0.000) | (0.000) | (0.612) | (0.000) | (0.000) | (0.520) | (0.002) | (0.000) | (0.427) |
| $\sum_{i=1}^{4} \pi_{t-i}$ | 0.4145*** | 0.6118*** | 0.3647*** | 0.5448*** | 0.5911*** | 0.3756*** | 0.3631*** | 0.5897*** | 0.3967*** |
| | (0.002) | (0.000) | (0.010) | (0.000) | (0.000) | (0.005) | (0.000) | (0.000) | (0.006) |
| $\emptyset$ | 0.0307*** | 0.0331*** | 0.0142 | 0.0379*** | 0.0402*** | 0.0177 | 0.0382*** | 0.0452*** | 0.0255 |
| | (0.000) | (0.000) | (0.224) | (0.000) | (0.000) | (0.162) | (0.000) | (0.000) | (0.133) |
| $\varphi$ | | | | | | | 0.0433 | 0.0929*** | 0.0447 |
| | | | | | | | (0.249) | (0.001) | (0.177) |
| R2 | 0.7746 | 0.6665 | 0.6121 | 0.8216 | 0.6606 | 0.6133 | 0.8263 | 0.7202 | 0.631 |
| Adjusted R2 | 0.7410 | 0.6109 | 0.5474 | 0.7950 | 0.6041 | 0.5489 | 0.7842 | 0.6469 | 0.5342 |
| F-statistic | 23.0291*** | 11.9908*** | 9.4678*** | 30.8565*** | 11.6797*** | 9.5160*** | 19.6588*** | 9.8157*** | 6.5192*** |
| | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) |
| $d$ | | | | | | | -0.0025*** | -0.0007 | -0.0009* |
| $t$ | | | | | | | -2.8265 | -0.4276 | -1.7393 |
| p-value | | | | | | | 0.006 | 0.670 | 0.087 |

Source: authors' own compilation. Note: see Table 2.

**Table A3**. Estimates of the augmented Phillips curve by IV-GMM (1999Q1-2019Q3)

| | **Baseline model** | | | **Oil prices in domestic currency** | | | **Augmented model** | | |
|---|---|---|---|---|---|---|---|---|---|
| | **Euro area** | **UK** | **Japan** | **Euro área** | **UK** | **Japan** | **Euro área** | **UK** | **Japan** |
| $E_t\pi_{t+1}$ | 0.4073*** | 0.6547*** | 0.3104*** | 0.5680*** | 0.6106*** | 0.3061** | 0.6347*** | 0.6650*** | 0.2899** |
| | (0.000) | (0.000) | (0.008) | (0.000) | (0.000) | (0.013) | (0.000) | (0.000) | (0.034) |
| $(y_t - \bar{y}_t)/\bar{y}_t$ | 0.0648*** | 0.0378** | 0.0905*** | 0.0667*** | 0.0223 | 0.0886** | 0.0653*** | 0.0558** | 0.0714** |
| | (0.000) | (0.028) | (0.004) | (0.000) | (0.160) | (0.018) | (0.000) | (0.040) | (0.038) |
| $Poil^{\$}{}_t$ | 0.0154*** | 0.0110*** | 0.0047*** | | | | 0.0177*** | 0.0121*** | 0.0053*** |
| | (0.000) | (0.000) | (0.004) | | | | (0.000) | (0.000) | (0.007) |
| $Poil^{\$}{}_{t-1}$ | 0.0009 | 0.0071*** | 0.0046*** | | | | 0.0007 | 0.0076*** | 0.0059*** |
| | (0.586) | (0.000) | (0.002) | | | | (0.594) | (0.000) | (0.009) |
| $Poil^{\$}{}_{t-2}$ | 0.0010 | -0.0002 | 0.0008 | | | | -0.0008 | 0.0019 | 0.0021 |
| | (0.226) | (0.838) | (0.525) | | | | (0.398) | (0.345) | (0.166) |
| $Poil^{\$}{}_{t-3}$ | 0.0020** | 0.0026** | -0.0015 | | | | -0.0003 | 0.0047*** | -0.0007 |
| | (0.020) | (0.014) | (0.450) | | | | (0.811) | (0.001) | (0.747) |
| $Poil^{\$}{}_{t-4}$ | -0.0008 | -0.0045*** | 0.0002 | | | | -0.0024 | -0.0037** | 0.0012 |
| | (0.521) | (0.000) | (0.922) | | | | (0.126) | (0.023) | (0.622) |
| $Poil^{dom}{}_t$ | | | | 0.0175*** | 0.0125*** | 0.0053*** | | | |
| | | | | (0.000) | (0.000) | (0.002) | | | |
| $Poil^{dom}{}_{t-1}$ | | | | 0.0011 | 0.0085*** | 0.0047*** | | | |
| | | | | (0.435) | (0.000) | (0.005) | | | |
| $Poil^{dom}{}_{t-2}$ | | | | -0.0001 | 0.0009 | 0.0012 | | | |
| | | | | (0.852) | (0.449) | (0.275) | | | |
| $Poil^{dom}{}_{t-3}$ | | | | 0.0003 | 0.0029** | -0.0003 | | | |
| | | | | (0.710) | (0.049) | (0.888) | | | |
| $Poil^{dom}{}_{t-4}$ | | | | -0.0021** | -0.0038** | 0.0001 | | | |
| | | | | (0.022) | (0.026) | (0.973) | | | |
| $er_t$ | | | | | | | 0.0250*** | 0.0083 | 0.0046 |
| | | | | | | | (0.000) | (0.220) | (0.461) |
| $er_{t-1}$ | | | | | | | -0.0028 | 0.0005 | 0.0048 |
| | | | | | | | (0.684) | (0.949) | (0.395) |
| $er_{t-2}$ | | | | | | | 0.0023 | 0.0149** | 0.0004 |
| | | | | | | | (0.301) | (0.043) | (0.976) |
| $er_{t-3}$ | | | | | | | -0.0050* | 0.0155** | 0.0143 |
| | | | | | | | (0.081) | (0.024) | (0.105) |
| $er_{t-4}$ | | | | | | | -0.0008 | 0.0104* | -0.0046 |
| | | | | | | | (0.828) | (0.070) | (0.615) |
| $VAT$ | | | 0.0228** | | | 0.0227* | | | 0.0263 |
| | | | (0.045) | | | (0.074) | | | (0.154) |
| $cons$ | 0.0021*** | 0.0017*** | -0.0002 | 0.0016*** | 0.0018*** | -0.0001 | 0.0014*** | 0.0014*** | -0.0002 |
| | (0.000) | (0.000) | (0.594) | (0.000) | (0.000) | (0.795) | (0.004) | (0.001) | (0.637) |
| $\emptyset$ | 0.0312*** | 0.0464*** | 0.0129** | 0.0384*** | 0.0539*** | 0.0158** | 0.0408*** | 0.0676*** | 0.0195** |
| | (0.000) | (0.000) | (0.037) | (0.000) | (0.000) | (0.044) | (0.000) | (0.000) | (0.014) |
| $\varphi$ | | | | | | | 0.0512 | 0.1479*** | 0.0274 |
| | | | | | | | (0.279) | (0.002) | (0.289) |
| R2 | 0.7616 | 0.555 | 0.5886 | 0.8112 | 0.5604 | 0.5871 | 0.8131 | 0.6248 | 0.5829 |
| Wald Chi2 | 646.07*** | 197.13*** | 808.23*** | 967.80*** | 169.91*** | 1061.67*** | 3473.44*** | 618.80*** | 909.34*** |
| | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) |
| Hansen-J | 1.9974 | 2.0378 | 1.9800 | 2.1232 | 2.1617 | 1.9516 | 2.7501 | 1.5336 | 0.9893 |
| | (0.574) | (0.565) | (0.577) | (0.547) | (0.540) | (0.583) | (0.432) | (0.675) | (0.804) |
| $d$ | | | | | | | -0.0023*** | -0.0012 | -0.0006 |
| $t$ | | | | | | | -2.781 | -0.962 | -0.563 |
| p-value | | | | | | | 0.007 | 0.339 | 0.573 |

Source: author's own compilation. Note: *, ** , and *** denote statistical significance at the 10%, 5%, and 1% level, respectively. p-values in parenthesis. Estimated by GMM, Newey-West HAC robust standard errors. Instrumented variable: $(y_t - \bar{y}_t)/\bar{y}_t$. Instruments: four lags of $(y_t - \bar{y}_t)/\bar{y}_t$ and the rest of exogenous variables. . $d = \theta_0^{base} - \theta_0^{aum}$ represents the different between coefficients of $Poil^{\$}{}_t$ in the baseline model and the augmented model, $t = d/s(d)$ is the t-student statistic and $s(d)$ is the standard deviation of $d$ (see Clogg et al., 1995).

# 5. Conclusiones

La presente memoria analiza de manera comprehensiva la evolución del mercado del petróleo a lo largo del siglo XXI. La investigación de dicha evolución, *per se,* constituye una materia de suma trascendencia para la economía por sus implicaciones distributivas y macroeconómicas, pero lo es también porque importantes decisiones económicas como las políticas monetarias son tomadas sobre la base de previsiones de la evolución del precio del petróleo y de la trasmisión de sus fluctuaciones a la inflación. A lo largo de los artículos que componen esta memoria hemos ido indagando en esta cuestión, pudiendo extraer las conclusiones que a continuación se exponen:

Del estudio de los shocks que determinan la evolución del precio del petróleo en el siglo XXI: - shocks de naturaleza económica y financiera, como es el estallido de la crisis financiera de 2008; - shocks de naturaleza política, entre los que destacan las guerras que han afectado países productores de petróleo (guerras de Libia y Siria), o a países que son importantes actores en este mercado (guerra de Ucrania); - y shocks de naturaleza tecnológica, como es el desencadenado por el desarrollo de la técnica *fracking* para la extracción de petróleo; hemos extraído como principales conclusiones las siguientes:

- En primer lugar, el estallido del mercado financiero en 2008, que dio lugar a la Gran Recesión, provocó una caída del precio del petróleo un 20% superior a la caída explicada por las variables fundamentales del mercado. Es decir, la incertidumbre generada por este evento causó una caída superior a la producida por la reducción de la demanda al inicio de la crisis y por tanto la crisis impactó más allá de los que se vio afectada la demanda.
- El estudio del impacto de las guerras muestra también efectos, pero sin observarse un efecto directo significativo sobre el precio del petróleo más allá de su impacto indirecto a través de otras variables fundamentales del mercado del petróleo. En el caso de la guerra de Libia (2011), ésta generó una caída de la producción de petróleo en el corto plazo, lo cual afecta indirectamente al precio del petróleo. Para el caso de la guerra de Ucrania (2014), los resultados muestran el carácter intrínsecamente político de los efectos, ya que los países reaccionaron aumentando sus reservas estratégicas. Este hecho está vinculado al aumento de la incertidumbre generado por la participación indirecta en el conflicto de las dos superpotencias militares: Rusia, con la propia intervención, y Estados Unidos, con las sanciones.
- Finalmente, la introducción del *fracking*, supuso el surgimiento de Estados Unidos como el principal productor de petróleo del mundo, lo que ha generado un impacto significativo sobre el precio del petróleo. Entre junio de 2014 y febrero de 2015, la cobertura del consumo de petróleo de Estados Unidos por su producción se incrementó en un 5,8%, lo que de acuerdo a nuestras estimaciones habría contribuido a una caída del precio del petróleo de en torno a 4 dólares por barril. Además, la reducción en la dependencia de petróleo importado por parte de Estados Unidos también supuso una caída de la producción de petróleo de los países de la OPEP que reaccionaron recortando su producción para estabilizar el precio del petróleo.

De los tres tipos de shocks tratado, el shock político generado por la guerra en Ucrania (en la actualidad conocida como la guerra del Donbás) resultaba más singular, de ahí que realizáramos un análisis particular del mismo. Se diseñó un mecanismo para detectar eventos relevantes durante los meses de contienda a través de noticias de prensa en los principales periódicos financieros, *Financial Times* y *Wall Street Journal*, para así poder estudiar el impacto a corto plazo de la guerra de Ucrania en la evolución del precio del petróleo y la principal conclusión que obtuvimos es que fueron pocos los eventos que tuvieron lugar durante el conflicto que afectaran directamente al precio del petróleo. concentrándose en los días de inicio de la guerra y en los días posteriores a los que se hacían públicas sanciones a Rusia por parte de Estados Unidos. Los primeros afectaban principalmente al mercado europeo (Brent) mientras que los últimos afectaban en mayor medida al mercado estadounidense (WTI). Esto implica que el mercado europeo reaccionó inicialmente debido a la proximidad del conflicto y su posible propagación, mientras que el mercado estadounidense, lejano de la zona de conflicto, reacciona en mayor grado a noticias relacionadas con la relación de Estados Unidos y Rusia y la imposición de sanciones. Finalmente, los resultados mostraban que los eventos que afectaban al precio del petróleo lo hacían en un muy corto plazo, de manera que el impacto en el precio del petróleo se producía principalmente en el día en que tenía lugar el evento, corrigiéndose rápidamente esas oscilaciones, de forma que esos eventos no producían un efecto persistente en el precio del petróleo.

El segundo objetivo de la presente tesis es analizar las principales consecuencias macroeconómicas provocadas por la evolución del mercado del petróleo. Para ello, nos centramos en dos importantes aspectos: el impacto de las rentas del comercio internacional de petróleo en la distribución internacional de la renta y el efecto de las variaciones del precio del petróleo en la inflación, concretamente en el papel que juega el entorno de inflación en el que se producen las variaciones, así como el papel de los tipos de cambio respecto al dólar en la transmisión de dichas variaciones del precio del petróleo. Para este último análisis, nos centramos en la zona euro, que está compuesta por países que son dependientes de las importaciones de petróleo.

Respecto al efecto redistributivo a nivel internacional de las rentas del petróleo, un trabajo sin precedentes en la literatura, diseñamos una metodología para extraer el componente de renta económica que incorpora el precio del petróleo comerciado a nivel internacional y a partir del estudio del mismo y de su evolución obtuvimos las conclusiones que se detallan a continuación:

- Las rentas implícitas que se transfieren internacionalmente a través del comercio de petróleo suponen en promedio un valor de 647.000 millones de dólares anuales a dólares constantes de 2010 en el periodo 1995-2016, alcanzando un valor máximo de 1.007.171 millones de dólares en el año 2008, previo al estallido de la Gran Recesión.
- El peso de las rentas sobre el PIB de países exportadores e importadores es sensiblemente distinto. Para los países exportadores, las rentas que obtienen del comercio del petróleo suponen de media el 8,05% de su PIB, alcanzando un máximo del 12,04% en 2010, mientras que, para los países importadores, las rentas que transfieren a través de sus importaciones suponen en promedio un

1,06% de su PIB. Esto implica que estas rentas suponen una transferencia reducida para los países importadores, pero unas rentas muy importantes para los países exportadores, especialmente aquellos que clasificamos como de alta (Azerbaiyán, Nigeria, Brunei, EAU y Catar) o muy alta dependencia de las rentas del comercio de petróleo (Congo, Angola, Libia, Kuwait, Gabón, Yemen y Arabia Saudí).

- Las rentas del comercio del petróleo tienen un efecto redistributivo positivo, es decir reducen la desigualdad internacional, cuando la renta es medida en dólares a tipo de cambio del mercado. Este efecto redistributivo llega a alcanzar 0,32 puntos del índice de Gini, un efecto considerable si tenemos en cuenta que Bourgignon et al. (2009) estiman que el efecto redistributivo de la ayuda oficial al desarrollo en 2004 fue de 0,44 puntos del índice de Gini. Sin embargo, su evolución muestra que el efecto redistributivo se ve reducido a lo largo del periodo analizado. Esta tendencia decreciente es aún más pronunciada cuando las rentas son medidas en dólares en paridad del poder adquisitivo. En este caso, tras un periodo inicial de redistribución positiva, observamos que a partir de 2001 las rentas del comercio del petróleo generan un efecto redistributivo negativo, es decir se comportan de forma regresiva y contribuyen a un aumento de la desigualdad.
- El efecto redistributivo de las rentas del comercio de petróleo se produce especialmente por la vía de las exportaciones, es decir, por el beneficio que obtienen de las rentas los países exportadores. Este resultado es coherente con el hecho de que las rentas de las exportaciones suponen un mayor porcentaje sobre el PIB para los países exportadores. Cuando medimos la renta en tipo de cambio de mercado, las rentas de las exportaciones siempre tienen un efecto positivo en la distribución internacional de la renta, es decir, reducen la desigualdad. Por su parte, las rentas pagadas en las importaciones tienen un menor impacto en la desigualdad, y presentan siempre un efecto regresivo, es decir, contribuyen a un aumento de la desigualdad internacional. Cuando la renta se mide en dólares en paridad del poder adquisitivo, el efecto redistributivo de las exportaciones experimenta una tendencia decreciente a lo largo del periodo analizado, pasando a ser negativo a partir de 2001 como consecuencia de un desplazamiento del efecto redistributivo hacia los países exportadores de rentas más alta. Además, en este escenario las rentas de las importaciones tienen un mayor papel, contribuyendo ambos a ese efecto redistributivo total negativo que se observa tras el año 2001.
- Analizando el impacto de las rentas por decilas de la distribución internacional, podemos concluir que el mayor impacto de estas rentas, tanto en los países exportadores como en los importadores, se produce en los países que ocupan las decilas de renta más baja, aunque en el caso de las exportaciones el efecto se reduce al final del periodo. Además, los países exportadores de renta alta presentan un desplazamiento hacia decilas superiores a lo largo del periodo, lo que, junto a la incorporación de Estados Unidos como principal productor de petróleo mundial, explica la reducción del efecto redistributivo que se observa en ambos escenarios.
- Por último, el efecto reordenación reduce el potencial redistributivo de las rentas del comercio del petróleo, especialmente cuando medimos la renta en dólares en paridad del poder adquisitivo. En este escenario, el efecto reordenación es 2,5 veces superior en promedio al escenario con dólares a tipo de cambio de mercado, ya que la desigualdad medida es más reducida, por lo que las variaciones de la

renta provocadas por el comercio del petróleo producen mayores cambios de orden en la distribución, lo que reduce el efecto redistributivo que producen las rentas del petróleo.

Para cualquier europeo, atendiendo al peculiar objetivo del BCE, que únicamente persigue el control de la inflación, y a la dependencia energética de los países que conforman la Unión, es fundamental el estudio del impacto del precio del petróleo en la inflación. En este aspecto, las conclusiones que obtenemos son las siguientes:

- Al analizar la transmisión de los shocks del precio del petróleo a la inflación, es imprescindible considerar el entorno de inflación en el que se producen estos shocks, ya que esto influye tanto en el grado de transmisión como en la existencia de asimetrías entre shocks positivos y negativos del precio del petróleo. Además, los resultados varían en función del origen del shock, es decir, según sea un shock de oferta de petróleo, de demanda específica de petróleo o de demanda agregada.
- Los shocks del propio mercado del petróleo (shocks de oferta y de demanda específica de petróleo) muestran una transmisión similar y en línea con la teoría. En entornos de alta inflación, los shocks positivos presentan una mayor transmisión a la inflación, tanto general como subyacente, que los shocks negativos. Esta relación encaja en el modelo teórico de Taylor (2000), donde las empresas, en un entorno de mayor inflación, tienen expectativas de mayor inflación futura y mayor persistencia de los shocks, por lo que trasladan en mayor medida esos mayores costes a los precios. Además, los resultados muestran que, en el caso de los shocks negativos, éstos se transmiten en mayor medida en entornos de baja inflación, mientras que en entornos de alta inflación su transmisión es muy reducida, en línea con los resultados teóricos de Ball y Mankiv (1994), que muestran que la frecuencia con la que aumentan los precios ante cambios en los costes se incrementa con una mayor inflación tendencial, mientras que la frecuencia de las reducciones de precios se reduce, dando lugar a una mayor asimetría.
- Por su parte, los shocks de demanda agregada muestran un patrón de reacción de la inflación, tanto general como subyacente, distinto al encontrado para los otros tipos de shocks. Tanto en entornos de baja como alta inflación, encontramos una elevada asimetría entre shocks positivos y negativos. Caídas en la actividad económica mundial generan una caída de forma persistente en los precios, mientras que aumentos de la actividad económica mundial tienen una transmisión muy reducida, incluso teniendo un impacto acumulado negativo en entornos de baja inflación. Esta singularidad encuentra una posible explicación en la mayor reacción de la política monetaria ante presiones de demanda en la economía, lo que vendría reflejado en la transmisión negativa que experimenta la inflación subyacente en nuestra estimación, que compensaría el efecto inflacionista del componente energético. Otra posible explicación es la existencia de un impacto asimétrico de la actividad económica global en las economías de la zona euro, de forma que aumentos de estas no se transmiten a una mayor actividad europea, mientras que las caídas de la actividad económica si generan una reducción en la demanda y, por tanto, en los precios de la zona euro.

- En el caso de la transmisión de los distintos shocks a la inflación subyacente, los resultados muestran que solo es significativa en entornos de alta inflación, mientras que en entornos de baja inflación la inflación subyacente no reacciona ante los shocks o su reacción es muy reducida. Estos resultados tienen importantes implicaciones para la política monetaria. Los shocks de costes, como son los del precio del petróleo, generalmente suponen un *trade-off* para la política monetaria entre estabilizar los precios a cambio de deprimir la producción, o estabilizar la producción, permitiendo un aumento de la inflación. Sin embargo, en entornos de baja inflación, este *trade-off* no se produce, ya que la inflación subyacente, que muestra la dinámica inflacionaria a medio y largo plazo y que es la que el Banco Central Europeo toma de referencia en su conducción de la política monetaria, no se ve incrementada por los efectos indirectos de los shocks, por lo que no es necesario que el banco central endurezca su política monetaria para evitar una espiral inflacionaria.

Para el estudio de la trasmisión de las variaciones del precio del petróleo a la inflación hay que tener en cuenta los efectos sobre el tipo de cambio de la moneda de los países importadores, como son los europeos. Si la variación del tipo de cambio opera en el mismo sentido que el precio del petróleo, el efecto se puede ver atenuado y viceversa. Por esta razón estudiamos el papel que juega el tipo de cambio euro/dólar en la transmisión de las variaciones del precio del petróleo a la inflación en la zona euro y las conclusiones que obtenemos son las siguientes:

- El tipo de cambio euro/dólar reduce el impacto directo de las variaciones del precio del petróleo en la inflación general. Es decir, existe una relación positiva entre el precio del petróleo y el tipo de cambio del euro respecto al dólar, de manera que un aumento del precio del petróleo está relacionado con una apreciación del euro respecto al dólar. Esto implica que los aumentos del precio del petróleo, en dólares, se ven parcialmente compensados por un aumento del valor del euro frente al dólar, de forma que el aumento del precio en euros, que es el que finalmente pagan los consumidores de la zona euro, es menor.
- Según nuestras estimaciones, el efecto amortiguador del euro reduce en un 15% el efecto directo de las variaciones del precio del petróleo en dólares. Sin embargo, este efecto no se encuentra ni en el caso del yen japonés ni en la libra de Reino Unido, ambas divisas de relevancia internacional.
- El efecto amortiguador del euro se ha intensificado a lo largo del periodo estudiado, especialmente tras la Gran Recesión. Esto implica que la relación entre el tipo de cambio euro/dólar y el precio del petróleo se ha incrementado durante este periodo. Este resultado puede explicarse por el hecho que la relación positiva entre el tipo de cambio y el precio del petróleo surge a partir de mediados de la década de los 2000s (Bénassy-Quéré et al., 2007; Coudert y Mignon, 2016). Previamente, esta relación había sido negativa (Clostermann y Schnatz, 2000; Bénassy-Quéré et al., 2007). Una posible explicación a este cambio es el surgimiento del euro como moneda internacional de reserva, de manera que una parte de los flujos comerciales y financieros de los países exportadores de petróleo se trasladara a bienes y activos denominados en euros, dando lugar a una relación

positiva entre los ingresos del petróleo (que dependen del precio) y el tipo de cambio del euro.

- Por otra parte, las variaciones del tipo de cambio relacionadas con las variaciones del precio del petróleo no solo afectan a la inflación a través del efecto amortiguador que provocan en el precio del petróleo. Las variaciones del tipo de cambio afectan al precio de los bienes importados que se facturan en dólares, reduciendo aún más el efecto inflacionario de un aumento del precio del petróleo como consecuencia de la apreciación del euro que le acompaña. Según nuestras estimaciones, una apreciación del euro respecto al dólar del 1% reduce la inflación en 0,1 punto porcentual en términos anualizados.
- En definitiva, el euro actúa como un amortiguador del efecto de las fluctuaciones del precio del petróleo sobre la inflación. Esto tiene importantes implicaciones para la política monetaria, ya que, tanto el tipo de cambio como el precio del petróleo son factores determinantes en el II pilar de la política monetaria del Banco Central Europeo (ECB, 2011). Por un lado, reduce la reacción requerida ante un shock del precio del petróleo, ya que la fluctuación del tipo de cambio estabiliza parcialmente el impacto de dicho shock. Por otra parte, las autoridades monetarias deben ser cautas a la hora de reaccionar ante aumentos de la inflación generados por shocks del precio del petróleo, ya que un aumento del tipo de interés puede generar una mayor apreciación del euro y, por tanto, desencadenar una reacción superior a la necesaria, llevando a la inflación por debajo del objetivo del banco central y generando una mayor volatilidad de la inflación.

Llegados aquí solo resta señalar que esta memoria no supone el final de un camino investigador. Durante los próximos años, en la medida en que se produzca la paulatina sustitución de los combustibles fósiles, veremos importantes acontecimientos en el mercado de petróleo y otras materias primas, que además están relacionados con la producción de la energía que a la postre sustituirá en gran medida al petróleo, la electricidad. En estos últimos meses estamos observado en Europa, cómo el precio del gas natural, que a su vez está muy relacionado con el del petróleo, está impactando en la inflación a través del precio de la electricidad. Esto abre un nuevo camino para nuestra investigación y pone de manifiesto algo que los economistas venimos manifestando desde el comienzo de nuestro devenir como ciencia: el papel determinante de los recursos en la evolución de la economía y en el bienestar de las personas (Malthus, 1798). Es eso lo que hace indispensable no cejar en su estudio.

# Conclusions

The present doctoral thesis offers a comprehensive analysis of the evolution of the oil market during the 21st century. Examining how this market has evolved is of key importance for the economy, given its distributional and macroeconomic implications, although it is also important because relevant economic policy decisions, such as monetary policies, are taken on the basis of forecasts concerning how oil prices will evolve and how such changes will be transmitted to inflation. We have studied these questions throughout the articles that make up this thesis, and have drawn the following conclusions:

By studying the shocks that determine the evolution of oil prices during the 21st century: economic and financial shocks, such as the financial crisis in 2008; political shocks, such as wars in oil producing countries (Libyan and Syrian wars) or involving countries that play an important role in the global oil market (Ukrainian war); and technological shocks, such as the shock triggered by the development of fracking as a technique for oil extraction; we draw the following conclusions:

- Firstly, the collapse of the financial market in 2008, which gave rise to the Great Recession, triggered a fall in the price of oil that was 20% higher than the fall explained by the evolution of fundamentals. In other words, the uncertainty generated by this event caused a slump in oil price beyond the fall that can be explained by the reduction in demand at the start of the crisis. Therefore, the crisis had an impact beyond that caused by lower demand.

- Wars are also found to have some effect on the oil market, without showing a significant direct impact on the price of oil beyond their indirect influence through other oil market variables. The Libyan war (2011) sparked a drop in OPEC oil production in the short term, which indirectly affected the price of oil. In the case of the war in Ukraine (2014), our findings show the intrinsically political nature of the effects, since countries reacted by increasing their oil stocks. This fact is linked to the increasing uncertainty caused by the indirect involvement of two military superpowers in the conflict: Russia, which directly intervened, and the United States, by imposing sanctions.

- Finally, the introduction of fracking led to the emergence of the United States as the biggest global oil producer, which had a major impact on the price of oil. Between June 2014 and February 2015, the coverage of oil consumption by national production in the United States increased by 5.8%, which would have contributed to a drop in the price of oil of around four dollars per barrel according to our estimates. Furthermore, the reduction of United States dependence on foreign oil also led to a drop in oil production in OPEC countries, who reacted by cutting their oil production to stabilise the price of oil.

The political shock caused by the war in Ukraine (currently known as the Donbas war) is the most particular among the three types of shock previously discussed; hence we undertake a specific analysis thereof. We design a new method to detect key events during the conflict through press articles in leading financial journals, such as the Financial

Times and the Wall Street Journal, in order to study the short-term impact of the war in Ukraine on the daily evolution of the price of oil. The main conclusion we draw is that few events during the conflict directly affected the price of oil and that those which did were concentrated around the early days of the conflict and after public sanctions were imposed on Russia by the United States. The former mainly affected the European benchmark (Brent) while the latter affected the US benchmark (WTI) to a greater extent. This implies that the European market initially reacted due to its proximity to the conflict and its possible spread, while the US market, far from the war zone, reacted to a greater degree to news related to the relationship between the United States and Russia and the imposition of sanctions. Finally, our findings show that the events impacted the price of oil in the very short term, such that the impact occurred mainly on the day of the event. These fluctuations were quickly corrected, such that the events had no persistent effects on the price of oil.

The second objective of this doctoral thesis is to analyse the main macroeconomic consequences triggered by the evolution of the oil market. To this end, we focus on two different aspects: firstly, the international distributive effects of oil rents, and secondly, the effect of oil price changes on inflation, specifically the role played by the inflationary environment in which the fluctuations occur, and the role of exchange rates vis-à-vis the dollar in the transmission of oil price fluctuations to inflation. For this latter analysis, we focus on the euro area, which is made up of countries that are dependent on oil imports.

As regards the international redistributive effect of oil rents, a hitherto unexplored area in the literature, we design a methodology to extract the economic rent component that incorporates internationally traded oil price, and we draw the following conclusions from the analysis of its evolution:

- The implicit rent transferred internationally through the oil trade represents on average a value of 647,000 million dollars per year in constant 2010 dollars during the period 1995-2016, reaching a maximum value of 1,007,171 million dollars in 2008, prior to the start of the Great Recession.

- The weight of oil rents on the GDP of exporting and importing countries differs significantly. For exporting countries, the rents obtained from the international oil trade represent an average of 8.05% of their GDP, reaching a maximum of 12.04% in 2010, while for importing countries, the rents they transfer through the oil trade average 1.06% of GDP. This implies that the rents represent a reduced transfer for importing countries, but are vital to exporting countries, especially those classified as highly dependent (Azerbaijan, Nigeria, Brunei, UAE, and Qatar) or very highly dependent (Congo, Angola, Libya, Kuwait, Gabon, Yemen, and Saudi Arabia).

- Oil trade rents have a positive redistributive effect; that is, they reduce international inequality when measured in dollars using exchange market rates. This redistributive effect reaches 0.32 Gini index points, a considerable effect if we bear in mind that Bourguignon et al. (2009) estimate a redistributive effect for Official Development Assistance (ODA) in 2004 of 0.44 Gini index points. However, its evolution shows a declining trend over the period analysed. This downward trend is even more pronounced when rents are measured in dollars in purchase parity power. In this case, after an initial period of positive redistribution, we observe that as of 2001 oil rents generate a negative redistributive effect; that is, they are regressive and contribute to increasing inequality.

- The redistributive effect of oil trade rents takes place mainly through exports; in other words, through the benefit that oil exporting countries received from rents implicit in exports. This result is consistent with the fact that rents from exports represent a higher share of GDP for exporting countries. When measured using exchange market rates, the effect of exports in the international distribution of income is always positive, such that they reduce inequality. On the other hand, rents paid on imports have a lower impact on inequality and always show a regressive effect; that is, they only slightly increase international inequality. When rents and GDP are measured in purchasing parity power, the redistributive effect of exports experienced a decreasing trend, turning negative after 2001 as a consequence of a shift in the redistributive effect towards high-income exporting countries. Furthermore, in this scenario, import rents play a greater role, with both contributing to the negative total redistributive effect seen after 2001.

- When analysing the impact of oil trade rents by deciles of international income distribution, we conclude that the highest impact of rents, both from exports and imports, takes place in those countries that form the lowest deciles, although in the case of export rents, the impact on the lowest decile declines at the end of the period analysed. In addition, high-income exporting countries experienced a shift towards higher deciles over the period which, together with the incorporation of the United States as the world's biggest producer, explains the reduction in the redistributive effect experienced in both scenarios.

- Finally, the reranking effect reduces the potential redistributive effect of oil trade rents, especially when we use income and rents at purchasing power parity. In this scenario, the reranking effect is 2.5 times higher on average than in the exchange market rate scenario, since as inequality is lower in the former, changes in income caused by oil rents generate greater changes in the order of the distribution, which reduces the final redistributive effect of oil trade rents.

For any European citizen, considering the singular objective of the ECB which only has a mandate to control inflation, and the energy dependence of the countries that form the European Union, it is essential to study the impact of oil prices on inflation. In this regard, the conclusions we draw from our analysis are the following:

- When analysing the transmission of oil price shocks to inflation, it is essential to take into account the inflationary environment in which these shocks occur, since this influences both the degree of transmission and the existence of asymmetries between positive and negative oil price shocks. In addition, this transmission differs depending on the source of the shock; that is, whether it is a supply shock, an oil-specific demand shock or an aggregate demand shock.

- Shocks originating in the oil market (supply and oil-specific demand shocks) show a similar transmission and are in line with theory. In high inflationary environments, positive shocks have a higher transmission to inflation, both headline and core, than negative shocks. This result is in line with the theoretical model of Taylor (2000), where firms have expectations of higher future inflation and more persistence of shocks in high inflation environments, with this transmitting the higher costs to consumer prices to a greater extent. Furthermore, our findings show that negative oil price shocks are transmitted to a greater degree in low inflation environments, while their transmission is muted in a high inflation environment, which is in line with the theoretical model of Ball and Mankiv (1994), who show that the frequency of price increases due to changes in costs increases with higher trend inflation, while the frequency of price reductions decreases, resulting in greater asymmetry.

- As regards aggregate demand shocks, these show a different reaction of both headline and core inflation with respect to the other type of shocks. In both low and high inflation environments, we find a high asymmetry between positive and negative shocks. Downturns in global economic activity trigger a persistent reduction in the price level, whereas upturns in global economic activity show very low transmission to prices, and even display a cumulative negative impact in low inflation environments. One possible explanation for this singularity may be the stronger reaction of monetary policy to demand pressures in the economy, which would be reflected in the negative transmission shown by core inflation in our estimates, and which would offset the inflationary pressures of the energy component. Another possible explanation lies in the existence of an asymmetric impact of global economic activity on euro area economies, such that upturns in global activity are not transmitted to greater euro area activity, while downturns in economic activity do depress economic activity in the euro area, and therefore exert deflationary pressures in euro area inflation.

- Analysis of the transmission of oil price shocks to core inflation shows that this is only significant in high inflation environments, while the reaction of core inflation in low inflation environments is negligible. These results have important implications for monetary policy. Cost-push shocks, such as oil price shocks, generally generate a trade-off for monetary policy between controlling inflation in exchange for depressing production or stabilizing production, thereby allowing inflation to rise. However, in low inflation environments, this trade-off does not exist, since core inflation, which represents inflation dynamics in the medium and long term and which is taken by the ECB as a reference when implementing monetary policy, does not increase through the indirect effects of oil price shocks. The central bank does not therefore need to tighten its monetary policy stance to avoid an inflationary spiral.

When examining the transmission of oil price shocks to inflation, the role of the exchange rate of importing countries, such as the euro, must be taken into account. If changes in the exchange rate move in the same direction as the price of oil, the effect can be dampened or vice versa. For this reason, we study the role of the euro/dollar exchange rate in the transmission of oil price changes to inflation in the euro area. The conclusions we obtain are the following:

- The euro/dollar exchange rate reduces the impact of oil price fluctuations on headline inflation. In other words, there is a positive relationship between the price of oil and the euro/dollar exchange rate, such that increases in the price of oil are related to an appreciation of the euro vis-à-vis the dollar. This implies that increases in the price of oil, traded in dollars, are partially offset by an increase in the value of the euro against the dollar, such that the increase in the price of oil in euros, which is the price paid by consumers in the euro area, is lower.

- According to our estimates, the dampening effect of the euro reduces the direct impact of oil price fluctuations on inflation by 15%. This effect, however, is not found in the case of the Japanese yen or the British pound, both of which are international currencies.

- The dampening effect of the euro intensified throughout the period studied, especially after the Great Recession. This implies that the relationship between the euro/dollar exchange rate and the price of oil has increased over this period. This result might be explained by the fact that the positive relationship between the exchange rate and the price of oil emerges after the mid-2000s (Bénassy-Quéré et al., 2007; Coudert and Mignon, 2016). Previously, this relationship was found to be negative (Clostermann and Schnatz, 2000; Bénassy-Quéré et al., 2007). This shift may be caused by the emergence of the euro as an international reserve currency, such that part of the commercial and financial flows from oil exporting countries was transferred to goods and assets denominated in euros, thereby giving rise to the positive relationship between oil revenues (which depend on the price of oil) and the euro exchange rate.

- Additionally, exchange rate movements related to oil price changes not only affect inflation through the dampening effect caused in the price of oil. These changes also affect the price of imported goods denominated in dollars, further reducing the inflationary effect of a rise in the price of oil as a result of the euro's appreciation. According to our estimates, a 1% appreciation in the euro against the dollar reduces the inflation rate by 0.1 percentage point in annualized terms.

- In conclusion, the euro acts as a buffer from the inflationary effect of oil price fluctuations. This has important implications for monetary policy, since both the price of oil and the exchange rate are relevant factors in the second pillar of the ECB monetary policy strategy (ECB, 2011). First, it reduces the required reaction to an oil price shock, since the exchange rate fluctuation partially stabilizes the impact of the shock. In addition, the monetary authority must be cautious when reacting to increases in inflation caused by oil price shocks, since an increase in the interest rate can generate a further appreciation of the euro and, therefore, trigger a greater reaction than is necessary, bringing inflation below the central bank's target and triggering higher inflation volatility.

At this stage, it only remains to point out that this thesis is not the end of my research in this field. Over the next few years, as a gradual transition away from fossil fuels takes place, we will be witnessing major developments in the oil market, which are also related to the production of the energy that will ultimately replace oil in most cases; namely, electricity. In recent months, we have been observing how the price of natural gas, which is closely linked to the price of oil, is having an impact on inflation through the price of electricity in Europe. This opens up a new avenue for our research and highlights something that economists have been stating since economics first emerged as a science: the determining role of resources on the evolution of the economy and the wellbeing of people (Malthus, 1798). This is why we must not cease in our research efforts.

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