OIL PRICE SURGES AND THE YIELD CURVE

A Master's Thesis

by
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İhsan Doğramacı Bilkent University
Ankara
July 2024

To my family

OIL PRICE SURGES AND THE YIELD CURVE

The Graduate School of Economics and Social Sciences
of
İhsan Doğramacı Bilkent University

by

ASİYE İREM DEŞDEMİR

In Partial Fulfillment of the Requirements for the Degree of
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İHSAN DOĞRAMACI BİLKENT UNIVERSITY
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By Asiye İrem Deşdemir

I certify that I have read this thesis and have found that it is fully adequate, in scope and in quality, as a thesis for the degree of Master of Arts in Economics.

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ABSTRACT

OIL PRICE SURGES AND THE YIELD CURVE

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July 2024

This thesis examines the effect of changes in oil prices on the term structure of interest rates. For this purpose, we consider The Organization of the Petroleum Exporting Countries (OPEC) announcements as the source of supply shocks since OPEC is the leading organization for oil supply in the world and has a significant influence on the market determination of oil prices (Känzig, 2021). We conduct an event study using oil supply shocks proxied by market based surprises as in Känzig (2021). Event study regressions show that oil supply news shocks significantly affect long term yields, while the effect does not exist in the short term in the United States (U.S.) context. We argue that these findings can be justified by the response of inflation risk premium where an increase in oil price increases the compensation for holding nominal bonds. We model this mechanism by using a simple consumption-based asset pricing setup. The model analytically shows that simultaneous, empirically supported, reverse direction movements in the consumption growth of goods other than oil and oil supply news shocks can increase the inflation risk premium and put upward pressure on yields.

Keywords: Oil Price, Yield Curve, OPEC, Term Structure of Interest Rates, Inflation Risk Premium

ÖZET

PETROL FİYATLARI VE GETİRİ EĞRİSİ

Deşdemir, Asiye İrem
Yüksek Lisans, İktisat Bölümü
Tez Danışmanı: Dr. Ögr. Üyesi Burçin Kısacıkoğlu

Temmuz 2024

Bu tez, petrol fiyatlarındaki değişimlerin faizlerin vade yapısına etkisini incelemektedir. Bu amaçla, Petrol İhraç Eden Ülkeler Örgütü (OPEC)'nün dünyada petrol tedarikinde lider kuruluş olması ve petrol piyasasının belirlenmesinde önemli bir etkiye sahip olması nedenleriyle (Känzig, 2021), petrol arz şoklarının kaynağı olarak OPEC'in duyurularını kullanıyoruz. Piyasa temelli sürprizler ile temsil edilen petrol arzı şoklarını Känzig (2021)'den alarak bir olay çalışması yürütüyoruz. Olay çalışmasının regresyon sonuçları, Amerika Birleşik Devletleri bağlamında petrol arzı haber şoklarının uzun vadeli getirileri önemli ölçüde etkilediğini ancak bu etkinin kısa vadede mevcut olmadığını göstermektedir. Bu bulgular, petrol fiyatlarındaki artışların nominal tahvillerin enflasyon risk primini yükseltmesi yoluyla açıklanabilir. Bu mekanizmayı basit bir tüketime dayalı varlık fiyatlama modeli kullanarak modelliyoruz. Model, petrol dışındaki malların tüketim büyümesi ile petrol arzı haber şoklarının eşzamanlı olarak ampirik açıdan desteklenen ters yönlü hareketlerinin risk primini artırdığını ve getiriler üzerinde yukarı yönlü baskı oluşturabileceğini analitik olarak göstermektedir.

Anahtar Kelimeler: Petrol Fiyatları, Getiri Eğrisi, Petrol İhraç Eden Ülkeler Örgütü, Faizlerin Vade Yapısı, Enflasyon Risk Primi

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CHAPTER 1

INTRODUCTION

Investigating the relationship between macroeconomic variables and oil prices has been an active research area since the oil crisis of 1973. In recent years, specifically after the COVID-19 pandemic started, changes in oil prices and their impact on other macroeconomic indicators have become even more salient for researchers and policymakers. In April 2020, oil prices turned negative due to the fact that the economy slowed down and oil demand decreased sharply, leading to a storage problem for crude oil producers (Ambrose, 2020). Moreover, the war that started on 24 February 2022 also affected oil supplies and prices as Russia is one of the most prominent oil producers in the world, and many countries employed embargoes on oil imports from Russia.

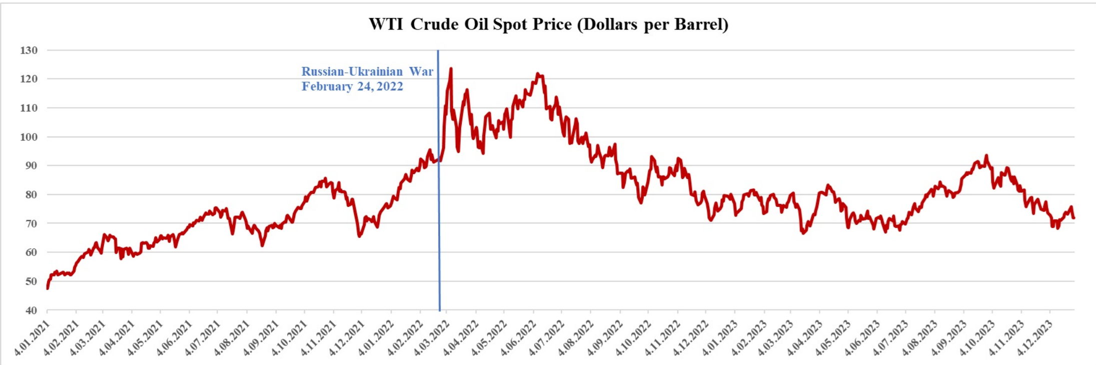

Figure 1: Crude Oil Spot Prices.

Data from U.S. Energy Information Administration (2024) from January 1, 2021 to December 31, 2023.

After the war started, the oil prices jumped, and this increase has persisted for a considerable amount of time as shown in Figure 1. These changes in oil prices have been affecting the economic conditions and policy decisions all around the world since then.

Due to the renewed interest, several studies have focused on the relationship between oil prices and main economic indicators, such as inflation, unemployment, stock market, and policy decisions. Gagliardone and Gertler (2023) emphasize the importance of oil shocks in the recent persistent inflation surge and unemployment through 2022 by providing a New Keynesian model in which they incorporate oil as a complementary production input for firms. They also underline the effect of easy monetary policy, meaning the delayed responses of the FED for the recent inflationary period coupled with the oil shocks. Kilian and Zhou (2022) state that the persistent rise in oil prices has had an impact on the increasing inflation expectations and U.S. inflation since the mid-2020s, while their results are in the direction that these shocks will not be effective in the longer term inflation. Känzig (2021) provides similar results: oil supply cut announcements lead to higher inflation expectations as the production cuts push oil prices up. Another channel Känzig (2021) mentions is that such news diminishes industrial production, and consumer prices experience a hike in the U.S. economy as a result. The effect of oil news shocks on the stock market side reveals that oil news shocks might have an effect on the stock price indices in the longer-term with heterogenous responses from different industries (Alsalman et al., 2023). Alsalman et al. (2023) also highlight that news of current oil price rises might have an information effect; that is, it may imply an expected higher demand for oil in the future when they extend the sample period to 2022, which is an important prediction for economic agents.

The literature on the aforementioned economic variables and oil prices suggests that oil prices have been one of the crucial topics of the recent macro developments. In this study, we focus on the relationship between oil prices and another important economic indicator, interest rates. We know that macro factors affect yields (Dewachter and Lyrio, 2006). Also, if oil prices increase inflation expectations, this should have an affect on the yield curve . Therefore, we specifically examine the effect of changes in oil prices on the term structure of interest rates, which is known as the yield curve. For this purpose, we consider The Organization of the Petroleum Exporting Countries (OPEC) announcements as the source supply shocks since OPEC is the leading organization for oil supply in the world, as it constitutes 44% of all oil exports around the world with its 13 members (Känzig, 2021). Its member countries gather several times yearly to plan oil production and set quotas and prices until the next meeting and they aim to stabilize the oil markets (OPEC, 2024). OPEC's decisions regarding oil supply policies can significantly influence the market as the financial markets price major economic news. It is evidenced that OPEC has the market power to remarkably affect the crude oil prices through announcements, and the impact of the type of announcements, i.e., production plan, quotas, and price setting, on oil prices may differ in magnitude (Kilian (2014); Lin and Tamvakis (2010); (Loutia et al., 2016)). Also, it is important to underline that the market immediately prices the information it already has. Hence, the unexpected components of these announcements will be those prone to sudden changes in the macroeconomic indicators. In this study, we use OPEC announcements' unanticipated components, which are identified by Känzig (2021), to examine the potential effect of oil supply news shocks on the term structure of interest rates.

To investigate the relationship between oil price changes and the term structure of interest rates, we first conduct an event study using zero-coupon yields and instantaneous forward rates at different maturities as the yield curve measure and oil supply news shocks by Känzig (2021). The event study follows the methodology of Gürkaynak et al. (2005) where we take the daily differences of the yields around the OPEC announcement dates. Then, we conduct separate event study regressions to observe what portion of the daily of between zero-coupon yields and instantaneous forward rates is constituted by the oil supply news shocks. All regression results consistently show that oil supply news shocks significantly affect 5-year and 10-year yields, while shorter-term yields do not respond to the changes in oil prices in U.S. context. Moreover, the regression coefficients get more extensive and significant as the maturity increases. One mechanism that can explain these event study results is that oil price changes lead to an increase in the inflation risk premium, resulting in pushing yield upward in the longer term.

We provide a modeling framework to analytically examine the relationship found in the event study. The model follows a standard consumption-based asset pricing setup. The consumption basket of the agent consists of a weighted average of two distinct sources: oil and goods other than oil. Consistently, inflation in this economy is also a weighted average of inflation of these two goods. Given the agent's preferences, we obtain nominal and real stochastic discount factors which allow us to find n-periods nominal and real yields in this economy. In this way, we can analyze the inflation risk premium component with a specific focus on the covariance term of consumption growth of goods other than oil and oil price, which we interpret through the event study findings. Finally, we provide some empirical evidence on the sign of the covariance term for 5-year and 10-year yields, which can lead to a rise in the inflation risk premium, resulting in an upward movement in the long end of the yield curve. This finding is the main motivation and contribution of this research.

The remainder of this study is organized as follows: we provide the details of the data we use for the event study in Chapter 2. Then, we describe the event study structure and provide the regression results in Chapter 3. After that, we present a modeling framework to examine the relationship between oil prices and the term structure of interest rates analytically and discuss the relation between event study results and the modeling framework in Chapter 4. Finally, Chapter 5 concludes the study.

CHAPTER 2

DATA

In this study, we use two different data sets to observe the effect of changes in oil prices on the term structure of interest rates. The first data set is the oil supply news shocks constructed by Känzig (2021). The second data set is the is the zero-coupon nominal yield curve and implied instantaneous forward rates provided by Gürkaynak et al. (2007).

Känzig (2021) identifies oil supply news shocks by focusing on the shift in the oil supply expectations and their impact on oil prices. For this purpose, Känzig (2021) uses OPEC announcements as the factor directly linked with the oil supply expectations. In a tight window around OPEC announcements, changes in oil futures allow for identifying the effects of surprise supply cuts on oil price expectations. The novel methodology developed by Känzig (2021) is based on the proxy VAR approach of Stock and Watson (2012) and Mertens and Ravn (2013) (as cited in Känzig (2021)) and devises an approach using this method and high-frequency oil news surprises as an external instrument, i.e., a proxy, for oil prices to identify the structural oil news shocks. This surprise series is correlated with the oil news shocks and uncorrelated with the other shocks. The data set used in this study consists of these oil supply news shocks on OPEC press release dates from July 19, 1983 to December 4, 2022.

We use zero-coupon yields and instantaneous forward rates to investigate the behavior of the term structure of interest rates constructed by Gürkaynak et al. (2007). Since the zero-coupon government bond yields do not make intermediate payments, they are considered a proxy for the risk-free rate. Hence, it is a helpful tool to observe the movements in the term structure. Also, instantaneous forward rates enable us to detect the immediate yield curve changes. Thus, we use these two daily series from the data set to observe the yield curve changes around the OPEC announcements. For this study, we use the sample period, that is, the OPEC press release dates from July 19, 1983, to December 4, 2022, for zero-coupon yields and instantaneous forward rates.

CHAPTER 3

EVENT STUDY

In this section, we present the event study, following the methodology of Gürkaynak et al. (2005), and the outcomes using data described in the previous part. We consider the OPEC announcements to be events for event study purposes. Therefore, utilizing the daily high-frequency data of zero coupon yields, instantaneous forward rates, and oil news shocks, we can evaluate the existence of the effect of changes in oil prices on the term structure of interest rates in the U.S. context. In the case of the existence of such an impact, the event study results provide the magnitude and statistical significance of the effect, allowing us to comment on the economic interpretation. We use ordinary least squares (OLS) regressions for different indicators and maturities around the OPEC announcement days to conduct the event study.

3.1 Zero-coupon Yields

To estimate the effects of oil prices on yields, we take the daily changes of yields around OPEC announcements. We directly use the oil news shocks constructed by Känzig (2021) as the right hand side variable. Then, we match the dates and obtain 143 observations in the sample period. Therefore, the event study regression using the zero-coupon yields for 1-year, 2-year, 5-year, and 10-year maturities separately is

$$\Delta z_t = \alpha^z + \beta^z o_t^s + \epsilon_t^z \tag{3.1}$$

Δz_t: Daily changes in the zero-coupon yields around OPEC announcements

o_t^s: Standardized oil supply news shocks due to OPEC announcements

t: OPEC announcement days: July 19, 1983 - December 4, 2022

In this way, we can observe what proportion of the changes in the zero-coupon yields can be explained by one standard deviation of oil supply news shocks for different maturities. The results in basis points for this regression coefficient β^z are as follows.

	(1) Daily 1-year Zero-coupon Yield Change	(2) Daily 2-year Zero-coupon Yield Change	(3) Daily 5-year Zero-coupon Yield Change	(4) Daily 10-year Zero-coupon Yield Change
Standardized Oil Supply News Shock	-0.0296	0.258	0.989*	1.77***
	(0.00400)	(0.00553)	(0.00561)	(0.00656)
Observations	143	143	143	143
R-squared	0.000	0.002	0.027	0.077

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 3.1: Regression Results for β^z from Equation (3.1) in Basis Points.

Data from Känzig (2021); Gürkaynak et al. (2007) from July 19, 1983 to December 4, 2022.

According to the regression results, it can be observed the oil supply news shocks do not explain the daily variation in the 1-year and 2-year zero-coupon yields, considering the small coefficients and high standard errors. However, it is remarkable that the 5-year and 10-year yield coefficients are 0.99 and 1.77 basis points with 90% and 99% statistical significance levels, respectively. This suggests that the explanatory component of oil supply news shocks in yield changes is increasingly higher and more significant towards the long end of the yield curve.

3.2 Instantaneous Forward Rates

Instantaneous forward rates refer to the rate at a very small time interval. It helps us understand the immediate changes in zero-coupon yields. Therefore, we use instantaneous forward rates to bond pricing according to the market expectations when a shock arrives in this study. Following the same methodology for the zero-coupon yields, we take the daily differences of consecutive working days for instantaneous forward rates as the dependent variable. We get 140 observations within the sample period using the same oil supply news shocks series and matching the dates. We separately conduct the OLS regression for 1-year, 2-year, 5-year and 10-year maturities formulated as follows.

$$\Delta if_t = \alpha^{if} + \beta^{if} o_t^s + \epsilon_t^{if} \tag{3.2}$$

Δif_t: Daily changes in the instantaneous forward rates around OPEC announcements

o_t^s: Standardized oil supply news shocks due to OPEC announcements

t: OPEC announcement days: July 19, 1983 - December 4, 2022

The regression results reveal the daily variations in instantaneous forward rates and the extent to which these changes can be attributed to oil supply news shocks for different maturities which is β^{if} in basis points, as below.

	(1) Daily 1-year Instantaneous Forward Rate Change	(2) Daily 2-year Instantaneous Forward Rate Change	(3) Daily 5-year Instantaneous Forward Rate Change	(4) Daily 10-year Instantaneous Forward Rate Change
Standardized Oil Supply News Shock	0.299	0.835	2.11***	2.69***
	(0.00715)	(0.00712)	(0.00771)	(0.00954)
Observations	140	140	140	140
R-squared	0.002	0.014	0.078	0.114

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 3.2: Regression Results for β^{if} from Equation (3.2) in Basis Points.

Data from Känzig (2021); Gürkaynak et al. (2007) from July 19, 1983 to December 4, 2022.

The results suggest that one can observe 2.11 and 2.69 basis points changes in the instantaneous forward rates for 5-year and 10-year maturities, respectively, with 99% statistical significance level for both maturities around the OPEC announcement dates. The effect is smaller for 1-year and 2-year maturities and they are not statistically significant.

3.3 5-year Forward Rates Beginning 5 Years Hence

As the forward rates are widely used to have an insight into market expectations of future interest rates, we check for the changes in the 5-year forward rates beginning 5 years hence around the OPEC announcements within the sample period. We use 10-year and 5-year zero-coupon rates to calculate the 5-year forward rate beginning 5-years hence. The regression result is formulated similarly to the previous event study regressions.

$$\Delta f_t = \alpha^f + \beta^f o_t^s + \epsilon_t^f \tag{3.3}$$

Δf_t: Daily change in 5-year forward rate beginning 5-years hence around OPEC announcements

o_t^s: Standardized oil supply news shocks due to OPEC announcements

t: OPEC announcement days: July 19, 1983 - December 4, 2022

	Daily 5-year Forward Rate Beginning 5-years Hence Change
Standardized Oil Supply News Shock	2.55***
	(0.00905)
Observations	143
R-squared	0.105

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 3.3: Regression Results for β^f from Equation (3.3) in Basis Points.

Data from Känzig (2021); Gürkaynak et al. (2007) from July 19, 1983 to December 4, 2022.

The regression result shows that 5-year forward rate beginning 5-years hence significantly changes by 2.55 basis points around the OPEC announcements from 1983 to 2022, providing an even stronger evidence to support the previous event study regression results.

3.4 Discussion of the Regression Results

We use several indicators of interest rates to examine the effect of oil supply news shocks on the interest rates. Specifically, we check daily zero-coupon yield changes and daily instantaneous forward rate changes for 1-year, 2-year, 5-year, 10-year, and daily 5-year forward rates beginning 5 years hence change around the OPEC announcement dates from July 19, 1983, to December 4, 2022. All regression results using these variables indicate that these variables for 1-year and 2-year maturities remain unchanged around the OPEC announcement dates. However, we observe that 5-year and 10-year variables move as we observe oil supply news shocks around the OPEC announcements. Moreover, we find that

10-year interest rates show a higher response than 5-year rates. Hence, one can deduce that the longer-term yields respond stronger than the shorter-term yields. From the above regressions, we observe that the coefficients are positive; that is, unexpected oil supply cuts lead to an increasing effect on the yields for the corresponding maturities. Therefore, we expect to observe an upward movement at the longer end of the yield curve and do not see any changes at the short end around the OPEC announcement dates. One possible explanation for this observation is that oil supply news shocks feed into the inflation risk premium in the longer term, leading to an upward movement in the yield curve, especially towards the long end.

CHAPTER 4

MODELING FRAMEWORK

In this chapter, we present a modeling framework to rationalize the event study findings. We show the impact of oil supply news shocks through inflation risk premium on the term structure of the interest rates using a consumption-based asset pricing model. In this way, we demonstrate that the oil supply news shocks accumulate and appear in the inflation risk premium component of the specified yield. Hence, we show that the effect of oil supply news shocks is larger in the further maturities, leading to an upward shift in the long end of the yield curve. In the end, we provide simple empirical support and reveal that the covariance between oil price inflation and consumption growth of goods other than oil is indeed negative, which feeds into the inflation risk premium and increases the yields at the 5-year and 10-year maturities potentially.

4.1 Setup

A representative agent has a preference over consumption expressed in aggregate consumption terms as

$$\mathbb{E}_t \left[\sum_{t=0}^{\infty} \beta^t u(C_t) \right] \tag{4.1}$$

where the agent exhibits constant relative risk aversion behavior and has the following utility function for aggregate consumption

$$u(C_t) = \frac{C_t^{1-\gamma}}{1-\gamma} \tag{4.2}$$

where γ is the risk aversion parameter.

Aggregate consumption, C_t, consists of two goods, which are oil consumption, C_{ot}, and goods consumed other than oil, C_{qt}. The aggregation of C_{ot} and C_{qt} in C_t is determined with the weight ω in the form

$$C_t = {C_{ot}}^{\omega} {C_{qt}}^{(1-\omega)} \tag{4.3}$$

where $0 < \omega < 1$.

Let P_{ot}, P_{qt}, P_{C_t} denote the oil price, other consumption goods price index, and aggregate consumption price index, respectively. There is one asset, B_t, in the economy which can be invested in period t to obtain the real gross rate of return on the asset R_t between t and t+1 per unit of investment. Endowment at time t is N_t. The budget constraint can be expressed as

$$P_{C_t} C_t + B_t K_t = N_t + R_{t-1} B_{t-1} K_{t-1} \tag{4.4}$$

or equivalently,

$$P_{ot} C_{ot} + P_{qt} C_{qt} + B_t K_t = N_t + R_{t-1} B_{t-1} K_{t-1} \tag{4.5}$$

where K_t denotes the number of assets purchased at time t.

Let $\frac{P_{C_{t+1}}}{P_{C_t}} = \Pi_{t+1}$ and denote the inflation in the economy. Assume that inflation follows a similar weighting structure for oil and other goods price inflation as in the aggregated consumption

$$\Pi_{t+1} = (\Pi_{ot+1})^{\theta}(\Pi_{qt+1})^{(1-\theta)} \tag{4.6}$$

$$\Pi_{ot+1} = \frac{P_{ot+1}}{P_{ot}} \tag{4.7}$$

$$\Pi_{qt+1} = \frac{P_{qt+1}}{P_{qt}} \tag{4.8}$$

where $0 < \theta < 1$.

In this setup, the representative agent chooses aggregate consumption, which can be expressed in terms of oil consumption and other goods consumption, and asset holdings.

4.2 Nominal Stochastic Discount Factor and Nominal Yields

The asset B_t with the gross return R_t can be priced using the fundamental theorem of asset pricing

$$\mathbb{E}_t[M_{t+1}R_{t+1}] = 1 \tag{4.9}$$

where M_{t+1} denotes the stochastic discount factor. In this study, the focus of the modeling framework is on the stochastic discount factor.

The nominal stochastic discount factor using the optimality conditions can be expressed as

$$M_{t+1}^{\$} = \mathbb{E}_t\left[\beta\left(\frac{C_{t+1}}{C_t}\right)^{-\gamma}\frac{P_{C_t}}{P_{C_{t+1}}}\right] \tag{4.10}$$

We can rewrite the nominal stochastic discount factor by explicitly incorporating the expressions for the aggregated consumption and inflation to obtain

$$M^{\$}_{t+1} = \mathbb{E}_t\left[\beta\left(\frac{{C_{ot+1}}^{\omega}{C_{qt+1}}^{(1-\omega)}}{{C_{ot}}^{\omega}{C_{qt}}^{(1-\omega)}}\right)^{-\gamma}\frac{1}{\Pi_{t+1}}\right] \tag{4.11}$$

In order to simplify the complexity of non-linear relations and their implications in this modeling framework, we log-linearize the stochastic discount factor. The following log-linearization notation is used for each of the specified variables for the rest of this study.

$$m^{\$}_{t+1} = \log M^{\$}_{t+1} \tag{4.12}$$

$$c_{ot+1} = \log C_{ot+1} \tag{4.13}$$

$$c_{qt+1} = \log C_{qt+1} \tag{4.14}$$

$$\pi_{t+1} = \log \Pi_{t+1} \tag{4.15}$$

$$\pi_{ot+1} = \log \Pi_{ot+1} \tag{4.16}$$

$$\pi_{qt+1} = \log \Pi_{qt+1} \tag{4.17}$$

$$\pi_{t+1} = \theta\pi_{ot+1} + (1-\theta)\pi_{qt+1} \tag{4.18}$$

Therefore, we can express the log-linearized nominal stochastic discount factor as

$$m^{\$}_{t+1} = \log\beta - \gamma[\omega c_{ot+1} + (1-\omega)c_{qt+1} - \omega c_{ot} - (1-\omega)c_{qt}] - \pi_{t+1} \tag{4.19}$$

Let the following denote the log-consumption growth for oil and other goods

$$c_{ot+1} - c_{ot} = \Delta c_{ot+1} \tag{4.20}$$

$$c_{qt+1} - c_{qt} = \Delta c_{qt+1} \tag{4.21}$$

Then, using the log-consumption growth expression, the nominal stochastic discount factor becomes

$$m_{t+1}^{\$} = \log \beta - \gamma[\omega \Delta c_{ot+1} + (1-\omega)\Delta c_{qt+1}] - \theta \pi_{ot+1} - (1-\theta)\pi_{qt+1} \tag{4.22}$$

when the inflation components are explicitly written.

The expected value of the nominal stochastic discount factor is

$$\begin{aligned} \mathbb{E}_t\left[m_{t+1}^{\$}\right] =& \log \beta - \gamma\omega \mathbb{E}_t[\Delta c_{ot+1}] - \gamma(1-\omega)\mathbb{E}_t[\Delta c_{qt+1}] \\ & - \theta \mathbb{E}_t[\pi_{ot+1}] - (1-\theta)\mathbb{E}_t[\pi_{qt+1}] \end{aligned} \tag{4.23}$$

The variance of the nominal stochastic discount factor is

$$\begin{aligned} \operatorname{var}_t\left[m_{t+1}^{\$}\right] =& \gamma^2\omega^2\sigma_{co}^2 + \gamma^2(1-\omega)^2\sigma_{cq}^2 + \theta^2\sigma_{\pi o}^2 + (1-\theta)^2\sigma_{\pi q}^2 \\ & + \gamma^2\omega(1-\omega)\operatorname{cov}_t(\Delta c_{ot+1}, \Delta c_{qt+1}) \\ & + \gamma\omega\theta \operatorname{cov}_t(\Delta c_{ot+1}, \pi_{ot+1}) \\ & + \gamma\omega(1-\theta)\operatorname{cov}_t(\Delta c_{ot+1}, \pi_{qt+1}) \\ & + \gamma(1-\omega)\theta \operatorname{cov}_t(\Delta c_{qt+1}, \pi_{ot+1}) \\ & + \gamma(1-\omega)(1-\theta)\operatorname{cov}_t(\Delta c_{qt+1}, \pi_{qt+1}) \\ & + \theta(1-\theta)\operatorname{cov}_t(\pi_{ot+1}, \pi_{qt+1}) \end{aligned} \tag{4.24}$$

where σ_{co}^2, σ_{cq}^2, $\sigma_{\pi o}^2$, and $\sigma_{\pi q}^2$ represent the variances in oil consumption growth, other goods consumption growth, oil prices, and other goods prices, respectively.

Using the fundamental theorem of asset pricing and doing recursive substitution, we can obtain n-period nominal bond yields, ${y_t}^{(\$,n)}$, in general form as follows

$$
{y_t}^{(\$,n)} = -\frac{1}{n}\mathbb{E}_t\left[\sum_{i=1}^{n} m^{\$}_{t+i}\right] - \frac{1}{n}\frac{1}{2}\operatorname{var}_t\left[\sum_{i=1}^{n} m^{\$}_{t+i}\right] \tag{4.25}
$$

Therefore, we can state n-period nominal yields for this model as

$$
\begin{aligned}
{y_t}^{(\$,n)} = &- \frac{1}{n}\sum_{i=1}^{n}\Big[\log\beta - \gamma\omega\mathbb{E}_t[\Delta c_{ot+i}] - \gamma(1-\omega)\mathbb{E}_t[\Delta c_{qt+i}] \\
&- \theta\mathbb{E}_t[\pi_{ot+i}] - (1-\theta)\mathbb{E}_t[\pi_{qt+i}]\Big] \\
&- \frac{1}{n}\frac{1}{2}\sum_{i=1}^{n}\Big[\gamma^2\omega^2\sigma^2_{co} + \gamma^2(1-\omega)^2\sigma^2_{cq} + \theta^2\sigma^2_{\pi o} + (1-\theta)^2\sigma^2_{\pi q} \\
&+ \gamma^2\omega(1-\omega)\operatorname{cov}_t(\Delta c_{ot+i}, \Delta c_{qt+i}) \\
&+ \gamma\omega\theta\operatorname{cov}_t(\Delta c_{ot+i}, \pi_{ot+i}) \\
&+ \gamma\omega(1-\theta)\operatorname{cov}_t(\Delta c_{ot+i}, \pi_{qt+i}) \\
&+ \gamma(1-\omega)\theta\operatorname{cov}_t(\Delta c_{qt+i}, \pi_{ot+i}) \\
&+ \gamma(1-\omega)(1-\theta)\operatorname{cov}_t(\Delta c_{qt+i}, \pi_{qt+i}) \\
&+ \theta(1-\theta)\operatorname{cov}_t(\pi_{ot+i}, \pi_{qt+i})\Big]
\end{aligned} \tag{4.26}
$$

4.3 Real Stochastic Discount Factor and Real Yields

We can obtain the real n-period return on the asset by using the real stochastic discount factor, M_{t+1}, which is

$$
M_{t+1} = \mathbb{E}_t\left[\beta\left(\frac{{C_{ot+1}}^{\omega}{C_{qt+1}}^{(1-\omega)}}{{C_{ot}}^{\omega}{C_{qt}}^{(1-\omega)}}\right)^{-\gamma}\right] \tag{4.27}
$$

Following the same notation as in the nominal stochastic discount factor, we obtain the following the log-linearized real stochastic discount factor.

$$m_{t+1} = \log\beta - \gamma[\omega\Delta c_{ot+1} + (1-\omega)\Delta c_{qt+1}] \tag{4.28}$$

The expected value of the real stochastic discount factor is

$$\mathbb{E}_t\left[m_{t+1}\right] = \log\beta - \gamma\omega\mathbb{E}_t[\Delta c_{ot+1}] - \gamma(1-\omega)\mathbb{E}_t[\Delta c_{qt+1}] \tag{4.29}$$

The variance of the real stochastic discount factor is

$$\begin{aligned} \mathrm{var}_t\left[m_{t+1}\right] =& \gamma^2\omega^2\sigma_{co}^2 + \gamma^2(1-\omega)^2\sigma_{cq}^2 \\ &+ \gamma^2\omega(1-\omega)\,\mathrm{cov}_t(\Delta c_{ot+1}, \Delta c_{qt+1}) \end{aligned} \tag{4.30}$$

Then, n-period real bond yields, ${y_t}^{(n)}$, become

$$\begin{aligned} {y_t}^{(n)} =& -\frac{1}{n}\sum_{i=1}^{n}\Big[\log\beta - \gamma\omega\mathbb{E}_t[\Delta c_{ot+i}] - \gamma(1-\omega)\mathbb{E}_t[\Delta c_{qt+i}]\Big] \\ & -\frac{1}{n}\frac{1}{2}\sum_{i=1}^{n}\Big[\gamma^2\omega^2\sigma_{co}^2 + \gamma^2(1-\omega)^2\sigma_{cq}^2 + \gamma^2\omega(1-\omega)\,\mathrm{cov}_t(\Delta c_{ot+i}, \Delta c_{qt+i})\Big] \end{aligned} \tag{4.31}$$

4.4 Inflation Risk Premium

Since the breakeven inflation is defined as the difference between the nominal and real yields for the specified number of periods, we can obtain it by using ${y_t}^{(\$,n)}$ and ${y_t}^{(n)}$ derived above. Then, the breakeven inflation for n-periods can be expressed as

$$
\begin{aligned}
{y_t}^{(\$,n)} - {y_t}^{(n)} =& \frac{1}{n}\sum_{i=1}^{n}\Big[\theta \mathbb{E}_t[\pi_{ot+i}] + (1-\theta)\mathbb{E}_t[\pi_{qt+i}]\Big] \\
& - \frac{1}{n}\frac{1}{2}\sum_{i=1}^{n}\Big[\theta^2\sigma^2_{\pi o} + (1-\theta)^2\sigma^2_{\pi q}\Big] \\
& - \frac{1}{n}\frac{1}{2}\sum_{i=1}^{n}\Big[\gamma\omega\theta \operatorname{cov}_t(\Delta c_{ot+i}, \pi_{ot+i}) \\
& + \gamma\omega(1-\theta)\operatorname{cov}_t(\Delta c_{ot+i}, \pi_{qt+i}) \\
& + \gamma(1-\omega)\theta \operatorname{cov}_t(\Delta c_{qt+i}, \pi_{ot+i}) \\
& + \gamma(1-\omega)(1-\theta)\operatorname{cov}_t(\Delta c_{qt+i}, \pi_{qt+i}) \\
& + \theta(1-\theta)\operatorname{cov}_t(\pi_{ot+i}, \pi_{qt+i})\Big]
\end{aligned} \tag{4.32}
$$

Breakeven inflation has expected inflation as the first term, Jensen's inequality component as the second term, and inflation risk premium as the third term. It is important to note that $\operatorname{cov}_t(\Delta c_{qt+i}, \pi_{ot+i})$ appears in the inflation risk premium. This means that negative covariance of oil price inflation and other goods' consumption growth leads to a higher inflation risk premium. Since the agents get higher marginal utility when their consumption growth of other goods declines and this happens simultaneously with the high oil price inflation, they require higher compensation to hold the nominal bonds. Hence, this drives the inflation risk premium upward which leads to an increase in yields.

4.5 Empirical Evidence and Connection with Event Study Results

In this part, we simply show that $\operatorname{cov}_t(\Delta c_{qt+i}, \pi_{ot+i})$ is empirically negative and it validates the model implication that negative covariance between other goods' consumption growth and oil price inflation has an increasing effect on inflation risk premium.

We use the seasonally adjusted quarterly dataset of real personal consumption expenditures excluding food and energy growth (Federal Reserve Bank of St. Louis, 2024) for other goods consumption growth, Δc_{qt}, from the third quarter of 1983 to the last quarter of 2022. For the oil prices, we use Känzig (2021) oil supply news shocks and sum the shocks up for each quarter to obtain the quarterly oil supply news shocks series for the same period. We calculate the covariances between other goods consumption growth and oil supply news shocks within each year for the quarters during which OPEC announcements are made and obtain a single covariance value for each year from 1983 to 2022.

Recalling from the event study results, we observe a movement in the 5-year and 10-year yields around the OPEC announcement dates. Therefore, we mainly focus on the model implications with the data for 5-year and 10-year yields. For 5-year and 10-year yields, n=5 and n=10, we sum consecutive five and ten years' covariances to obtain the inflation risk premium component of the covariance term, respectively. The averages of the covariance terms in the inflation risk premium for 5-year and 10-year yields are obtained as -0.4640 and -0.4508, respectively. As they emerge as negative numbers, it provides a supporting result that the increase in inflation risk premium at 5-year and 10-year maturities may lead to an increase in 5-year and 10-year yields.

CHAPTER 5

CONCLUSION

The recent global changes have shown that they remarkably affect macroeconomic indicators, and we reveal that oil price changes have an impact on the term structure of interest rates in this study. It is evidenced that OPEC has a significant market power to impact oil prices through its announcements. Therefore, we use oil supply news shocks of OPEC announcements as the unexpected changes in oil prices. We consider zero-coupon yields and instantaneous forward rates to demonstrate the effect on the term structure of interest rates. We first conduct an event study to provide empirical evidence for the existence and magnitude of this effect and provide a consumption-based capital asset pricing modeling framework to analyze the potential effect analytically.

Event study results demonstrate that oil supply news shocks significantly affect the yield curve in the longer term, while the effect does not exist in the short term in the U.S. context. One potential channel that can create such a scenario is that the inflation risk premium is affected by the changes in oil prices, accumulating especially through the long end of the yield curve. Then, we model this mechanism by using a consumption-based asset pricing setup. The model analytically shows that simultaneous, reverse direction movements in the consumption growth of goods other than oil and oil price inflation increase the risk premium and put upward pressure on the yields. Moreover, we provide empirical evidence that a negative covariance exists between these two variables. Thus, event study results can be supported by a modeling framework using data.

Further improvements can still be made to this research. The event studies can be improved by using econometric estimation methods other than OLS, as OLS may cancel the short-term effects due to its averaging nature. Also, the event study may provide more evidence for the result by checking other financial indicators, conducting a detailed sub-sample analysis, or even using different oil news shocks series. Moreover, for the modeling part, one can extend the analysis by providing more empirical support by estimating and calibrating the model. In this way, we can ensure the consistency of the model with the data.

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