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How does ENSO impact U.S. Oil Spot and Future Prices?

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Abstract

This paper examines the impact of El Niño-Southern Oscillation (ENSO) shocks on U.S. oil futures and goods market prices from 1983:03 to 2024:10 via the Time-Varying Parameter Local Projections (TVP-LP) model. By allowing impulse responses to evolve over time, we capture dynamic shifts in the oil market's sensitivity to El Niño and La Niña events across different time-horizons. Our findings reveal an asymmetric response, where El Niño shocks exhibit a negative effect on oil futures and goods market prices, while La Niña shocks—especially extreme ones—lead to persistent upward price pressures. The effect becomes more pronounced at horizons within 12 months, indicating delayed transmission mechanisms through supply chain disruptions and changes in global energy demand. Additionally, the response intensifies in extreme ENSO episodes, highlighting non-linearities in climate-driven oil price fluctuations.

Keywords: Oil futures and goods market price, ENSO, Local Projections.
JEL: E31, E32, D24

Highlights

- The effect of ENSO shocks due to La Nina is generally larger in magnitude than El Niño.
- El Niño events tend to have a muted or slightly negative impact on oil futures and goods market prices, whereas La Niña events—especially extreme ones—are associated with persistent upward pressure on prices.
- Using a TVP-LP model, the impact of ENSO on oil prices has a more pronounced effects at longer horizons less than 12 months.
- Anomalous ENSO events (defined as upper quantile in historical distribution) exhibit stronger responses on oil futures and goods market prices.

1. Introduction

The El Niño–Southern Oscillation (ENSO) is among the most influential climate phenomena, driving global weather variability and affecting a broad spectrum of economic sectors—including agriculture, energy, and financial markets (Ropelewski and Halpert, 1987, Rosenzweig et al., 2001, McPhaden et al., 2006, Dai, 2013, Brönnimann et al., 2007. The National Oceanic and Atmospheric Administration (NOAA) recognizes ENSO as "one of the most important climatic phenomena on Earth," due to its far-reaching impacts on economic activity, inflation, and global trade.[1]

While previous studies have examined the relationship between ENSO and oil prices (Cashin et al., 2017, Dufrénot et al., 2024), the evidence remains mixed. This paper contributes to the literature by investigating how ENSO-driven climate shocks influence oil prices, with a particular focus on futures markets. Futures markets play a crucial role in price discovery, rapidly incorporating information from diverse sources—including climate, weather, and economic conditions. As a result, oil futures prices often reflect anticipations of ENSO patterns, adjusting swiftly to new information about potential impacts. Because oil is a key input in global production and consumption, fluctuations in its price have cascading effects on inflation, trade balances, and economic policy. Notably, financial markets may react to ENSO-related news before supply and demand imbalances materialize, making oil futures a potential early indicator of climate-driven disruptions.

Early economic analyses of ENSO largely overlooked oil prices. For instance, Brunner (2002) focused on the effects of El Niño on non-oil commodity prices, finding that a one-standard-deviation El Niño shock increased non-oil commodity prices by 3.5 to 4 percentage points. Laosuthi and Selover (2007) found insignificant effects of El Niño on most commodities, without focusing on oil. More recent studies have considered oil prices, but report mixed results. Cashin et al. (2017), using a GVAR framework, found that El Niño events led to short-term increases in oil prices due to higher demand from major industrialized economies. In contrast, Solomou and Tian (2025) reported negative effects of El Niño shocks on oil prices. Dufrénot et al. (2021), Dufrénot et al. (2024) and Dufrénot et al. (2025) further show that ENSO effects on globally traded commodities are asymmetric. Extending this line of research to inflation, Ginn (2025) estimates an ENSO-augmented Phillips Curve, showing that La Niña exerts stronger inflationary effects than El Niño.

[1] See https://www.weather.gov/mhx/ensowhat.

Several studies have explored how El Niño affects oil market demand, supply, and price volatility. Changnon (1999) found that El Niño events reduce heating oil demand and prices. Cruz and Krausmann (2013) showed that more frequent extreme weather events, such as hurricanes, threaten oil production, reducing supply and increasing prices.

Recognizing that ENSO events operate across multiple time scales, some studies have adopted multi-scale approaches to analyze their effects on energy prices (Qin et al., 2020; Dufrénot et al., 2021). Qin et al. (2020), using wavelet analysis, found a time- and frequency-dependent relationship between the El Niño index and oil prices: negative in the long run (1997–2016), but positive in the short (2015–2016) and medium term (2007–2011). Dufrénot et al. (2021) allowed for varying smoothness in ENSO regime transitions, uncovering asymmetric influences of El Niño and La Niña on energy commodities, with prices more sensitive to short-cycle shocks.

This paper advances the literature in two key ways. First, we highlight the importance of "ENSO diversity" (McPhaden et al., 2020; Yu and Kao, 2007), distinguishing between EP and CP-ENSO types, which differ in spatial structure, intensity, and temporal profile (Geng et al., 2022; Dieppois et al., 2021; Capotondi et al., 2020). We assess whether different ENSO types have distinct effects on oil prices. Second, we employ an econometric methodology that allows for time-varying effects, investigating the dynamic relationship between ENSO shocks and oil futures and spot prices using a Time-Varying Parameter Local Projections (TVP-LP) model (Inoue et al., 2024). This approach captures the evolving sensitivity of oil markets to ENSO anomalies across different forecast horizons. We also differentiate between moderate and extreme ENSO events to assess potential nonlinearities in the relationship.

The remainder of the paper is structured as follows: Section 2 summarizes the data; Section 3 describes the methodology; Section 4 presents the empirical results; and Section 5 concludes.

2. Data

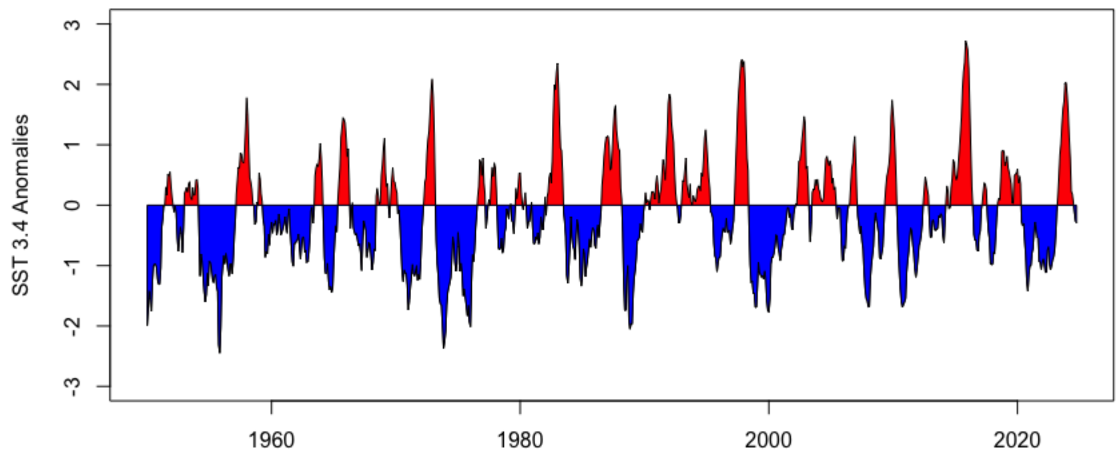
2.1. Global ENSO Climate Patterns

ENSO relates to cyclical, environmental conditions that occur across the equatorial Pacific Ocean. Changes to ENSO are due to natural interactions between sea surface temperature, rainfall, air pressure, atmospheric and oceanic circulation. The effects of ENSO, commonly called "teleconnections", emphasize that changing conditions can have a profound effect on global climate, which can in turn directly affect people's livelihoods (e.g., Barlow et al., 2001, Diaz et al., 2001, Alexander et al., 2002).

When a major El Niño (La Niña) occurs, there is an anomalous loss (increase) of heat from the ocean to atmosphere so that global mean temperatures rise (fall) (McPhaden et al., 2020). The anomalous atmospheric patterns are known as the Southern Oscillation.

Figure 1 plots the Sea Surface Temperature (SST) anomalies, which is used as a measure of ENSO.

Figure 1: Sea Surface Temperature



Note: Area shaded "red" ("blue") indicates El Nino (La Nina) conditions.

2.2. Economic Data

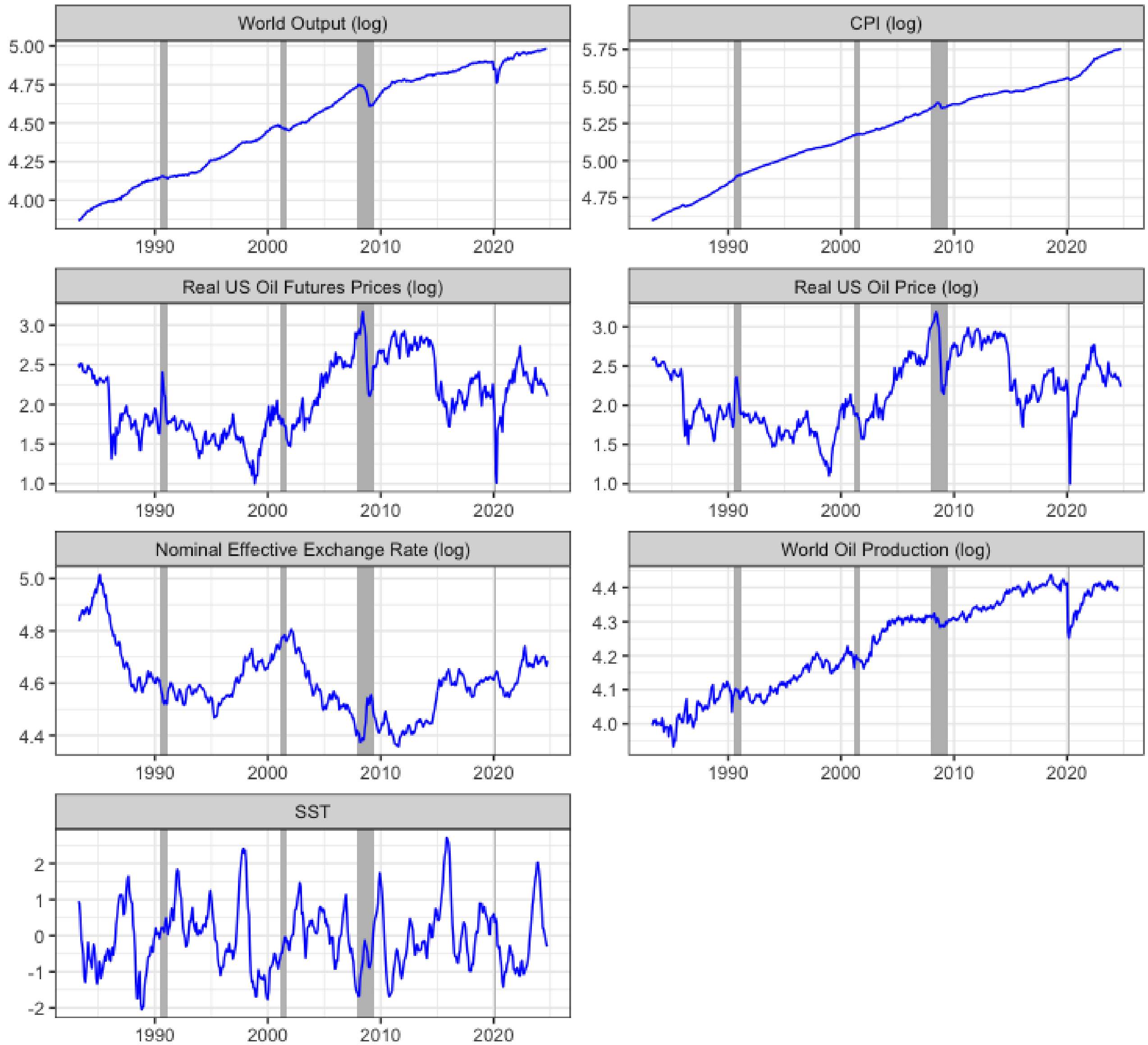
The model includes world output (Y_t);[2] U.S. WTI (West Texas Intermediate) oil futures prices (op_t^F) on the New York Mercantile Exchange (NYMEX), which is part of the Chicago Mercantile Exchange Group (CME); the U.S. WTI oil goods market price (op_t^G); global oil (o_t) production (million barrels per day); and the U.S. nominal effective exchange rate $(NEER_t)$. The sample period is monthly which covers 1983:03 to 2024:10. We utilize SST anomalies in the Niño 3.4 region as a primary indicator of the ENSO, which is collected from the National Oceanic and Atmospheric Administration (NOAA).

The oil futures and goods prices are seasonally adjusted via ARIMA X-12 algorithm from the U.S. Census Bureau. The oil futures and goods prices data, denominated in U.S. dollars, are deflated by dividing both indices by the U.S. consumer price index (CPI).

We plot the economic data in Figure 2. The data is summarized in Table 1.

[2]This is an updated version of the dataset in Baumeister and Hamilton (2019).

Figure 2: Economic Data



Note: Shaded areas indicate NBER recession dates.

3. Methodology

We employ the TVP-LP method, introduced by Inoue et al. (2024), to investigate the impact of ENSO shocks on oil futures and goods market prices. The LP method (Jordà, 2005) offers several benefits, such as single equation OLS estimation at each horizon, straightforward inference for impulse response coefficients, and effects that are specific to each horizon (i.e., no cross-period constraints). It also facilitates the estimation of highly nonlinear and flexible models.

Furthermore, Olea et al. (2024) recently provided formal proof that conventional LP confidence intervals

Table 1: Variable Selection

Item	Symbol	Source	Description
World Output	Y_t	See [a]	World Industrial Production
Aggregate CPI	P_t	OECD	U.S. CPI: All items
Oil Futures Price	$op_t^{WTI,F}$	CME	U.S. WTI Futures Price
Oil Goods Price	$op_t^{WTI,G}$	FRED	U.S. WTI Goods Price
Exchange Rate	$\ln NEER_t$	BIS	U.S. Nominal Effective Exchange Rate
Oil Production	o_t	EIA	Global Crude Oil Production
ENSO	$ENSO_t$	NOAA	Sea Surface Temperature anomalies

[a]: See https://sites.google.com/site/cjsbaumeister/datasets (Baumeister and Hamilton, 2019).

for impulse responses remain robust despite misspecification. In the context of our study, the TVP-LP method facilitates time-varying dynamic insights into the causal impact of ENSO shocks. The TVP-LP has been applied to the recent econometric applications. Saadaoui et al. (2025) analyze the responsiveness of critical minerals prices to geopolitical risk. Ginn and Saadaoui (2025) estimate the impact of geopolitical risks on monetary policy.

Unlike other VAR/LP-based models that incorporate time variation (like TVP-(B)VAR or state-dependent LPs), the TVP-LP does not require a parametric specification of the instability process. Essentially, the TVP-LP generates a path estimator for each time horizon. For instance, at horizon 1, our sample spans T = 499 months (from March 1983 to November 2024) and the horizon h = 1 month, resulting in 498 impulse response functions at horizon 1. This allows for flexibility in time variation without imposing uniformity in the response across horizons. The use of lag-augmented Local Projections addresses potential nonstationarity, improving the reliability of our estimated responses for oil prices and climate indicators (Montiel Olea and Plagborg-Møller, 2021; Li et al., 2024).

We estimate the TVP-LP model as follows:

$$op_{t+h}^{WTI,x} = \alpha_{t+h} + \beta_{h,t+h}\epsilon_{ENSO,t} + \sum_{j=1}^{12} \alpha'_{j,t+h}\mathbf{z}_{t-j} + v_{t+h}, h = 0, 1, ..., T \quad (1)$$

where $op_t^{WTI,x}$ is the real US WTI price for the set $x \in \{F, G\}$ relating to the futures and goods market, respectively. α is an intercept term. $\epsilon_{ENSO,t}$ is a one standard deviation shock to a transitory increase $ENSO_t \in \{EN_t, LN_t\}$. The vector $z_t = \{\ln Y_t, \ln o_t, \ln NEER_t\}$ includes world output, world crude oil production and NEER. World output captures global demand conditions. Crude oil production reflects supply-side fundamentals that directly affect oil prices. Controlling for NEER helps isolate the impact of

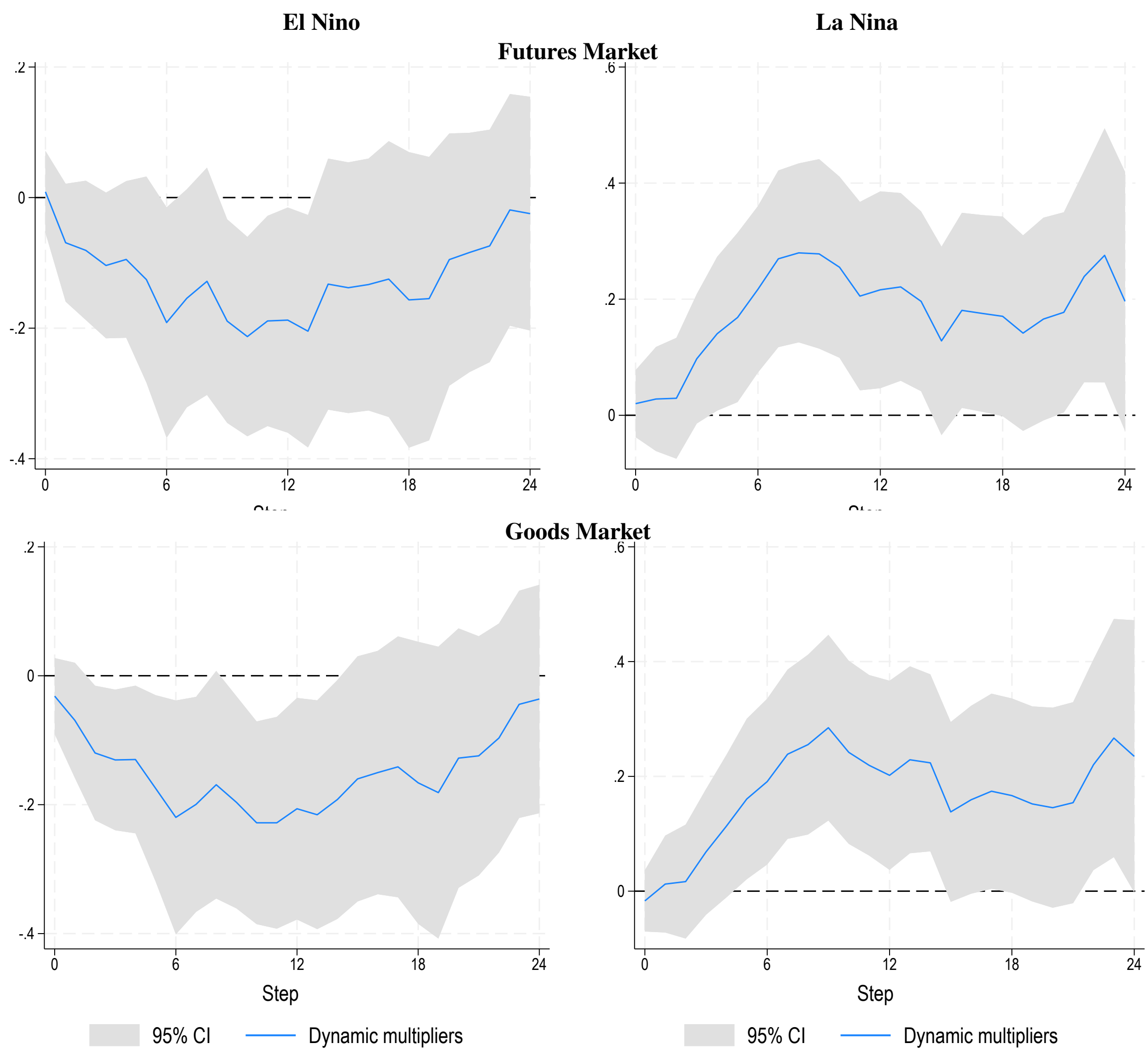
ENSO shocks from currency-driven price movements. These variables are used to control for macroeconomic fundamentals. v_t relates to the error term. The coefficient β_h in Equation (1) traces out the effect of the shock at time t on oil futures and goods market prices at time $t + h$.

4. Empirical Results

4.1. Time-Series Local Projections

Figure 3 plots the (time-invariant) LP IRFs. Accordingly, the IRFs show that an El Nino (a La Nina) corresponds with lower (higher) oil futures and goods market prices. This finding for the futures market also aligns with Dufrénot et al. (2024) and Dufrénot et al. (2025), such that La Nina tends to be more inflationary in the goods market for the Brent oil price than an El Nino.

Figure 3: Response of Oil Price to ENSO



4.2. Time-varying Local Projections

Figures 15 and 16 plots the IRFs from a TVP-LP model, estimating the impact of El Niño shocks on oil futures (left-pane) and goods market (right-pane) prices across different horizons (i.e., 1, 3, 6, 9, 12 and 24 months). The solid line represents the time-varying response of oil futures and goods market prices to El Niño shocks, while the dashed lines indicate the 95% confidence interval. Additionally, the "blue" shaded area represents the SST anomalies (displayed in absolute units) during El Niño periods. The right-side y-axis captures the magnitude of El Niño shocks, showing periods of intensified ENSO activity, such as during the late 1990s, early 2010s, and more recently in the 2020s.

The response of oil futures and goods market prices appears to fluctuate around zero prior to the mid-1990s, yet become more negative since then.[3] At horizons 1, 3 and 6, the response becomes more negative from the mid-1990s onward, where it breaches the confidence bounds in 2015. By horizon 12, the response is negative.

Interestingly, the stronger El Niño events appear to align with periods of increasing negative oil futures and goods market price responses, particularly at longer horizons. These findings suggest that the impact of El Niño on oil market is not immediate but materializes over extended periods, likely through its influence on supply chains, energy demand, and broader macroeconomic conditions.

Figures 17 and 18 display the IRFs from a TVP-LP model, estimating the impact of La Niña shocks on oil futures and goods market prices across different horizons. The light blue shaded area captures the absolute SST anomalies during La Niña episodes.

Oil futures and goods market prices tends to exhibit a positive response to La Niña shocks. Since around the mid-1990s, we find evidence of a positive shift in more recent periods. Since then, the impact of La Niña shocks becomes more apparent at horizons 6 and 9.

[3] We posit that ENSO may have been absent in policy discussions and usability for a part of the 1980s and prior. According to Barnston (2016), "[t]he strong 1982-83 El Niño took us nearly completely by surprise. Although it developed steadily in spring and summer 1982, most experts did not recognize it was in progress even at the Climate Diagnostics Workshop in October 1982 when it had become strong. The main reason for this blindness was the lack of coherent, believable data. Satellite data had been developed since the mid-1970s, but there were some breaks in the data before 1979, so a climatology was unable to be defined with so few years in the history. The ship track data were viewed separately from the satellite data, and some of the ship data showed positive anomalies so strong that they were believed to be erroneous, being more than 3 standard deviations above the mean. While this data may have been puzzling, few (or no) leading scientists actually considered that a huge El Nino was in progress." Moreover, Borrallo et al. (2024) show that ENSO newspaper popularity index spiked numerous times since 1996, however prior to that period there were no spikes despite the 1982-83 El Nino was one of, if not, the strongest El Niño events recorded. NOAA began formally reporting on ENSO in 1980s with the establishment of the Climate Prediction Center (CPC). The CPC was created to monitor and predict ENSO cycles using advanced models and observational data, including sea surface temperatures and atmospheric variables. While research into ENSO had been ongoing for years, particularly in response to the significant impacts of El Niño events, it was during the mid-1980s that systematic ENSO monitoring and forecasting took shape under NOAA.

The right-side y-axis captures the magnitude of La Niña shocks, showing periods of intensified events, particularly in the late 1980s, early 2000s, and 2010s. These episodes coincide with fluctuations in the IRFs, reinforcing the notion that La Niña may have a more delayed and potentially inflationary effect on oil futures market.

Figures 19 and 20 plot the TVP-LP IRFs of oil futures and goods prices to an ENSO shock, respectively, to also include the effect of an anomalous El Nino and La Nina shock (defined as the fourth quantile in the historical distribution) at different horizons. The responses are shown for the full sample (top row) and for extreme ENSO events (bottom row, denoted as "High"). In the top-left panel (El Niño), the response of oil futures and goods market prices tends to be negative. The top-right panel (La Niña) shows a contrasting pattern, with oil futures and goods market prices generally reacting positively to La Niña shocks. This suggests that La Niña events may lead to upward pressure on oil futures and goods market prices over time.

In the bottom panels, which focus on extreme ENSO events, the responses become more volatile. The bottom-left panel (El Niño - High) exhibits a wide range of possible reactions, with no clear consistent trend, indicating that extreme El Niño events may have highly heterogeneous effects on oil market. Conversely, the bottom-right panel (La Niña - High) shows a stronger and more consistently positive response, reinforcing the idea that intense La Niña events are associated with rising oil futures and goods market prices.

Overall, the findings suggest that while El Niño's impact on oil futures and goods market prices tends to be negative, whereas La Niña shocks tends to exhibit a positive effect.

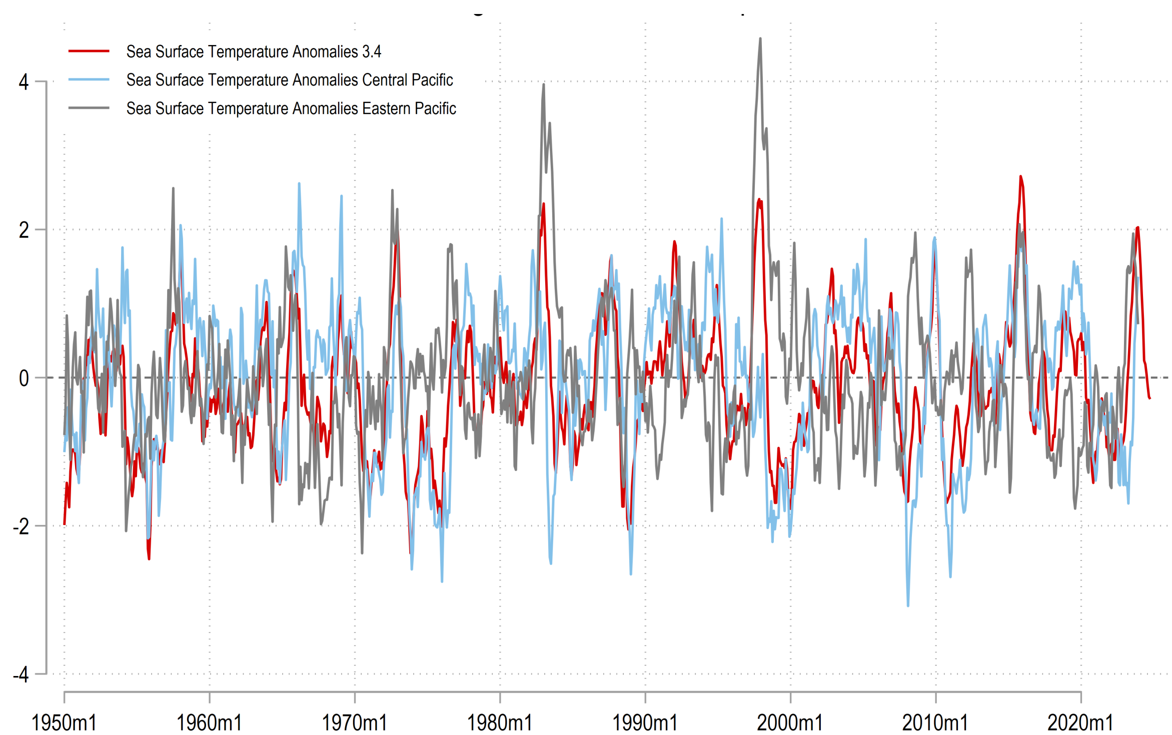
4.3. Model Extension: ENSO Heterogeneity

In this section, we extend the baseline analysis by explicitly accounting for the heterogeneity of ENSO events. We incorporate the concept of ENSO diversity (McPhaden et al., 2020; Yu and Kao, 2007; Yu and Kim, 2010) by distinguishing between Eastern-Pacific (EP) and Central-Pacific (CP) ENSO types. These two regimes differ markedly in their spatial structures, intensities, and temporal evolution (Geng et al., 2022; Dieppois et al., 2021; Capotondi et al., 2020). This distinction represents a conceptually important refinement, as EP and CP events are fundamentally different climatic phenomena, each associated with distinct atmospheric teleconnection patterns and, consequently, potentially divergent economic impacts.

Figure 4 illustrates the three ENSO anomaly measures. To capture the spatial characteristics of EP and CP El Niño events, we employ the dataset developed by Kao and Yu (2009) and extended by Yu and Kim (2010), which utilizes the regression–Empirical Orthogonal Function (EOF) method. As detailed in Section

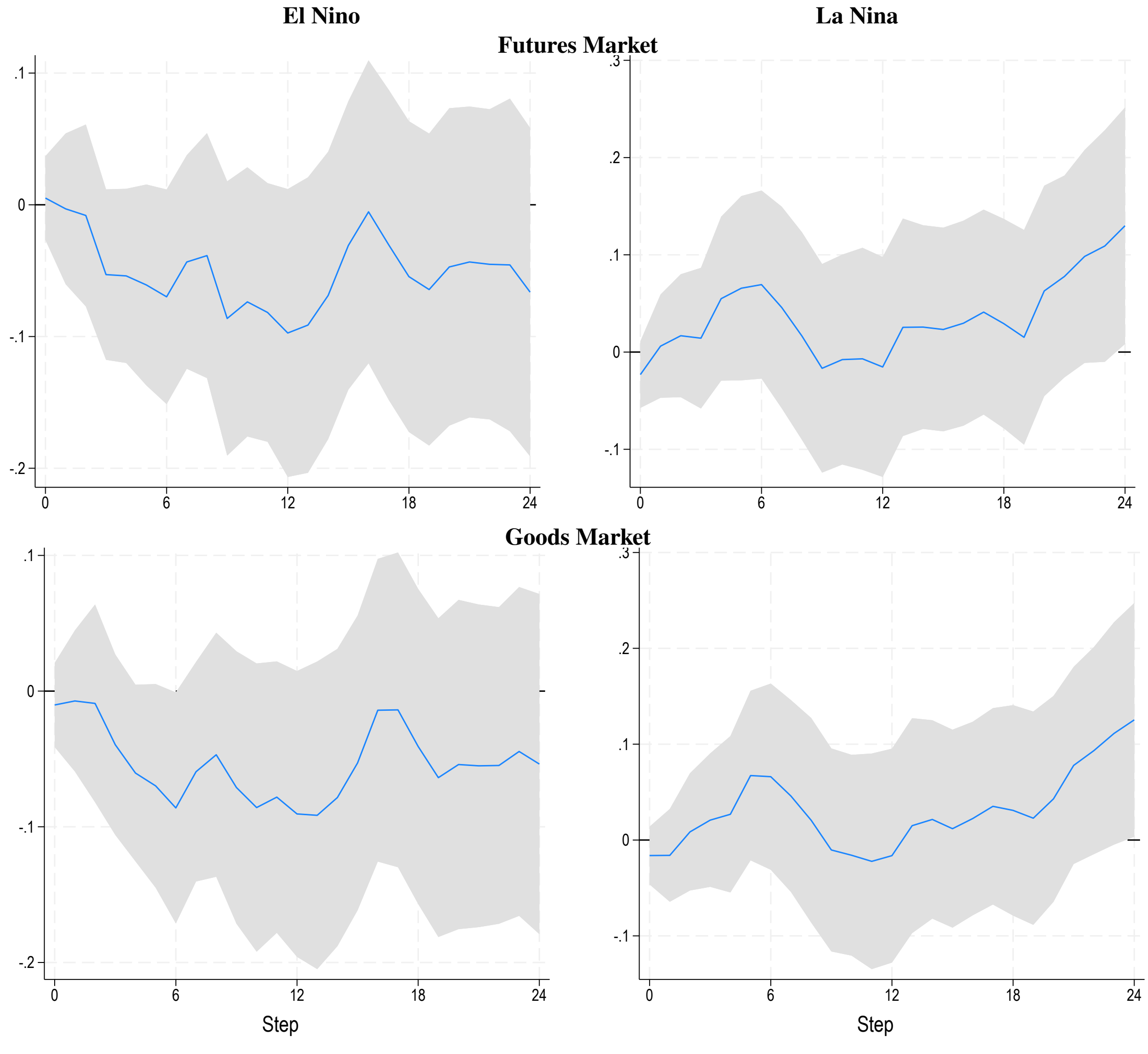
6.3.1 in the Appendix, CP events exhibit a stronger correlation with sea surface temperature (SST) anomalies (0.67), while EP events show a weaker association (0.38), underscoring their distinct spatial signatures. Our cross-correlation analysis further confirms that ENSO shocks are heterogeneous rather than uniform. Although SST anomalies are commonly used as a proxy for ENSO activity, our findings reveal that EP and CP events follow distinct dynamic patterns. These different ENSO types affect climate teleconnections. Several studies (Ashok et al., 2017; Strnad et al., 2022; Alizadeh, 2024) have shown that CP and EP events have very different climate teleconnections; for example, whilst EP-ENSO is associated with heavy rain in Western South America, CP-ENSO shifts this impact away from Latin America.

Figure 4: Sea Surface Temperature



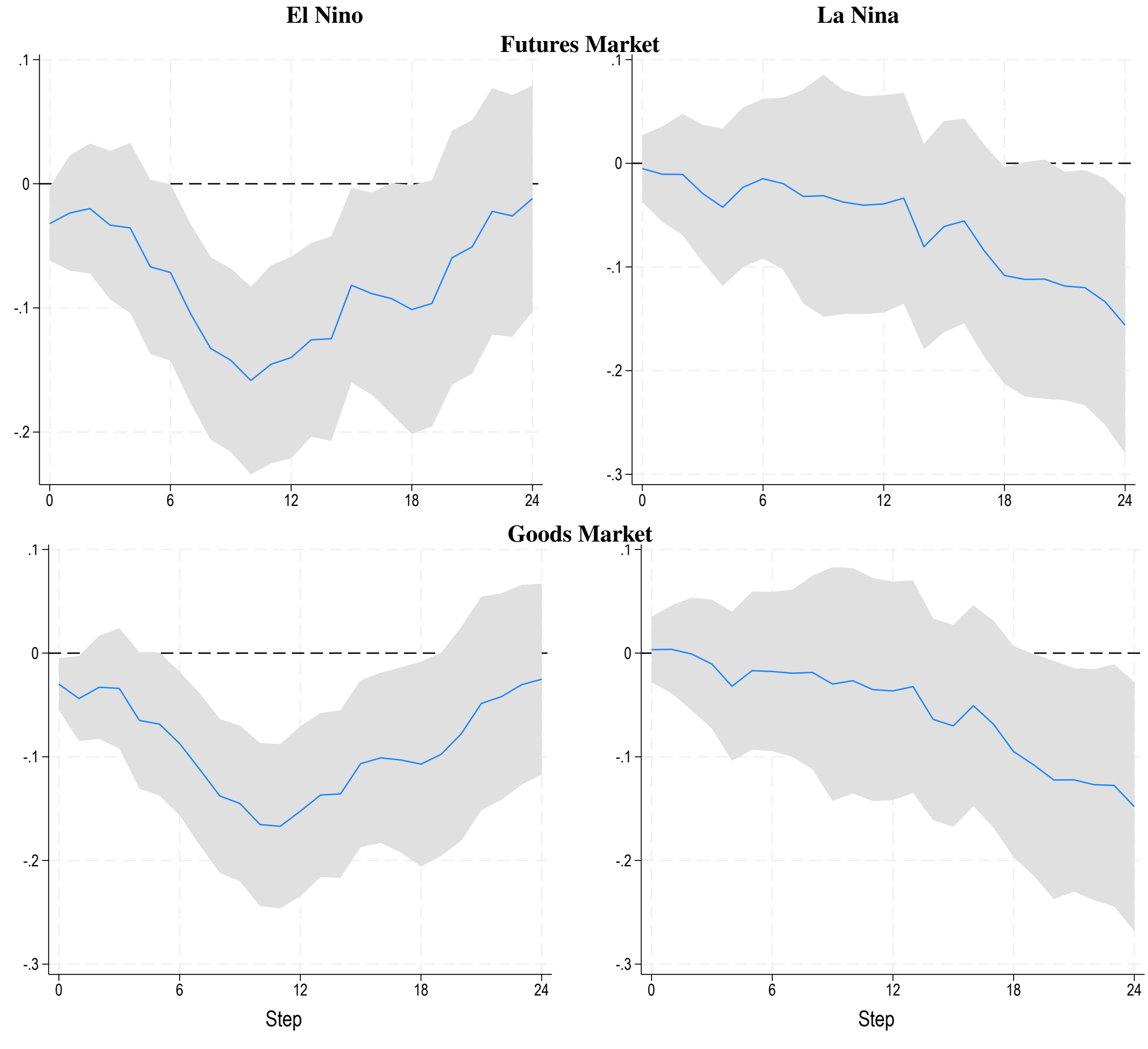
The IRFs for the CP and EP ENSO shocks for the futures and good markets are plotted in Figures 5 and 6, respectively. The results highlight important heterogeneity between CP and EP ENSO shocks. For CP-type events (Figure 5), El Niño shocks tend to exert a muted or slightly negative effect on both futures and goods prices, while La Niña shocks display more persistent upward pressure. By contrast, the EP-type events (Figure 6) exhibit a more pronounced and consistent negative response to El Niño shocks with effects that extend across multiple horizons. However, La Niña shocks in the EP regime show negative effects. Taken together, these patterns suggest that CP events are more inflationary for oil prices—especially during La Niña phases.

Figure 5: Response of Oil Price to CP ENSO



The impulse responses suggest that the mean effects of CP and EP ENSO shocks on oil prices are generally statistically insignificant, as indicated by the near-zero estimates from the constant-parameter specification. However, the distribution of time-varying estimates reveals that extreme El Niño and La Niña events (defined as the upper quantile) tend to repel oil prices away from the zero baseline. The TVP-LP impulse responses are plotted in Figures 19–20 and 25–26 for CP and EP events, respectively. In particular, anomalous El Niño episodes are associated with negative deviations, while anomalous La Niña shocks generate positive swings, especially at medium horizons. These findings highlight that although the average response for CP and EP ENSO shocks is muted, extreme ENSO phases introduce considerable state-dependent volatility,

Figure 6: Response of Oil Price to EP ENSO



underscoring a destabilizing role in the US oil market.

The time-varying parameter plots are provided in Figures 15–18 and 21–24 for CP and EP events, respectively. The TVP-LP IRFs further show that ENSO effects evolve both over time and across horizons. Extreme La Niña episodes exhibit the strongest and most consistent positive responses, underscoring their inflationary potential.

Overall, these results emphasize that distinguishing between EP and CP ENSO types is essential for correctly modeling the ENSO–oil price nexus. At the same time, accounting for horizon-specific propagation and temporal variation through TVP IRFs reveals that the magnitude and persistence of these effects evolve across episodes, with CP La Niña and EP El Niño shocks emerging as the dominant inflationary and deflationary forces, respectively. Treating ENSO as a homogeneous and time-invariant phenomenon risks overlooking critical spatial differences in climatic drivers, their global teleconnections, and their dynamic macroeconomic consequences.

5. Conclusion

This study examines the dynamic impact of El Niño-Southern Oscillation (ENSO) shocks on U.S. WTI oil futures and goods market prices via Time-Varying Parameter Local Projections (TVP-LP) model. Our findings reveal novel insights that contribute to the burgeoning literature on climate shocks and commodity market.

First, we show that the effects of ENSO on oil prices are time-varying, with responses evolving over different horizons. Unlike traditional static models, our approach captures the varied sensitivity of oil futures and goods markets to ENSO phases.

Second, our results highlight asymmetric responses. While an El Niño phase tend to have a negative impact on oil futures and goods market prices, La Niña shocks—particularly extreme ones—lead to persistent upward price pressures. This asymmetry suggests that La Niña phases, possibly through shifts in global energy demand, have a stronger influence on oil market.

Third, we uncover non-linearities in extreme ENSO events, finding that the impact of El Niño and La Niña becomes significantly more pronounced when focusing on high-intensity episodes. This suggests that standard models, which assume a uniform ENSO impact, may underestimate the risks posed by extreme climate anomalies.

Finally, our results indicate that the transmission of ENSO shocks to oil futures and goods market prices occurs mostly within 12 months, reinforcing the idea that these climatic ENSO phases trigger lagged adjustments in the oil market. This delayed response underscores the importance of incorporating climate risks into oil price forecasting, policy design, and risk management strategies.

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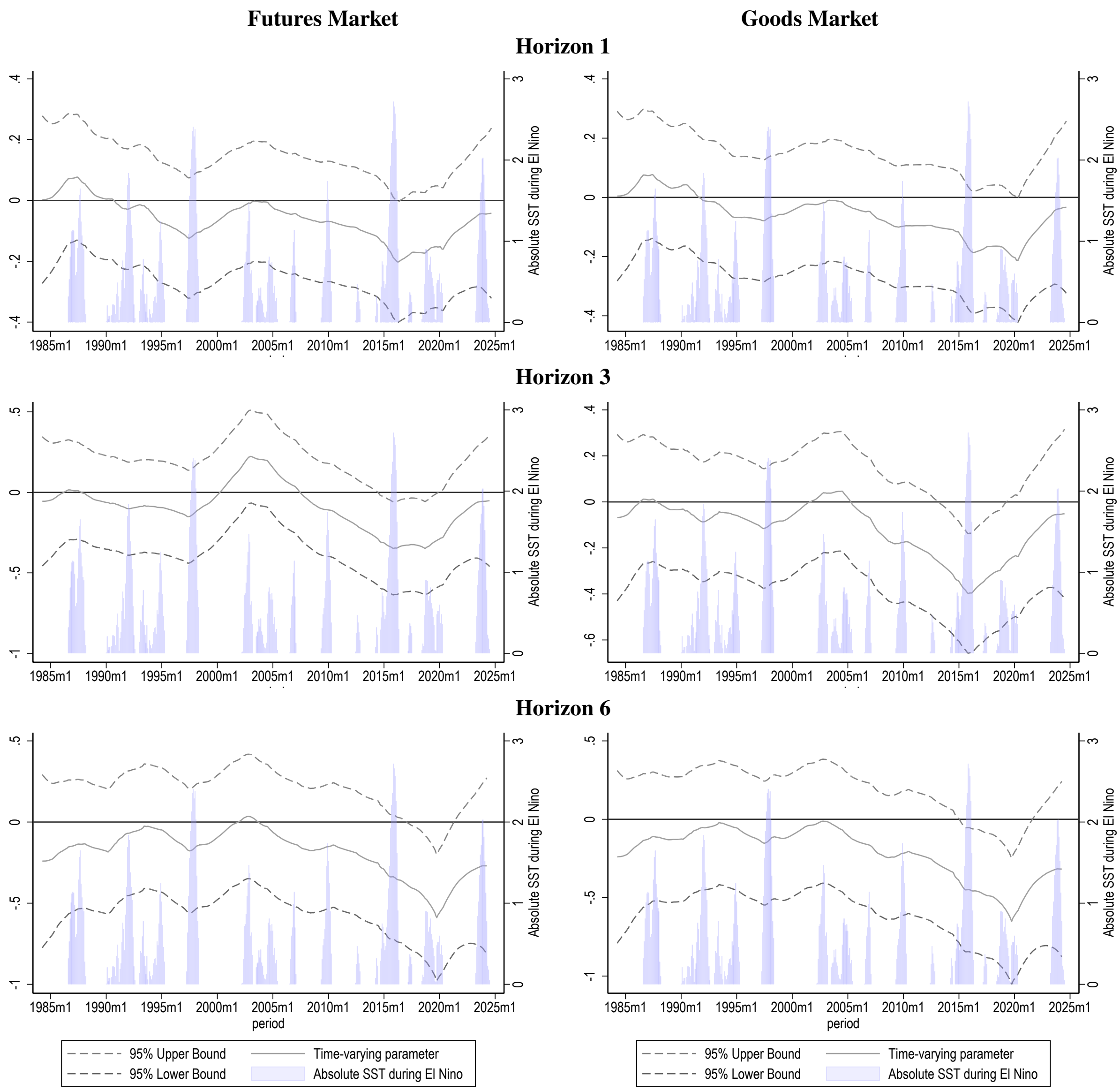
6. Appendix

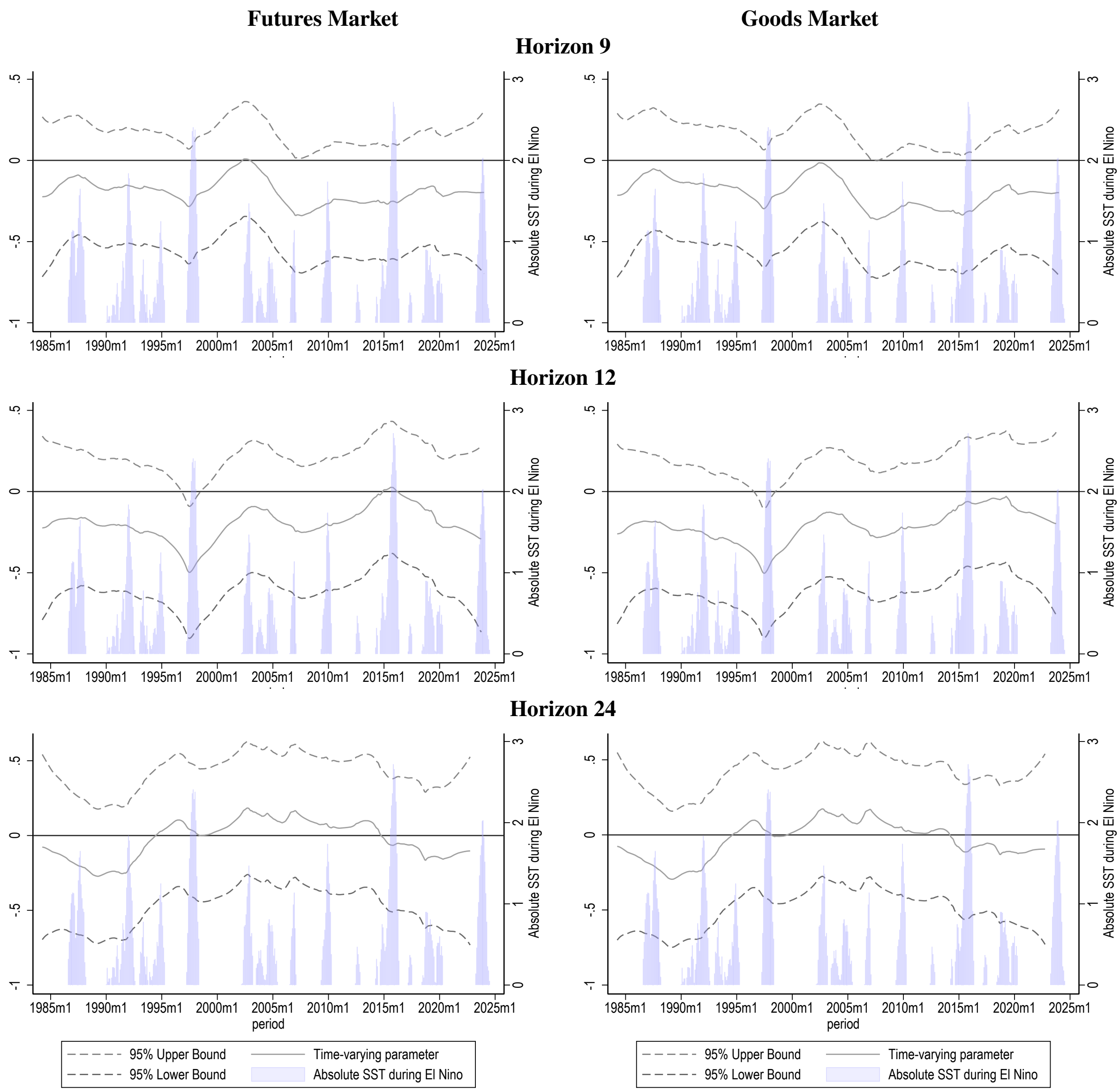
6.1. Impulse Responses to El Nino (Baseline Model)

Figure 7: Oil Price Reaction to El Nino at Different Horizons



Note: Left (right) axis refers to IRFs (absolute SST during El Nino).

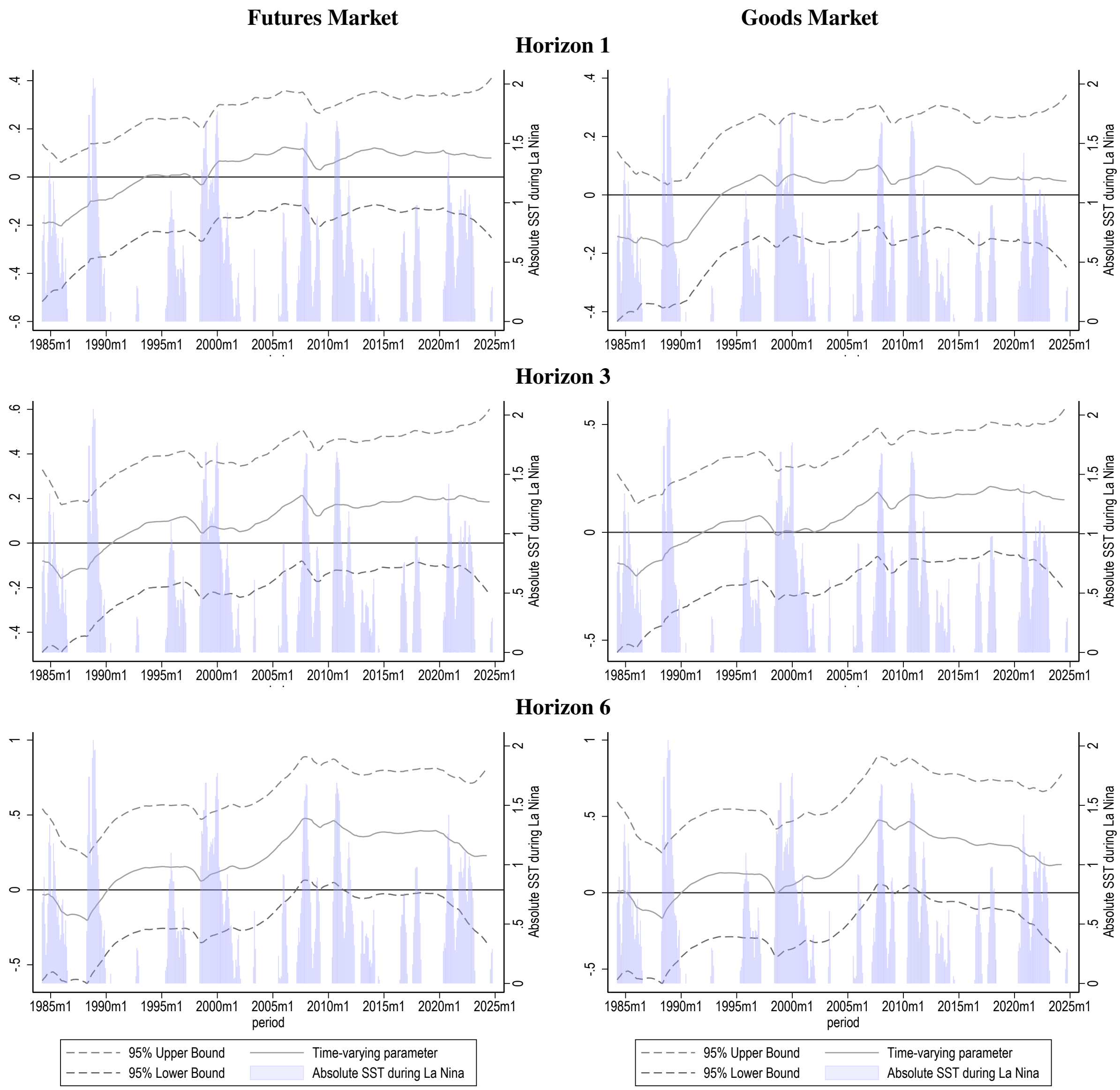
Figure 8: Oil Price Reaction to El Nino at Different Horizons (continued)



Note: Left (right) axis refers to IRFs (absolute SST during El Nino).

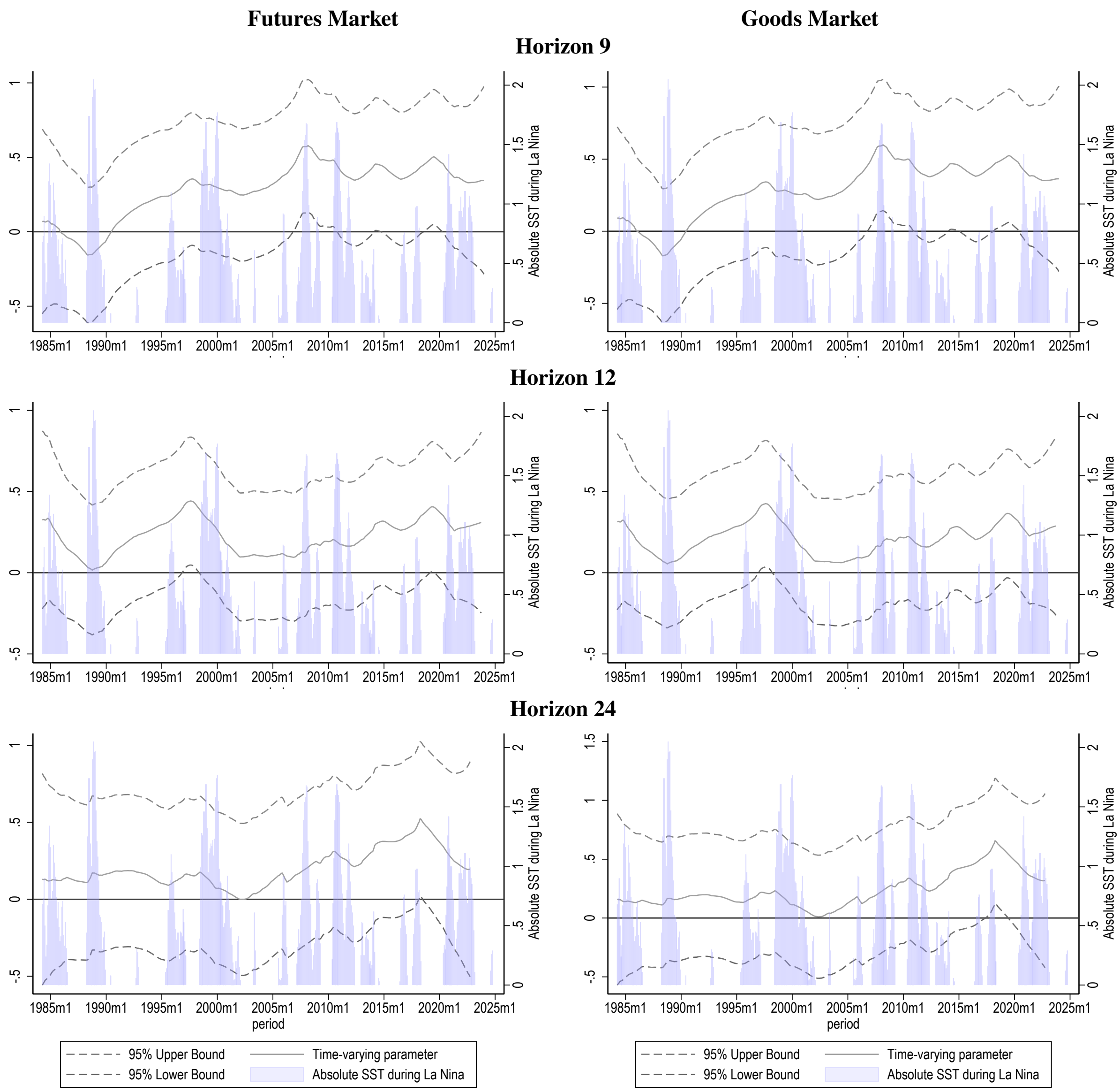
6.2. Impulse Responses to La Nina (Baseline Model)

Figure 9: Oil Price Reaction to La Nina at Different Horizons



Note: Left (right) axis refers to IRFs (absolute SST during La Nina).

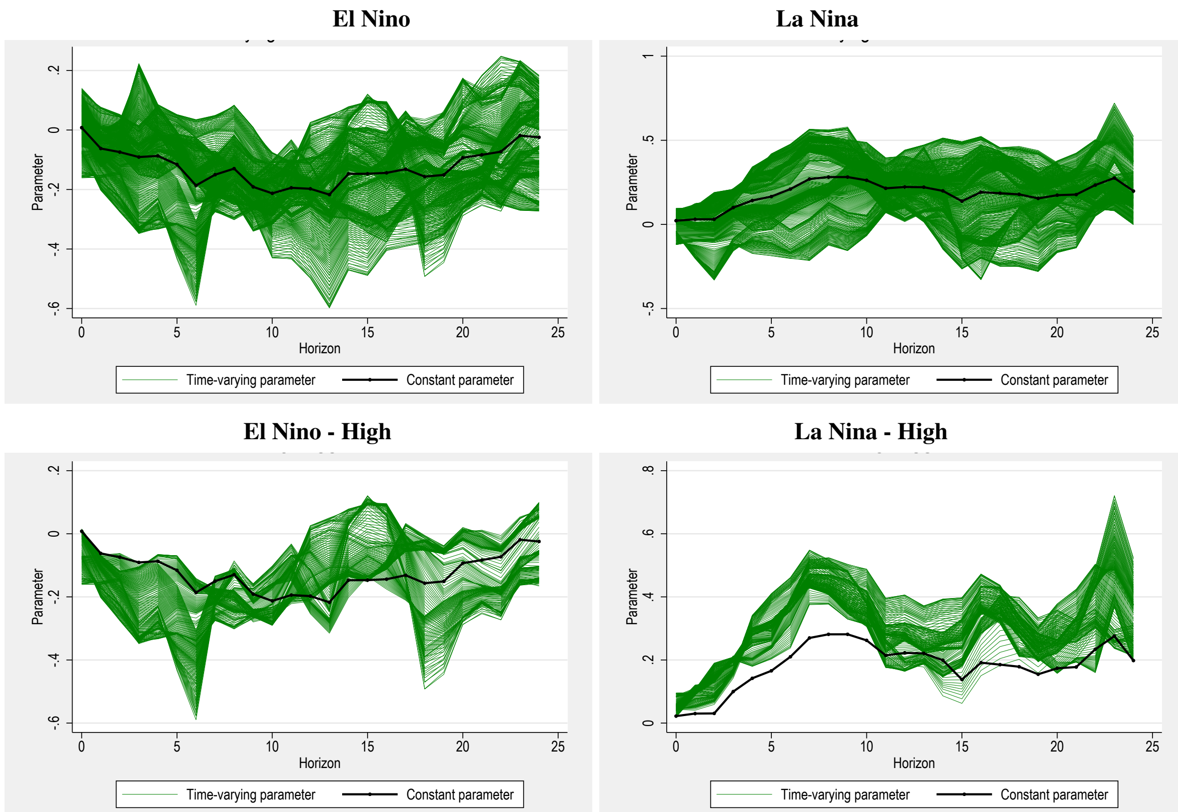
Figure 10: Oil Price Reaction to La Nina at Different Horizons (continued)



Note: Left (right) axis refers to IRFs (absolute SST during La Nina).

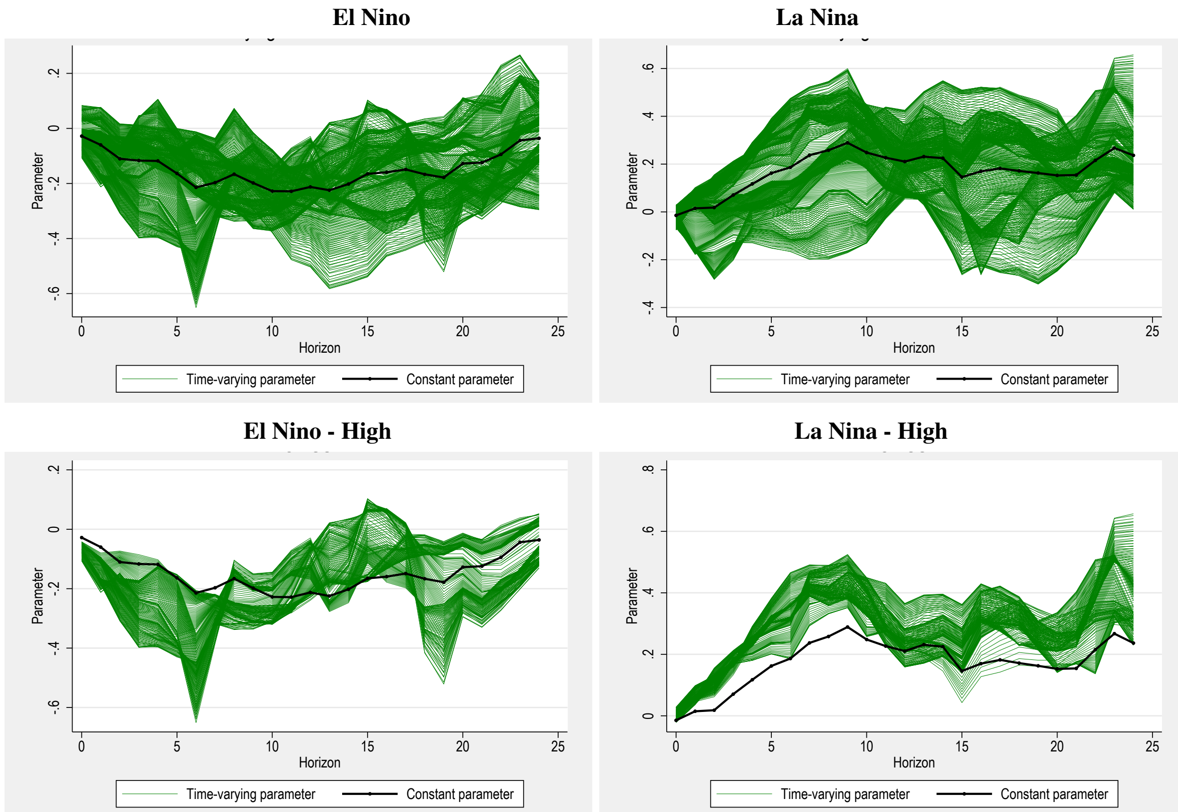
6.3. TVP-LP Impulse Responses to ENSO (Baseline Model)

Figure 11: Oil Futures Price Reaction to ENSO (TVP-LP)



Note: "High" refers to anomalous El Nino (bottom left-pane) and La Nina (bottom right-pane) shock defined as the fourth quantile in the historical distribution.

Figure 12: Oil Goods Market Price Reaction to ENSO (TVP-LP)



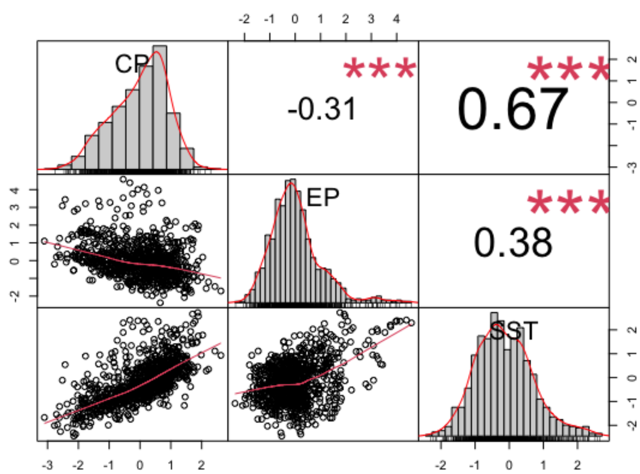
Note: "High" refers to anomalous El Nino (bottom left-pane) and La Nina (bottom right-pane) shock defined as above the fourth quantile in the historical distribution.

6.3.1. ENSO Heterogeneity

Figure 13 highlights the heterogeneity across ENSO types. CP events exhibit a strong correlation with SST anomalies (0.67), whereas EP events show a weaker association (0.38), reflecting distinct spatial patterns. The cross-correlation analysis reveals that ENSO shocks are heterogeneous rather than uniform. While SST anomalies are often used as an ENSO proxy, our results indicate distinct dynamics between Eastern-Pacific (EP) and Central-Pacific (CP) ENSO events. The results reveal that ENSO heterogeneity may matter. While both El Niño and La Niña influence oil price dynamics, their effects differ by ENSO type.

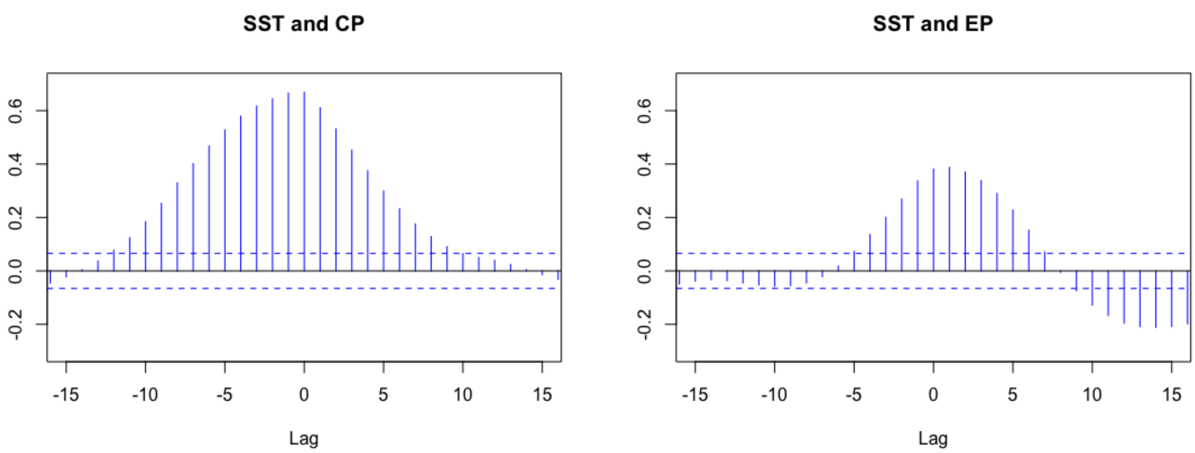
Further insights arise from the cross-correlation analysis, which shows that ENSO shocks are not uniform. Figure 6 shows the cross-correlation functions (CCFs) between SST anomalies and the two ENSO indices. For CP, the contemporaneous correlation with SST is circa 0.7, with significant positive correlations spanning around −11 to +9 months, indicating a strong and persistent relationship with central Pacific warming. By contrast, EP exhibits a contemporaneous correlation of circa 0.3, with significant values concentrated over a shorter horizon (roughly -4 to +5 months). These findings demonstrate that CP events are more closely tied to SST anomalies.

Figure 13: Contemporaneous Correlation of ENSO Anomalies



Note: Correlation based on Pearson correlation test. *** represents p-value of 1%.

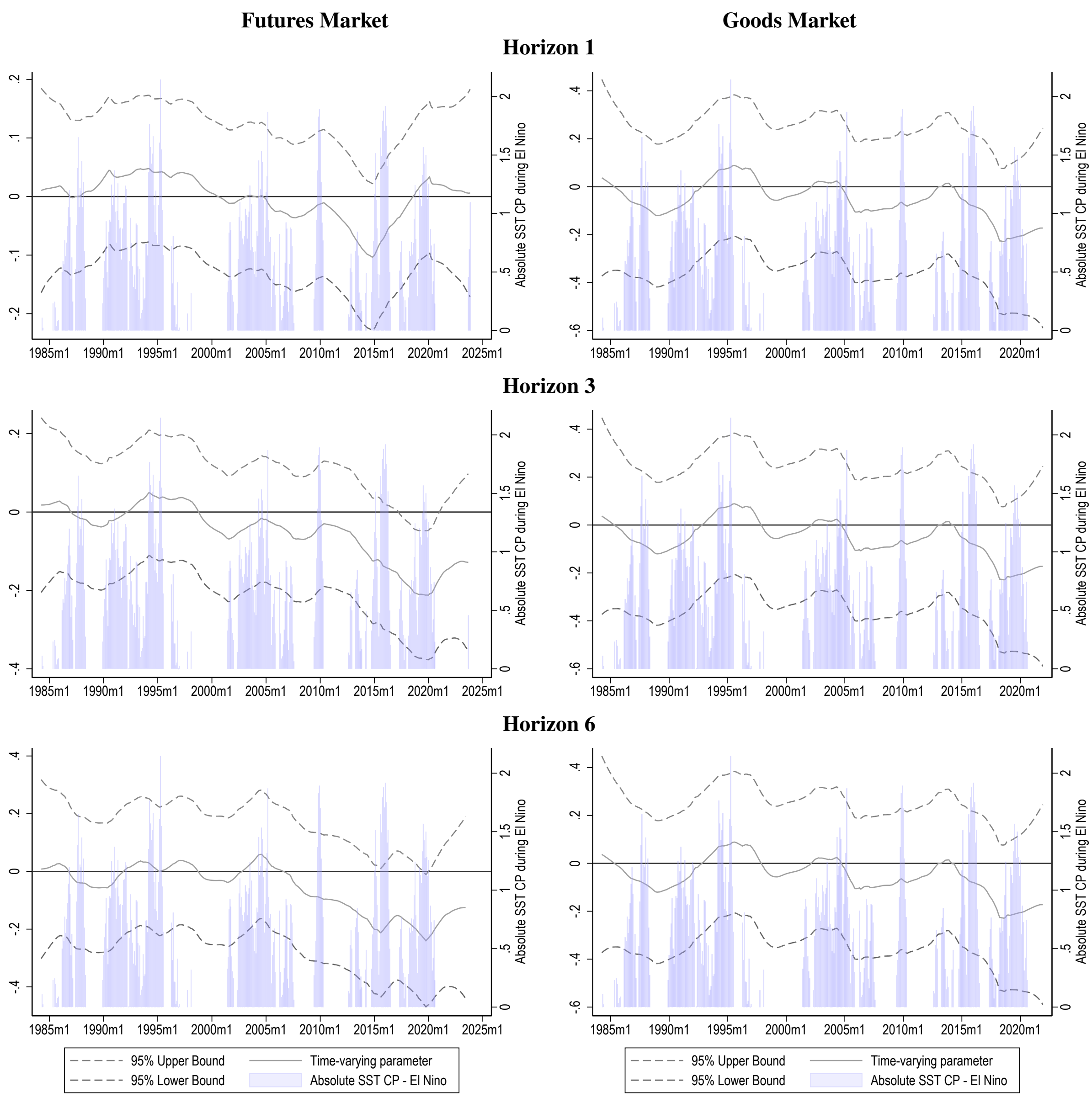
Figure 14: Cross-Correlation Analysis



6.4. Alternative Model: ENSO CP

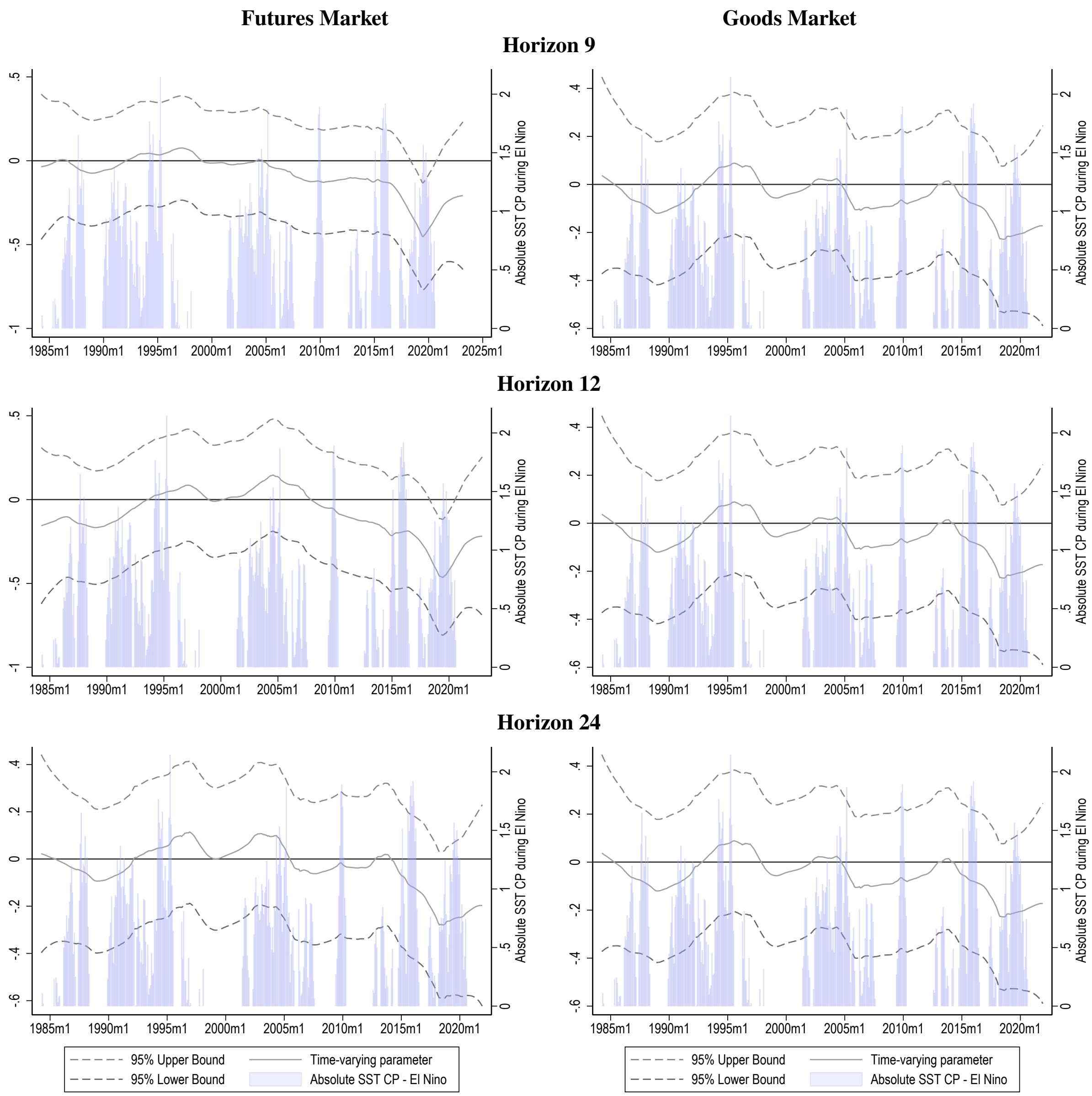
6.4.1. Time-varying parameter plot by El Nino (CP ENSO)

Figure 15: Oil Price Reaction to El Nino at Different Horizons (CP ENSO)



Note: Left (right) axis refers to IRFs (absolute SST during El Nino).

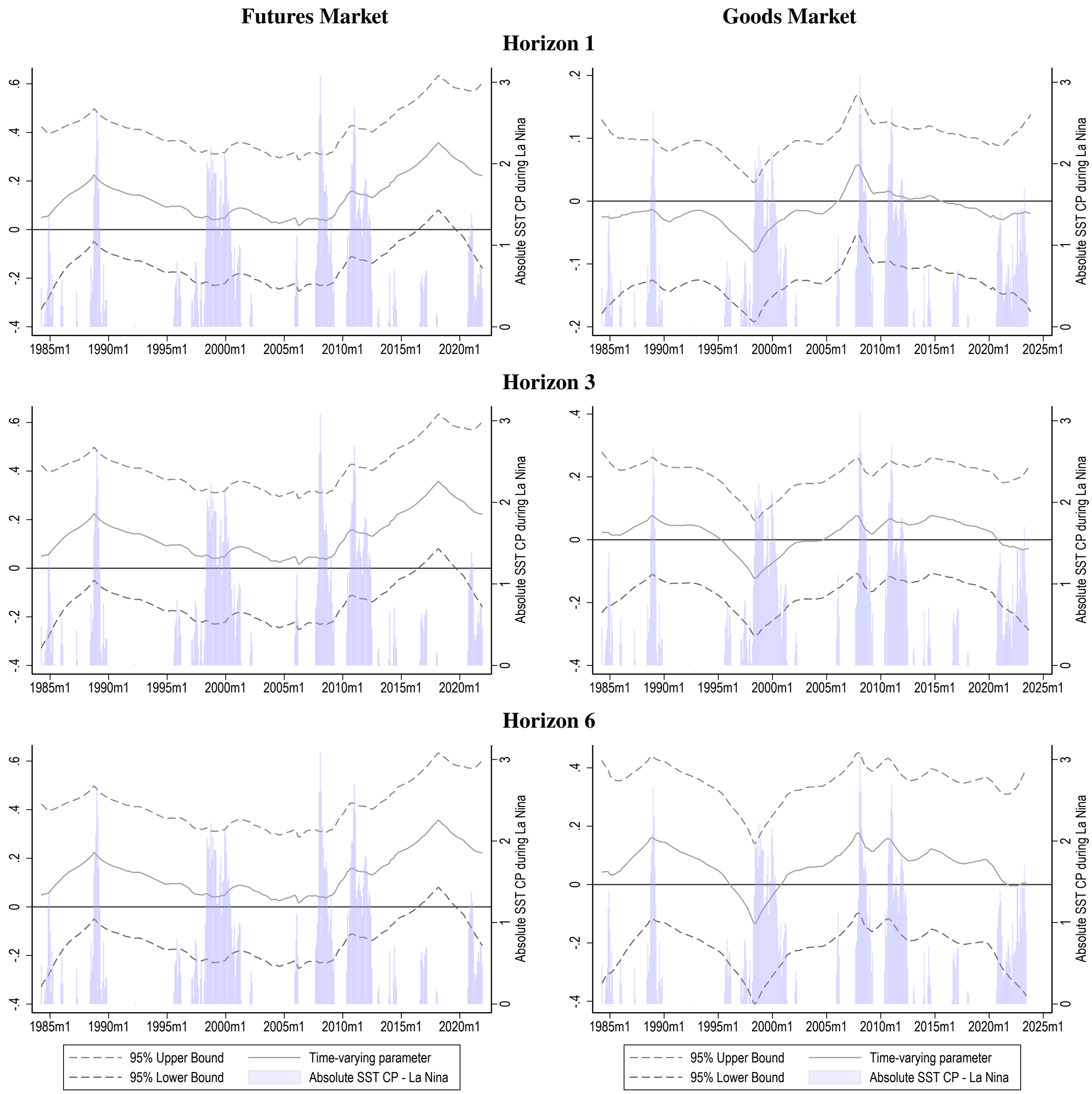
Figure 16: Oil Price Reaction to El Nino at Different Horizons (CP ENSO) (continued)



Note: Left (right) axis refers to IRFs (absolute SST during El Nino).

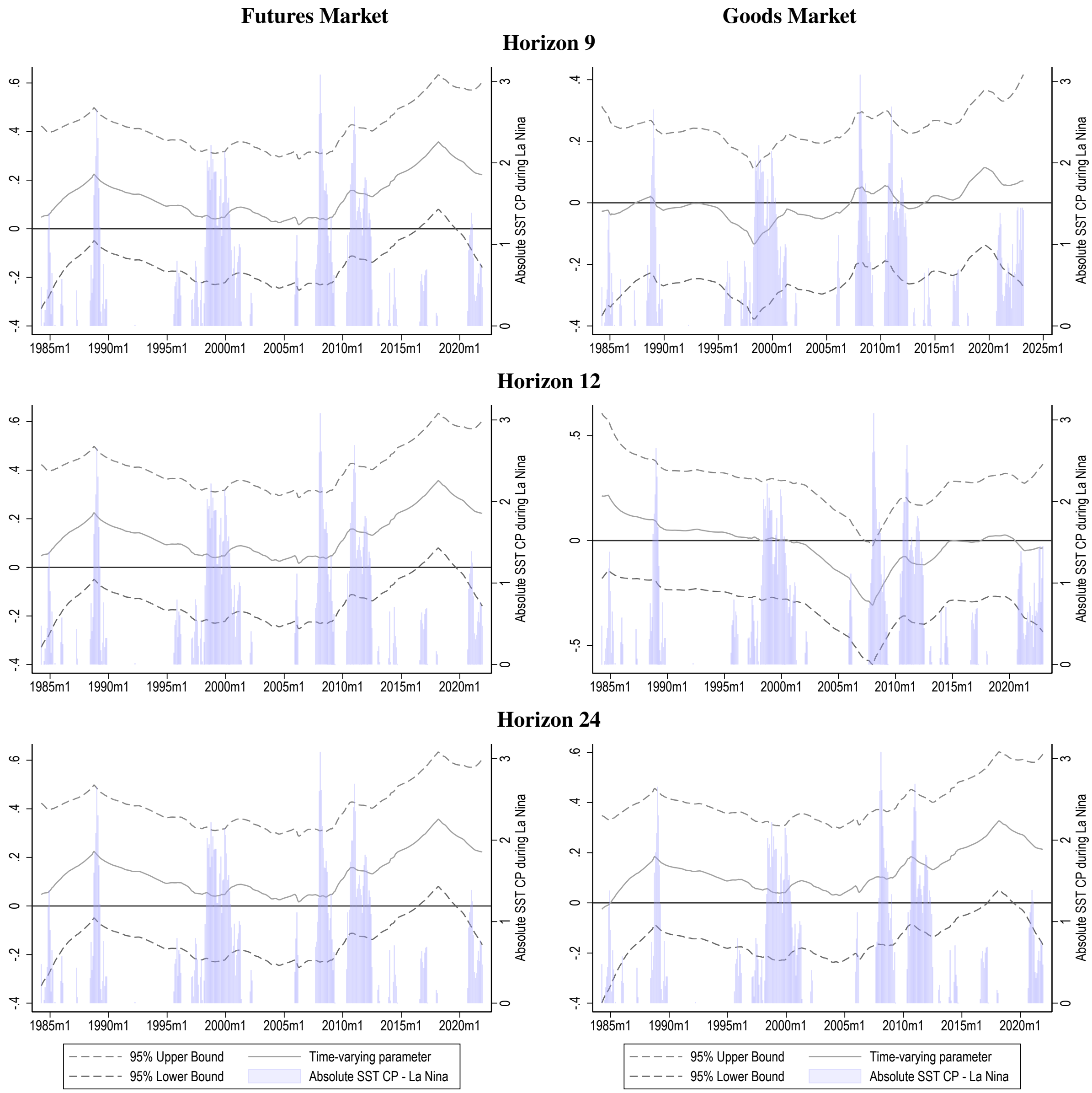
6.4.2. Time-varying parameter plot by horizon to La Nina (CP ENSO)

Figure 17: Oil Price Reaction to La Nina at Different Horizons (CP ENSO)



Note: Left (right) axis refers to IRFs (absolute SST during La Nina).

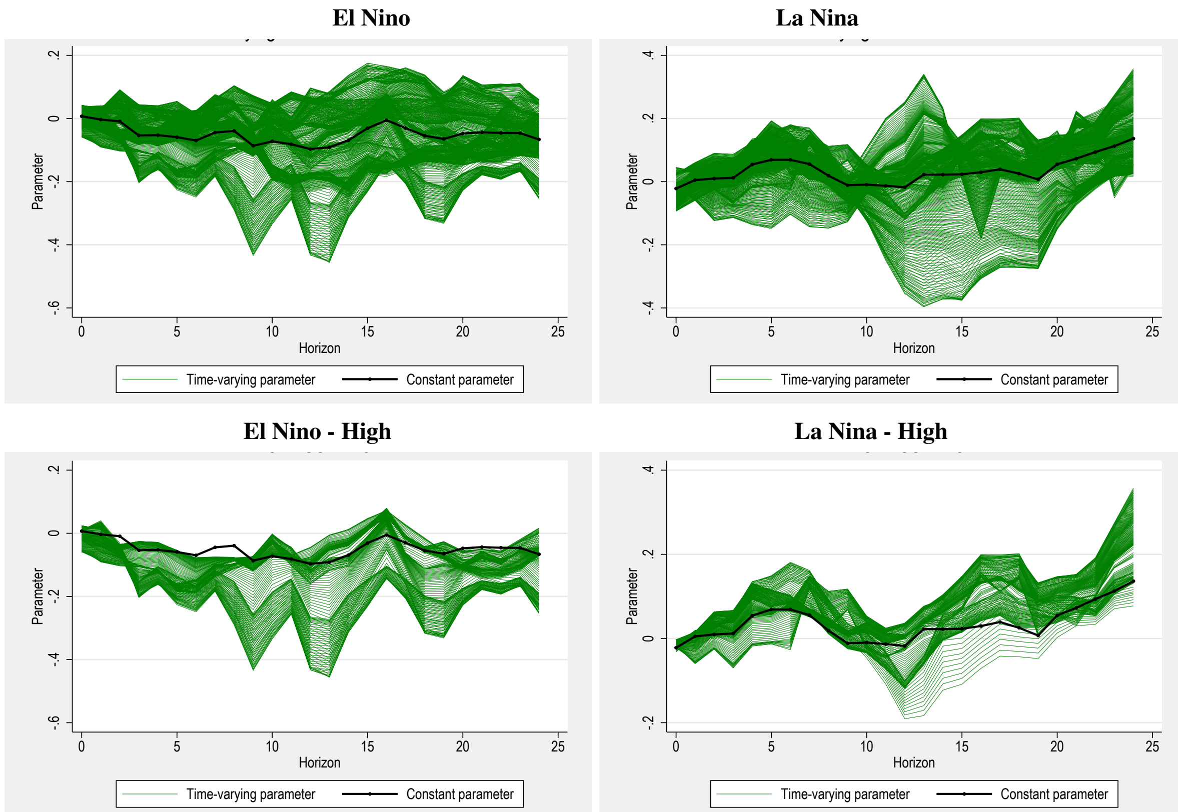
Figure 18: Oil Price Reaction to La Nina at Different Horizons (CP ENSO) (continued)



Note: Left (right) axis refers to IRFs (absolute SST during La Nina).

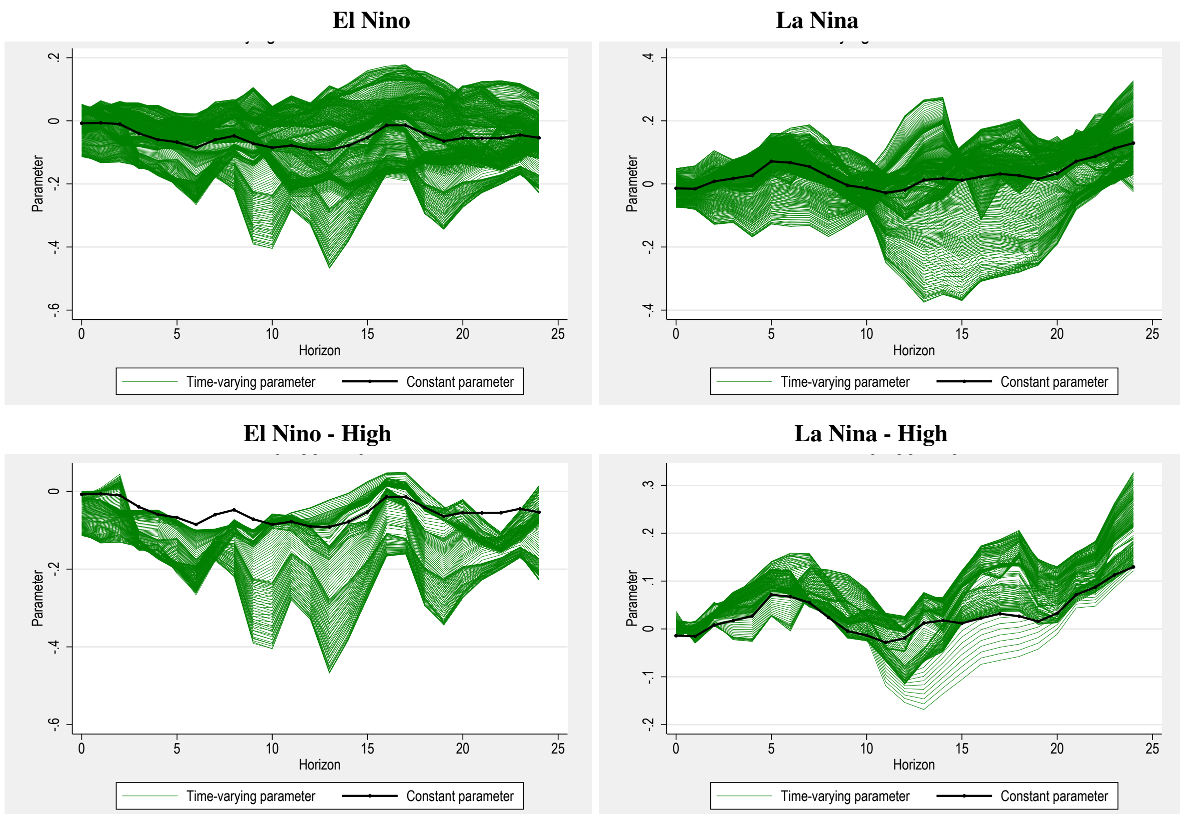
6.4.3. TVP-LP Impulse Responses to CP ENSO

Figure 19: Oil Futures Price Reaction to CP ENSO (TVP-LP)



Note: "High" refers to anomalous El Nino (bottom left-pane) and La Nina (bottom right-pane) shock defined as the fourth quantile in the historical distribution.

Figure 20: Oil Goods Market Price Reaction to CP ENSO (TVP-LP)

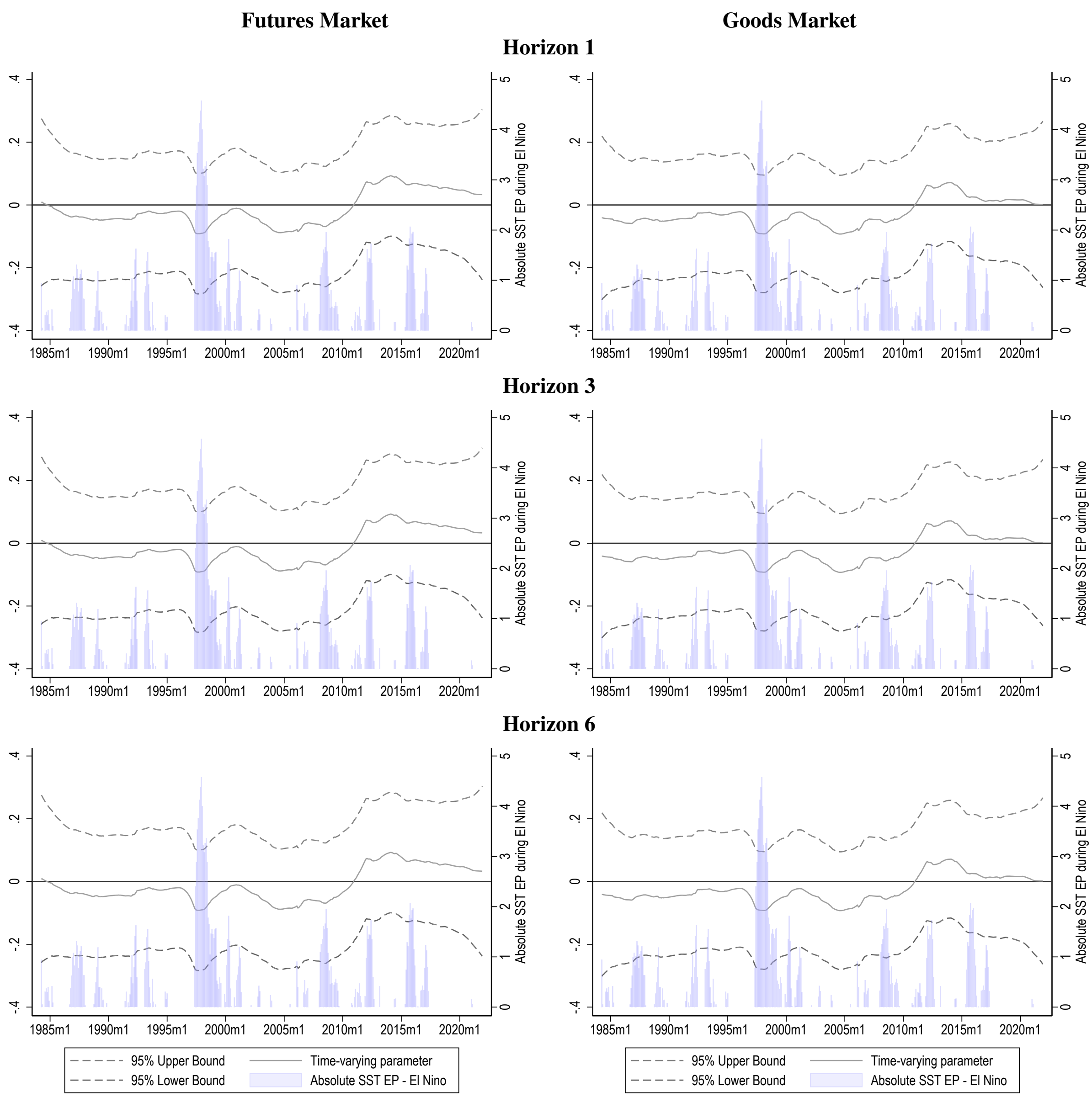


Note: "High" refers to anomalous El Nino (bottom left-pane) and La Nina (bottom right-pane) shock defined as above the fourth quantile in the historical distribution.

6.5. *Alternative Model: ENSO EP*

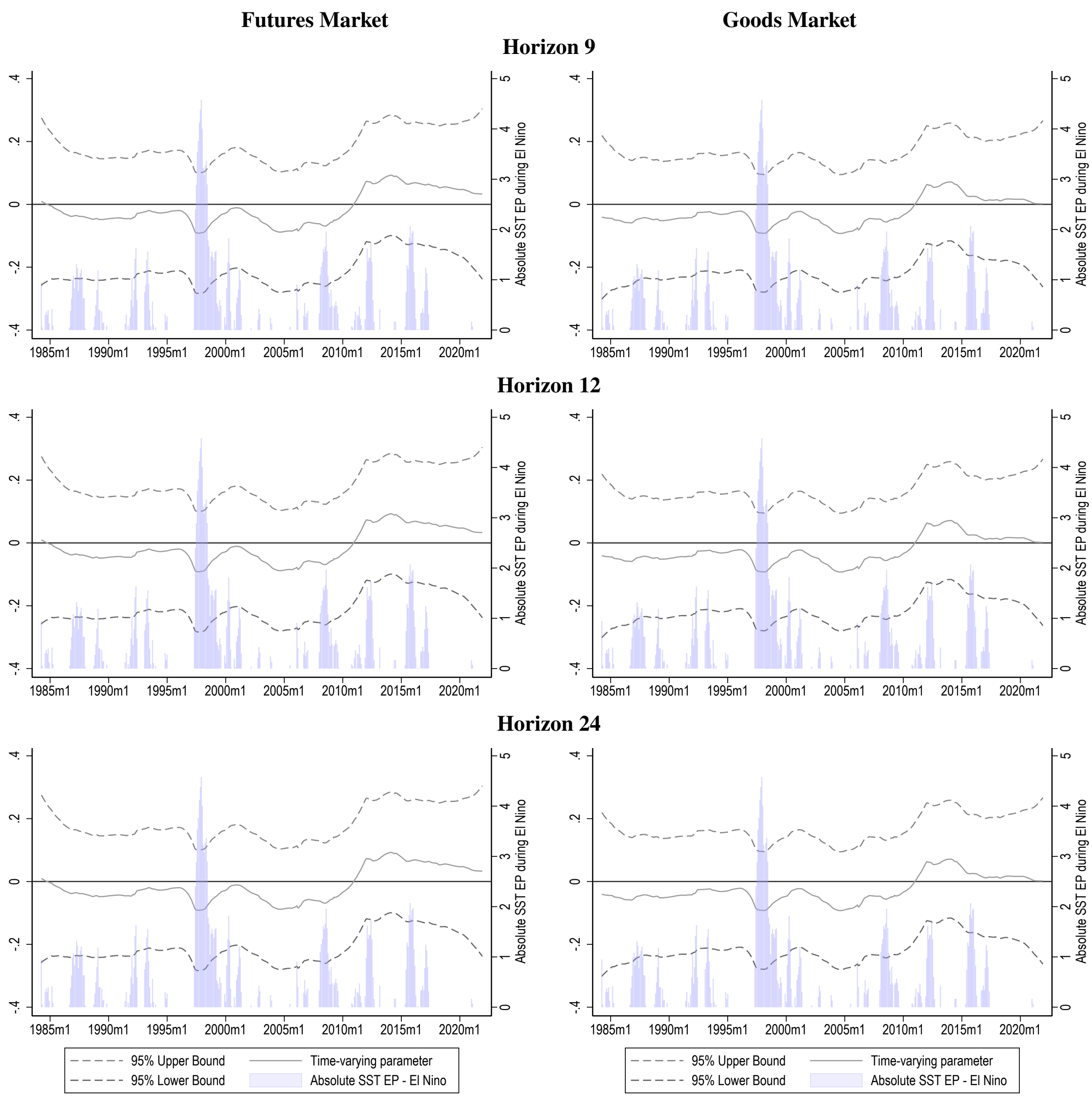
6.5.1. *Time-varying parameter plot by to El Nino (EP ENSO)*

Figure 21: Oil Price Reaction to El Nino at Different Horizons (EP ENSO)



Note: Left (right) axis refers to IRFs (absolute SST during El Nino).

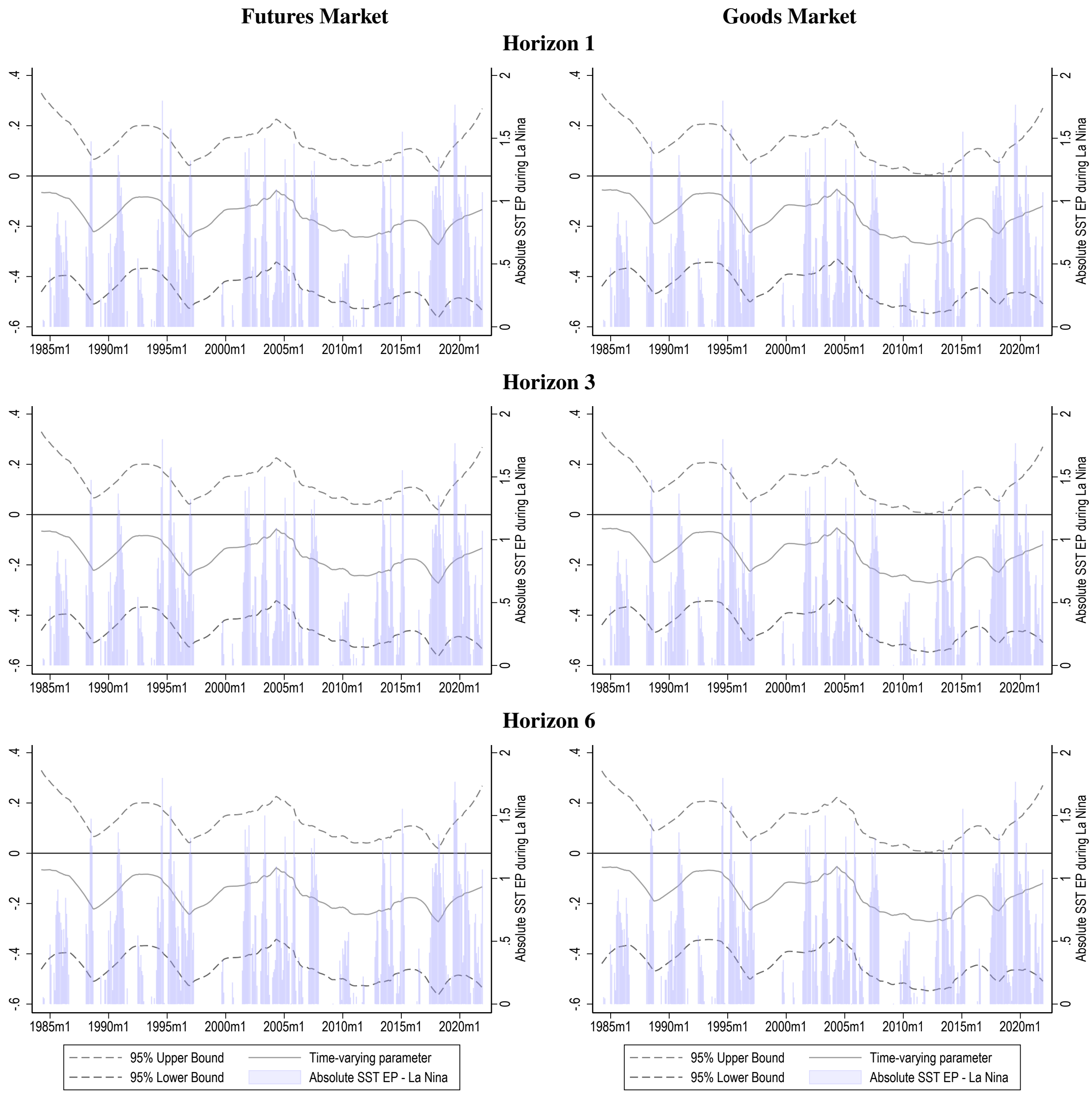
Figure 22: Oil Price Reaction to El Nino at Different Horizons (EP ENSO) (continued)



Note: Left (right) axis refers to IRFs (absolute SST during El Nino).

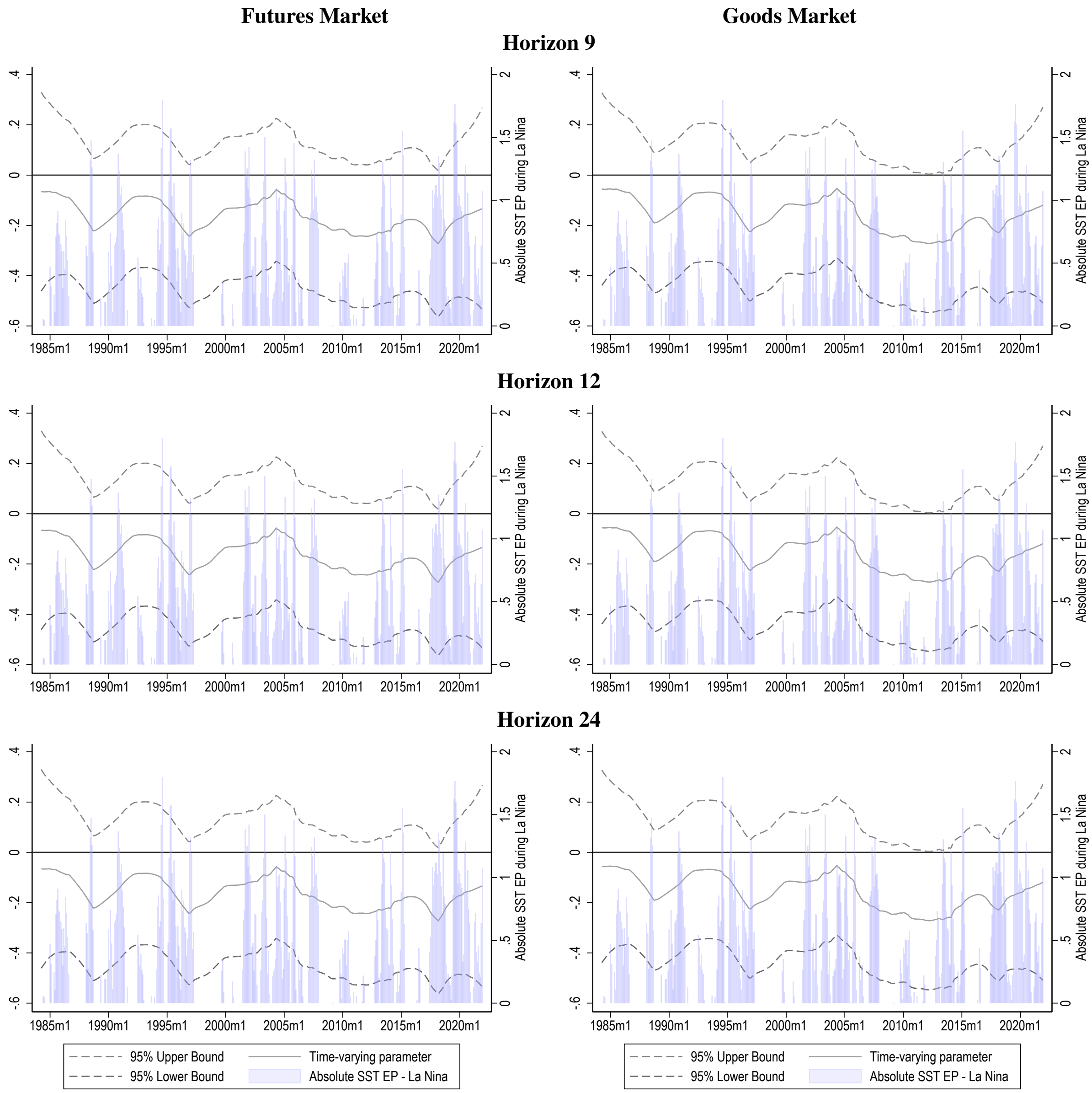
6.5.2. *Time-varying parameter plot by La Nina (EP ENSO)*

Figure 23: Oil Price Reaction to La Nina at Different Horizons (EP ENSO)



Note: Left (right) axis refers to IRFs (absolute SST during La Nina).

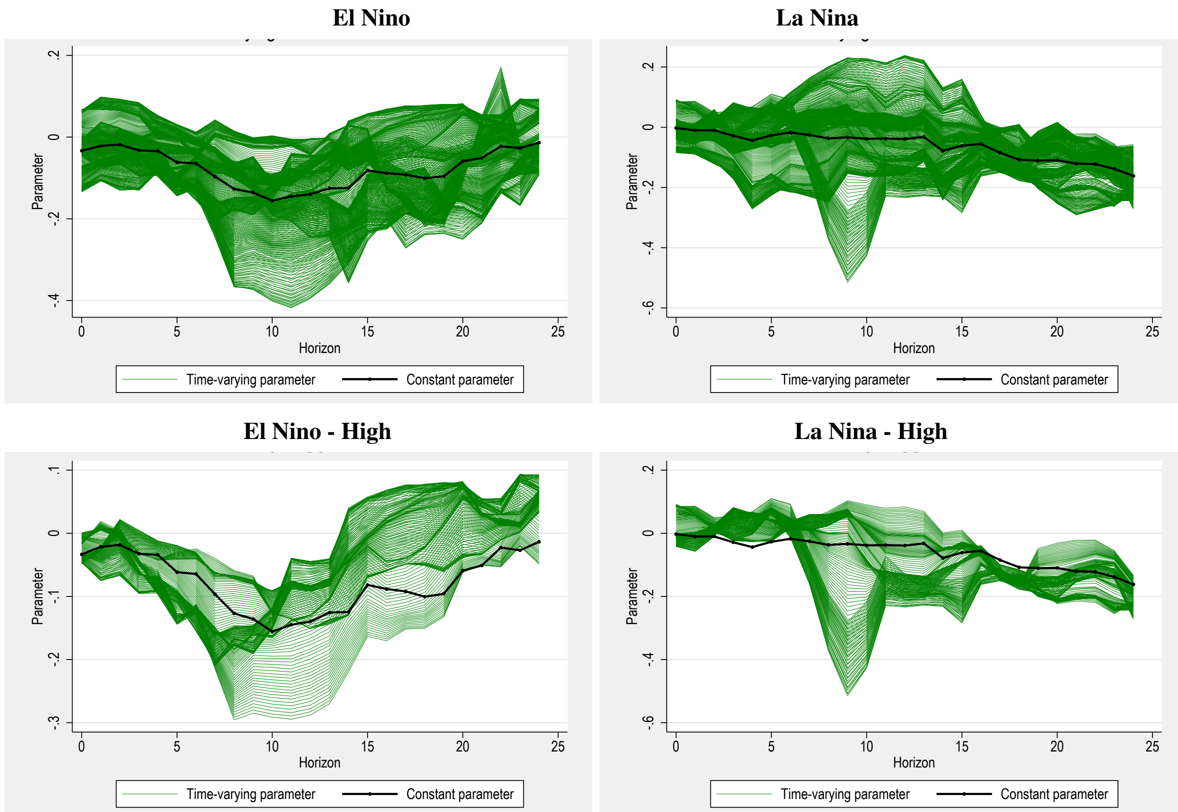
Figure 24: Oil Price Reaction to La Nina at Different Horizons (EP ENSO) (continued)



Note: Left (right) axis refers to IRFs (absolute SST during La Nina).

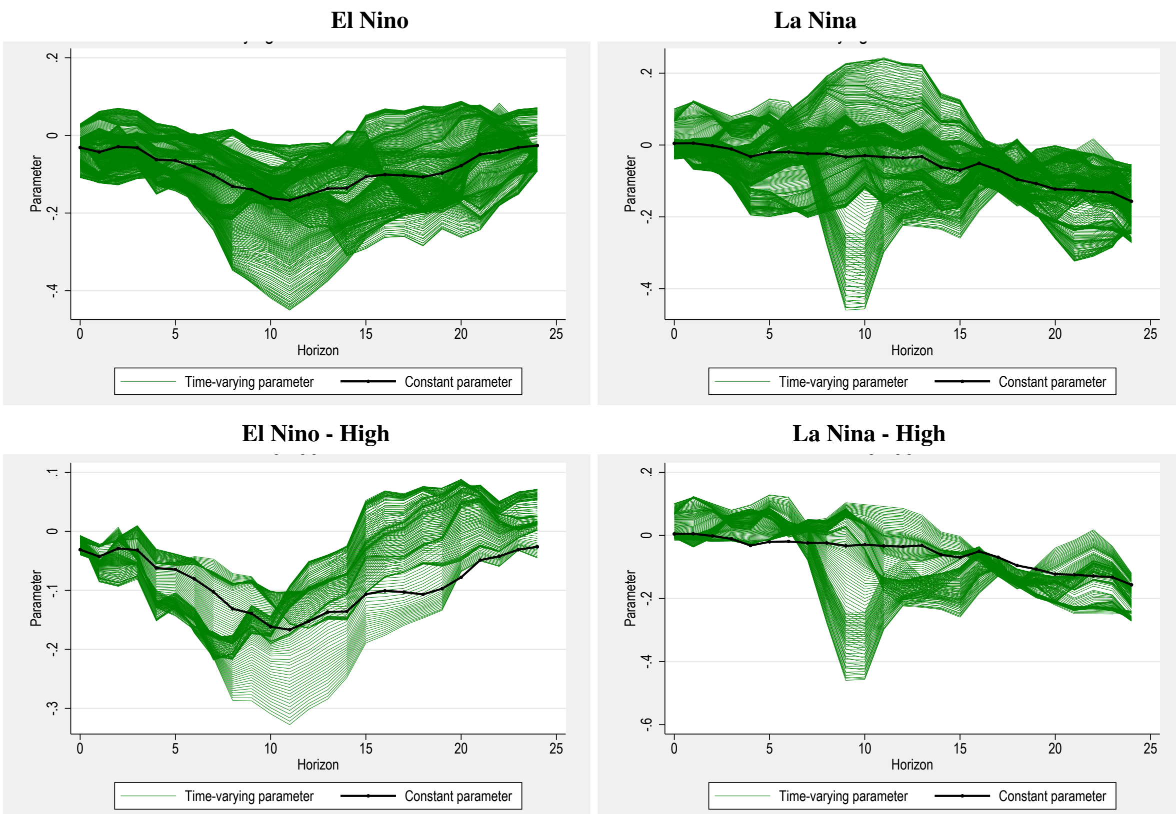
6.5.3. TVP-LP Impulse Responses to EP ENSO

Figure 25: Oil Futures Price Reaction to EP ENSO (TVP-LP)



Note: "High" refers to anomalous El Nino (bottom left-pane) and La Nina (bottom right-pane) shock defined as the fourth quantile in the historical distribution.

Figure 26: Oil Goods Market Price Reaction to EP ENSO (TVP-LP)



Note: "High" refers to anomalous El Nino (bottom left-pane) and La Nina (bottom right-pane) shock defined as above the fourth quantile in the historical distribution.