Journal of
Risk and Financial Management

MDPI

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An Empirical Examination of Asymmetry on Exchange Rate Spread Using the Quantile Autoregressive Distributed Lag (QARDL) Model

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Abstract: In economics, some transactions are conducted by the bid rate, and some are conducted by the ask rate. The spread between these two rates creates an essential cost and inefficiency for the economy. Taking these problems into account, the purpose of this study was to analyze the effects of macroeconomic and financial variables on the USD/TL exchange rate bid–ask spread for Türkiye using daily data spanning the period between 2 January 1990 and 2 August 2022. The quantile autoregressive distributed lag (QARDL) model was drawn upon to capture possible asymmetry in parameters and distinguish the results between different locations. The results obtained in this study may differ from the linear model and may change by the location, implying that the spread is reduced by the volume while it is increased by volatility and interest rates in the long run for some quantiles. Stock prices stir it in the long run, yet they decline it in the short run, indicating an asymmetry. Following the examples from the literature that analyzed the relationship via linear models, this paper employed a QARDL model for exploring location and sign asymmetry in the results for some quantiles. As the results indicate, efficiency in the bid–ask exchange rate spread can be controlled; therefore, it is our suggestion for policymakers to consider the extreme levels and asymmetry of the bid–ask exchange rate spread while evaluating its penetrating macro-financial variates.

Keywords: foreign exchange rate; bid–ask spread; QARDL

Citation: Sahin, Goktug, and Afsin Sahin. 2023. An Empirical Examination of Asymmetry on Exchange Rate Spread Using the Quantile Autoregressive Distributed Lag (QARDL) Model. *Journal of Risk and Financial Management* 16: 38. https://doi.org/10.3390/jrfm16010038

Academic Editor: Gulasekaran Rajaguru

Received: 16 December 2022
Revised: 2 January 2023
Accepted: 3 January 2023
Published: 6 January 2023

1. Introduction

As usual, in goods and services, demand and supply dynamics play an essential role in determining the optimum point in the foreign exchange market of emerging markets. The demand for foreign currency is motivated mainly through its expected return, the import level, and interest rates (Mishkin 2018, pp. 466–73). On the other hand, the supply side is fundamentally affected by the foreign currency reserves of the central bank and commercial banks.[1] The level is determined by the interaction of these two actors. Especially in an inflationary environment where the purchasing power of money loses its value, foreign currency is considered a value saver. At this point, the stability and market structure of foreign exchange will matter to the volume of foreign investment and value of assets in terms of substitution and complementary behavior.[2] The United States Dollar to Turkish Lira (USD/TL) exchange rate affects the macroeconomic variables such as inflation, trade deficit, output, and the stock market, and studying it is essential, especially for emerging markets. One may refer to Victor et al. (2021) and Cespa et al. (2022) for the importance of the foreign exchange rate market. There are also recent papers such as those of Bostan et al. (2018); Thuy and Thuy (2019); Bosupeng et al. (2019); Shuabiu et al. (2021); Lee et al. (2022);

and Edwards and Cabezas (2022) that attempt to explore the effects of exchange rate on the other variables.

In accordance with the exchange rate, the bid–ask spread gains attention as an interesting topic in economics as it was initially pointed out by Garman (1976) who established an earlier notion of the market structure. It is important to study the bid–ask spread since it is typically regarded as a reimbursement for the costs. Tinic (1972)[3] was the first to classify these costs, which can be listed as order processing costs (see Demsetz 1968), inventory holding costs[4] (see Garman 1976), and asymmetric information costs (see Copeland and Galai 1983) in accordance with the market microstructure theory. This classification served as the foundation for a substantial body of work that examines both the theoretical modeling of these costs and the evaluation of their empirical applicability. According to the recent literature, there were studies carried out by Frömmel and Van Gysegem (2015) focusing on measuring the effects of these costs on the Hungarian Forint/Euro exchange rate where the order processing cost has a dominant share. There are also some papers undervaluing the effect of order processing cost. As observed by Chelley-Steeley and Tsorakidis (2013, p. 19), the effect of these costs on the bid–ask spread is restricted compared to volatility, volume, and revenue motives of the actors; they heighten their own past shocks.

There are possible factors including trading volume, volatility[5], risk, uncertainty, asymmetric information, and competition that can drastically alter the spread's size in the foreign exchange market. Moreover, the bid–ask spread arises from transaction costs, taxes, and banks' profit in general (Seyidoglu 2009, p. 359). According to Seyidoglu (2009, p. 360), the volume of transactions decreases the bid–ask spread. This scale effect is essential for high-volume currencies since the average cost declines as the scale goes up. He underlines the upward tendency of the spread during a time of instability in exchange rates where the volatility is high. Moreover, the high foreign currency liquidity position of a bank may turn out to be a factor pressing it to lower its spreads. Therefore, banks are heterogeneous in terms of determining their liquidity positions.

In our study, the variety of approaches in the literature related to the bid–ask exchange rate spread is underlined in the light of examples from empirical papers that explore its macroeconomic and financial influences. For instance, Melvin and Tan (1996) benefit from panel data to indicate that the volatility and the riskiness of a country increase the bid–ask exchange rate spread. Davutyan (1997) claims that interest rate, volatility of the exchange rate, and volatility of interest rate have positive effects on the bid–ask exchange rate spread. According to Becker and Sy (2006), the exchange rate volatility increases it for all Asian currencies, but the effect of volume is not significant and positive for all cases. Ding and Hiltrop's (2010) findings show that electronic trading systems decrease but the exchange rate volatility increases the bid–ask spread. Dornbusch and Pechman (1985) take interest rate as a measure of cost and variance as a risk where both increase the bid–ask spread in the Brazilian black market for the United States (US) dollar.[6] Zhong and Shang (2020) calculated the daily spread between the US dollar to Chinese Yuan (USD/CNH) spot rate in the Hong Kong offshore market and the central parity rate of the China Foreign Exchange Trading Center. They found that the exchange rate reform in 2015 and the interest rate differential increased the spread by using a generalized autoregressive conditional autoregressive heteroscedasticity (GARCH) model. Li et al. (2020) analyzed the determinants of the spread between offshore and onshore renminbi foreign exchange markets by using a nonlinear autoregressive distributed lag (NARDL) model. They found that the economic policy uncertainty increased the spread in the long run but decreased it in the short run. Moreover, according to their findings, interest rate differential affects it positively in both terms, and the exchange rate expectation and intervention affects the spread negatively in the long run. Fullerton and Pallares (2022) calculated the commercial bank and currency kiosk bid–ask spreads for the northern Mexico metropolitan economy and claimed that the latter is negatively affected by total northbound border crossings by using a generalized least square autoregressive moving average model. Henao-Londono and Guhr (2022) stress the dissociation of the bid–ask exchange rate spread from the Markovian behavior.

This paper benefits from the quantile autoregressive distributed lag (QARDL) model utilized in several scientific analyses. For example, Abbas et al. (2022) applied the QARDL model to study the effects of price risks on the U.S. stock prices. Moreover, using the QARDL model, Benkraiem et al. (2018b) explored different results for the short run and long run while analyzing the effect of oil prices on the stock prices for the European countries. Conversely, Benkraiem et al. (2018a) benefitted from the QARDL model to analyze the effect of energy prices on stock prices, while Chang et al. (2020) analyzed the impact of macroeconomic variables on the stock prices for the Pakistani economy using the same model. Omoke and Unche (2021) examined the effect of oil price shocks on purchasing power, whereas Zhan et al. (2021) applied QARDL to environmental issues. Furthermore, Lahiani et al. (2017) used the model to investigate the relationship between different oil grade prices. Finally, Jiang et al. (2021); Solarin and Bello (2020); Nor et al. (2020, p. 3); Zhu et al. (2016); and Wang et al. (2021) adopted the QARDL model in their investigations as well. As for our study, we first used the QARDL methodology to investigate the determinants of the foreign exchange rate in the bid–ask spread.

It is obvious that our paper contributes to the field in many aspects. There are several contributions of the paper: To the best of our knowledge, reviewing the abovementioned past attempts briefly about the USD/TL bid–ask rate spread, we observed that there was no paper addressing the possible nonlinearities; thus, we aimed to fill the gap in the literature using the QARDL model and Türkiye data that spans the period from 2 January 1990 through to 2 August 2022. We hypothesized that if we tested the expected signs of volume (negative), volatility (positive), interest rate (positive), and stock prices (positive) variables on the basis of the results of the previous empirical observations and studies in the literature, it would help to understand the determinants of the bid–ask spread. Therefore, the research question in this study was to investigate the possible effects of volume, volatility, interest rate, and stock prices on the bid–ask exchange rate spread in Türkiye during the past thirty years using a QARDL model. The results are in line with the expectations of the study and mainly the previous literature. The findings revealed that the error correction term was significantly negative for all autoregressive distributed lag (ARDL) models but turned out to be positive for upper quantiles of QARDL models. In the long run, the coefficients for the volume were positive for ARDL models, but we may obtain negative coefficients for the highest and lowest quantiles for QARDL models. The volatility had a negative effect on some ARDL models and turned out positive in marginal quantiles for QARDL models. The effect of interest rate was not statistically significant for ARDL models but was positive for some quantiles of the QARDL models. The effect of the stock prices was positive for all ARDL models along with some quantiles of the QARDL models. Considering the short-run coefficients, the volume effect was seen to be positive for all ARDL specifications, and none of the QARDL models had a negative result. The volatility's coefficient was observed as being positive for a one ARDL specification and several quantiles of the QARDL models. The interest rate's coefficient was not statistically significant for the ARDL models but was significantly positive for some quantiles of the QARDL. The effect of the stock prices appeared to be positive only for one ARDL model and was mostly negative in QARDL models. The following section describes the data and methodology. The third section presents the results obtained from the models. The fourth section discusses the results, and the last section is reserved for the conclusion.

2. Materials and Methods

Gathering the data for analyzing the point interaction for Türkiye is not an easy task, and Table 1 provides some of the potential data sources to be able to realize our objectives. Foreign banknotes (*VOL*) are only available for the period from 14 October 2002 to 25 July 2022. Between 2 April 2004 and 2 August 2022, there are no data for The Foreign Exchange Market (FOREX) number of transactions (*FOREXN*) and FOREX volume of transactions (*FOREXV*), and the existing data are not continuous. Considering the TL/FOREX Number of Transactions, we found some data between 25 September 1990 and

27 April 2016 (*TLN*), and the pre-2001 number of transactions was much higher compared to post-2001. TL/FOREX volume of transactions (*TLV*) has a similar pattern within the same period. TL/BANKNOTES number of transactions (*TLBN*) and the volume of transactions (*TLBV*) data are available for the period from 3 January 1992 to 28 June 2002, thus not being sufficient to conduct an analysis. Therefore, FOREX/BANKNOTES volume of transactions (*FOREXBV*) was found to be the best data source appropriate for the research topic due to its longest span and rich content. It should be taken into consideration that The Central Bank of the Republic of Türkiye (the CBRT) has a practice direction regarding the foreign exchange market determining the main principles in the exchange market within the CBRT (see CBRT 2021). According to Article 8 of this practice direction, banks conduct foreign exchange transactions against TL by Euro or the US dollar where the limit is one million.

Table 1. Definition of variables.

Variable	Data Code	Explanations	Source	Data Start	Data End
VOL	TP.TLDOV06.EFK	Foreign banknotes-level	CBRT, EVDS	14 October 2002	25 July 2022
BUA	TP.ALIM.USD	BID amount (USD)-level	CBRT, EVDS	-	-
AUA	TP.SATIM.USD	ASK amount (USD)-level	CBRT, EVDS	-	-
FOREXN	TP.DF.DD.ADED	FOREX/FOREX number of transactions (transaction amounts and volumes are two sided)-level	CBRT, EVDS	11 June 1991	2 April 2004
FOREXV	TP.DF.DD.HACM	FOREX/FOREX volume of transactions (USD) (transaction amounts and volumes are two sided)-level	CBRT, EVDS	11 June 1991	2 April 2004
FOREXBN	TP.DF.DE.ADED	FOREX/BANKNOTES number of transactions (transaction amounts and volumes are two sided)-level	CBRT, EVDS	25 September 1990	1 August 2022
FOREXBV	TP.DF.DE.HACM	FOREX/BANKNOTES volume of transactions (USD) (transaction amounts and volumes are two sided)-level	CBRT, EVDS	25 September 1990	1 August 2022
TLN	TP.DF.TD.ADED	TL/FOREX number of transactions (transaction amounts and volumes are two sided)-level	CBRT, EVDS	25 September 1990	27 April 2016
TLV	TP.DF.TD.HACM	TL/FOREX volume of transactions (USD) (transaction amounts and volumes are two sided)-level	CBRT, EVDS	25 September 1990	27 April 2016
TLBN	TP.DF.TE.ADED	TL/BANKNOTES number of transactions (transaction amounts and volumes are two sided)-level	CBRT, EVDS	3 January 1992	28 June 2002
TLBV	TP.DF.TE.HACM	TL/BANKNOTES volume of transactions (USD) (transaction amounts and volumes are two sided)-level	CBRT, EVDS	3 January 1992	28 June 2002
USDB	TP.DK.USD.A.EF.YTL	(USD) US Dollar (banknote buying)-level (bid price)	CBRT, EVDS	2 January 1990	2 August 2022
USDA	TP.DK.USD.S.EF.YTL	(USD) US Dollar (banknote selling)-level (ask price)	CBRT, EVDS	2 January 1990	2 August 2022
USDBAS		Spread variable. Own calculations.		2 January 1990	2 August 2022

There are two ways to calculate the bid–ask spread (*USDBAS*). When they are graphed, it is seen that *USDBAS* from effective (only banknotes) is much more volatile than the total (exchange rate) both for USD and EURO. The EURO banknote and total (exchange rates) spread was higher than the USD banknote and exchange rate between 3 January 2000 and 2 August 2022. The EURO banknote and exchange rate spread was 23% higher than the USD banknote and exchange rate. However, both *USDBAS* and *EUROBAS* moved together. The two decreased on 19 February 2013 and 22 February 2021, whereas they increased on 31 August 2018 and 26 November 2020. Moreover, starting from 2018, we observed persistent increases in both currencies. Spreads for both currencies were very high, especially in 2021 and 2022. Moreover, EURO and USD volatilities were similar, wherein the spread's standard deviation was nearly (0.01) in both series.

Since the USD/TL had a higher span compared to EURO/TL, we decided to use the USD/TL. The annualized moving average of the USD/TL exchange rate return between 2 January 1990 and 2 August 2022 was 19.02%. On 28 April 1994 (175%), 21 March 2001 (152%), 31 October 2008, 9 October 2018, and 13 January 2022 (108%), the value of the USD/TL exchange rate return was much higher compared to the average. Therefore, it was essential to use an appropriate method to calculate the volatility. The conditional volatility data for the exchange rate may be acquired via panel analysis, as Koutmos and Martin (2011) suggest. Depending on conditional variances of the unexpected changes in the exchange rate, they claim that the flexibility and the volatility of the exchange rate increase the spread. Following Koutmos and Martin (2011), we also calculated the spread for the TL/USD foreign exchange rate as follows:

$$USDBASN_t = \frac{USDA_t - USDB_t}{(USDA_t + USDB_t)/2}$$

We also obtained the volatility data from *USDA* by the exponential general autoregressive conditional heteroskedastic (EGARCH (1,1)) model, but it should be continuous in order to be able to obtain the conditional variance data (*COND*). As mentioned by Boothe and Gurun (2008), exchange rate exhibits volatility clustering. Additionally, we calculated the volatility by taking standard deviation of 20 days return and multiplying it by the square root of two hundred fifty-two.

The following equations were used to estimate the linear ARDL and QARDL model parameters.[7] We considered the Schwarz information criterion (SIC) to determine the optimal lags for the autoregressive (p) and moving average (q) lag orders within the maximum lag order of twelve. ARDL models are useful compared to others when the order of integration is different among the variables (see Shrestha and Bhatta 2018, p. 79). The augmented Dickey–Fuller (ADF) and Phillips–Perron (PP) unit root test results indicated heterogeneity in the results (see Tables 2 and 3).

The ARDL models are presented by Model a, and the Quantile ARDL (QARDL) models for the 10 quantiles are shown as Model b: within the equation, $\Gamma = \sum_{i=1}^{p-1} \kappa_i$ and $\Lambda_1 = \varpi_0$, $\Lambda_2 = \vartheta_0$, $\Lambda_3 = \chi_0$, and $\Lambda_4 = \zeta_0$. It was observed that the long-run coefficients were normalized by the lagged coefficient of the dependent variable. See Cho et al. (2015) and Park (2020) for models.

Model 1a: *USDBASD FOREXBV MAV RIO PINDICE* (ARDL) (1)

$$\begin{aligned}\Delta USDBASD_t = {} & Constant + \lambda(USDBASD_{t-1} - \psi_1 FOREXBV_{t-1} - \psi_2 MAV_{t-1} - \psi_3 RIO_{t-1} - \psi_4 PINDICE_{t-1}) \\ & + \sum_{i=1}^{p-1} \kappa_i \Delta USDBASD_{t-1} + \sum_{j=0}^{q-1} \varpi_j \Delta FOREXBV_{t-j} + \sum_{j=0}^{q-1} \vartheta_j \Delta MAV_{t-j} + \sum_{j=0}^{q-1} \chi_j \Delta RIO_{t-j} + \sum_{j=0}^{q-1} \zeta_j \Delta PINDICE_{t-j} + \varepsilon_t\end{aligned}$$

Model 1b: *USDBASD FOREXBV MAV RIO PINDICE* (QARDL) (2)

$$\begin{aligned}\Delta USDBASD_t = {} & Constant(\tau) + \lambda(t)(USDBASD_{t-1} - \psi_1(\tau) FOREXBV_{t-1} - \psi_2(\tau) MAV_{t-1} - \psi_3(\tau) RIO_{t-1} \\ & - \psi_4(\tau) PINDICE_{t-1}) + \sum_{i=1}^{p-1} \kappa_i(\tau) \Delta USDBASD_{t-1} + \sum_{j=0}^{q-1} \varpi_j(\tau) \Delta FOREXBV_{t-j} + \sum_{j=0}^{q-1} \vartheta_j(\tau) \Delta MAV_{t-j} + \\ & \sum_{j=0}^{q-1} \chi_j(\tau) \Delta RIO_{t-j} + \sum_{j=0}^{q-1} \zeta_j(\tau) \Delta PINDICE_{t-j} + \varepsilon_t\end{aligned}$$

Table 2. Phillips–Perron (PP) unit root test results.

		VOL	*FOREXBN*	*FOREXBV*	*TLN*	*TLV*	*TLBN*	*TLBV*	*USDB*	*USDA*	*USDBASN*	*USDBASD*	*DUSDA*	*MAV*	*COND*	*RIO*	*AFO*	*MK*	*PINDICE*	*ONW*
WC	t	−71.33	−19.92	−49.24	−70.60	−39.24	−24.39	−24.21	8.00	8.00	−1.73	6.81	−76.37	−10.62	−49.03	−0.80	−0.92	−8.94	4.29	−1.27
	p	0.00	0.00	0.00	0.00	0.0000	0.00	0.00	1.00	1.00	0.4151	1.00	0.00	0.00	0.00	0.81	0.78	0.00	1.00	0.64
	s	***	***	***	***	***	***	***	Ns	ns	ns	ns	***	***	***	ns	ns	***	ns	ns
WCT	t	−76.73	−30.88	−47.67	−72.83	−38.85	−25.79	−25.37	7.03	7.03	−2.78	6.08	−76.94	−10.67	−49.03	−2.29	−2.38	−11.86	3.14	−1.49
	p	0.00	0.00	0.00	0.00	0.0000	0.00	0.00	1.00	1.00	0.20	1.00	0.00	0.00	0.00	0.43	0.38	0.00	1.00	0.83
	s	***	***	***	***	***	***	***	Ns	ns	ns	ns	***	***	***	ns	ns	***	ns	ns
OTC	t	−24.64	−14.51	−46.85	−64.52	−40.12	−19.69	−21.59	8.3807	8.37	−0.75	7.09	−76.55	−8.17	−49.04	−0.95	−0.95	−7.87	4.95	−0.00
	p	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	1.00	0.39	1.00	0.00	0.00	0.00	0.30	0.30	0.00	1.00	0.68
	s	***	***	***	***	***	***	***	Ns	ns	ns	ns	***	***	***	ns	ns	***	ns	ns
WC	t	−717.2	−310.96	−198.49	−190.91	−328.10	−381.65	−223.15	−84.03	−84.03	−94.69	−85.81	−1024.91	−78.06	−1627.88	−92.21	−92.20	−186.79	−92.79	−45.41
	p	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00
	s	***	***	***	***	***	***	***	***	***	***	***	ns	***	ns	***	***	***	***	***
WCT	t	−727.1	−324.98	−195.81	−191.28	−331.02	−566.52	−219.67	−84.63	−84.63	−94.69	−86.27	−1024.84	−78.05	−1627.83	−92.20	−92.20	−193.09	−92.87	−45.40
	p	0.0001	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00
	s	***	***	***	***	***	***	***	***	***	***	***	ns	***	ns	***	***	***	***	***
OTC	t	−689.8	−301.18	−198.96	−190.67	−326.22	−277.05	−222.92	−84.16	−84.16	−94.70	−85.63	−1025.02	−78.06	−1628.04	−92.21	−92.21	−182.55	−92.73	−45.42
	p	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00
	s	***	***	***	***	***	***	***	***	***	***	***	ns	***	ns	***	***	***	***	***

Notes: WC: with constant, WCT: with constant and trend, OTC: without constant and trend, t: t-statistics, *p*: *p*-value, s: significancy, ns: not significant; *** significant at the 1% level. These results are the output of Eviews 12 Software Add-In for All Unit Root Tests developed by Dr. Imadeddin AlMosabbeh, College of Business and Economics, Qassim University-KSA.

Table 3. Augmented Dickey–Fuller (ADF) unit root test results.

		VOL	*FOREXBN*	*FOREXBV*	*TLN*	*TLV*	*TLBN*	*TLBV*	*USDB*	*USDA*	*USDBASN*	*USDBASD*	*DUSDA*	*MAV*	*COND*	*RIO*	*AFO*	*MK*	*PINDICE*	*ONW*
	t	−5.93	−3.49	−10.54	−6.78	−2.73	−16.17	−15.36	7.74	7.7383	−1.7426	6.22	−45.84	−9.01	−49.03	−0.807	−0.92	−7.28	3.75	−1.34
WC	*p*	0.00	0.00	0.00	0.00	0.06	0.00	0.00	1.00	1.00	0.40	1.00	0.00	0.00	0.00	0.81	0.78	0.00	1.00	0.61
	s	***	***	***	***	*	***	***	ns	ns	ns	ns	***	***	***	ns	ns	***	ns	ns
	t	−6.86	−4.30	−10.82	−7.63	−2.89	−16.37	−15.57	6.91	6.91	−2.78	5.52	−55.89	−9.06	−49.03	−2.29	−2.38	−7.08	2.77	−1.58
WCT	*p*	0.00	0.00	0.00	0.00	0.16	0.00	0.00	1.00	1.00	0.20	1.00	0.00	0.00	0.00	0.43	0.38	0.00	1.00	0.80
	s	***	***	***	***	ns	***	***	ns	ns	ns	ns	***	***	***	ns	ns	***	ns	ns
	t	−3.0	−2.83	−2.94	−3.49	−1.88	−2.25	−2.61	8.04	8.03	−0.75	6.42	−13.29	−6.29	−49.02	−0.951	−0.95	−7.31	4.29	−0.23
OTC	*p*	0.00	0.00	0.00	0.00	0.05	0.02	0.00	1.00	1.00	0.38	1.00	0.00	0.00	0.00	0.30	0.30	0.00	1.00	0.60
	s	***	***	***	***	*	**	***	ns	ns	ns	ns	***	***	***	ns	ns	***	ns	ns
	t	−30.99	−32.99	−33.21	−23.43	−20.25	−17.34	−14.69	−17.73	−17.73	−94.64	−17.88	−34.99	−23.84	−29.30	−92.21	−92.20	−8.42	−12.85	−20.40
WC	*p*	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0001	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	s	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***
	t	−30.98	−32.99	−33.29	−23.41	−20.26	−17.35	−14.69	−18.20	−18.20	−94.64	−18.25	−34.99	−23.84	−29.30	−92.20	−92.20	−8.71	−12.89	−20.40
WCT	*p*	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	s	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***
	t	−30.99	−32.99	−33.19	−23.45	−20.24	−17.34	−14.68	−17.48	−17.48	−94.65	−17.66	−35.00	−23.84	−29.30	−92.21	−92.21	−8.31	−12.78	−20.41
OTC	*p*	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	s	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***

Notes: WC: with constant, WCT: with constant and trend, OTC: without constant and trend, t: t-statistics, *p*: *p*-value, s: significancy, ns: not significant; *** significant at the 1% level, ** significant at the 5% level, * significant at the 10% level. This result is the output of the Eviews 12 Software Add-In for All Unit Root Tests developed by Dr. Imadeddin AlMosabbeh, College of Business and Economics, Qassim University-KSA. Becker and Sy (2006) used this normalized spread measure. Following the study of Chung and Zhang (2014) that applied it for the daily stock prices, Su and Tokmakcioglu (2021) used this spread specification for the daily bond data. They claim that it is superior to other spread measures they define in their paper, citing a substantial amount of the previous literature. Since the $USDBASN_t$ was not volatile at the time of our sample, we decided not to use these data.

Model 2a: *USDBASD FOREXBV MAV AFO PINDICE* (ARDL) (3)

$$\Delta USDBASD_t = Constant + \lambda(USDBASD_{t-1} - \psi_1 FOREXBV_{t-1} - \psi_2 MAV_{t-1} - \psi_3 AFO_{t-1} - \psi_4 PINDICE_{t-1}) + \sum_{i=1}^{p-1} \kappa_i \Delta USDBASD_{t-1} + \sum_{j=0}^{q-1} \varpi_j \Delta FOREXBV_{t-j} + \sum_{j=0}^{q-1} \vartheta_j \Delta MAV_{t-j} + \sum_{j=0}^{q-1} \chi_j \Delta AFO_{t-j} + \sum_{j=0}^{q-1} \zeta_j \Delta PINDICE_{t-j} + \varepsilon_t$$

Model 2b: *USDBASD FOREXBV MAV AFO PINDICE* (QARDL) (4)

$$\Delta USDBASD_t = Constant(\tau) + \lambda(t)(USDBASD_{t-1} - \psi_1(\tau) FOREXBV_{t-1} - \psi_2(\tau) MAV_{t-1} - \psi_3(\tau) AFO_{t-1} - \psi_4(\tau) PINDICE_{t-1}) + \sum_{i=1}^{p-1} \kappa_i(\tau) \Delta USDBASD_{t-1} + \sum_{j=0}^{q-1} \varpi_j(\tau) \Delta FOREXBV_{t-j} + \sum_{j=0}^{q-1} \vartheta_j(\tau) \Delta MAV_{t-j} + \sum_{j=0}^{q-1} \chi_j(\tau) \Delta AFO_{t-j} + \sum_{j=0}^{q-1} \zeta_j(\tau) \Delta PINDICE_{t-j} + \varepsilon_t$$

Model 3a: *USDBASD FOREXBV COND ONW PINDICE* (ARDL) (5)

$$\Delta USDBASD_t = Constant + \lambda(USDBASD_{t-1} - \psi_1 FOREXBV_{t-1} - \psi_2 COND_{t-1} - \psi_3 ONW_{t-1} - \psi_4 PINDICE_{t-1}) + \sum_{i=1}^{p-1} \kappa_i \Delta USDBASD_{t-1} + \sum_{j=0}^{q-1} \varpi_j \Delta FOREXBV_{t-j} + \sum_{j=0}^{q-1} \vartheta_j \Delta COND_{t-j} + \sum_{j=0}^{q-1} \chi_j \Delta ONW_{t-j} + \sum_{j=0}^{q-1} \zeta_j \Delta PINDICE_{t-j} + \varepsilon_t$$

Model 3b: *USDBASD FOREXBV COND ONW PINDICE* (QARDL) (6)

$$\Delta USDBASD_t = Constant(\tau) + \lambda(t)(USDBASD_{t-1} - \psi_1(\tau) FOREXBV_{t-1} - \psi_2(\tau) COND_{t-1} - \psi_3(\tau) ONW_{t-1} - \psi_4(\tau) PINDICE_{t-1}) + \sum_{i=1}^{p-1} \kappa_i(\tau) \Delta USDBASD_{t-1} + \sum_{j=0}^{q-1} \varpi_j(\tau) \Delta FOREXBV_{t-j} + \sum_{j=0}^{q-1} \vartheta_j(\tau) \Delta COND_{t-j} + \sum_{j=0}^{q-1} \chi_j(\tau) \Delta ONW_{t-j} + \sum_{j=0}^{q-1} \zeta_j(\tau) \Delta PINDICE_{t-j} + \varepsilon_t$$

In this paper, QARDL model estimations were conducted through taking into consideration the possible endogeneity and multicollinearity problems among variables. According to Chang et al. (2020), due to the absent correlation of residuals in the ARDL model, there is no endogeneity. Suwandaru et al. (2021) also mention that the ARDL model corrects the endogeneity problem. As mentioned by Sun et al. (2021b, p. 3), the QARDL model keeps in view the possible endogeneity problem. The blind side of the QARDL model is that it is not possible to estimate coefficients at the quantile-on-quantile level, as mentioned by Sharif et al. (2020).

3. Results

The original MATLAB software QARDL model program codes only allow bivariate estimates; therefore, we modified the code to allow for the obtaining of our results presented in this section for our multiple regressions. Moreover, short- and long-run standard errors were estimated with the delta method, and they should be modified for the alternatives (see Jin et al. 2021 for the delta method). Table 4 summarizes the results for all variables stressing the signs. Table 5 provides the results for both ARDL and QARDL specifications with the same notations. Additionally, graphs of the long- and short-run parameters are given in Table 6.

Table 4. Sign map.

Models	τ	λ	ψ_1	ψ_2	ψ_3	ψ_4	Γ	Λ_1	Λ_2	Λ_3	Λ_4
Model 1a: ARDL	Woq	−	+	−	ns	+	ns	+	−	na	ns
Model 2a: ARDL	Woq	−	+	−	ns	+	ns	+	−	na	ns
Model 3a: ARDL	Woq	−	+	ns	ns	+	na	+	+	na	+
Model 1b: QARDL	0.05	0.05−	0.05−	0.05−	0.05+	0.05ns	0.05+	0.05+	0.05−	0.05ns	0.05−
	0.10	0.10−	0.10+	0.10−	0.10+	0.10+	0.10ns	0.10+	0.10−	0.10ns	0.10−
	0.20	0.20−	0.20+	0.20−	0.20+	0.20+	0.20ns	0.20ns	0.20−	0.20ns	0.20−
	0.30	0.30−	0.30+	0.30−	0.30+	0.30+	0.30ns	0.30+	0.30ns	0.30+	0.30−
	0.40	0.40ns	0.40ns	0.40ns	0.40ns	0.40ns	0.40ns	0.40+	0.40ns	0.40ns	0.40−
	0.50	0.50ns	0.50ns	0.50ns	0.50ns	0.50ns	0.50ns	0.50ns	0.50ns	0.50ns	0.50−
	0.60	0.60+	0.60+	0.60ns	0.60−	0.60ns	0.60ns	0.60ns	0.60+	0.60ns	0.60−
	070	0.70+	0.70+	0.70−	0.70−	0.70ns	0.70ns	0.70ns	0.70+	0.70ns	0.70−
	0.80	0.80+	0.80+	0.80−	0.80ns	0.80ns	0.80ns	0.80ns	0.80ns	0.80ns	0.80−
	0.90	0.90+	0.90−	0.90−	0.90ns	0.90ns	0.90+	0.90+	0.90+	0.90ns	0.90−
	0.95	0.95+	0.95−	0.95−	0.95ns	0.95ns	0.95+	0.95+	0.95+	0.95ns	0.95−
Model 2b: QARDL	0.05	0.05−	0.05−	0.05−	0.05+	0.05ns	0.05+	0.05+	0.05−	0.05ns	0.05−
	0.10	0.10−	0.10−	0.10−	0.10+	0.10+	0.10ns	0.10+	0.10−	0.10+	0.10−
	0.20	0.20−	0.20+	0.20−	0.20+	0.20ns	0.20ns	0.20ns	0.20−	0.20ns	0.20−
	0.30	0.30−	0.30+	0.30−	0.30+	0.30+	0.30ns	0.30+	0.30ns	0.30+	0.30−
	0.40	0.40−	0.40ns	0.40ns	0.40ns	0.40ns	0.40ns	0.40+	0.40+	0.40ns	0.40−
	0.50	0.50ns	0.50ns	0.50ns	0.50ns	0.50ns	0.50ns	0.50ns	0.50ns	0.50ns	0.50−
	0.60	0.60+	0.60+	0.60ns	0.60−	0.60ns	0.60ns	0.60ns	0.60+	0.60ns	0.60−
	070	0.70+	0.70+	0.70−	0.70−	0.70ns	0.70ns	0.70ns	0.70+	0.70ns	0.70−
	0.80	0.80+	0.80+	0.80−	0.80ns	0.80ns	0.80ns	0.80ns	0.80ns	0.80ns	0.80−
	0.90	0.90+	0.90−	0.90−	0.90ns	0.90ns	0.90+	0.90+	0.90+	0.90ns	0.90−
	0.95	0.95+	0.95−	0.95−	0.95ns	0.95−	0.95+	0.95+	0.95+	0.95ns	0.95−
Model 3b: QARDL	0.05	0.05−	0.05ns	0.05+	0.05ns	0.05ns	0.05na	0.05ns	0.05ns	0.05ns	0.05ns
	0.10	0.10−	0.10+	0.10ns	0.10ns	0.10ns	0.10na	0.10+	0.10ns	0.10ns	0.10ns
	0.20	0.20ns	0.20ns	0.20ns	0.20ns	0.20ns	0.20na	0.20+	0.20+	0.20ns	0.20−
	0.30	0.30ns	0.30+	0.30ns	0.30ns	0.30ns	0.30ns	0.30+	0.30+	0.30−	0.30−
	0.40	0.40ns	0.40ns	0.40ns	0.40ns	0.40ns	0.40na	0.40	0.40+	0.40ns	0.40−
	0.50	0.50+	0.50ns	0.50ns	0.50ns	0.50ns	0.50na	0.50+	0.50+	0.50ns	0.50−
	0.60	0.60+	0.60ns	0.60ns	0.60ns	0.60ns	0.60na	0.60+	0.60+	0.60ns	0.60−
	070	0.70+	0.70ns	0.70ns	0.70ns	0.70ns	0.70na	0.70+	0.70+	0.70ns	0.70−
	0.80	0.80+	0.80−	0.80ns	0.80ns	0.80+	0.80na	0.80+	0.80+	0.80ns	0.80−
	0.90	0.90+	0.90−	0.90ns	0.90ns	0.90ns	0.90na	0.90+	0.90+	0.90ns	0.90−
	0.95	0.95+	0.95−	0.95+	0.95+	0.95ns	0.95	0.95na	0.95+	0.95+	0.95−

Notes: −: negative, +: positive, ns: not significant.

Table 5. ARDL and QARDL model estimation results.

Without Quantiles		Model 1a: ARDL			Model 2a: ARDL			Model 3a: ARDL		
	λ	−0.0031	(0.0005)	***	−0.0031	(0.0005)	***	−0.0085	(0.0020)	***
	ψ_1	0.0000	(0.0000)	***	0.0002	(0.0001)	**	0.0001	(0.0001)	**
	ψ_2	−0.5880	(0.2707)	**	−190.0921	(114.7104)	*	0.0000	(0.0000)	ns
	ψ_3	−0.0140	(0.3698)	ns	−6.7727	(95.8411)	ns	158.2198	(316.9364)	ns
	ψ_4	0.0582	(0.0301)	*	18.6244	(5.7219)	***	21.6043	(6.4183)	***
	Γ	0.0194	(0.0137)	ns	0.0194	(0.0137)	ns	na	(na)	na
	Λ_1	0.0000	(0.0000)	***	0.0000	(0.0000)	***	0.0000	(0.0000)	***
	Λ_2	−12.2745	(1.1782)	***	−12.2754	(1.1782)	***	0.0000	(0.0000)	***
	Λ_3	na	(na)	na	na	(na)	na	na	(na)	na
	Λ_4	0.6919	(0.4550)	ns	0.6916	(0.4550)	ns	2.7082	(0.9212)	***
$\tau = 0.05$		Model 1b: QARDL			Model 2b: QARDL			Model 3b: QARDL		
	λ	−0.0091	(0.0008)	***	−0.0090	(0.0008)	***	−0.0096	(0.0020)	***
	ψ_1	−0.0001	(0.0000)	***	−0.0001	(0.0000)	***	0.0000	(0.0001)	ns
	ψ_2	−625.1724	(99.7463)	***	−635.9955	(106.7249)	***	0.0000	(0.0000)	**
	ψ_3	96.2496	(14.2797)	***	75.4892	(10.1315)	***	−320.9575	(457.7866)	ns
	ψ_4	−0.0076	(1.3306)	ns	−0.7529	(1.2711)	ns	6.1906	(6.75299)	ns
	Γ	0.0596	(0.0153)	***	0.0598	(0.0143)	***	0.0000	(0.0000)	na
	Λ_1	0.0000	(0.0000)	***	0.0000	(0.0000)	***	0.0000	(0.0000)	ns
	Λ_2	−13.1838	(2.3895)	***	−13.0549	(2.4004)	***	0.0000	(0.0000)	ns
	Λ_3	6.7089	(6.9700)	ns	6.8517	(5.9510)	ns	−32.9425	(52.2245)	ns
	Λ_4	−1.9769	(0.7194)	***	−1.9978	(0.7148)	***	0.1540	(0.8192)	ns
$\tau = 0.10$		Model 1b: QARDL			Model 2b: QARDL			Model 3b: QARDL		
	λ	−0.0091	(0.0007)	***	−0.0089	(0.0007)	***	−0.0033	(0.0011)	***
	ψ_1	0.0000	(0.0000)	***	0.0000	(0.0000)	***	−0.0002	(0.0003)	ns
	ψ_2	−268.3560	(68.5333)	***	−287.6221	(74.7255)	***	0.0000	(0.0000)	ns
	ψ_3	80.3394	(11.6796)	***	61.7898	(8.9923)	***	−1352.4067	(1396.7083)	ns
	ψ_4	4.5610	(1.3664)	***	3.9313	(1.4113)	***	6.2775	(13.2861)	ns
	Γ	0.0312	(0.0350)	ns	0.0324	(0.0358)	ns	0.0000	(0.0000)	na
	Λ_1	0.0000	(0.0000)	***	0.0000	(0.0000)	***	0.0000	(0.0000)	***
	Λ_2	−8.5568	(2.2496)	***	−8.9839	(2.3565)	***	0.0000	(0.0000)	ns
	Λ_3	7.2830	(4.4855)	ns	5.8403	(3.5094)	*	−29.7635	(22.6166)	ns
	Λ_4	−2.8704	(0.7571)	***	−2.8699	(0.7753)	***	−0.5686	(0.6729)	ns
$\tau = 0.20$		Model 1b: QARDL			Model 2b: QARDL			Model 3b: QARDL		
	λ	−0.0061	(0.0005)	***	−0.0061	(0.0005)	***	−0.0008	(0.0015)	ns
	ψ_1	0.0000	(0.0000)	***	0.0000	(0.0000)	***	−0.0004	(0.1179)	ns
	ψ_2	−94.4184	(31.9482)	***	−98.0361	(34.0847)	***	0.0000	(0.0000)	ns
	ψ_3	65.3630	(15.3118)	***	48.5001	(11.4353)	***	−8002.6262	(1,784,809.3211)	ns
	ψ_4	3.3773	(1.7672)	*	2.8435	(1.7620)	ns	84.8871	(15,458.8456)	ns
	Γ	−0.0091	(0.0460)	ns	−0.0091	(0.0459)	ns	0.0000	(0.0000)	na
	Λ_1	0.0000	(0.0000)	ns	0.0000	(0.0000)	ns	0.0000	(0.0000)	***
	Λ_2	−1.7406	(0.9722)	*	−1.7915	(1.0068)	*	0.0000	(0.0000)	**
	Λ_3	2.1328	(2.0467)	ns	1.6429	(1.4873)	ns	−17.8438	(18.1064)	ns
	Λ_4	−4.5859	(0.4401)	***	−4.6118	(0.4352)	***	−1.8259	(0.5528)	***
$\tau = 0.30$		Model 1b: QARDL			Model 2b: QARDL			Model 3b: QARDL		
	λ	−0.0035	(0.0003)	***	−0.0034	(0.0003)	***	0.0004	(0.0006)	ns
	ψ_1	0.0000	(0.0000)	***	0.0000	(0.0000)	***	0.0009	(0.0012)	ns
	ψ_2	−46.6534	(11.6021)	***	−47.7835	(12.3569)	***	0.0000	(0.0000)	ns
	ψ_3	52.4636	(10.7470)	***	38.1963	(7.7186)	***	15,066.7049	(13,508.6692)	ns
	ψ_4	7.1941	(2.1523)	***	6.5759	(2.2038)	***	−73.5517	(119.3130)	ns
	Γ	0.0148	(0.0513)	ns	0.0146	(0.0513)	ns	0.0000	(0.0000)	ns
	Λ_1	0.0000	(0.0000)	*	0.0000	(0.0000)	*	0.0000	(0.0000)	***
	Λ_2	−0.3399	(0.3409)	ns	−0.3396	(0.3397)	ns	0.0000	(0.0000)	***
	Λ_3	1.6823	(0.6403)	***	0.9581	(0.3801)	**	−41.8760	(21.2461)	**
	Λ_4	−3.6634	(0.5204)	***	−3.6920	(0.5294)	***	−1.3594	(0.4389)	***

Table 5. *Cont.*

		Model 1b: QARDL			Model 2b: QARDL			Model 3b: QARDL		
$\tau = 0.40$	λ	−0.0005	(0.0002)	ns	−0.0005	(0.0002)	**	0.0005	(0.0003)	ns
	ψ_1	0.0000	(0.0003)	ns	0.0000	(0.0001)	ns	0.0005	(0.0021)	ns
	ψ_2	−61.8681	(2100.8489)	ns	−62.2110	(809.5235)	ns	0.0000	(0.0000)	ns
	ψ_3	42.1970	(856.1632)	ns	33.1533	(244.5699)	ns	4355.7234	(12,345.5659)	ns
	ψ_4	15.2560	(108.8934)	ns	15.0664	(43.3401)	ns	−27.1676	(59.2556)	ns
	Γ	0.0025	(0.0089)	ns	0.0026	(0.0089)	ns	0.0000	(0.0000)	na
	Λ_1	0.0000	(0.0000)	*	0.0000	(0.0000)	*	0.0000	(0.0000)	***
	Λ_2	−0.1058	(0.1889)	ns	−0.1051	(0.1895)	ns	0.0000	(0.0000)	***
	Λ_3	0.3701	(0.2627)	ns	0.2552	(0.2014)	ns	−10.2195	(8.4246)	ns
	Λ_4	−0.4836	(0.2510)	*	−0.4865	(0.2546)	*	−0.5887	(0.2303)	***
		Model 1b: QARDL			Model 2b: QARDL			Model 3b: QARDL		
$\tau = 0.50$	λ	0.0000	(0.0000)	ns	0.0000	(0.0000)	ns	0.0008	(0.0004)	***
	ψ_1	0.0002	(0.0043)	ns	0.0002	(0.0006)	ns	−0.0003	(0.0008)	ns
	ψ_2	136.2309	(1821.7047)	ns	53.5214	(447.7035)	ns	0.0000	(0.0000)	ns
	ψ_3	−2420.7751	(49,854.9922)	ns	−1628.6003	(3897.4219)	ns	1072.9241	(830.7986)	ns
	ψ_4	−86.3550	(2141.6467)	ns	−62.0560	(170.8145)	ns	−13.1955	(14.8330)	ns
	Γ	0.0002	(0.0007)	ns	0.0001	(0.0007)	ns	0.0000	(0.0000)	na
	Λ_1	0.0000	(0.0000)	ns	0.0000	(0.0000)	ns	0.0000	(0.0000)	***
	Λ_2	0.1064	(0.1185)	ns	0.0966	(0.1148)	ns	0.0000	(0.0000)	***
	Λ_3	−0.0007	(0.1558)	ns	0.0099	(0.1201)	ns	−0.1949	(7.6831)	ns
	Λ_4	−0.0560	(0.0245)	**	−0.0501	(0.0218)	**	−0.3747	(0.1228)	***
		Model 1b: QARDL			Model 2b: QARDL			Model 3b: QARDL		
$\tau = 0.60$	λ	0.0011	(0.0002)	***	0.0011	(0.0002)	***	0.0014	(0.0006)	**
	ψ_1	0.0000	(0.0000)	**	0.0000	(0.0000)	**	−0.0005	(0.0005)	ns
	ψ_2	6.6603	(7.1331)	ns	9.8621	(7.3743)	ns	0.0000	(0.0000)	ns
	ψ_3	−168.7485	(41.1448)	***	−126.5757	(29.8815)	***	100.2626	(730.6826)	ns
	ψ_4	−9.2531	(5.8079)	ns	−8.1305	(5.4618)	ns	−7.6643	(14.3901)	ns
	Γ	0.0218	(0.0330)	ns	0.0223	(0.0330)	ns	0.0000	(0.0000)	na
	Λ_1	0.0000	(0.0000)	ns	0.0000	(0.0000)	ns	0.0000	(0.0000)	***
	Λ_2	0.4195	(0.2146)	*	0.4370	(0.2138)	**	0.0000	(0.0000)	***
	Λ_3	−0.6193	(0.5762)	ns	−0.3986	(0.4305)	ns	5.1340	(12.5056)	ns
	Λ_4	−2.7744	(0.7777)	***	−2.8112	(0.7718)	***	−1.1832	(0.5702)	**
		Model 1b: QARDL			Model 1b: QARDL			Model 1b: QARDL		
$\tau = 0.70$	λ	0.0033	(0.0004)	***	0.0033	(0.0004)	***	0.0039	(0.0009)	***
	ψ_1	0.0000	(0.0000)	*	0.0000	(0.0000)	*	−0.0003	(0.0002)	ns
	ψ_2	−13.9384	(7.6540)	*	−13.2322	(7.5925)	*	0.0000	(0.0000)	ns
	ψ_3	−25.2990	(14.0431)	*	−18.4987	(10.1368)	*	−354.3237	(343.0140)	ns
	ψ_4	−3.2228	(2.1915)	ns	−3.0256	(2.1309)	ns	5.0584	(8.9398)	ns
	Γ	0.0460	(0.0538)	ns	0.0461	(0.0539)	ns	0.0000	(0.0000)	na
	Λ_1	0.0000	(0.0000)	ns	0.0000	(0.0000)	ns	0.0000	(0.0000)	***
	Λ_2	0.6884	(0.3209)	**	0.6949	(0.3236)	**	0.0000	(0.0000)	***
	Λ_3	0.2780	(0.4976)	ns	0.2002	(0.3241)	ns	30.6142	(34.4622)	ns
	Λ_4	−5.1948	(0.5737)	***	−5.1880	(0.5706)	***	−2.3500	(0.4783)	***
		Model 1b: QARDL			Model 2b: QARDL			Model 3b: QARDL		
$\tau = 0.80$	λ	0.0062	(0.0005)	***	0.0061	(0.0005)	***	0.0064	(0.0013)	***
	ψ_1	0.0000	(0.0000)	**	0.0000	(0.0000)	**	−0.0003	(0.0001)	***
	ψ_2	−86.0690	(37.3402)	**	−86.6570	(37.3670)	**	0.0000	(0.0000)	ns
	ψ_3	9.2518	(9.6000)	ns	6.4761	(7.0347)	ns	−535.6187	(349.3986)	ns
	ψ_4	−1.1405	(1.6788)	ns	−1.3071	(1.6462)	ns	14.4847	(4.8126)	***
	Γ	0.0639	(0.0437)	ns	0.0636	(0.0440)	ns	0.0000	(0.0000)	na
	Λ_1	0.0000	(0.0000)	ns	0.0000	(0.0000)	ns	0.0000	(0.0000)	***
	Λ_2	2.1543	(1.5365)	ns	2.1281	(1.5272)	ns	0.0000	(0.0000)	**
	Λ_3	0.0551	(1.5200)	ns	−0.2263	(0.9234)	ns	52.4449	(50.5133)	ns
	Λ_4	−6.2178	(0.5041)	***	−6.2135	(0.5069)	***	−2.2401	(0.6048)	***

Table 5. *Cont.*

		Model 1b: QARDL			Model 2b: QARDL			Model 3b: QARDL		
$\tau = 0.90$	λ	0.0082	(0.0010)	***	0.0081	(0.0010)	***	0.0070	(0.0017)	***
	ψ_1	−0.0001	(0.0000)	***	−0.0001	(0.0000)	***	−0.0003	(0.0001)	***
	ψ_2	−434.3892	(101.4838)	***	−436.5584	(101.9626)	***	0.0000	(0.0000)	ns
	ψ_3	16.4573	(16.4401)	ns	12.9699	(11.5915)	ns	−528.3017	(635.9480)	ns
	ψ_4	−2.9852	(2.7999)	ns	−3.0761	(2.6946)	ns	4.0422	(7.5342)	ns
	Γ	0.1327	(0.0411)	***	0.1321	(0.0416)	***	0.0000	(0.0000)	na
	Λ_1	0.0000	(0.0000)	***	0.0000	(0.0000)	***	0.0000	(0.0000)	***
	Λ_2	7.6953	(1.7939)	***	7.6762	(1.7386)	***	0.0000	(0.0000)	**
	Λ_3	1.8638	(5.4757)	ns	1.2123	(4.2727)	ns	51.2780	(40.8789)	ns
	Λ_4	−6.9047	(0.7826)	***	−6.8943	(0.7784)	***	−3.1123	(0.8836)	***
		Model 1b: QARDL			Model 2b: QARDL			Model 3b: QARDL		
$\tau = 0.95$	λ	0.0110	(0.0010)	***	0.0110	(0.0010)	***	0.0144	(0.0012)	***
	ψ_1	−0.0001	(0.0000)	***	−0.0001	(0.0000)	***	−0.0002	(0.0000)	***
	ψ_2	−503.8702	(89.6625)	***	−500.2626	(87.4982)	***	0.0000	(0.0000)	***
	ψ_3	−6.5853	(18.6921)	ns	−3.3152	(13.4342)	ns	168.2680	(77.8569)	**
	ψ_4	−4.1966	(2.6128)	ns	−4.0833	(2.2971)	*	0.4519	(2.9035)	ns
	Γ	0.1491	(0.0471)	***	0.1490	(0.0450)	***	0.0000	(0.0000)	na
	Λ_1	0.0000	(0.0000)	***	0.0000	(0.0000)	***	0.0000	(0.0000)	***
	Λ_2	5.9545	(2.6093)	**	6.0218	(2.5140)	**	0.0000	(0.0000)	ns
	Λ_3	6.4920	(6.9530)	ns	4.7327	(6.0444)	ns	77.1439	(37.3265)	**
	Λ_4	−7.9587	(0.9431)	***	−7.9473	(0.9277)	***	−4.6852	(0.7610)	***

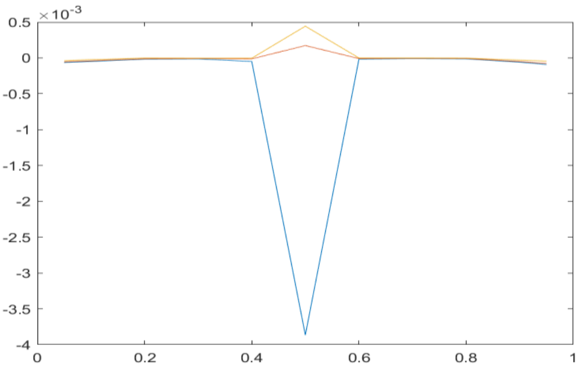
ns: not significant; *** significant at the 1% level, ** significant at the 5% level, * significant at the 10% level.

Table 6. Graphs for Model 1b: (*USDBASD FOREXBV MAV RIO PINDICE*), for Model 2b: (*USDBASD FOREXBV MAV AFO PINDICE*), and for Model 3b: (*USDBASD FOREXBV COND ONW PINDICE*).

Graphs for Model 1b: (*USDBASD FOREXBV MAV RIO PINDICE*)

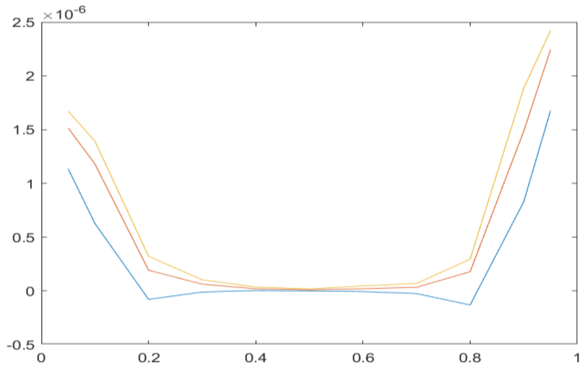
Long-Run Parameters

Panel A: *FOREXBV*

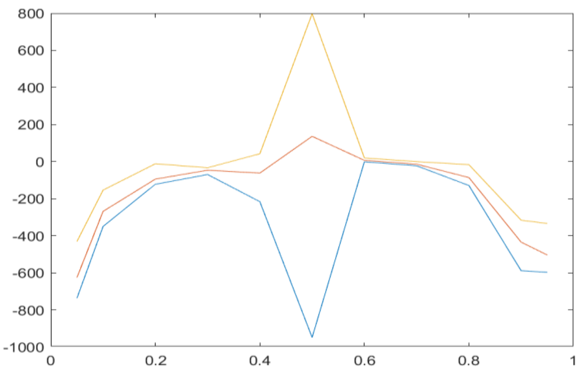


Short-Run Parameters

Panel E: *FOREXBV*



Panel B: *MAV*



Panel F: *MAV*

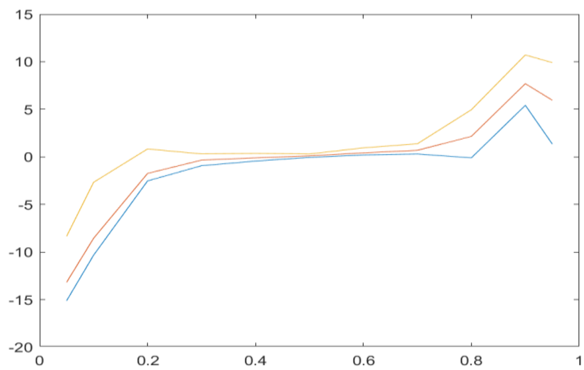
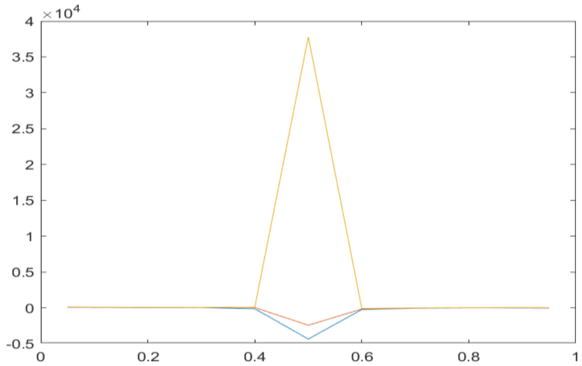
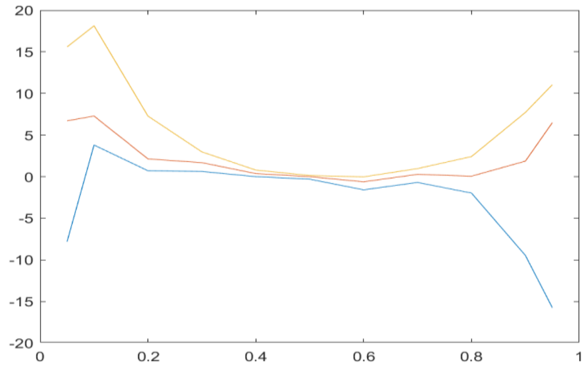


Table 6. *Cont.*

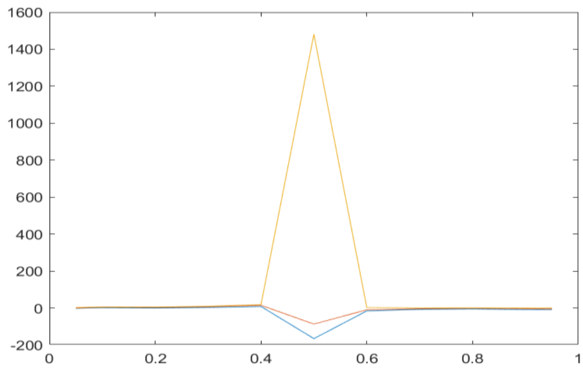
Panel C: *RIO*



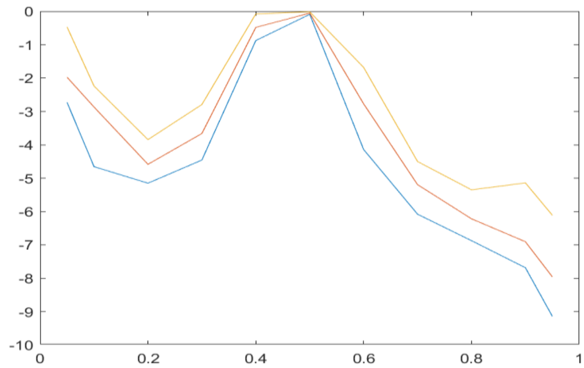
Panel G: *RIO*



Panel D: *PINDICE*



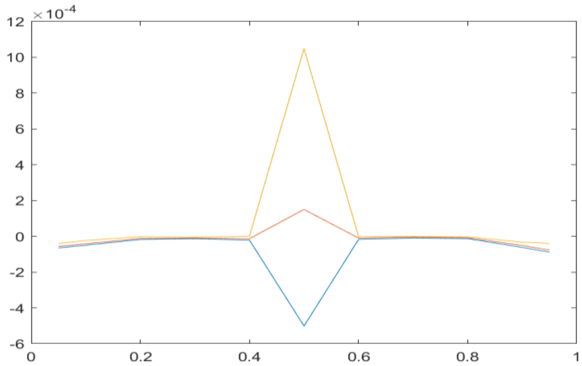
Panel H: *PINDICE*



Graphs for Model 2b: (*USDBASD FOREXBV MAV AFO PINDICE*)

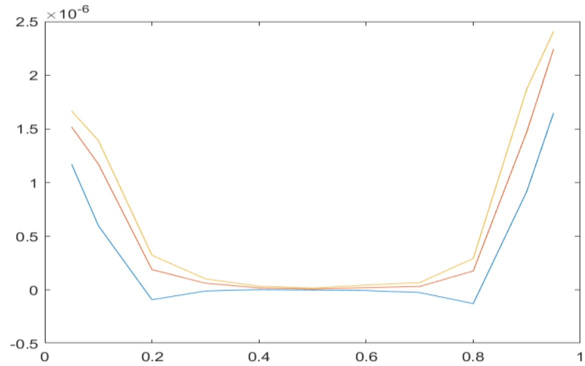
Long-Run Parameters

Panel A: *FOREXBV*

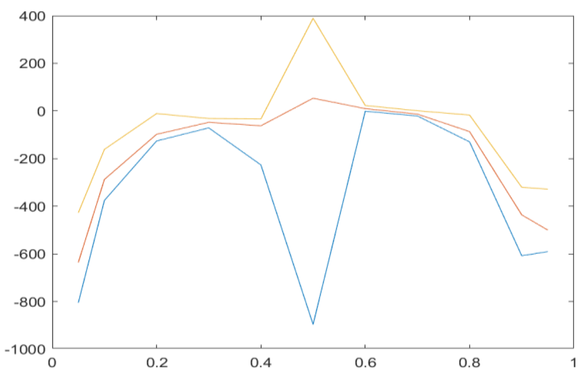


Short-Run Parameters

Panel E: *FOREXBV*



Panel B: *MAV*



Panel F: *MAV*

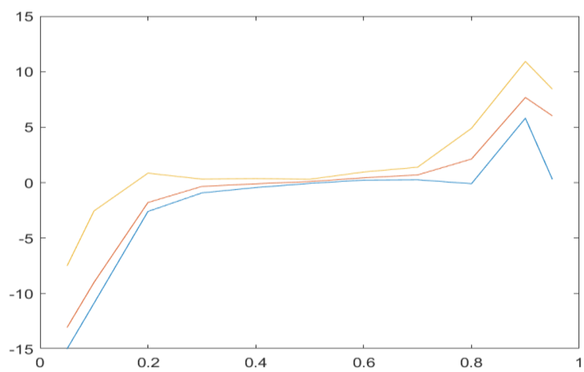
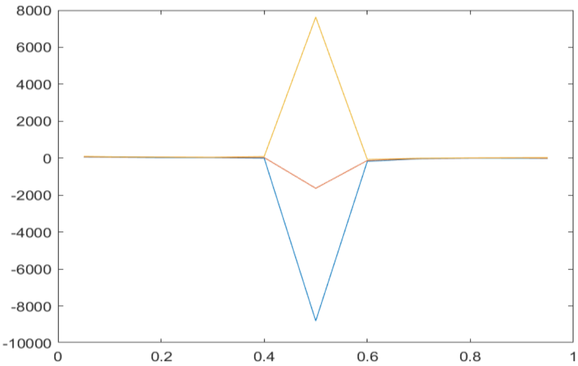
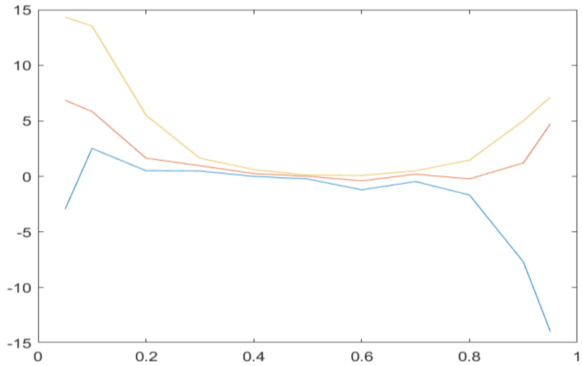


Table 6. *Cont.*

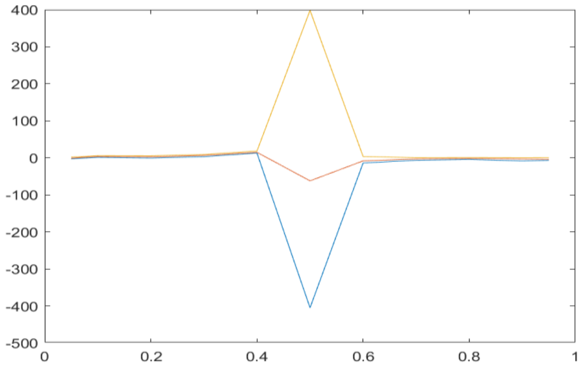
Panel C: *AFO*



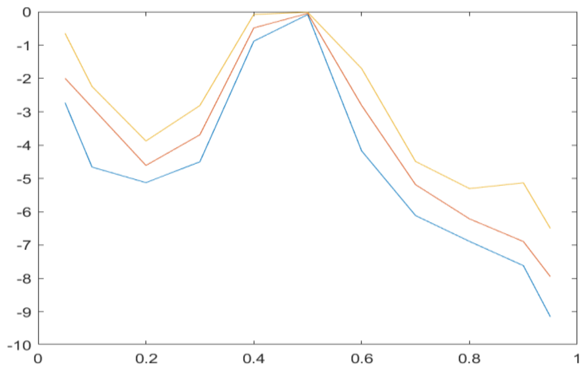
Panel G: *AFO*



Panel D: *PINDICE*



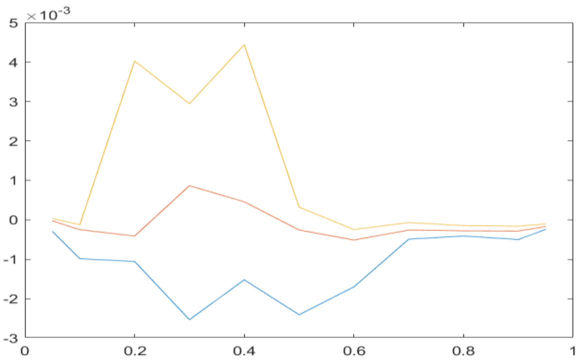
Panel H: *PINDICE*



Graphs for Model 3b: (*USDBASD FOREXBV COND ONW PINDICE*)

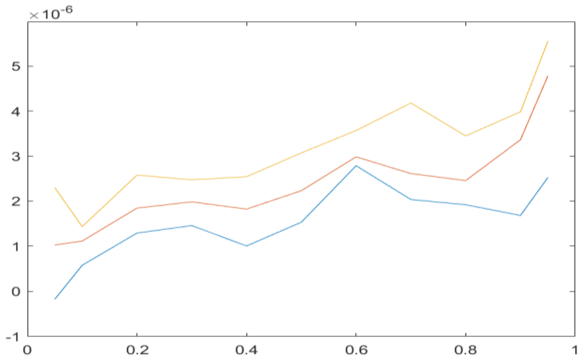
Long-Run Parameters

Panel A: *FOREXBV*

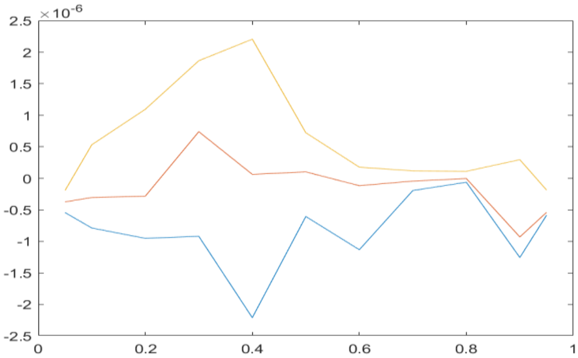


Short-Run Parameters

Panel E: *FOREXBV*



Panel B: *COND*



Panel F: *COND*

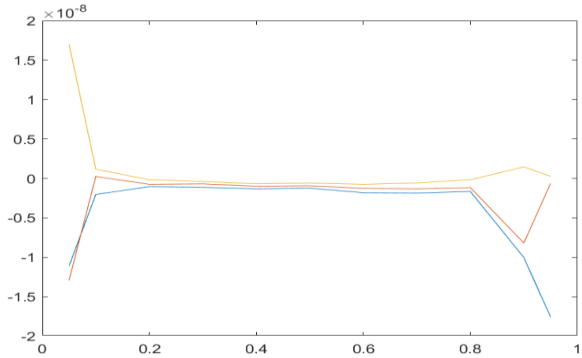
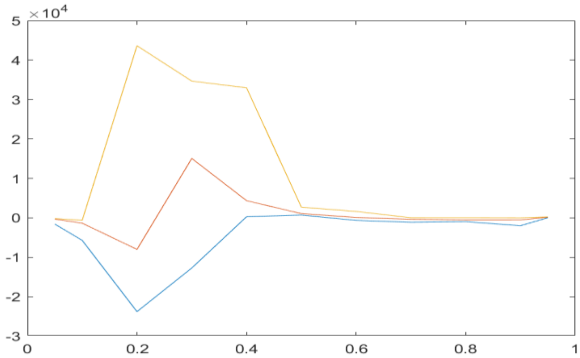
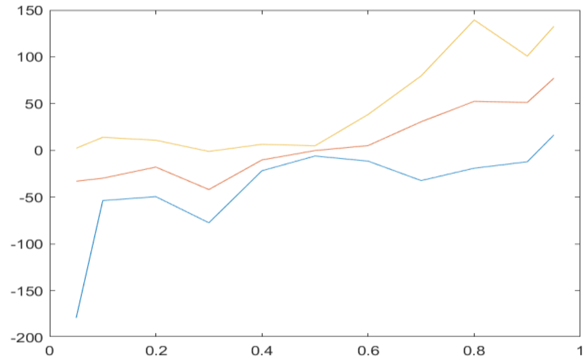


Table 6. *Cont.*

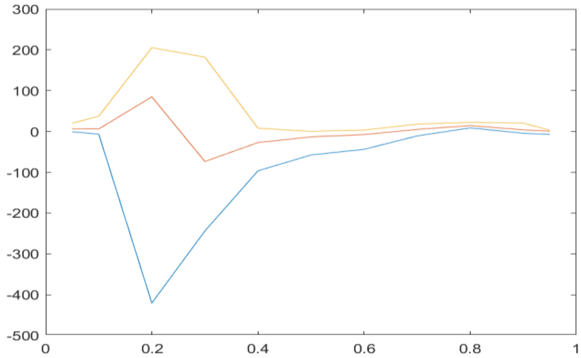
Panel C: *ONW*



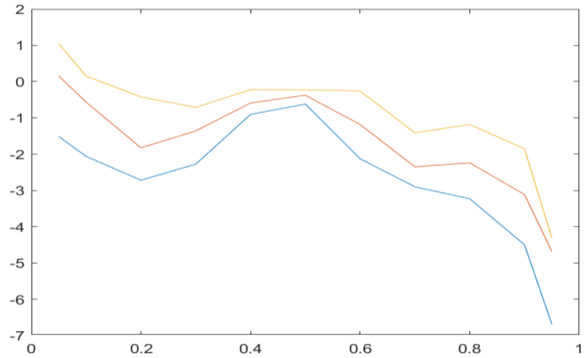
Panel G: *ONW*



Panel D: *PINDICE*



Panel H: *PINDICE*



Notes: yellow line: 95% confidence level estimates of the parameters, orange line: parameter estimates, blue line: 5% confidence level estimates of the parameters.

Establishing a cointegration is essential to be able to present long-run associations. The *F*-Bounds test results for the three models were statistically significant, allowing us to investigate possible long-run and short-run relationships between independent and dependent variables. Following the work of Sun et al. (2021a), we applied Granger causality and Johansen cointegration tests. There was a cointegration relationship between the variables for the two specifications. The Johansen cointegration test allowed us to strengthen our choice of selecting QARDL in regard to ARDL since it gave less than three cointegration relationships due to possible nonlinearity in the data. We rejected the null of no causality for the independent variables *FOREXBV* and *COND*. The Granger causality test results provided us insight into the direction of the relationship among variables.

Testing the transition among terms were executed by the error correction term (λ), and it should be significantly negative in the QARDL model; moreover, it may catch cointegration in heterogeneous quantiles, as mentioned by Solarin and Bello (2020). It was significantly negative for all ARDL models: Model 1b: QARDL (1, 2, 3, 4) and Model 2b: QARDL model (1, 2, 3, 4, 5), including Model 3b: QARDL (1, 2). Corresponding with long-run and short-run coefficients in the models, the first four were for the long run and the latter five coefficients were for the short run. ψ_1 was significantly positive for the ARDL models, yet we could obtain negative coefficients for the quantiles of Model 1b: QARDL (1, 10, 11), and the lowest and highest quantiles for Model 2b: QARDL (1, 10, 11) and Model 3b: QARDL (9, 10, 11). ψ_2 was negative for Model 1a: ARDL, Model 2a: ARDL, Model 1b: QARDL (1, 2, 3, 4, 8, 9, 10, 11), and Model 2b: QARDL (1, 2, 3, 4, 8, 9, 10, 11) specification but positive for Model 3b: QARDL (1, 11).

ψ_3 was not statistically significant for ARDL models, although it looked positive for Model 1b: QARDL (1, 2, 3, 4), Model 2b: QARDL (1, 2, 3, 4), and Model 3b: QARDL (11).

ψ_4 was positive for all ARDL specifications along with Model 1b: QARDL (2, 3, 4), Model 2b: QARDL (2, 4), and Model 3b: QARDL (9).

As for the short-run parameters, Λ_1 was positive for all ARDL specifications, and none of the QARDL models had a negative result. Λ_2 was positive for Model 3a: ARDL, Model 1b: QARDL (7, 8, 10, 11), Model 2b: QARDL (5, 7, 8, 10, 11), and for almost all of Model 3b: QARDL (3, 4, 5, 6, 7, 8, 9, 10). Λ_3 was not statistically significant for the ARDL models but was statistically positive for Model 1b: QARDL (4), Model 2b: QARDL (2, 3, 4), and Model 3b: QARDL (11). On the other hand, Λ_4 was only positive for Model 3a: ARDL.

Considering Table 5, some information about the aberrations are provided: ns: not significant; na: not applicable; Coeff: coefficient; λ: ECM coefficient; ψ_1: long-run coefficient (volume); ψ_2: long-run coefficient (volatility); ψ_3: long-run coefficient (interest rate); ψ_4: long-run coefficient (stock prices); Γ: momentum; Λ_1: impact reaction parameter (volume); Λ_2: impact reaction parameter (volatility); Λ_3: impact reaction parameter (interest rate); Λ_4: impact reaction parameter (stock prices). F-Bounds test results were as follows: 6.7224 ***, 6.7231 ***, 3.6095 ***, respectively, for Models 1, 2, and 3. The sample periods were 28 September 1990–1 August 2022, 28 September 1990–1 August 2022, and 3 January 2011–1 August 2022, respectively, for Models 1, 2, and 3. Selected lag specification of ARDL models by Schwarz information criterion were (2, 3, 4, 0, 3), (2, 3, 4, 0, 3), and (1, 2, 6, 0, 3), respectively, for Models 1, 2, and 3. The standard errors are provided in parentheses.

The Wald test is based on the chi-squared distribution and used to test whether the parameters are the same or not. Rejecting the null of this test provides an asymmetry among short-run and long-run parameters in each quantile. The Wald test is designed to analyze the equality of each coefficient in different quantiles for the long run and short run. Therefore, if the null of equality is rejected, we may claim that the effect of that variable on the spread is heterogeneous or asymmetric. The Wald statistics for the Models 1b, 2b, and 3b rejected the null hypothesis that indicates asymmetry within short-run and long-run coefficients in different quantiles. Therefore, the estimated coefficients, which distorted the linearity condition of some previous methods, were not found to be consistent in the sample.

The results are in line with the preceding literature. Our results are proof of higher marginal effects in higher quantiles compared to lower bounds. This finding is common in the literature provided by Mensi et al. (2019) who utilized the QARDL model to prove that interest rate and volatility have a higher positive effect on the credit risk in the upper quantiles. Considering the variables in the academic literature, we found several studies that are consistent with and supportive for our findings: for negative sign of volume (see Boothe 1988; Copeland and Galai 1983; Ding 1999; Becker and Sy 2006), for positive sign of volatility (see Bessembinder 1994; Bollerslev and Melvin 1994; Jorion 1995; Ding 1999; Huang and Masulis 1999; Hartmann 1998; Khemraj and Pasha 2008; Melvin and Taylor 2009)[8], and for positive sign of interest rate (Becker and Sy 2006) in the foreign exchange rate bid–ask spread.

4. Discussion

The aim of this paper was to estimate the macroeconomic and financial determinants of the bid and ask exchange rate spread for Türkiye using a nonlinear method, namely, the QARDL model. The overall results of our study had two significant indications related to Türkiye's economy. First, macroeconomic and financial variables had an influence on the USD/TL bid–ask spread. Second, these variables were affected by quantiles, and they exhibited asymmetry. As follows, we discuss what the results imply in an economic sense and why they matter to the financial sector via an interpretation of the estimated coefficients of the error correction term such as volume, volatility, interest rate, and stock prices.

In our investigation, the error correction term depicts a convergence of the long-term equilibrium, and its sign turned out to be positive in upper quantiles, demonstrating an asymmetry. Therefore, the linear model's negative coefficient may vary in different locations. The expected negative effect of the second coefficient, the volume, at the tails can be explained with transaction costs.[9] If the bid–ask spread was moderate, the possibility of the foreign exchange market's efficacy would be higher, transaction costs would be lower, and its movement would readily turn to its mean. However, if the spread was at the marginal state with an extreme level, persistent behavior would create a case of not all rises and inefficiency due to transaction costs. Our findings indicate that the linear model may be misleading, and the sign of the coefficient may turn negative for different coefficients in the long run. The high volume of transactions would lower the spread, and thus the low transaction cost might be a source of stability. Moreover, the same point load might decrease the spread when the spread level is highest and lowest. In the short run, since it is not easy to lower these costs, non-negative coefficients may exist due to the inefficiency and rigidities in the foreign exchange market.

Considering the volatility, although the ARDL model results were negative or not significant, we may obtain a positive coefficient in marginal quantiles in the long run and in certain quantiles in the short run. As Galati (2000, p. 2) underlined, inventory costs and exchange rate volatility had a positive relationship, but the trading volume did not have a significant effect on spreads. Moreover, the volatility widening spreads led to an increase in the price risk.[10] Our study utilized basic sciences to interpret and explain these findings.

Analogically, physics and economics have some common behavioral properties, especially considering volatile movements. In the foreign exchange rate market, actors may act individually, and the system may be heterogeneous.[11] This can be interrelated with the physics of Eric A. Cornell, Wolfgang Ketterie, and Wieman Carl E., who were awarded the Nobel Prize for their findings and who produced a Bose–Einstein concentration by cooling atoms with a laser light.[12] If we could reach the same line and the difference between two data points shrinking to zero, then we would obtain a case like the Bason–Einstein concentration. Meanwhile, the probability of the bid–ask spread of being zero depends on different situations and determinants. As a matter of fact, bid and ask are at distinguishable levels, for ask is generally higher than bid. However, as the Bose–Einstein concentration proved, individuals may act within the system, thus turning into a homogeneous actor. This stationary point may be reacted with a natural or an artificial reaction. The possibility of obtaining a natural stationary behavior appears, but there might be counteraction because of external interventions such as the central bank that sells and buys foreign currency in the market. In Bose–Einstein concentration, this point is zero where the atoms become stationary. In the exchange rate market, on the other hand, this equilibrium point may vary in the meantime, depending on either state or time. During periods of high volatility, because one expects high uncertainty, the asymmetric information increases and the asymmetric cost stimulates the spread upwards; therefore, it would try to depart from stationarity. In such cases, it is really hard and has a low probability for a spread to move like a Bose–Einstein condensate.

The stability of the local currency in terms of reserve currencies is sought by countries such as Saudi Arabia, which exports oil (Hasanov et al. 2022), as well as oil-dependent countries such as Türkiye. If you have a stable currency, you pursue making more investment in financial and real markets. You calculate your profit in the future easily due to foreign currency earning activities. However, if the stability is low and the volatility of the exchange rate is high, you seek to conduct transactions in the foreign currency market. Therefore, the speculative money demand for foreign currency declines.

The spread becomes narrower in a country where financial markets are regulated well and are deep in value. Narrow spread means less profit for a financial institution, and when a transaction is operated, its profit level becomes restricted. However, a wide spread enables a potential for earning. These spread changes begin especially by the time when there are sudden and unexpected occurrences in the economy, increasing the volatility, as was experienced on 25 June 2022 on a Friday night, when the Banking Regulation Supervision Agency (BRSA) changed the legislation about foreign currency deposits belonging to the firms in Türkiye. It was an attempt to reduce the foreign currency demand. It was timed at the end of the second term of the exchange rate preserving deposits and reduced the

USD/TL to a level of 16.88 TL from 17.35 TL, which was nearly a 3% drop. In this case, the government budget would have been better off while investors would have lost. Actually, analyzing the bid–ask spread is valuable during these actions. When one has a foreign debt, they buy US dollars and increase their money demand for the foreign currency. The low value of the bid price increases one's profit. However, when one wants to sell their available amount of foreign currency, a high ask price stimulates one's profit.

The effect of the currency-protected deposit on the spread was an investment tool designated in 2022 in Türkiye to control the high level of exchange rate and decrease its volatility. It was initially successful in decreasing the rate from 18 USD/TL to 11 USD/TL in the country, yet nearly three months later, we observed similar hikes up to 17.35 TLs. BRSA's regulatory attempt to support decreasing foreign currency demand was also initially successful when it decreased to 16.88 TLs. Economic actors sold their foreign currency in both cases. The BRSA's action forced firms to sell their foreign currency if they wanted to lend TL loans from banks. As a result, the regulation limited TL demand for firms that owned foreign currency deposits. The US dollar was 16.70 USD/TL on 27 June 2022. Firms sold their US dollars, which was followed by a decrease in the exchange rate. This led to the supply for the US dollar going up and the margin to be high again as banks bought the US dollar with a minimum price.

In our analysis, there were several mentions of previous studies that focused on the staggering interest rate. In one of these, which was implemented by Omrane and Savaser (2017), the state dependency of the exchange rate caused by the news about interest rates and new home sales was stressed. In terms of ARDL results, although coefficients were not statistically significant for some of the quantiles, the nonlinear model provided a positive effect in the long run and the short run. That is plausible since interest rate plays a transaction costs role for financial institutions and an opportunity cost, namely, the interest rate, which is the price of money. When the CBRT increases interest rates, the opportunity cost of money also increases. In theory, one would expect capital inflows and appreciation of the local currency. In a floating exchange rate regime, volatility and volume increase at the time of movements. Since interest rates are the costs of the economy, an increase in the cost would stimulate the bid and ask spread. Consequently, bid and ask spread would escalate by high costs to the economy, and these results are consistent with our positive coefficients' findings both in the long run and short run.

Inflationary economic environment is another possible source of the direct effect of interest rates on the spread. It should be highlighted that developing countries have had much more inflation compared to developed countries in the last couple of decades. Therefore, one may expect a higher spread because of higher costs reflected in interest rates. This creates a disadvantage among countries since the ratio of costs to the volume of transactions is expected to be much lower in developed countries. Moreover, some of the costs in developed countries are linked to the exchange rate. For instance, banks usually obtain sources in foreign countries through syndication or lending. Following the major central banks' lending rate hikes, the opportunity costs of banks increased. Gathering liquidity from abroad became harder for the banks in developing countries, and inflation elevated their fixed and variable costs. Contrarily, the transaction volume diminished because of the competition effect on the spread. Therefore, they could not create a scale effect in their foreign currency transactions. For the time being, the foreign currency market in developing countries has started to become more competitive. Moreover, we cannot talk about monopolies without the capability of either price determination or putting their marginal revenue below their average revenue.

In the market, there are numerous players from whom one may obtain information. The equality of the marginal revenue to marginal cost has a higher probability. In the short run, there may be a profit opportunity caused by a high margin, especially in turbulent times. The greater the number of transactions, the higher the profit opportunity, due to the momentary high spread. However, in the long run, actors' profit may decrease due to the lower spread. Therefore, the short-term high spread and transactions in the foreign exchange market are positively related in contrast to the long-term low spread and profit, which are negatively related.

Both linear and nonlinear models provided positive coefficients in the long term. Nevertheless, QARDL results were negative in the short term in nearly all quantiles, making the effect of stock prices return on the bid–ask spread striking, for there was an asymmetry. As was proven by the Gordon growth model, if the economy expands, stock prices increase, and if interest rates increase, the economy shrinks. When the expected return of buying a stock is stimulated, investors buy that stock, and its price moves upward. An increase in stock prices, in turn, would decrease demand for the exchange rate, meaning a higher bid–ask spread. It is also possible that in emerging markets, an increase in stock prices may decrease their expected return along with the demand for them. Additionally, a rise in foreign currency might appear when foreign investors sell the stocks at high prices in order to buy foreign currency, which causes the spread to decrease.

High profit for the banking sector and the central bank is expected if the bid–ask spread increases due to the high margin. However, the profit from transactions will be eliminated when there is no margin, and the bid is equal to the ask. Both the government (because of the tax losses) and the bank (due to foreign exchange transactions) will lose. The negative and positive consequences of eliminating the margin should be discussed among scholars and policymakers. Profit (P) = bid–ask spread (BAS) $\times$ number of transactions (N) $-$ taxes (T) is a function where P depends on BAS and N. The margin may depend on time and the state of the economy. Thus, $BAS = f(M, S)$, where M = time and S = state. $T = N \times t$. t is the tax rate. $P = f(M, S) \times N - N^2 \times t$. In times of economic crisis, the bid–ask spread is expected to increase, but the margin is to be ordinarily lower. Alternatively, the margin may periodically be altered by policymakers. In negative circumstances, the margin may rise, whereas it is lower in positive states. The government may also decide to decrease the profit of intermediate firms by increasing tax rates. The number of transactions changes both the first and second parts of the identity. The second term includes a nonlinear term; thus, the variable may initially increase the profit, and then it may decrease it. For instance, a cost function rises to a certain point, which later decelerates due to diminishing returns. The more the government increases the tax rate, the more the profit of the financial firm decreases. The number of transactions affects the quantity of positive profit to be obtained once the second part of the identity is lower than the profit coming from the bid–ask spread side. The explained identity may be estimated via an appropriate method on the condition that we have convenient data. The movement of the bid–ask spread can be observed temporarily at least by a simple two-dimensional graph where the change during the boom-and-bust periods yields essential information regarding the behavior. Some micro-data about the profit structure might assist in differentiating between the winners in the high margin and low margin. In order to earn a profit from currency transactions, an investor should be able to buy from a low exchange rate but sell it at a high exchange rate. Therefore, the price of the currency should be followed very keenly by the investor, namely, the potential recipient of our recommendations for future research.

Transparency and the liquidity elasticity of the spread: Osterberg (1992) claims that interventions in the foreign exchange market do not cause the exchange rate in terms of Granger causality. As a contribution to Osterberg's observation, the foreign exchange market has the closest comparable market structure to perfect competition and is the most liquid decentralized worldwide market for exchanging currencies. In an extremely large and globalized market, it is a challenge to foresee or provide a detailed explanation, especially for emerging markets that may have a considerable impact on market pricing, currency movements, and political concerns. Banks are heterogeneous in terms of determining their liquidity positions. If one gathers bank-based micro-data of the daily exchange rate and its foreign currency reserves, it is easy to calculate the liquidity elasticity of the spread. Publishing this margin information by the authorities would stimulate competition in the Forex market, and the transparency would let us converge to a more competitive foreign exchange rate market.

In a competitive market, there are a large number of firms and households that cannot affect the level of the exchange rate that is a given price for them. In imperfect markets such as the monopoly, the price is not equal to the marginal cost and the marginal revenue; thus, the profit maximization dynamics are different. Accordingly, the equilibrium exchange rate becomes lower in a competitive market compared to the monopoly, whereas the equilibrium foreign currency quantity becomes higher. Moreover, the margin will be lower in a competitive market as the market is more efficient compared to the monopoly. Because a monopoly bank is expected to determine the limits of the margin, it will have a higher profit.

The role of a financial transaction tax: A bank earns the margin as profit, but this creates a rigidity in the market as transaction cost. The spread sets the cost of transactions and hedging, which has an impact on trade and the efficacy of the policy. It eventually carries substantial real costs to the economy. It is known that a financial transaction tax must be paid when one sells foreign currency. The reason for this is to discourage speculative transactions and unexpectedly high demand for foreign currency. In order to not pay large amounts of tax, an investor makes less transactions and speculative operations. Besides gathering income through taxing welfare, another reason for the government to follow fiscal policy is to decrease the speculative demand for foreign currency. Therefore, transaction tax may be successful if it is high enough. One may conduct behavioral research on the possible consequences of the financial transaction tax on the Forex market to decrease speculative attacks and volatility.

Banking sector profit: The exchange rate movements affect the profitability of the banking sector (see Kaplan 2022, pp. 85–98; Altintas 2021, pp. 235–83 for further on the concepts mentioned and basic risk management methods widely used in the banking sector as a consequence of international regulations). The profit gained via transactions in foreign currency may be a possible source for them. We need individual data to calculate this amount that can be observed in the balance sheets of the banking sector. Accordingly, banks may calculate their profits obtained through currency transactions and present them in their balance sheets.

The findings of the study suggest several implications for policymakers. First, during turbulences, the foreign currency profit of a bank is expected to be affected. While banks increase their spread due to high risk, the transaction volume becomes less. Second, in some countries such as Türkiye, the transmission of exchange rate to inflation rate is high; thus, it is closely scrutinized by the policymakers. In order to handle the issue of high inflation, Türkiye adopted a fixed exchange rate regime for the pre-2002 period, just before the 2001 economic and financial crisis, yet the attempt was not successful. Delivering lessons from mistakes, during the post-2005 period, the CBRT adopted an inflation-targeting regime with a floating exchange rate, and the bid–ask spread became critical as a consequence of the high volume of the exchange rate and its volatility.[13] Especially in economics, since different types of topics require different bounds of the margin, economic actors focus on this margin either for a transaction, a speculative motivation, or an obligatory situation. For instance, the bid exchange rate is used to calculate the account balance in the currency-protected deposit. If vadium vivum in terms of foreign currency is established, CBRT's bid price at the time of transaction is taken as a basis. It is an alternative for countries such as Türkiye to prefer the bid rate in accounting during transactions about bookkeeping. Third, the level of spread impacts the economic situation of the actors, which may also disturb the income distribution and the deadweight loss. Moreover, the high spread may lead financial actors to behave speculatively and try to use arbitrage opportunities, which exacerbates the demand for the foreign currency that generates inefficiency. It appears to be efficacious to lower the demand for lessening the speculative transactions. In conclusion, it is our recommendation to determine the macroeconomic and financial factors impacting the margin so that the high and inefficient spread problem along with the welfare loss can be solved.

5. Conclusions

The probability of being positive of a point in the bid–ask spread area is restricted. The equality of these two lines' starting points makes the probability of being equal null. This probability depends on the positive distance between these two lines, wherein the latter is assumed to be above the first. In the quantile regression model, the point moves within the area, and the spread will be stochastic where each independent variable influences it heterogeneously. The macroeconomic and financial variables stimulate high and low values. High values represent the inefficient area, and low values represent the efficiency.

In accordance with the estimations in our analysis, the error correction term was significantly negative for all autoregressive distributed lag (ARDL) models but turned out to positive for the upper quantiles of QARDL models. In the long term, the coefficients for the volume were positive for ARDL models, although negative coefficients may be obtained for the highest and lowest quantiles for QARDL models. The volatility impacted some ARDL models negatively, yet it became positive in marginal quantiles for QARDL models. While the effect of interest rate was not statistically significant for ARDL models, it was positive for some quantiles of the QARDL models. As for the stock prices, they positively impacted all ARDL models, along with some quantiles of the QARDL models. The volume effect was positive for all ARDL specifications in terms of the short-term coefficients, and none of the QARDL models displayed a negative result. The volatility's coefficient was positive for one ARDL specification and several quantiles of the QARDL models. Additionally, the interest rate's coefficient was not statistically significant for the ARDL models but was significantly positive for some quantiles of the QARDL. The effect of the stock prices was only positive for one ARDL model was and mostly negative in the QARDL models. More importantly, these results may be different from the linear model and change in terms of the location, which indicates that the volume reduces the spread, whereas volatility and interest rates boost it in the long term for some quantiles. Stock prices stimulate in the long run but diminish in the short run, which suggests an asymmetry. Taking into consideration the previous literature analyzing the relationship via linear methods, this paper used a QARDL model to explore location and sign asymmetry for some quantiles. Our analysis is important as it revealed that it is possible to control efficiency in bid–ask exchange rate spread whose extreme levels and asymmetry should be taken into account for a good evaluation of its penetrating macro-financial variates.

Author Contributions: Conceptualization, G.S. and A.S.; methodology, G.S. and A.S.; software, G.S. and A.S.; validation, G.S. and A.S.; formal analysis, G.S. and A.S.; writing—review and editing, G.S. and A.S.; visualization, G.S. and A.S. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: Not applicable.

Acknowledgments: We would like to thank Jin Seo Cho, School of Economics, Yonsei University, Republic of Korea, and Sangwoo Park for allowing us to use MATLAB computer software codes for the QARDL model and providing support and information during the QARDL model estimation phase. We also acknowledge Hilal Sengenc, School of Foreign Languages, Ege University, Izmir, Türkiye, for valuable suggestions during the English language editing phase of the paper.

Conflicts of Interest: The authors declare no conflict of interest.

Notes

1 There are different ways to represent the market mechanism for foreign currency. For instance, Mankiw (2019, pp. 152–58) used net exports to represent the demand side and net savings for the supply side. Therefore, the real exchange rate is determined by the interaction of trade balance and net savings. In the short run, since prices are rigid, we may reflect the movements in the

nominal exchange rate to the real exchange rate. Moreover, an increase in the domestic inflation compared to the US economy causes the local currency to depreciate (Mankiw 2019, pp. 159–60).

2 Meanwhile, domestic currency substantially loses its value compared to major reserve currencies. For instance, the value of 10 Turkish Lira (TL) as of 1 January 1990 becomes nearly 60 thousand TL when calculated by USD/TL and 170 thousand TL when calculated by taking average of USD/TL bid and ask rates, Deutsche mark, gold, interest rate, wage, consumer price index (CPI), and wholesale price index (WPI) on 29 April 2022 in terms of the compensatory justice principle. Therefore, economic actors always seek a stationary behavior of exchange rates and bid–ask spreads be able to calculate their expected return.

3 Tinic (1972) refers to three costs regarding the bid–ask spreads, namely, order processing, inventory, and adverse selection costs.

4 Bessembinder (1994) underlines that inventory-carrying costs increase spreads.

5 Gulhan and Hetemi (2020, pp. 77–78) suggest that money laundering increases volatility in exchange rates due to the changing capital inflow and outflow dynamics. The money earned through money laundering circulates around the world. The dirty money is deployed in a country where regulations are loose. Capital outflow tends to depreciate the local currency as the transaction volume of the currency is affected at this stage.

6 In some countries such as Lebanon, there is a black market for the exchange rate besides the official exchange rate. The rate in the black market is much higher than the official rate.

7 MATLAB Version 2022a (February 2022) is used to estimate parameters. The MATLAB codes for the QARDL model are available at as of 24 September 2022: URL: https://web.yonsei.ac.kr/jinseocho/qardl.htm (accessed on 1 October 2022).

8 Pan and Misra (2021) explored a negative effect of volatility on the spread in the stock market.

9 One may review Allen (1999) for a history and roles of transaction and information costs in economics and finance. The transaction costs in the foreign exchange market inherit both commissions and taxes, and they are staggered. Commissions are operation costs of banks, and taxes are collected by the government.

10 Treepongkaruna et al. (2014); Huang and Masulis (1999); and Bollen et al. (2004) estimated the models for several currencies and explored volatility for both models. Following Galati (2000), volatility and volume were also included in our specification.

11 If we think of the exchange rate as colder versions of atoms, it would behave as a wave function. One may also apply a wavelet-based nonlinear ARDL model to capture this property.

12 See Schwartz (2019); Nobel (2001); and Cornell (1996) regarding the Bose–Einstein condensation and its historical background.

13 This is normal, as most central banks also benefit from inflation targeting regime. In the future, the policy may be structured in a different direction following the examples of the European Central Bank (ECB) and Board of Governors of the Federal Reserve System (FED) who started debating the flexibility of the regime. Traditionally, the flexible exchange rate is seen as creating more stability than the fixed exchange rate due to its shock observer property. However, studies held by Bergin et al. (2017) claim that the flexible exchange rate does not always create stability in the European economy. The distinction between a flexible and fixed regime is an essential point for the bid–ask spread. The targeted rate may change, or depending on the target, the policy may change. For instance, if the CBRT targets an 5% annual inflation rate and the actual rate exceeds it, the CBRT should increase interest rates in normal circumstances. However, if the rate increases persistently, the CBRT will act with a different policy strategy. The flexibility policy should consider the stance of the monetary policy, which leads to a problem related to the measuring stance of the policy. As a result, when the flexible inflation becomes the target, the flexible exchange rate should be watched keenly, for it becomes beneficial to analyze the bid–ask spread.

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