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Full Length Article

Optimal hedge ratios and hedging effectiveness: An analysis of the Turkish futures market

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Abstract

The main purpose of this comprehensive study is to determine the optimal hedge ratios and hedging effectiveness of different futures contracts traded on the Borsa Istanbul (BIST), namely the BIST 30 equity index, US dollar−Turkish lira currency futures (USD-TRY), euro−Turkish lira (EUR-TRY) currency futures, and gold futures. The efficiency of hedge ratios estimated through constant and time-varying econometric models, such as ordinary least squares (OLS) and diagonal VECH—a multivariate generalized autoregressive conditional heteroskedasticity (GARCH) model—are compared with a minimum variance hedge ratio framework. The periods before and after the merger of the Turkish Derivatives Exchange are analyzed with the models to capture changes in the hedging effectiveness of the contracts. We find that the diagonal VECH and constant models produce almost identical positive results for both periods, suggesting similar high hedging effectiveness for BIST 30 equity futures contracts. We conclude that BIST 30 equity futures contracts provide an efficient hedging mechanism for investors aiming to protect their spot equity portfolios. However, after Turkey's foreign exchange regulation amendment in 2017, the percentage of variance reduction improves greatly for the dynamic GARCH model, compared to the static OLS model, for USD-TRY and EUR-TRY futures contracts. Furthermore, the hedging effectiveness of currency futures contracts is negatively affected during the COVID-19 pandemic period beginning in 2020. Unlike other contracts, the hedging effectiveness of gold contracts is low in all periods.

JEL classification: C58; G11; G13

Keywords: BIST; Diagonal VECH; Futures market hedging; Hedging effectiveness; Minimum variance; Optimal hedge ratio

1. Introduction

The recent global financial crises have shown the importance of financial derivatives contracts, especially when used for hedging purposes. It is increasingly evident that high volatility in financial markets has harmful effects on different industries. Companies need to hedge their exposure with different derivatives contracts; the effectiveness of the hedge is the key to avoiding the effects of crises.

A growing number of studies focus on the relationship between spot and futures market price fluctuation to measure the hedging effectiveness of different underlying assets using constant and dynamic hedging models. Kharbana and Singh (2020) study currency futures in India and compare three models for evaluating the effectiveness of hedges. Chiou-Wei et al. (2020) analyze US natural gas spot and futures prices in terms of hedging effectiveness. Kumar and Bose (2019) investigate the hedging effectiveness of Nifty index traded on the National Stock Exchange (NSE), India and cross-listed

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Nifty futures traded on the Singapore Stock Exchange (SGX) and compare the performance of constant and dynamic hedging strategies. All these studies find that a dynamic multivariate GARCH model outperforms other static models and improves hedging effectiveness. However, Kumar and Bose (2019) observe that constant hedging models have better hedging effectiveness than time-variant hedging models.

In this respect, the main objective of this paper is to measure hedging effectiveness in the Turkish derivatives market, using various futures contracts, and to compare different constant and dynamic hedging models. The Borsa Istanbul (BIST) 30 equity index, US dollar−Turkish lira (USD-TRY), euro−Turkish lira (EUR-TRY) currency futures, and ounce-based gold futures contracts are analyzed in this study. To the best of our knowledge, this is the most extensive study in terms of the number of underlying instruments analyzed in Turkey under Ederington's (1979) hedging effectiveness (EHE) framework.

According to trading volume data for 2019 from the Futures Industry Association, BIST's Futures and Options Market (VIOP) was ranked the sixteenth-most-liquid derivatives exchange in the world, with a very impressive growth rate of 64 percent that year. This growth rate is the third highest, after the Indian Commodity Exchange and the China Financial Futures Exchange. VIOP is a good model of an emerging futures exchange for other countries to emulate.

The main reason for choosing these futures contracts is that the Istanbul Stock Exchange (ISE) 30 equity futures is the exchange's flagship product and the most liquid financial instrument in the country, widely used by both local and foreign institutional investors. According to volume data from the Futures Industry Association, in 2018 BIST 30 equity futures contracts were the fourteenth-most-liquid equity index contracts in the world and ranked the ninth most liquid if the US and European exchange contracts are omitted. USD-TRY and EUR-TRY futures contracts are also used by a variety of actors, such as fund managers, exporters, and importers.

All the future contracts analyzed are settled in cash, such as nondeliverable forward (NDF) contracts on the over-the-counter (OTC) market. Cash-settled future contracts have no physical delivery of the underlying asset for the buyer or seller; rather, the counterparties agree to accept a cash credit or debit resulting from their trading price relative to the settlement price of a futures contract. At the end of each day, the exchange declares the daily settlement prices, and profit/loss amounts are calculated for each account. If there is a profit, the investors might withdraw this excess cash over its required margin, and, if there is a loss, the amount is deducted from the account. All the required margin deposited to the clearinghouse also earns daily interest. This is another positive aspect of the futures market in Turkey, as the payment of interest is rare in other developed and developing countries. Investors also have the choice of not accepting the interest payment for religious reasons.

This study is designed to be the first to examine changes in hedging effectiveness after the merger between the Turkish Derivatives Exchange (TurkDex) and the BIST.[1] The effect of this merger on the hedging effectiveness of derivatives contracts is another focus of this study, which also aims to discover how hedging effectiveness changed during this transition period. The merger was a remarkably successful and pioneering project, and it represents a particularly good example of an exchange merger for both developed and developing countries.

A second aim of this study is to analyze the effect of new foreign exchange (FX) regulations in Turkey on the hedging effectiveness of Turkish currency futures contracts. After these regulations introduced more restrictions on foreign exchange (FX) spot trading, trading volumes shifted to currency futures traded on the BIST. This regulatory change also offers a good example for other developed and developing futures markets to follow.

This study's main contribution is that it estimates the hedge ratios and tests the hedging effectiveness of the most frequently traded currency futures contracts, in addition to stock and gold futures. The literature generally focuses on the role of hedging effectiveness and the protective role of gold in stock exchange risk by analyzing stock and gold futures together, especially during a crisis (Chkili, 2016; Kumar, 2014). However, in terms of portfolio risk reduction, currency futures contracts offer an alternative investment to stock and gold futures. Because the value of the dollar and the euro is highly volatile in Turkey, this study contributes to the literature on the efficiency of currency futures contracts, as opposed to other investment options (Hill & Schneeweis, 1982). The study finds that, in Turkey's developing futures market, the FX regulations increased the reduction in the potential variance of dollar and euro contracts compared to gold futures, but the COVID-19 pandemic has a negative effect on the hedging effectiveness of currency futures contracts, because it created a high volatility environment.

The remainder of this study is organized as follows. Section 2 reviews the literature. Section 3 describes the methodology, and Section 4 presents the data and preliminary analysis. Section 5 discusses the empirical results of the analysis. Finally, Section 6 presents concluding remarks.

2. Literature review

The hedging effectiveness measure proposed by Ederington (EHE; 1979) remains the most common criterion for evaluating the value of different hedging instruments. Ederington's fundamental idea originates with Johnson (1960) and Stein (1961), who introduced portfolio theory to hedging. Ederington demonstrates the existence of an optimal hedge ratio, which minimizes the variance in the portfolio value. Different

[1] TurkDex was established as a separate entity from the ISE on February 4, 2005, to offer financial derivatives contracts for hedging, speculation, and arbitrage purposes. In 2013, TurkDex was acquired by and incorporated into the BIST, Turkey's main stock exchange of, and all contracts were transferred to the BIST's trading platform. Currently, futures and exchange-traded options contracts for different underlying instruments, such as equity index, currency and commodity futures, are traded on the BIST's derivatives market (VIOP).

hedging strategies and instruments have been compared in terms of their EHE. The strategy with the highest EHE is deemed the most appropriate. Specifically, the EHE is the percentage reduction in the return variance of the hedged portfolio compared with the return variance of the unhedged portfolio.

Further developments in the futures hedging literature focus on conditional dynamic hedging strategies. The EHE remains the major criterion for evaluating the usefulness of these strategies; however, this approach is inappropriate, because, although the conditional hedge strategy is constructed to minimize conditional variance, its usefulness is measured by unconditional variance. Without a linear relation between the conditional and unconditional variances, the EHE is unsuitable as a benchmark for evaluating a conditional hedge strategy. Many unconditional and conditional variance studies calculate optimal hedge ratios, as well as the EHE. We conclude that, in many studies, different GARCH models that allow for the calculation of conditional variances generally outperform the unconditional variance calculated by Ederington's (1979) ordinary least squares (OLS). Baillie and Myers (1991) study US beef, corn, cotton, gold, and soybean markets using OLS, bivariate GARCH (B-GARCH), and diagonal VECH models and find that GARCH hedge ratios perform best in terms of reducing the conditional variance of the portfolio returns for all six commodities. Park and Switzer (1995) analyze Standard & Poor's (S&P) 500 and Toronto 35 Index data and conclude that the B-GARCH model outperforms all the others.

Further support for various multivariate GARCH (M-GARCH) models—such as the modified Baba−Engle−Kraft−Kroner (BEKK), vector autoregressive (VAR)-M-GARCH, diagonal VEC (DVEC), B-GARCH, Dynamic Conditional Correlation M-GARCH (DCC-M-GARCH)—is provided by Bhaduri and Durai (2008), Caldarelli and Souza (2011), Choudhry and Zhang (2013), Kumar and Bose (2019) Moschini and Myers (2001), and Kumar et al. (2008). However, Alexander and Barbosa (2007), Gupta and Singh (2009), Gupta and Kaur (2019), and Park and Jei (2010) report that unconditional hedge ratios either outperform or are virtually identical to conditional hedge ratios, which are calculated by different conditional variance models. Chunhachinda et al. (2019) also used a multivariate GARCH model (DCC-GARCH) framework, and showed that portfolios consisting of commodities and emerging market equities have higher hedging effectiveness than portfolios with commodities and developed market equities.

A few studies have focused on the hedging effectiveness of the Turkish derivatives market. Aksoy and Olgun (2009) investigate static hedge strategies using OLS, bivariate vector autoregression (VAR), an error correction model (ECM), and GARCH and M-GARCH models to examine ISE 30 stock index futures. They point out that the hedge ratio estimated by the M-GARCH model gives the best results in terms of hedging effectiveness criteria and outperforms other models' estimates for both in- and out-of-sample data.

Olgun and Yetkiner (2011) aim to determine an optimal hedge strategy for ISE 30 stock index futures in Turkey by comparing the hedging performance of constant and time-varying hedge ratios under mean−variance utility criteria. They employ standard regressions, the OLS method of Vishwanath (1993), and the bivariate diagonal VECH GARCH framework of Bollerslev et al. (1988). They use the mean−variance utility criteria of variance reduction to compare constant and time-varying hedge ratios, respectively. The empirical results of Olgun and Yetkiner (2011) reveal that the dynamic hedge strategy outperforms static and traditional strategies.

Another study that analyzes the hedging effectiveness of BIST 30 equity futures contracts, conducted by Celik (2014), uses static methods, such as conventional OLS regression, a simple ECM, VECM, and ECM-GARCH models. Furthermore, time-varying hedge ratios are estimated by employing a multivariate GARCH (M-GARCH) model, such as VEC-constant conditional correlation (CCC) GARCH and VEC-Diagonal-BEKK. The dynamic models provide the best hedge ratios.

Gümrah and Gökbulut (2017) also show that optimal hedge ratios are not constant over time for BIST 30 equity index futures. They use a BEKK parameterization of the multivariate GARCH(1,1) model, which nests the hypothesis of the constancy of the ratio of conditional covariance into the conditional variance of one of the variables. They estimate a GARCH-BEKK model using daily data for the ISE 30 index. The optimum hedge ratio during the first year of the TurkDex was found to be highly volatile, implying informational inefficiency related to the structure of the new futures market. Lack of trade, in particular, can stem from the valuation of new information.

Evci and Kandır (2017) apply a linear regression model and several symmetric and asymmetric GARCH models to estimate the optimum hedge ratio for USD-TRY futures contracts traded on the BIST. They find that the best model for determining the hedge ratio is the generalized error distribution (GED)-E-GARCH(1,2,2) model.

Our study, like those of Baillie and Myers (1991), Bhaduri and Durai (2008), and Olgun and Yetkiner (2011), the optimal hedge ratio estimates are determined by a diagonal VECH model, which outperform other constant and dynamic models in many studies. The VECH model is expected to be better than other models because, in many studies, the optimal hedge ratios determined by this model are found to decrease portfolio variance the most effectively. Table 1 summarizes past studies in which dynamic GARCH methods outperform static methods using various underlying instruments.

3. Methodology

It is possible to hedge a spot portfolio by shorting futures contracts in the futures market. The question is, how much spot exposure will be hedged by the futures contract? As Ederington (1979) suggests, the optimal hedge ratio is the proportion of futures to spot positions, which minimizes both the variance for the entire portfolio and price change risk.

First, we calculate the hedge ratio using constant and time-varying econometric models (e.g., Baillie & Myers, 1991;

Table 1
Past studies which favor dynamic hedging models.

Authors (Year of Study)	Asset Analyzed	Data Period	Data Freq.	Methodology Applied	Conclusion: Methods with Highest Hedging Effectiveness
Baillie and Myers (1991)	Beef, coffee, corn, cotton, gold, and soybeans (US)	In sample: 1986; Out-of-sample: 1982	D	OLS, B-GARCH: Diagonal VECH	GARCH
Park and Switzer (1995)	S&P 500, Toronto 35 Index (US/Canada)	June 8, 1988—December 18, 1991	W	OLS, OLS with cointegration, B-GARCH	B-GARCH
Kumar et al. (2008)	S&P CNX Nifty, NCE Gold, and NCE Soybeans	S&P CNX Nifty Index (January 1, 2004—May 8, 2008), gold (July 22, 2005—May 8, 2008), soybeans (October 4, 2004—May 8, 2008)	D	OLS, VAR, VECM, VAR-M-GARCH	VAR-M-GARCH
Bhaduri and Durai (2008)	NSE Stock Index Futures, S&P CNX Nifty Index	September 4, 2000—August 4, 2005	D	OLS, bivariate VAR, VECM, multivariate GARCH (DVEC-GARCH)	DVEC-GARCH
Gupta and Singh (2009)	Nifty, BankNifty, and CNXIT	January 1, 2003—December 31, 2006	D	OLS, GARCH (p,q), Threshold ARCH (p,q), Exponential GARCH (p,q), VAR, and VECM	VAR or VECM
Aksoy and Olgun (2009)	ISE30	May 2, 2005—April 30, 2009	D	OLS, bivariate VAR, ECM, GARCH, M-GARCH	M-GARCH
Olgun and Yetkiner (2011)	ISE30	May 2, 2005—September 15, 2009	D	OLS, B-GARCH	B-GARCH
Celik (2014)	ISE30	February 2005—August 2013	D	OLS, ECM, VECM, ECM-GARCH VEC—CCC—GARCH and VEC-Diag-BEK	ECM-GARCH
Gümrah and Gökbulut (2017)	ISE30	February 2, 2005—July 7, 2009	D	OLS, GARCH-BEKK	GARCH-BEKK
Evci and Kandır (2017)	USD-TRY	March 1, 2005—March 31, 2016	D	OLS, Generalized Error Distribution (GED)-E-GARCH (1,2,2)	GED-E-GARCH
Kumar and Bose (2019)	Nifty Index	July 15, 2010—July 15, 2016	D	OLS, bivariate VAR, CCC and DCC-M-GARCH	DCC-M-GARCH
Chiou-Wei et al. (2020)	US Natural Gas	January 2000—December 2013	D, W	VECM, DCC-M-GARCH	DCC-M-GARCH
Kharbana and Singh (2020)	USD, GBP, EURO, and JPY against INR	February 2010—May 2017	D	OLS, VECM, DCC-M-GARCH	DCC-M-GARCH

Bhaduri & Durai, 2008; Olgun & Yetkiner, 2011). The hedging effectiveness of hedged, unhedged, and naively hedged portfolios are then compared for two subperiods: before and after the BIST—TurkDex merger. A naively hedged portfolio (i.e., where the hedge ratio equals one) is one for which the hedger takes an equal but opposite position in the futures contract.

3.1. Optimal hedge ratio calculation

As stated previously, two models are used to evaluate the optimal hedge ratio, namely, the conventional constant OLS and multivariate GARCH models. A constant hedge ratio is found using OLS, and a time-varying optimal hedge ratio is calculated using diagonal VECH, a multivariate GARCH model. Some studies (e.g., Aksoy & Olgun, 2009; Baillie & Myers, 1991; Park & Switzer, 1995) observe that optimal hedge ratios found through multivariate GARCH models, such as diagonal VECH, outperform constant and time-varying hedge ratio estimates. A sample portfolio is constructed with a certain amount of spot underlying and futures contracts. Short futures contracts are used to hedge the spot exposure. Hedging is implemented for the following underlying assets: BIST 30, USD-TRY, EUR-TRY, and gold. Daily spot and futures returns are calculated as follows:

$$R_s = \ln\left(\frac{S_t}{S_{t-1}}\right) \quad (1)$$

$$R_f = \ln\left(\frac{F_t}{F_{t-1}}\right) \quad (2)$$

where

R_s = daily spot return
R_f = daily futures return
S_t = spot price at time t
S_{t-1} = spot price at time t - 1
F_t = futures price at time t
F_{t-1} = futures price at time t - 1

The number of contracts to sell for hedging purposes is found by estimating the hedge ratio. The hedge ratio is calculated by using the following two methods and can be applied throughout the entire hedging process.

Model 1: OLS. A conventional way of finding the constant optimum hedge ratio is employed, using the simple OLS methodology of Ederington (1979):

$$R_s = \alpha + b^* \times R_f + \varepsilon \quad (3)$$

where α and b^* are the regression parameters, ε is the error term, R_s (the dependent variable) is the spot market return, R_f (the independent variable) is the futures market return, and b^*, which is also the slope of the regression, represents the hedge ratio. For example, if the slope coefficient is one, then the hedge ratio is one, and the portfolio is naively hedged. In other words, one unit of a spot portfolio is hedged with exactly one unit of a futures portfolio.

Hedge effectiveness can be measured by R^2, which is the coefficient of determination of the regression of futures price returns (the independent variable) on cash price returns (the dependent variable). The R^2statistic is an indication of the maximum risk reduction potential of a hedge. In this case, R^2 represents the percentage reduction in the variance of unhedged cash price changes that is explained by futures price changes. A high R^2value indicates better hedging effectiveness.

The constant hedge ratio is obtained first, using OLS for four different underlying assets (BIST 30, USD-TRY, EUR-TRY, and gold), and then applied to calculate the number of futures contracts that must be sold each trading day.

Model 2: Diagonal VECH. Commodity prices are better represented with a time-varying covariance matrix, so the OLS assumption of homoskedasticity is not achieved; therefore, the B-GARCH model allows for a time-varying covariance matrix. The time-varying hedge ratios are estimated using the following diagonal VECH model, a multivariate GARCH(p, q) model suggested by Bollerslev et al. (1988), which is applied to returns from the spot and futures markets:

$$Y_t = \mu + \delta(z_{t-1}) + \varepsilon_t \quad (4)$$

$$\varepsilon_t|\Omega_{t-1} \sim N(0, H_t) \quad (5)$$

$$vech(H_t) = C + \sum\nolimits_{i=1}^{p} A_i vech(\varepsilon_{t-i})^2 + \sum\nolimits_{j=1}^{q} B_j vech(H_{t-j}) \quad (6)$$

where $Y_t = (r_t^s, r_t^f)$ is a 2 × 1 vector containing returns from the spot and futures markets, H_t is a 2 × 2 conditional covariance matrix, C is 3 × 1 parameter vector of constants, A_i and B_j are 3 × 3 parameter matrices, and *vech* is the column stacking operator that stacks the lower triangular portions of a symmetric matrix. The error correction term (z_t) from the cointegration represents short-run deviations from a long-run relation between the spot price and the futures price. A significant positive coefficient (δ) on the error term implies that an increase in short-run deviations raises the logarithmic difference of spot and/or futures prices; if the error term coefficient is negative and significant, the opposite is true.

To make the estimation more manageable, Engle and Kroner (1995) suggest various restrictions on the parameters of the A_i and B_j matrices. A parsimonious representation can be achieved by imposing a diagonal restriction on the parameter matrices, so that each variance and covariance element depends only on its own past values and prediction errors. The following are the conditional variance equations for diagonal VECH B-GARCH(1,1):

$$H_{11,t} = C_1 + A_{11}(\varepsilon_{1,t-1})^2 + B_{11}H_{11,t-1} \quad (7a)$$

$$H_{12,t} = C_2 + A_{22}(\varepsilon_{1,t-1}, \varepsilon_{2,t-1}) + B_{22(}H_{12,t-1)} \quad (7b)$$

$$H_{22,t} = C_3 + A_{33}(\varepsilon_{2,t-1})^2 + B_{33}H_{22,t-1} \quad (7c)$$

Using the B-GARCH model, we compute the time-varying hedge ratio as

$$h_t^* = \frac{H_{12,t}}{H_{22,t}} \quad (8)$$

where $H_{12,t}$ is the estimated conditional covariance between the spot and futures returns and $H_{22,t}$ is the estimated conditional variance of futures returns. Because the conditional covariance is time varying, the optimal hedge will also be time varying. However, $H_{11,t}$ is the estimated conditional variance of spot returns. This equation is important because of the changes over time in the variance of futures price and the covariance between movements in the spot and futures prices.

We find a constant hedge ratio using the OLS method. The time-varying optimal hedge ratios are calculated with the diagonal VECH B-GARCH model for BIST 30, USD-TRY, EUR-TRY, and gold contracts. Different hedge ratios are found for each day for the entire period, and the numbers of contracts that need to be sold are calculated.

3.2. Hedging effectiveness

The hedging performance of each portfolio (hedged, unhedged, and naively hedged) is analyzed using the hedge ratios calculated with the OLS and diagonal VECH models. The total portfolio consists of the spot and futures exposures. The hedge ratios are used to calculate the number of futures contracts that must be sold and the total return of the entire portfolio for each day. The most effectively hedged portfolio is the one with the lowest variance; in other words, hedging effectiveness is calculated by the reduction in variance in the hedged portfolio, compared to that of the unhedged portfolio. The aim is to balance the change in the spot portfolio with that in the futures portfolio by using the hedge ratio, as in Ederington's (1979) model.

The returns of unhedged and hedged portfolios are estimated by the following equations, respectively.

$$R_{unhedged} = S_{t-1} - S_t \tag{9}$$

$$R_{hedged} = (S_{t-1} - S_t) + h_t^* \times (F_{t-1} - F_t) \tag{10}$$

where $R_{unhedged}$ is the daily return on the unhedged portfolio and R_{hedged} is the daily return on the hedged portfolio, using constant and time-varying optimum hedge ratios. The term h_t^* is the optimum hedge ratio calculated for day t.

The risk of the position is then defined in terms of the variance in the returns of the whole portfolio (hedged and unhedged):

$$var_u = \sigma_s^2 \tag{11}$$

$$var_h = \sigma_s^2 + h_t^2 \times \sigma_f^2 - 2h_t^* \times \sigma_{sf} \tag{12}$$

var_u = variance of the unhedged portfolio
var_h = variance of the hedged portfolio
σ_s^2 and σ_f^2 = variances of the spot and futures price changes, respectively
σ_{sf} = covariance between spot and futures price changes

Ederington (1979) proposes the percentage reduction in the variances of the hedged and unhedged portfolios as a measure of hedging effectiveness. The following EHE equation is used.

$$Hedging\ Effectiveness(HE) = \frac{var_u - var_h}{var_u} \tag{13}$$

In addition, by employing the OLS methodology, we check that the coefficient of determination, R^2, determines the ex post proportion of the variability of spot price changes that can be hedged successfully by employing the minimum variance hedge ratio, h_t^* .

4. Data and preliminary analysis

All the data for the spot and futures market are obtained from a Matriks terminal, a local data provider for BIST. All the data for the futures contracts are nearest-month futures contracts. The sample period for the BIST 30, USD-TRY, and EUR-TRY spot and futures prices spans from January 5, 2010, to December 15, 2017, for a total of 2002 observations. Gold is an exception in terms of the sample period, because USD/ounce contracts were not launched until late in 2010; gold data are available between December 23, 2010, and December 15, 2017, for a total of 1678 observations. Because of a currency shock in 2018, the data are restricted to the period through the end of 2017.

The hedging effectiveness and optimal hedge ratios are analyzed in two subperiods: from January 5, 2010, to August 2, 2013 (period 1) and from August 5, 2013, to December 15, 2017 (period 2). August 5 is chosen as the date when all TurkDex derivatives contracts were transferred to the BIST system.

In addition to these two subperiods, to analyze the effect of the 2017 FX regulatory change and the COVID-19 pandemic starting in 2020, an identical empirical study is conducted for currency futures contracts during two additional, more recent subperiods, from June 5, 2017, until June 1, 2018 (period 3) and from January 2, 2020, until October 16, 2020 (period 4) respectively. This regulatory change puts some restrictions on retail trades, significantly decreasing the maximum allowed leverage and, as a result, considerably decreasing FX spot volumes.

Table 3
Augmented Dickey−fuller test results for spot and future returns.

Variables	t-Statistics	p-Value	Level of Significance	Critical Values
BIST30 spot	−45.9129***	0.0001	1%	−3.4340
BIST30 future	−46.2182***	0.0001	5%	−2.8631
USD-TRY spot	−45.5501***	0.0001	10%	−2.5676
USD-TRY future	−44.7176***	0.0001		
EUR-TRY spot	−43.1260***	0.0000		
EUR-TRY future	−41.7760***	0.0000		
Gold spot	−39.7160***	0.0000		
Gold future	−43.5800***	0.0001		

Note: *** indicates significance at the 1 percent level.

Table 4
OLS constant hedge ratios (CHR) and R-squared values.

Period	BIST 30		USD-TRY		EUR-TRY		GOLD[a]	
	CHR	R^2	CHR	R^2	CHR	R^2	CHR	R^2
Period 1: 1/5/2010-8/2/2013	0.95	0.93	0.75	0.52	0.61	0.38	0.48	0.49
Period 2: 8/5/2013-12/15/2017	0.94	0.93	0.73	0.52	0.79	0.57	0.70	0.53

[a] Gold period 1: 12/22/2010-8/2/2013.

Table 2
Summary statistics of return series.

Contract	Obs.	Mean	Max.	Min.	Std. Dev.	Skewness	Kurtosis	JB	LB-Q(36)
BIST 30 Spot	1999	0.0345	6.96	−10.90	1.5121	−0.4063	6.1882	901.64 (0.0000)	(0.0000)
BIST 30 Futures	1999	0.0345	7.39	−10.03	1.5406	−0.3549	6.0344	808.91 (0.0000)	(0.0000)
USD-TRY spot	2002	0.0482	4.98	−3.18	0.7293	0.5179	5.7669	728.15 (0.0000)	(0.0000)
USD-TRY futures	2002	0.0476	4.10	−4.29	0.7112	0.4837	6.5275	1116.04 (0.0000)	(0.0000)
EUR-TRY spot	1879	0.0406	4.92	−3.25	0.7496	0.3416	6.1304	803.79 (0.0000)	(0.0000)
EUR-TRY futures	1879	0.04	4.26	−2.76	0.7293	0.4765	5.9631	758.55 (0.0000)	(0.0000)
Gold spot	1678	0.0058	4.65	−8.87	1.0569	−0.6763	9.2812	2886.48 (0.0000)	(0.0000)
Gold futures	1678	0.0059	6.94	−9.21	1.1225	−0.5504	11.5447	5189.48 (0.0000)	(0.0000)

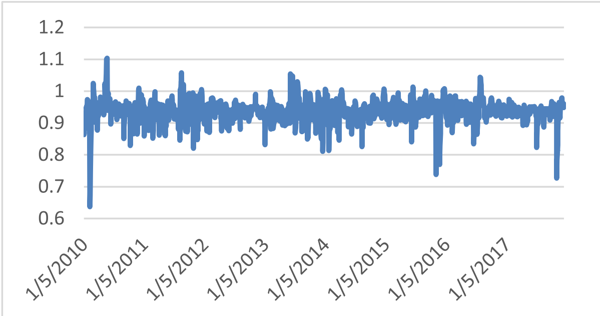

Fig. 1. Time-varying hedge ratios for BIST 30.

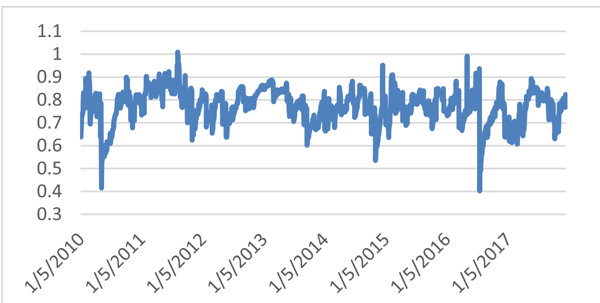

Fig. 2. Time-varying hedge ratios for USD-TRY

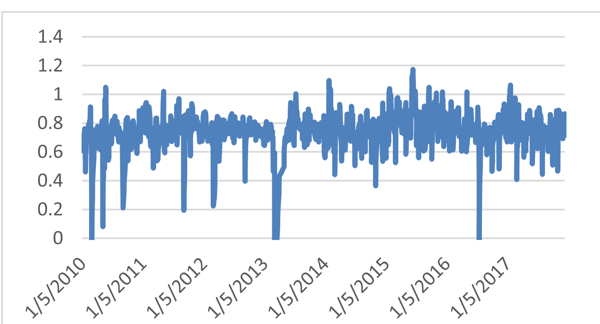

Fig. 3. Time-varying hedge ratios for EUR-TRY

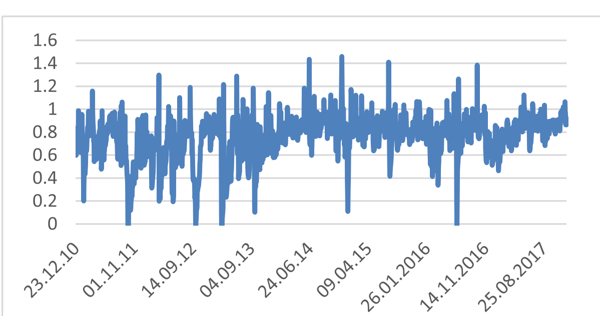

Fig. 4. Time-varying hedge ratios for gold.

Preliminary statistics for the Jarque−Bera (1980) normality test and Ljung−Box (1978) Q(36) statistics for the first thirty-six lags of the sample are used to find any serial correlation (see Table 2). All the data in the first lag are presented as the result of serial correlation, indicating that each day's price is derived from that of the previous day. Neither spot returns nor futures price returns exhibit a normal distribution. In addition, Table 3 shows that all the return data are stationary, because all the *t*-values are lower than the critical value at the 1 percent significance level, according to augmented Dickey−Fuller tests.

5. Empirical findings

In the first part of our analysis, we examined the hedging effectiveness of Turkish futures contracts using different hedging methods for the periods before and after the Turk-Dex merger (periods 1 and 2). Therefore, we first find the constant and time-varying hedge ratios for the BIST 30, USD-TRY, EUR-TRY, and gold portfolios by applying the OLS and diagonal VECH methods, respectively. Using these hedge ratios, we then apply OLS and GARCH methods to find the variance of naively hedged and model-based hedged portfolios to obtain Ederington's (1979) minimum variance portfolio.

In the second part, we apply the same analysis to two more recent subperiods to verify the effect of the new FX regulation and COVID-19 pandemic for the USD-TRY and EUR-TRY currency contracts.

5.1. Hedging effectiveness of Turkish future contracts before and after the TurkDex merger

Compared to other USD-TRY, EUR-TRY, and gold contracts, we observe the highest constant hedge ratio for BIST 30 futures contracts, using OLS. As shown in Table 4, the hedge ratios for periods 1 and 2 are 0.95 and 0.94, respectively.

Figs. 1−4 illustrate the time-varying hedge ratios based on the diagonal VECH model. Because we use a dynamic method, we observe different hedge ratios each day for both periods. The time-varying hedge ratios calculated with the diagonal VECH method for the BIST 30 range from 0.63 to 1.09, and those for USD-TRY contracts range from 0.40 to 0.98. The trading volumes are much higher for these two contracts than for EUR-TRY and gold contracts, and therefore their spikes appear to be limited. Because the volume and depth of EUR-TRY and gold futures contracts are relatively low, we observe a much wider range of time-varying hedge ratios for EUR-TRY and gold contracts. For EUR-TRY, the hedge ratios range from zero to 1.18 and those for gold, from zero to 1.45.

According to Ederington (1979), a hedging strategy is effective only if it reduces a significant portion of the variance compared with its unhedged strategy. In this respect, the mean return, standard deviation, and risk-adjusted return of portfolios are calculated using the optimum hedge ratios stated above (estimated by both the OLS and GARCH models). These measures are then compared with those of the unhedged and naively hedged portfolio. Table 5 shows this comparison, and Table 6 provides the variances and hedging effectiveness ratios of each portfolio for both periods.

Table 5
Mean return, standard deviation, and risk-adjusted returns.

	Period 1			Period 2		
	Mean	Std. Dev.	Risk-Adjusted Returns (*100)	Mean	Std. Dev.	Risk-Adjusted Returns (*100)
BIST 30						
Unhedged	0.0314	1.6286	1.9267	0.0371	1.4078	2.6338
GARCH hedged	0.0190	0.5007	3.7932	0.0192	0.4537	4.2372
Naively hedged	0.0169	0.4959	3.4093	0.0191	0.4396	4.3355
OLS hedged	0.0181	0.4971	3.6419	0.0203	0.4524	4.4840
USD-TRY						
Unhedged	0.0295	0.6595	4.4673	0.0636	0.7815	8.1399
GARCH hedged	0.0088	0.5033	1.7524	0.0415	0.8067	5.1480
Naively hedged	0.0053	0.5132	1.0402	0.0349	0.8339	4.1896
OLS hedged	0.0300	0.6562	4.5644	0.0634	0.7791	8.1387
EUR-TRY						
Unhedged	0.0239	0.6615	3.6161	0.0526	0.8060	6.5199
GARCH hedged	0.0053	0.5412	0.9831	0.0328	0.7060	4.6428
Naively hedged	0.0035	0.5948	0.5826	0.0238	0.7243	3.2847
OLS hedged	0.0247	0.6566	3.7623	0.0523	0.8021	6.5210
Gold						
Unhedged	−0.0093	1.2761	−0.7316	−0.0040	0.9194	−0.4307
GARCH hedged	−0.0152	1.2110	−1.2563	0.0016	0.6396	0.2467
Naively hedged	0.0017	1.3674	0.1238	0.0021	0.6719	0.3085
OLS hedged	−0.0008	1.1160	−0.0695	0.0011	0.5930	0.1876

Notes: This table compares the realized risk-adjusted returns of unhedged and hedged portfolios, measured by calculating the ratio of each portfolio's mean to its standard deviation. Period 1 includes data before the TurkDex merger and period 2 after the TurkDex merger.

The results in Table 5 show that hedging the spot portfolio using BIST futures contracts improves the risk-adjusted return ratio, calculated as the ratio of the mean return to its standard deviation. More important, this result holds for both periods and for almost all the models considered. Among the eight cases (two periods for four different underlying instruments), in all but one the hedged portfolio's risk-adjusted return is higher than that of the unhedged portfolio. The hedging model based on OLS provides the best risk-adjusted return ratio in four of the eight cases, followed by the naively hedged model, which prevails in two cases.

We conclude that hedging with BIST futures contracts also helps to lower the variance of portfolios and to increase hedging effectiveness. As Table 6 indicates, we observe strong variance reduction and hedging effectiveness in BIST 30 equity futures contracts. Significant and similar variance reduction is seen in both periods, before and after the TurkDex merger: on average, 90 percent for BIST 30 equity futures. The naively hedged portfolio outperforms these two methods slightly, with variance reductions of 90.73 percent and 90.25 percent before and after the merger, respectively. These percentages are very close to each other, as found by Alexander and Barbosa (2007), providing no evidence that complex econometric models, such as GARCH, are superior to simpler models, such as OLS and naively hedged portfolios. No single method can be considered better than the other two, because the variance reductions, whether the model used is constant or dynamic, are almost equal. However, the naively hedged portfolio produced slightly better results for both periods, contradicting Aksoy and Olgun's (2009) finding that the multivariate GARCH method is superior for BIST 30 equity futures contracts. In fact, the percentages of hedging effectiveness of the different methods are similar in our study. However, the OLS regression R^2 values are also quite high for BIST 30 contracts, indicating their relatively high hedging effectiveness.

Table 6
Variances and hedging effectiveness ratios.

	Period 1		Period 2	
	Variance	Hedging Effectiveness (%)	Variance	Hedging Effectiveness (%)
BIST 30				
Unhedged	2.6552		1.9837	
GARCH hedged	0.2510	90.5466	0.2060	89.6143
Naively hedged	0.2462	**90.7284**	0.1934	**90.2502**
OLS hedged	0.2473	90.6843	0.2013	89.8519
USD-TRY				
Unhedged	0.4354		0.6113	
GARCH hedged	**0.2536**	**41.7543**	0.6514	−6.5726
Naively hedged	0.2636	39.4596	0.6960	−13.8627
OLS hedged	0.4310	1.0105	0.6514	**−6.5663**
EUR-TRY				
Unhedged	0.4381		0.6503	
GARCH hedged	0.2933	**33.0562**	0.4989	**23.2837**
Naively hedged	0.3543	19.1301	0.5251	19.2530
OLS hedged	0.4317	1.4741	0.5558	14.5330
Gold				
Unhedged	1.6313		0.8460	
GARCH hedged	1.4690	9.9481	0.4095	51.5936
Naively hedged	1.8730	−14.8171	0.4519	46.5867
OLS hedged	1.2475	**23.5285**	0.3520	**58.3957**

Notes: This table reports the portfolio variance and hedge effectiveness ratios, computed using Eq. (13). Values in boldface indicate the hedged portfolio with the highest variance reduction. Period 1 includes data before the TurkDex merger and period 2 after the TurkDex merger.

Other than for BIST 30 equity futures, hedging effectiveness ratios are lower for USD-TRY, EUR-TRY, and gold contracts for both periods. For the GARCH method for period 1, we observe variance reductions of 41.75 percent and 33.06 percent for USD-TRY and EUR-TRY contracts, respectively. The GARCH method outperforms the others for this period. Because we have a variance increase of 6.27 percent in period 2, we conclude that the first impact of the TurkDex merger on hedging effectiveness is negative for USD-TRY futures contracts. In other words, during period 2, hedging through currency futures does not improve hedging effectiveness. In contrast, we observe that the hedging effectiveness of gold contracts improves considerably after the TurkDex merger. The variance reduction increases to 58.40 percent with the OLS method, compared with only 23.54 percent before the TurkDex merger; but the OLS regression R^2 values are very low for USD-TRY, EUR-TRY, and gold futures contracts, indicating an inefficient hedging mechanism for spot portfolios.

5.2. Hedging effectiveness of currency futures contracts after the new foreign exchange regulation and during COVID-19 pandemic

In February 2017, FX trading regulations in Turkey changed, and new restrictions on spot FX trading significantly decreased the volume of spot FX contracts, causing FX volumes to move to either foreign countries or VIOP currency futures. The FX VIOP futures trading volume increased significantly after the first half of 2017. A similar pattern of increases in the trading volume is seen in 2020, when the Turkish lira depreciated 30 percent against US dollar and 36 percent against the euro because of negative effects of the COVID-19 pandemic. High volatility caused by the pandemic was another recent factor that increased the trading volume of VIOP FX future contracts. To determine the effect of this recent regulatory change and the pandemic, the same analysis is conducted for two more recent subperiods, from June 5, 2017, to June 1, 2018, and from January 2 to October 16, 2020, for USD-TRY and EUR-TRY contracts. The empirical findings of this study are presented in Table 7.

As revealed in Table 7, our analysis of more recent data for periods 3 and 4 shows a much higher reduction in variance for USD-TRY contracts. The portfolio variance of the optimally hedged USD-TRY portfolio with a diagonal VECH model is 78.21 percent and 47.01 percent lower than the unhedged portfolio variance for periods 3 and 4, respectively. The dynamic hedge model with conditional variance outperforms the constant models, the naively hedged portfolio, in which the hedge ratio is one, and the OLS hedged portfolio, following Aksoy and Olgun (2009), Baillie and Myers (1991), Bhaduri and Durai (2008), Olgun and Yetkiner (2011) and Park and Switzer (1995) for period 3. By contrast, the naively hedged portfolio slightly outperforms the dynamic model for period 4. The highest risk-adjusted returns are obtained through the use of the diagonal VECH model for USD-TRY for period 3 and the OLS hedged portfolio for period 4.

We also observe that the variance reduction is higher during periods 3 and 4 for EUR-TRY futures contracts than in other periods. Compared with the unhedged portfolio variance, the

Table 7
Hedging effectiveness of currency contracts for periods 3 and 4.

	Mean	Std. Dev.	Risk-Adjusted Returns (*100)	Variance	Hedging Effectiveness (%)
Period 3					
USD-TRY					
Unhedged	0.1049	0.7319	14.3360	0.5379	
GARCH hedged	0.0503	0.3416	**14.7118**	**0.1172**	**78.2198**
Naively hedged	0.0156	0.3845	4.0482	0.1485	72.3980
OLS hedged	0.1046	0.7325	14.2834	0.5387	−0.1448
EUR-TRY					
Unhedged	0.1196	0.7320	16.3391	0.5379	
GARCH hedged	0.0480	0.3804	12.6156	**0.1453**	**72.9860**
Naively hedged	0.0173	0.3986	4.3452	0.1595	70.3437
OLS hedged	0.1204	0.7295	**16.5097**	0.5343	0.6809
Period 4					
USD-TRY					
Unhedged	0.1446	0.6769	**21.3653**	0.4606	
GARCH hedged	0.0626	0.4927	12.7120	0.2440	47.0131
Naively hedged	0.0237	0.4870	4.8568	**0.2384**	**48.2435**
OLS hedged	0.1438	0.6780	21.2126	0.4620	−0.3164
EUR-TRY					
Unhedged	0.1727	0.7498	23.0274	0.5651	
GARCH hedged	0.0701	0.6038	11.6171	**0.3665**	**35.1384**
Naively hedged	0.0313	0.6208	5.0391	0.3874	31.4435
OLS hedged	0.1728	0.7487	**23.0826**	0.5634	0.2988

Notes: This table reports the risk-adjusted returns, portfolio variance, and hedge effectiveness ratios, computed using Eq. (13) for periods 3 and 4. Values in boldface indicate the hedged portfolio with the lowest variance and the highest risk-adjusted return and hedging effectiveness.

Table 8
Hedging effectiveness of currency futures for all periods.

Underlying Asset	Period	GARCH Hedged Portfolio	Naively Hedged Portfolio	OLS Hedged Portfolio
USD-TRY	1	**41.7543**	39.4596	1.0105
	2	−6.5726	−13.8627	**−6.5663**
	3	**78.2198**	72.3980	−0.1448
	4	47.0131	**48.2435**	−0.3164
EUR-TRY	1	**33.0562**	19.1301	1.4741
	2	**23.2837**	19.2530	14.5330
	3	**72.9860**	70.3437	0.6809
	4	**35.1384**	31.4435	0.2988

Notes: Values in boldface indicate the hedged portfolio with the highest hedging effectiveness. Period 1 includes data before the TurkDex merger and period 2 after the TurkDex merger. Period 3 includes data that covers the effect of the 2017 FX regulatory change and period 4 the COVID-19 pandemic.

portfolio variance of the optimally hedged portfolio with a diagonal VECH model for periods 3 and 4 is 72.98 percent and 35.13 percent lower, respectively. We conclude that the GARCH method outperforms both naively hedged portfolios and portfolios based on the OLS method for EUR-TRY futures contracts.

However, the results in Table 7 show that the risk-adjusted return is higher for the euro portfolio than for the US dollar portfolio in both periods. This ratio is 14.28 percent for the US dollar OLS hedged portfolio in period 3, and the euro OLS hedged portfolio's risk-adjusted return is 16.50 percent. This result also holds in period 4, in which the euro OLS hedged portfolio risk-adjusted return is higher than the US dollar portfolio return. A summary of the variance reduction levels is presented in Table 8 for currency futures in all periods. The results indicate that hedging effectiveness increased significantly, especially after the FX regulation was implemented in 2017 (period 3) for USD-TRY and EUR-TRY contracts but decreased during the COVID-19 pandemic (period 4).

6. Conclusion

In this study, the BIST 30 equity index and USD-TRY, EUR-TRY, and gold futures contracts on the BIST are analyzed in terms of their hedging effectiveness. Constant OLS, naively hedged, and a dynamic diagonal methods are used to test hedging effectiveness for periods before and after the BIST−TurkDex merger. In addition, the same study is conducted in two subperiods to analyze the effects of FX regulations imposed in 2017 and the COVID-19 pandemic beginning in 2020 on the hedging effectiveness of currency future contracts.

This study includes more abundant and more recent data on the Turkish derivatives market than in previous studies. It is the most extensive study on hedging effectiveness for many different Turkish futures contracts, in addition to equity index futures. We also point out the effect of important events such as merger, FX regulation and COVID-19 pandemic.

Both the OLS and GARCH models exhibit relatively high hedging effectiveness for BIST 30 equity futures contracts in the period after 2010, in contrast to the analysis of Olgun and Yetkiner (2011), which covers the period between 2005 and 2009. The diagonal VECH and constant OLS models produce almost identical results for both periods, suggesting similar hedging effectiveness. However, hedging effectiveness is higher with the naively hedged portfolio than that of other methods, but only slightly; we can therefore conclude that, in general, all the methods can be effective hedging tools by significantly reducing variance and improving returns.

We also observe that hedging effectiveness for currency futures contracts is low both before and after the TurkDex merger, until the regulatory change in 2017. The recent regulatory change in the FX market seems to have had a positive effect on VIOP USD-TRY and EUR-TRY futures contracts in terms of increasing the trading volume and hedging effectiveness. However, the hedging effectiveness of currency futures contracts are negatively affected by the COVID-19 pandemic starting in 2020. Despite a significant increase in the hedging effectiveness of both contracts since the new regulation was imposed, it remains lower than that of BIST 30 equity futures contracts. The percentage of the variance reduction for the dynamic GARCH model is much better than with the static OLS and naively hedged models for currency futures. Because gold contracts were introduced in late 2010, their hedging effectiveness during the first period is relatively low. For both the OLS and GARCH models, the variance reduction increases during period 2, but not sufficiently to warrant the claim that BIST gold futures contracts are equally effective as other contracts in hedging price risk.

We conclude that BIST 30 equity and currency futures contracts seem to hedge financial risks on the BIST effectively. However, the hedging effectiveness of both USD-TRY and EUR-TRY contracts is lower than that of BIST 30 equity futures, and gold contracts have the lowest effectiveness. With the exception of gold, no significant improvement is seen in hedging effectiveness since the 2013 TurkDex merger in any of the contracts analyzed. However, the hedging effectiveness of currency contracts improves significantly after the FX regulation in 2017, with a shift in trading volume from the spot FX market to currency futures contracts, resulting in an increase in trading volume and liquidity.

In this study, we analyze the contracts that have higher trading volume and liquidity, that is, BIST 30, USD-TRY, EUR-TRY, and gold futures contracts. After the trading volume reaches a certain level, the same study could be conducted for equity futures and option contracts.

One potential avenue for further research is the addition of different GARCH models to determine the dynamic volatility and time-varying hedge ratios for the underlying instruments analyzed in this paper. Such a study could contribute to differentiation of the hedging effectiveness of hedged portfolios with alternative dynamic econometric models.

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Declaration of competing interest

None.

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