International Review of Financial Analysis 31 (2014) 80–87

Contents lists available at ScienceDirect

International Review of Financial Analysis

Price discovery for cross-listed firms with foreign IPOs

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ARTICLE INFO

Article history:
Received 5 December 2012
Received in revised form 25 August 2013
Accepted 28 September 2013
Available online 12 October 2013

JEL classification:
F30
G32
G1

Keywords:
Bivariate GARCH
Price discovery
Return and volatility spillovers
Cross-listed stocks
Multi-market trading

ABSTRACT

We investigate the inter-market return and volatility linkages for an atypical case of firms with foreign IPOs that subsequently cross-listed in their domestic market. In particular, our data set consists of a unique sample of 29 Israeli firms that went public in the US (host market) and then cross-listed in the Israeli market (home market). To estimate the spillover effects, we employ bivariate GARCH models, assuming both constant and dynamic conditional correlation specifications. At the aggregate market level, we find unidirectional mean and volatility spillovers from the US to the Israeli market. For the portfolios of Israeli cross-listed stocks, we report significant spillovers, at both the mean and volatility levels, from the underlying stocks in the Israeli market to their American Depository Receipts (ADRs) but not vice versa. Thus, the home market dominates the host market in the price discovery process in this atypical international cross-listing case, providing new evidence in support of the home bias hypothesis. We also find that external shocks originating from the Middle East peace process have no impact on the conditional correlation between the two markets but external shocks originating from the world and regional markets impact the conditional correlation positively.

1. Introduction

In the last three decades, the international finance literature has witnessed a growing number of studies revolving around international cross-listing. Cross-listed stocks are highly demanded by local investors seeking diversified foreign portfolios. Therefore, return and volatility linkages across markets are a question of interest in the field of international cross-listing. To a great extent, return and volatility transmissions have a large influence on the price co-movements across markets and can contribute significantly in driving future stock prices or what is known as the price discovery process. Two strands have been postulated in the literature to explain the different patterns of inter-market feedbacks in price discovery. The first one suggests a unidirectional information flow from only one market to the other (but not vice versa) and encompasses the home bias and global center hypotheses. The second strand argues for a bidirectional flow of informational transfer pricing with both home and host markets being important sources of information creation and transmission.

The home bias hypothesis argues that the home market dominates in producing important information and determining future price behavior. Studies in favor of this hypothesis have concluded that return and volatility spillovers from the home market are significantly larger in magnitude than those from the host market suggesting that influential information in the stock return generating process is produced in the home market. More specifically, Choi and Kim (2000) find that the home market effect dominates the US market effect for a comprehensive sample of American Depository Receipts (ADRs) and their underlying stocks. Grammig, Melvin, and Schlag (2005) report the dominance of the local market over the host market in pricing three German firms cross-listed in the US market. Pascual, Pascual-Fuster, and Climent (2006) document that the Spanish market dominates the US market in pricing Spanish ADRs listed in NYSE. In the same vein, Agarwal, Liu, and Rhee (2007) confirm home market dominance in the price discovery process for 17 dually listed stocks in Hong Kong and London. They also report that their finding holds even under extreme circumstances in which the majority of trading in London is conducted by London-based institutional investors. Using an error correction model, Frijns, Grilbert, and Tourani-Rad (2010) find that the home market is the one dominating the price discovery for both Australian cross-listings in New Zealand and New Zealand cross-listings in Australia. Chen, Guangzhong, and Wu (2010) document similar evidence in support of the home bias hypothesis for China-backed ADRs listed in NYSE. More recently, Chen and Choi (2012) report that for Canadian cross-listed stocks the Toronto Stock Exchange is more informative than the US exchanges. Additional studies that

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1057-5219/$ – see front matter © 2013 Elsevier Inc. All rights reserved.
http://dx.doi.org/10.1016/j.irfa.2013.09.006

support home-market dominance include, but not limited to, Wong and Zurbruegg (1998), Hauser, Tanchuma, and Yaari (1998), Lieberman, Ben-Zion, and Hauser (1999), von Furstenberg and Tatora (2004), Mak and Ngai (2005), and Kutan and Zhou (2006).

The second argument in the literature consistent with a unidirectional impact of one market on the other is the global center hypothesis, which suggests that the information flow is more likely to occur from the market with higher liquidity to the one with less liquidity. Consistent with this hypothesis, a unidirectional return and volatility spillover transmission from the host to the home market can be created if the host market has a higher level of liquidity relative to the home market. As a result, the host market will dominate price discovery and have a more important role in determining future prices of cross-listed stocks. Kim, Szakmary, and Mathur (2000) examine price discovery for a comprehensive sample of ADRs and report that the US market dominates the home markets in pricing their ADRs. They also find that while ADRs underreact to changes in their underlying shares in the home markets, they overreact to changes in the US market. Using a bivariate GARCH model, Alaganar and Bhar (2002) find the US market to have more influence on the Australian ADRs at both the mean and volatility levels. In a more recent study, Phylaktis and Korczak (2006) investigate the potential effect of individual specialists on stock prices for 64 British and French firms cross-listed in NYSE over the a six-month period spanning January 2003 to June 2003 using intraday data. They find the US market to be more influential in pricing stocks when these stocks are concentrated in an individual specialist's portfolio. Studies by Hedvall, Liljeblom, and Nummelin (1997), Menkveld, Koopman, and Lucas (2007), Jaiswal-Dale and Jithendranathan (2009), among others, also document that trades occurring in the host exchanges convey more important information in pricing cross-listed stocks than the home capital markets.

The second strand in the literature postulates a two-way, bidirectional flow of returns and volatility inter-market spillovers, suggesting that both home and host markets are important sources of information generation and transmission. Thus both markets should play a significant role in the price discovery process. Werner and Kleidon (1996) analyze the intraday data patterns of British firms listed in NYSE and AMEX during the two-hour overlapping trading interval in the US and UK markets for the year 1991. Their results indicate that both markets contribute significantly to the pricing of the cross-listed stocks. Park and Kim (2001) and Kim (2005) find significant two-way first- and second-moment interactions between ADRs and their underlying stocks for Korean firms. Eun and Sabherwal (2003) examine price discovery for a sample of 62 Canadian firms listed in the Toronto Stock Exchange (TSE) and US exchanges. They use an error correction model to analyze a 6-month period of intraday data between February and July of 1998. Their findings suggest that both markets contribute significantly to the price discovery process for the sample of cross-listed stocks. However, a narrow analysis for each of the cross-listed stocks unveils that the US contribution to price discovery dominates that of the TSE for the majority of the stocks. Iwatsubo and Inagaki (2007) report bilateral return and volatility feedbacks for 22 NYSE-traded stocks issued by Asian firms during 1997–2005 with the US causal effects being stronger than those in the reverse direction. Using a bivariate GARCH model, Poshakwale and Aquino (2008) investigate volatility transmission and information flow for a sample of 70 ADRs and their underlying stocks from 13 countries over the period January 1990 to December 2000 at the daily frequency. Their empirical evidence documents that none of the two markets, home or host, dominates price discovery for the cross-listed stocks. In addition, their finding is robust across all markets and different sub-periods in the sample.

Karolyi (2006) provides a comprehensive survey of studies in the field of global cross-listing considering both conventional and newly offered arguments. One of his main conclusions is that the home market continues to play a dominant role in the price discovery process for cross-listed stocks but the more recent evidence suggests that the host markets, often the US market, are increasingly influential in price discovery.

In this study, we investigate the dynamic nature of information flow (return and volatility feedbacks) for an atypical international dual listing case. Previous studies have only considered the typical case where a company goes public in the domestic capital market and subsequently cross-lists its stock in the foreign market.[1] In particular, we examine the inter-market information flow dynamics for a unique sample of 29 Israeli firms that went public in the US (host market) and then cross-listed in the Israeli (home) market.[2] In order to test for international transfer pricing at both the mean and volatility levels, we employ a bivariate GARCH modeling strategy, allowing for both constant and dynamic conditional correlation specifications. In addition, we analyze the effects of three different external shocks on the correlation structure between the two markets. For comparison purposes, we also investigate mean and volatility spillover effects between the Israeli and US markets at the aggregate market index level.

Given that the Israeli stocks have gone public in the US and have access to the US capital market (which has a high level of liquidity), one may expect that the US market could serve as the home market and play a major role in pricing these Israeli stocks.[3] However, one cannot ignore the important role of the home market as a source of valuable information in determining future price movements, as implied by the home bias hypothesis, especially for a young, recently liberalized market, like the Israeli market. The main contribution of this research is to provide new evidence regarding the inter-market information flows obtained in this atypical international cross-listing framework, which may be characterized by additional complexities in the dynamic interactions.

At the aggregate market level, we find unidirectional US-led mean and volatility spillover influences on the Israeli market. However, in the inter-market transfer pricing for the portfolios of dually-listed Israeli stocks with US IPOs, we find a unidirectional influence of the underlying stocks in the home market (Israel) on their ADRs in the host market (US). Thus, the underlying stocks dominate their ADR counterparts in determining the equilibrium price of the cross-listed Israeli stocks (home dominance) in this atypical framework of international dual listing. The spillover interactions are more pronounced in the dynamic conditional correlations model. We also find that the inter-market correlation is positively dependent upon external shocks in the world and regional markets but it is not influenced by news in the Middle East peace process.

The plan of the paper is as follows. Section 2 provides a brief summary of important information regarding cross-listing in the Tel-Aviv Stock Exchange (TASE) followed by a description of the data in Section 3. In Section 4, we present the estimation methodology employed. The empirical evidence is presented in Section 5 and we conclude in Section 6 with a summary of our results and open questions.

[1] Bruner, Chaplinsky, and Ramchand (2004) document that foreign firms that go public in the US bypassing their domestic home markets are larger and of better quality than their IPO issuers in their home markets. Valero, Lee, and Cai (2009) provide a detailed analysis of the characteristics and motivating factors for the cross listing of foreign firms that went public in the US.

[2] There are two studies in the literature that focus exclusively on cross-listing of Israeli stocks. Hauser et al. (1998) use ARIMA and VAR models to investigate the causality in price changes for five Israeli firms cross-listed in NASDAQ using daily data from July 1988 to September 1993. They find unidirectional price causality from the home market to the host market suggesting a stronger role of the Israeli market in pricing its cross-listed stocks in the US. Lieberman et al. (1999) employ an error correction model to test the price behavior of six Israeli stocks cross-listed in the US over the period June 1988 to May 1998 at the daily frequency. They report that the Israeli market dominates price discovery for all sample stocks. Both studies focus on dually listed Israeli stocks in the typical cross-listing case, that is, the Israeli stocks go public in Israel and then cross-list in the US. In our study, however, we analyze return and volatility spillover effects for the reverse order (direction) of cross-listing, referred to as an atypical case, in which Israeli firms have US IPOs and then cross-list in their domestic capital market.

[3] The US capital market is known as the most liquid market; hence, it is expected to provide the Israeli stocks with more liquidity than the Israeli market.

2. Cross-listing in the Tel-Aviv stock exchange (TASE)

In October 2000, TASE initiated the Dual-Listing Law that enables firms traded in the US stock exchanges to cross-list in TASE with no additional regulatory requirements. Initially, the law was only applied to firms traded in NYSE, the NASDAQ national market, and AMEX. The law was subsequently expanded to include firms traded in the London Stock Exchange (LSE) main market and firms listed in the NASDAQ small cap with a market capitalization greater than $30 million. Firms that seek to cross-list in TASE under the Dual-Listing Law also have to be listed for at least one year in the US markets or the LSE. Firms that have traded for less than one year but maintained a market capitalization exceeding $150 million are also included in the law.

Besides having access to raise capital in TASE, the cross-listed stocks can benefit from the extended trading hours available to Israeli investors. Trading in TASE starts at 10:00 am and the US stock exchanges open at 4:00 pm Israeli time, almost the end of trading in TASE. Trade continues in the US market until 11:00 pm Israeli time, giving the Israeli investors the advantage of continuous trading for 13 hours in the cross-listed stocks. Furthermore, Israeli investors can trade the cross-listed stocks on US holidays.

To cross-list in TASE, firms have to submit a simple listing application and receive TASE's approval for listing. No other approvals are required and firms are not required to pay TASE listing fees or annual fees for the first year of cross-listing. Following cross-listing, firms are expected to file with the Israeli Securities Authority (ISA) their quarterly, semi-annual, and annual reports as well as their news releases filed in the US. All financial reports must be filed according to the US time schedule. In summary, if a firm is originally listed in the US or London exchanges and decides to cross-list in TASE, it will not experience any changes in its accounting practices or disclosure requirements.

3. Data

The final sample consists of 29 Israeli firms with US IPOs (unseasoned public offerings) that subsequently cross-listed in TASE over the five-year period spanning September 1, 2006 to September 1, 2011 at the weekly frequency (a total of 262 weekly observations for each portfolio).[4] Our sample is identified from the official website of TASE, which offers a complete list of all dually-listed stocks in the US and other foreign stock exchanges around the world. Appendix A provides the list of sample firms, their ticker symbol, the US exchange in which they are listed, and their industry.

One major limitation to the studies of international cross-listing occurs when trading days across markets are different and overlapping trading hours between the markets exist. To overcome such a problem, the recent literature started using intra-day data, when available, which enable the study of price transmission across markets precisely. However, the availability of intra-day data in the home market is very limited, especially for smaller and less organized markets like the Israeli capital market (Karolyi, 2006). Also Karolyi and Stulz (1996) suggest the use of the portfolio approach when trading days are different and overlapping hours between markets exist, which is the case for the Israeli and US markets. To avoid any biasness in our estimation caused by the nonsynchronous trading periods and overlapping hours between the two markets, we use weekly returns for two value-weighted portfolios constructed from our sample firms, namely, the underlying stock and ADR portfolios referring to the Israeli stocks listed in TASE and their ADR counterparts in the US market. All weekly returns are denominated in US dollars and the exchange rate of the Israeli shekel used to calculate stock returns traded in the Israeli market is obtained from the official website of the Bank of Israel. The source of all Israeli data is the official website of TASE while the source of the US data is the Center for Research in Security Prices (CRSP).

To better understand the price transmission mechanism between the Israeli and US markets, we also perform a comparative analysis by examining the inter-market linkages at the aggregate market level. Toward that purpose, we use weekly returns for the Morgan Stanley Capital Index (MSCI) US and Israeli indices. In addition, the effects of three different external shocks on the conditional correlation structure are considered. The first external shock is the political instability represented by the presence of bad news from the Middle East peace process. The sources of the second and third external shocks originate from the MSCI world market index and the MSCI regional index EMEI (Europe and Middle East Index).

4. The econometric model

Initially, we evaluate the inter-market return and volatility linkages using an extended version of Bollerslev's (1990) multivariate generalized autoregressive conditional heteroscedasticity model with constant conditional correlation (CCC-GARCH), referred to as the extended constant conditional correlation GARCH (ECCC-GARCH) model. Such a model assumes constant conditional correlations across markets but allows for correlation shifts due to external shocks. Compared to the standard CCC-GARCH model, the ECCC-GARCH model allows for a more abundant autocorrelation structure (He & Terasvirta, 2004).[5]

Let y_t denote an $M \times 1$ vector of system variables with time-varying conditional covariance matrix H_t, given by

$$y_t = E(y_t|\omega_{t-1}) + \varepsilon_t \tag{1}$$

$$Var(\varepsilon_t|\omega_{t-1}) = H_t \tag{2}$$

where ω_{t-1} is the conditional information set up to time $t-1$ and H_t is almost surely positive definite for all t. In the multivariate CCC-GARCH model, the full conditional covariance matrix H_t is given by

$$H_t = D_t \rho D_t \tag{3}$$

where D_t denotes the $M \times M$ stochastic diagonal matrix with elements $\sigma_{1t},\dots,\sigma_{Mt}$ and ρ is an $M \times M$ time invariant correlation matrix. The parameters of the model in Eqs. (1)–(3) are obtained by maximum likelihood estimation using a joint multivariate normal density function.

The specific model estimated in this study is a bivariate ($M = 2$) ECCC-GARCH (1, 1) model given by

$$R_{1,t} = w_{10} + w_{11}R_{1,t-1} + w_{12}R_{2,t-1} + \varepsilon_{1,t} \tag{4}$$

$$R_{2,t} = w_{20} + w_{21}R_{1,t-1} + w_{22}R_{2,t-1} + \varepsilon_{2,t} \tag{5}$$

$$\begin{bmatrix} \varepsilon_{1,t} \\ \varepsilon_{2,t} \end{bmatrix} \sim N(0, H_t) \tag{6}$$

where $R_{1,t}$ and $R_{2,t}$ are the portfolio returns at time t for the underlying Israeli portfolio of stocks and their US-listed ADRs, respectively. When evaluating the spillover effects between the two markets at the aggregate level, $R_{1,t}$ and $R_{2,t}$ refer to the returns of the MSCI Israeli and US stock indices, respectively. The conditional-mean spillovers in Eqs. (4) and (5) are captured by the coefficients w_{12} and w_{21}, respectively.

[4] As a robustness check, a wider time window covering the period August 1, 2002 to August 1, 2011 was considered resulting in a sample of 20 stocks and a total of 470 weekly observations (there is a tradeoff between the time window used and the number of firms included in the final sample, since firms cross-listed in TASE at different dates). Test statistics of this smaller firm-sample with a wider time window (available upon request) are qualitatively similar to those of the larger sample with a narrower time window reported in this study.

[5] See Bauwens, Laurent, and Rombouts (2006) for a comprehensive survey of multivariate GARCH theoretical modeling and applications.

Table 1
Summary statistics of the weekly portfolio returns.

Portfolio	Mean	Standard deviation	Skewness	Kurtosis	$LB(1)$	$LB(12)$	$ARCH(6)$
Underlying stocks	0.002242	0.029473*	0.020341***	19.2583***	3.033**	16.609	29.659***
ADRs	0.003643	0.028705**	0.113283	4.663261***	5.974*	21.999	14.096**
Israeli index	0.003952	0.024104***	−0.011873	4.574668***	1.137	14.630	68.831***
US index	0.001616	0.018166**	−0.203248	4.235504***	0.213	14.256	15.709**

Notes: The underlying stock portfolio is a value-weighted index of 29 Israeli firms with US IPOs that later cross-listed in TASE over the five-year period September 1, 2006 to September 1, 2011. The portfolio of ADRs corresponds to the American Depository Receipts of the underlying stock portfolio. The Israeli and US stock market indices are obtained from the Morgan Stanley Capital Index (MSCI). Weekly returns in US dollars are used for all four portfolios for a total of 262 observations. $LB(k)$ is the Ljung–Box test statistic for correlation of order k. $ARCH(k)$ is Engle's (1982) Lagrange multiplier test statistic for autoregressive conditional heteroscedasticity of order k.
*** Indicate statistical significance at the 1% level.
** Indicate statistical significance at the 5% level.
* Indicate statistical significance at the 10% level.

The conditional variance–covariance matrix is given by

$$H_t = \begin{bmatrix} h_{11,t} & h_{12,t} \\ h_{21,t} & h_{22,t} \end{bmatrix} \tag{7}$$

where

$$h_{11,t} = \alpha_{10} + \alpha_{11}\varepsilon^2_{1,t-1} + \alpha_{12}\varepsilon^2_{2,t-1} + \beta_{11}h_{11,t-1} \tag{8}$$

$$h_{22,t} = \alpha_{20} + \alpha_{21}\varepsilon^2_{1,t-1} + \alpha_{22}\varepsilon^2_{2,t-1} + \beta_{22}h_{22,t-1} \tag{9}$$

$$h_{12,t} = (\rho + \gamma \cdot \varphi_t)\sqrt{h_{11,t} \cdot h_{22,t}}. \tag{10}$$

The volatility spillovers in Eqs. (8) and (9) are captured by the coefficients α_{12} and α_{21}, respectively. Although it is assumed in this model that the correlation, ρ, is time invariant, it is influenced by an external shock, φ_t, with the coefficient γ controlling for the correlation shift due to the proposed external shock.

The external shock is defined as a Heaviside variable and three sources of shock are considered. For the shock originating from the Middle East peace process the indicator variable φ_t equals 1 when bad news occurs and equals 0 otherwise.[6] When the source of external shocks is the MSCI world market index or the MSCI regional index EMEI (Europe and Middle East Index), the indicator variable equals 1 when $|index_t - index_{t-1}| > median$ and equals 0 otherwise.

A drawback of the ECCC-GARCH model is that it assumes a time-invariant conditional correlation, although it is documented in the literature that the correlations across equity markets vary over time. We initially use the ECCC-GARCH model in order to measure the impact of the external shocks on correlation. Solnik, Bourcrelle, and Fur (1996) suggest that the level of correlation between markets is positively impacted by volatility. Therefore, the ECCC-GARCH model can be used to evaluate the finding of Solnik et al. with respect to the Israeli and US markets.

To gain model flexibility by allowing for time-varying correlations among the system variables, we subsequently utilize Engle's (2002) dynamic conditional correlation GARCH (DCC-GARCH) model. The conditional covariance matrix H_t in this model is given by

$$H_t = D_t \rho_t D_t \tag{11}$$

where ρ_t is a time-varying correlation matrix and D_t is an $M \times M$ diagonal matrix of standardized residuals, ε_t, obtained from the univariate GARCH models. The log-likelihood of the DCC estimator can be written as

$$L = -\frac{1}{2}\sum_{t=1}^{T}\left(M\log(2\pi) + 2\log(|D_t|) + \log(|\rho_t|) + \varepsilon_t'\rho_t^{-1}\varepsilon_t\right). \tag{12}$$

For our specific bivariate DCC-GARCH model, the dynamic conditional correlation matrix ρ_t is

$$\rho_t = (1-\theta_1-\theta_2)\bar{\rho} + \theta_1\varepsilon_{t-1}\varepsilon'_{t-1} + \theta_2\rho_{t-1} \tag{13}$$

where $\theta_1 + \theta_2 < 1$ and $\theta_1 > 0, \theta_2 > 0$. The scalar parameters θ_1 (news term) and θ_2 (decay term) capture the effects of previous standardized shocks and dynamic conditional correlations on current dynamic conditional correlations, respectively. If $\theta_1 = \theta_2 = 0$, the constant correlation model is obtained as $\rho_t = \bar{\rho}$ in that case. In the case that $\theta_1 + \theta_2 = 1$, the dynamic correlations have an integrated structure.

5. Empirical estimates

Table 1 reports the summary statistics for the weekly returns of all four portfolio series used in this study, namely, the portfolio of the underlying cross-listed stocks in the Israeli market, their ADR counterparts in the US, the MSCI stock market index for Israel, and the MSCI stock market index for the US. The normality assumption is rejected for all stock portfolio returns as they are characterized by excess kurtosis (leptokurtosis). Based on the Ljung–Box test, there is evidence of low-order linear dependence in the returns of the cross-listed stock portfolios but not for the stock market indices. Application of Engle's (1982) Lagrange multiplier test for autoregressive conditional heteroscedasticity indicates significant time variation in the second moment (time-varying conditional volatilities) for all returns series. These results offer preliminary justification for the use of a multivariate GARCH approach to modeling the first- and second-moment dependencies for the two markets. Table 2 presents the correlation matrix for the four stock portfolio returns. As expected, the correlation coefficient estimate between the underlying stock and ADR portfolios is much larger (0.854) compared to the one between the Israeli and US indices (0.548).

Table 2
Cross-correlation of the weekly portfolios returns.

Portfolio	Underlying stocks	ADRs	Israeli index	US index
Underlying stocks	1	0.8544	0.7025	0.2678
ADRs		1	0.7183	0.2811
Israeli index			1	0.5485
US index				1

[6] Data for the bad news from the Middle East peace process are obtained from the LexisNexis database. We include only major events that are likely to have a major influence on the Israeli capital market (e.g., suicide bombing, assassination from the Israeli or Palestinian side, the invasion of Gaza, and Israel's Lebanon war).

Table 3

Bivariate ECCC-GARCH model estimation results for the system of Israeli and US stock indices. This table reports the test statistics for the bivariate ECCC-GARCH model specified in Eqs. (4) through (10), which assumes a constant conditional correlation between the Israeli and US stock market indices. Three external shocks are proposed to evaluate their impact on the conditional correlation: bad news from the Middle East peace process (MEPP news), MSCI Europe & Middle East Index (EMEI), and MSCI world market index.

Portfolios		Mean equation		Mean spillover	Volatility equation		Volatility spillover	GARCH effect	Correlation	Correlation shift due to shock	Log-likelihood
Israeli index		w_{10}	w_{11}	w_{12}	a_{10}	a_{11}	a_{12}	β_{11}	ρ	γ	
No shock		0.0033	−0.0273	0.5343	0.0000	0.1046	0.0285	0.8821	0.5121		1826.12
		(2.43)	(−0.4)	(8.32)	(1.03)	(2.23)	(2.61)	(12.57)	(4.95)		
Source of external shock	MEPP news	0.0032	−0.0203	0.5371	0.0001	0.1026	0.0288	0.8875	0.4895	−0.0221	
		(2.41)	(−0.28)	(8.38)	(1.01)	(2.16)	(3.16)	(12.19)	(6.01)	(−0.35)	
	MSCI-EMEI	0.0034	−0.0308	0.5152	0.0000	0.1136	0.0311	0.8706	0.5067	0.0448	
		(2.63)	(−0.45)	(7.78)	(1.82)	(2.74)	(2.70)	(10.46)	(5.65)	(3.22)	
	MSCI-world	0.0037	−0.0339	0.5428	0.0003	0.1167	0.0351	0.8629	0.5041	0.0912	
		(3.12)	(−0.05)	(8.71)	(3.65)	(2.89)	(2.47)	(9.07)	(4.61)	(2.97)	
US index		w_{20}	w_{22}	w_{21}	a_{20}	a_{22}	a_{21}	β_{22}			
No shock		0.0023	0.1416	0.1163	0.0000	0.056	0.0112	0.902			
		(2.24)	(2.25)	(0.75)	(1.30)	(2.03)	(0.26)	(23.01)			
Source of external shock	MEPP news	0.0028	0.1399	0.0948	0.0000	0.0782	0.0154	0.8611			
		(2.67)	(2.21)	(0.61)	(1.26)	(1.58)	(0.26)	(19.7)			
	MSCI-EMEI	0.0022	0.1261	0.1179	0.0000	0.0523	0.0129	0.8247			
		(2.16)	(1.9)	(0.77)	(1.45)	(2.03)	(1.19)	(23.73)			
	MSCI-world	0.0016	0.154	0.0932	0.0003	0.0563	0.0133	0.8419			
		(1.38)	(2.56)	(0.55)	(1.13)	(1.84)	(1.16)	(20.01)			

Notes: *t*-test statistics for the coefficient estimates are given in parentheses.

We next present the ECCC-GARCH empirical estimates to be followed by those obtained from the DCC-GARCH model. Both models allow for time-varying conditional volatilities with the first model imposing a constant conditional correlation among the system variables while the latter model drops this assumption and allows for dynamic and non-constant correlations.

5.1. Constant conditional correlation (CCC) results

To provide a basis for comparative analysis, we first present the empirical estimates at the aggregate market level and subsequently those for the portfolios of the cross-listed stocks. Table 3 reports the bivariate ECCC-GARCH(1, 1) estimation results, Eqs. (4) through (10), for the US and Israeli aggregate stock indices. We estimate the model without imposing any shocks to the constant conditional correlation initially and then allow for external shocks originating from three sources. The coefficients w_{11} and w_{22} represent the own first-order autoregressive, AR(1), coefficients for the Israeli and US markets, respectively. While the AR(1) coefficient in the conditional-mean equation for the US index is significantly positive, it is not statistically significant for the Israeli index. The mean spillover coefficient from the US to the Israeli market, $w_{12} = 0.534$, is significant, suggesting a positive impact of the US market on the Israeli market at the aggregate market level, but not vice versa. There is volatility persistence, captured by the large values for the β_{11} and β_{22} coefficients for the Israeli and US markets, respectively. Volatility spillovers (volatility-on-volatility effects), on the other hand, exist only in the direction of the US to the Israeli market reflected in the significantly positive $\alpha_{12} = 0.028$ coefficient. These results for the aggregate market indices show that the US market has a strong unidirectional influence on the Israeli market at both the conditional mean and volatility levels. The correlation between the two markets is significantly positive (0.512). When an external shock is allowed to shift the constant correlation between the two markets, we find that the bad news from the Middle East peace process has no impact on the inter-market correlation. However, external shocks originating from the world (MSCI world index) and regional (MSCI regional index EMEI) markets cause a positive shift in the correlation with the world market shocks being more than twice as impactful as the regional market shocks (0.091 versus 0.044). Thus the inter-market conditional correlation is dependent upon external market shocks. This result is consistent with the findings of Odier and Solnik (1993) and Solnik et al. (1996) suggesting an unfavorable connection between volatility and correlation among international markets.

In Table 4 we present the estimation results from the bivariate ECCC-GARCH(1, 1) model applied to the portfolios of the cross-listed stocks in the Israeli market (underlying stocks) and their ADR counterparts listed in the US market.[7] The AR(1) coefficient for the portfolio of cross-listed stocks in TASE (home market), w_{11}, is significantly positive. However, the corresponding autoregressive coefficient for the ADRs (host market), w_{22} is statistically insignificant. There are significantly positive mean spillovers from the underlying stocks to the ADRs, captured by $w_{21} = 0.351$, but such spillover effects do not exist in the opposite direction. A similar unidirectional volatility spillover is observed from the underlying stocks to the portfolio of ADRs ($a_{21} = 0.141$ is significantly positive but a_{12} is statistically insignificant). Thus, at both the mean and volatility levels, the evidence suggests a unidirectional influence of the underlying stocks on their ADR counterparts, which is contrary to the direction of information flow at the aggregate market level. When bad news originating from the Middle East peace process is allowed for in the estimation process, the conditional correlation between the two portfolios is not influenced. External shocks originating from the world and regional markets cause a positive shift in the correlation between the two portfolios. World market shocks are more potent than regional market shocks (0.080 versus 0.061).

5.2. Dynamic conditional correlation (DCC) results

The assumption of constant conditional correlation is a restrictive one in modeling inter-market linkages. The dynamic conditional correlation (DCC) model provides flexibility and pragmatism by allowing for time-varying correlations among the system variables. We extend our analysis by estimating a bivariate DCC-GARCH(1, 1) model to capture the dynamic interdependencies between the Israeli and US markets. At the aggregate market index level, the results reported in Table 5 show that the DCC parameters θ_1 and θ_2 are statistically significant indicating a dynamic and non-constant conditional correlation structure. In addition,

[7] The nature of the empirical results that follow and the inferences drawn are invariant to the method of constructing the portfolio index for the underlying stocks and their corresponding ADRs. More specifically, the reported findings remain essentially unaltered if equally-weighted (as opposed to value-weighted) portfolios are used in the analysis.

Table 4
Bivariate ECCC-GARCH model estimation results for the system of the underlying cross-listed Israeli stocks and their ADRs. This table reports the test statistics for the bivariate ECCC-GARCH model specified in Eqs. (4) through (10), which assumes a constant conditional correlation between the underlying cross-listed Israeli stocks and their ADR counterparts. Three external shocks are proposed to evaluate their impact on the conditional correlation: bad news from the Middle East peace process (MEPP news), MSCI Europe & Middle East Index (EMEI), and MSCI world market index.

Portfolios		Mean equation		Mean spillover	Volatility equation		Volatility spillover	GARCH effect	Correlation	Correlation shift due to shock	Log-likelihood
Underlying stocks		w_{10}	w_{11}	w_{12}	a_{10}	a_{11}	a_{12}	β_{11}	ρ	γ	
No shock		0.0004	0.1801	−0.1104	0.0005	0.0517	0.0138	0.8320	0.8781		2270.70
		(1.17)	(2.01)	(−1.13)	(6.67)	(4.57)	(1.25)	(8.20)	(32.94)		
Source of external shock	MEPP news	0.0006	0.1699	−0.0996	0.0003	0.0636	0.0161	0.823	0.8817	0.0369	
		(0.42)	(1.92)	(−1.16)	(4.53)	(2.60)	(1.48)	(8.82)	(37.37)	(0.11)	
	MSCI-EMEI	−0.001	0.1719	−0.1191	0.0004	0.0698	0.0129	0.8263	0.8725	0.0613	
		(−0.74)	(2.13)	(−1.55)	(7.62)	(5.81)	(1.34)	(8.56)	(35.22)	(2.29)	
	MSCI-world	0.0035	0.1746	−0.0837	0.0004	0.0526	0.014	0.8246	0.8840	0.0801	
		(1.83)	(1.97)	(−1.01)	(2.09)	(2.66)	(1.15)	(7.37)	(44.02)	(2.72)	
ADRs		w_{20}	w_{22}	w_{21}	a_{20}	a_{22}	a_{21}	β_{22}			
No shock		0.0038	−0.1389	0.3511	0.0001	0.1308	0.1417	0.8297			
		(1.93)	(−0.97)	(5.04)	(1.81)	(2.72)	(8.46)	(7.71)			
Source of external shock	MEPP news	0.0033	−0.1245	0.3441	0.000	0.1337	0.1312	0.8089			
		(2.12)	(−1.15)	(4.32)	(1.09)	(2.45)	(6.55)	(6.31)			
	MSCI-EMEI	0.0029	−0.1578	0.361	0.0001	0.1099	0.1429	0.8373			
		(1.81)	(−1.12)	(4.97)	(1.77)	(2.37)	(8.84)	(10.15)			
	MSCI-world	0.0029	−0.1508	0.3581	0.0002	0.1233	0.1388	0.8333			
		(1.86)	(−1.45)	(4.09)	(2.64)	(2.89)	(7.01)	(5.29)			

Notes: *t*-test statistics for the coefficient estimates are given in parentheses.

we applied the Lagrange multiplier (LM) test of Tse (2000) and the x^2 test of Engle and Sheppard (2001) for the null hypothesis that $\rho_t = \overline{\rho}$. Both tests strongly reject the null hypothesis of conditional correlation constancy: the test statistic and associated p-value are 6.138 and 0.000, respectively, for the LM test and 89.47 and 0.000, respectively, for the x^2 test. The large value for the decay parameter θ_2 (0.968) suggests a high degree of persistence in the memory of the correlation process between the US and Israeli markets. A shock to the correlation process is likely to persist for a long time period. The dynamic interactions are similar to the ones obtained from the CCC model. Specifically, there are positive mean and volatility spillovers only from the US to the Israeli market, as captured by the statistically significant $w_{12} = 0.512$ and $a_{12} = 0.039$ coefficients.

For the bivariate system of the cross-listed stock portfolios, the DCC estimator is also warranted given the statistical significance of the parameters θ_1 and θ_2. Both Tse's LM and Engle and Sheppard's x^2 tests provide strong support in favor of the dynamic conditional correlation model. The LM (x^2) test statistic and associated p-value are 4.237 (33.21) and 0.003 (0.000), respectively. As evidenced in Table 6, the large value of the θ_2 parameter demonstrates correlation persistence but of lesser degree compared to the correlation persistence exhibited between the Israeli and US markets at the aggregate level (0.885 versus 0.968). This implies that shocks are more likely to shift the correlation between market indices away from its long-run average than it would for the system of the Israeli stocks and their ADRs. This finding is expected as one would assume the correlation between the Israeli underlying stocks and their ADRs to be more stable than the one between the market indices. The return and volatility spillovers are unidirectional from the underlying stocks in the Israeli (home) market to their ADRs in the US (host) market and positive in sign, $w_{21} =$

Table 5
Bivariate DCC-GARCH model estimation results for the system of Israeli and US stock indices. This table reports the test statistics for the bivariate DCC-GARCH model specified in Eqs. (4) through (9) and (13), which assumes dynamic conditional correlations between the Israeli and US stock market indices.

Portfolios	Mean equation		Mean spillover	Volatility equation		Volatility spillover	GARCH effect	DCC parameters		Log-likelihood
Israeli index	w_{10}	w_{11}	w_{12}	α_{10}	α_{11}	α_{12}	β_{11}	θ_1	θ_2	
	0.0046	−0.0331	0.5120	0.0000	0.1130	0.0390	0.8699	0.0172	0.9680	1918.30
	(3.01)	(−1.01)	(6.48)	(0.94)	(3.19)	(3.66)	(14.01)	(3.36)	(33.84)	
US index	w_{20}	w_{22}	w_{21}	α_{20}	α_{22}	α_{21}	β_{22}			
	0.0039	0.2133	0.0988	0.0000	0.051	0.0183	0.8911			
	(2.67)	(2.25)	(0.66)	(1.04)	(2.03)	(0.77)	(26.09)			

Notes: *t*-test statistics for the coefficient estimates are given in parentheses.

Table 6
Bivariate DCC-GARCH model estimation results for the system of the underlying cross-listed Israeli stocks and their ADRs. This table reports the test statistics for the bivariate DCC-GARCH model specified in Eqs. (4) through (9) and (13), which assumes dynamic conditional correlations between the underlying cross-listed Israeli stocks and their ADRs counterparts.

Portfolios	Mean equation		Mean spillover	Volatility equation		Volatility spillover	GARCH effect	DCC parameters		Log-likelihood
Underlying stocks	w_{10}	w_{11}	w_{12}	α_{10}	α_{11}	α_{12}	β_{11}	θ_1	θ_2	
	0.0012	0.2110	−0.1005	0.0000	0.1529	0.0211	0.8161	0.0181	0.8852	2292.29
	(1.02)	(2.44)	(−0.99)	(3.81)	(3.06)	(1.29)	(10.12)	(3.17)	(23.48)	
ADRs	w_{20}	w_{22}	w_{21}	α_{20}	α_{22}	α_{21}	β_{22}			
	0.0042	−0.1471	0.4229	0.0000	0.1938	0.1883	0.7889			
	(2.87)	(−1.01)	(5.81)	(1.17)	(2.88)	(9.26)	(9.04)			

Notes: the *t*-test statistics for the coefficient estimates are given in parentheses.

0.422 and $a_{21} = 0.188$, respectively. Compared to the CCC results, the dynamic interdependencies are stronger in the DCC model as evidenced by the larger coefficient estimates for the mean spillover (0.422 versus 0.351) and volatility spillover (0.188 versus 0.141). However, the spillover effects in the DCC model are qualitatively similar to those obtained from the CCC model.

These results support Israeli market dominance in the price discovery process for the dually listed stocks. Thus, the evidence in this atypical international cross-listing framework validates the home bias hypothesis, which argues that the home market is the active, driving source of all valuable and relevant information in pricing cross-listed stocks. Despite the much higher level of liquidity in the US market compared to the Israeli market, the evidence does not support the global center hypothesis. The hypothesis that calls for bidirectional spillover effects is not empirically supported as well.

6. Conclusions

This investigation attempts to shed light on an ignored side of international cross listing, namely, the atypical case where a firm bypasses its home market to have a foreign IPO and later cross-lists in its home market. Particularly, we analyze the inter-market information flows for a unique sample of Israeli firms with US IPOs that subsequently cross listed in the Israeli market. We empirically estimate these dynamic interactions (mean and volatility spillovers) in a bivariate GARCH framework using both constant and dynamic conditional correlation specifications.

For both specifications, but even more so for the dynamic conditional correlation estimator, we find unidirectional mean and volatility spillover effects from the home market to the host market, rejecting the global center hypothesis. Thus, this study provides new evidence to the ongoing debate of international transfer pricing for cross-listed stocks in support of the home dominance. At the aggregate market index level though, the US capital market reserves its role as the central, information-producing market in the price discovery process.

We consider the atypical international cross listing framework as an interesting avenue for future research. The causal relationships between prices of cross-listed stocks in atypical frameworks across different home and host capital markets may be characterized by additional complexities and thus may offer further insights into price discovery. Different markets have differential levels of liquidity, institutional frameworks, legal and market structures, and other characteristics which may impact the issue of dominance in the transfer of pricing information under alternative cross-listing frameworks.

Appendix A. List of cross-listed Israeli firms with US IPOs

Name	Ticker symbol	US stock exchange	Industry
ALVARION	ALVR	NASDAQ	Wireless communications
AUDIOCODES	AUDC	NASDAQ	Communication equipment
BLUE SQUARE ISR	BSI	NYSE	Grocery stores
BLUEPHOENIX	BPHX	NASDAQ	Business software & services
CERAGON	CRNT	NASDAQ	Communication equipment
COMPUGEN	CGEN	NASDAQ	Biotechnology
ELBIT IMAGING	EMIT	NASDAQ	Property management
ELBIT SYSTEMS	ESLT	NASDAQ	Aerospace/defense products & services
ELRON	ELRN	NASDAQ	Information technology services
EZCHIP	EZCH	NASDAQ	Semiconductor equipment & materials
FORMULA	FORT	NASDAQ	Business software & services
FUNDTECH	FNDT	NASDAQ	Application software
GILAT	GILT	NASDAQ	Communication equipment
GIVEN IMAGING	GIVN	NASDAQ	Medical appliances & equipment
INTERNET GOLD	IGLD	NASDAQ	Diversified communication services
ITURAN	ITRN	NASDAQ	Electronics wholesale

Appendix A (*continued*)

Name	Ticker symbol	US stock exchange	Industry
JACADA	JCDA	NASDAQ	Internet software & services
MAGAL SYSTEMS	MAGS	NASDAQ	Security & protection services
MAGIC	MGIC	NASDAQ	Application software
NICE	NICE	NASDAQ	Computer peripherals
ORCKIT	ORCT	NASDAQ	Communication equipment
PARTNER	PTNR	NASDAQ	Wireless communications
PERRIGO	PRGO	NASDAQ	Drug related products
RADVISION	RVSN	NASDAQ	Processing systems & products
RETALIX	RTLX	NASDAQ	Application software
SILICOM	SILC	NASDAQ	Networking & communication devices
TAT TECHNO	TATTF	NASDAQ	General building materials
TEVA	TEVA	NASDAQ	Drug manufacturers — other
TOWER	TSEM	NASDAQ	Semiconductor — integrated circuits

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