Bid–Ask Spreads and Implied Volatilities of Key Players in a FX Options Market

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This study proposes a simultaneous estimation of the bid–ask spreads (BAS) and implied volatility (IV), based on trading options of various key players in the Israeli OTC FX options market. It explores the surface shape of both variables based on a "clientele effect." We employ detailed data on OTC foreign exchange options trading that enable us to examine the behavior of the key players (financial companies, non-financial firms, households, and foreign investors) during relatively turbulent and tranquil periods. Using simultaneous unbiased estimates of BAS and IV, we find substantial differences in BASs among key players while insignificant differences in IV. This evidence reflects differences in key players' profile such as trading size, sophistication and contestability on one hand and a "no arbitrage opportunities" of IV on the other hand. © 2013 Wiley Periodicals, Inc. Jrl Fut Mark

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1. INTRODUCTION

This study focuses on the microstructure of an OTC FX options market and investigates the behavior of key players such as: financial companies, non-financial local firms, households, and foreign investors in the market. We propose a more robust estimation of the bid–ask spread (BAS) and implied volatility (IV) in the Israeli OTC FX options market by examining them simultaneously, and exploring the microstructure biases across players, across moneyness and maturity, and across turbulent and tranquil periods. Thus, we offer "clientele" explanations to the observed various BAS and IVs.

We employ a unique dataset of the Israeli OTC FX options market based on a comprehensive and reliable data collected by the central bank—the Bank of Israel. The regulatory filing of such data is complete and enables us to identify the counterparties to each transaction. The sample period is extensive and covers both turbulent and tranquil periods. While many studys are engaged in modeling the microstructure of FX markets (see an extensive survey by Vitale, 2007), they are constrained mainly by data limitations.

By exploring the behavior of the key players in the Israeli FX option market during turbulent and tranquil periods, we are able to derive robust estimators of the key players' BAS and IV surfaces. In practice BAS and IV are simultaneously determined and we find positive relations between them in generalized method of moments regressions (GMM). We also show how the surfaces of BAS and IV are changing as a function of moneyness (MON) and days-to-expiration (DTE) and how net demand for FX options of a key player (termed as "net buying pressure") affects those surfaces.

This study is the first to examine such information and to explore contemporaneous impacts between players, BAS, and IV. George and Longstaff (1993) examined the influence of MON and DTE on BAS for call and put options on the S&P100. Our study is different from George and Longstaff in at least three aspects: (1) We examine the "clientele effects" and focus on various players' option trading (e.g., the demand for options of households versus foreign investors) rather than naked call and put options, (2) Their data are based on intraday quotes of options on S&P100 while the data in our study are actual daily options on ILS/USD exchange rate, (3) We examine both BAS and IV as two-equation system whilst they examine the influence of IV on BAS but not the other way around. We find that despite the similarities among the key players' IV their respective BAS are quite different, for example, foreign investors' BAS is much lower than other key players' BAS especially households. The findings, which are consistent with Menkhoff, Osler, and Schmeling (2007), are explained by the different characteristics of the key players, for example, foreign investors are large sophisticated players compared to small naïve households. Another difference is players' motivation, for example, financial companies usually trade for speculation purposes while non-financial (corporate) firms trade for hedging purposes. This explains why during turbulent periods financial companies increased their activity compared to non-financial companies. We also find cross subsidization between households and other key players' BAS especially during turbulent periods.

The study is organized as follows: Section 2 surveys the literature and Section 3 describes the sample data and the methodology. In Section 4 we present the behavior of the key players in the OTC FX market and their strategies. Section 5 tests hypotheses regarding BAS and implied volatilities (IV) while Section 6 summarizes the main findings.

2. LITERATURE SURVEY

Many studies have explored the microstructure of OTC markets, including that of FX option markets. These studies, however, tend to be limited in scope from the standpoint of data coverage. Given the opacity and loose regulation of these markets, data are typically gathered by a specific investment bank, or by surveys of specific companies (see Bodnar, Hayt, Marston, & Smithson, 1995; Bodnar, Jong, & Macrae, 2003; Chong, Ding, & Tan, 2003; Muller & Verschoor, 2006; Ding, 2009; Grover & Thomas, 2012, and a survey by Vitale, 2007). Usually, they examine the behavior of either BAS or IV but not both of them, simultaneously. We shall see later why including both BAS and IV in a two-equation system is important. Illiquidity is mentioned as an important factor affecting IV. For example, Grover and Thomas (2012) argue that IV should be higher for illiquid options due to the lack of informativeness of the prices. Brenner, Eldor, and Hauser (2001) found in the Israeli FX option markets substantial illiquidity premium embedded in IVs of nontraded options. Lately, Christoffersen, Goyenko, Jacobs, and Karoui (2011) found that option returns of large stocks are influenced by the illiquidity of the underlying stocks. These findings point to the effect of illiquidity, measured mostly by BAS, on IV.

Becker and Sy (2005) argue that among the three cost types affecting the BAS: (1) Order processing costs (2) Asymmetric information costs and (3) Inventory costs, only (2) and (3) are substantial in FX markets. They also argue that information risk, which can affect IV, is the most salient factor explaining changes in BAS. As IV reflects the expected volatility in financial markets, and particularly in FX option markets, one should expect that BAS is positively correlated with IV. Cost type (3) may occur, when there is a mismatch between the market maker's long and short position (net buying pressure). In such a case, market makers may bear price losses on their net position. In addition, they bear opportunity costs as they forego interest rates that can be earned on less liquid instruments. One way to indirectly assess this cost type is to regressing BAS on the difference between long and short positions. It is found that market makers increase spreads to offset the increased risk of losses during turbulent periods (see, Cheung & Wong, 2000; Becker & Sy, 2005).

Another phenomenon found in FX markets called by Menkhoff et al. (2007) "strategic dealing." They argue that rational FX dealers might strategically vary spreads to gain information exploited in future trades. Thus, FX dealers effectively subsidize spreads to attract large transactions from informed investors most likely to carry useful information on the expense of small novice investors. Moreover, they argue that financial investors are more informed than commercial investors are. Thus, the former's BAS should be higher than the respective latter's BAS (all other things being equal).

3. DESCRIPTION OF THE DATA

The data include all Israeli Shekel (ILS) options on the exchange rate of the US dollar bought and sold in the local OTC market during the period 1/2002–6/2006. ILS/USD options are also traded on the Tel-Aviv Stock Exchange (TASE). Brenner and Schreiber (2013) found relations between the two FX option markets through the local banks. These FIs who served as market makers possibly took advantage of the simultaneity of the two markets by hedging in one market their exposures in the other market. However, as there are no statistics on the nature of the buyers and sellers of TASE's options, we did not add these options to our database.[1] The OTC FX options market in Israel is limit-order driven with direct negotiation between the bank who serves as a market maker or the strategic FX dealer *a la* Menkhoff et al. (2007), and the client. All OTC transactions are reported by the local banks to the central bank on a daily basis. The filings include information both regarding the identity of the bank's counterparties and details on the transaction itself. This information enables us to categorize investors into four groups: financial companies, non-financial firms (corporates), retail investors (households), and foreign investors. This categorization is mutually exclusive. Bank disclosures include: (1) IV of the particular transaction which is reported by the reporting bank,[2] (2) option premium paid or received from the market maker (a local bank), (3) notional value (total underlying) in US

[1] In addition to the OTC and TASE markets, there was a very small market for ILS/USD currency options organized by the Bank of Israel during the sample period. As this market was negligible and the players are anonymous, we discarded this market too.

[2] In approximately one fourth of the observations, IV data were missing from the bank filings. For these cases, we calculated IV using information from the local banks and complementary market data, that is, interest and the "representative" spot rates. As all options in our sample are plain vanilla, the IV for these cases was derived using the Black and Scholes formulae. Brenner and Schreiber (2013) showed that the use of calculated IVs rather than the reported IVs did not substantially change the resulting IVs.

dollars, (4) DTE, and (5) strike price. All investors are classified according to guidelines established by Israel's Central Bureau of Statistics. However, some inaccuracies in the classification exist. For example, a household can be a sophisticated private investor, whose activity is substantial in terms of both number of transactions and volumes. In addition, the distinction between financial and non-financial companies is not always clear-cut. In all of the above classification inaccuracies, we changed the classification accordingly. "Financial companies" do not include banks therefore we excluded all inter-bank transactions from the data set. Foreign investors include individuals, investment banks, and commercial banks. Since we cannot distinguish between a transaction made by the foreign bank for its final investors from a transaction for the bank itself (the "nostro"), we included all kinds of foreigners under the same classification.

In order to limit potential errors, we restricted the minimum IV to 3% and the maximum to 19%, the minimum DTE to 5 days and the maximum to 365 days, the minimum notional value to USD10,000 and the maximum to USD100,000,000, and the maximum distance from the ATMF in both directions to 10%. As a result, the number of transactions in the data set after the exclusion of extreme values amounted to 43,159.

In order to derive the BAS we calculated IVs for both bid rates (IV_{bid}) using all bought options by the reporting banks and ask rates (IV_{ask}) using all sold options by the banks per each trading day. The BAS was calculated as IV_{ask}–IV_{bid} per each key player (sector) every trading day. However, as the volatility during our sample period changed from high volatility periods (HIV) in the first period to low volatility periods (LIV) in the second period we distinguished HIV from LIV in the regressions by adding a dummy for the two sub-periods.

Based on daily IV and BAS, we calculated weekly means of IV and BAS only for those days in which all sectors (corporate, financial companies, foreign investors, and households) were active in the market. As a result, our data set consisted of 131 weekly means of matched daily data (matched samples). We also calculated MON for Call and Put options, respectively:

$$M_C = \log\left(\frac{Se^{-r^* \mathrm{d}t}}{Xe^{-r\,\mathrm{d}t}}\right) \quad \text{and} \quad M_P = \log\left(\frac{Xe^{-r\,\mathrm{d}t}}{Se^{-r^* \mathrm{d}t}}\right),$$

where, S is the spot rate, X is the striking price, r^* and r are the Libid and Makam (the T-bill's counterpart) rates, respectively, and dt is time to expiration in annual terms.

Table I presents basic statistics on the key players using all options (the upper panel) and periodical statistics on BAS and IV using 131 weekly means of daily data (panels a–c).

TABLE I
Basic Statistics of the Key Players in Israel's OTC FX Options Market

	CORPORATE	*FINANCE*	*FOREIGN*	*HOUSEHOLD*	*ALL*
# Transactions	18,903	12,696	7,281	4,279	43,159
% of total	44%	29%	17%	10%	100%
# Short transactions	8,737	6,413	4,011	2,179	21,340
# Long Transactions	10,166	6,283	3,270	2,100	21,819
Days-to-expiration (DTE)	97	40	65	51	70
Moneyness (MON)	0.18%	0.35%	0.23%	0.12%	0.23%
Notional value ($ millions)	2.98	2.96	8.40	2.74	3.86

	BAS					*IV*				
	CORPORATE	*FINANCE*	*FOREIGN*	*HOUSEHOLD*	*ALL*	*CORPORATE*	*FINANCE*	*FOREIGN*	*HOUSEHOLD*	*ALL*
(a) All period										
Mean	0.65%	0.77%	0.47%	1.06%	0.66%	7.3%	7.7%	7.2%	7.3%	7.4%
Std	0.42%	0.53%	0.56%	0.80%	0.36%	1.7%	1.9%	1.8%	1.9%	1.8%
Max	2.15%	2.52%	3.92%	3.08%	1.87%	11.2%	12.6%	11.3%	12.0%	11.5%
Min	−0.38%	−0.41%	−0.44%	−0.38%	−0.22%	4.6%	4.4%	4.2%	3.9%	4.5%
Skewness	0.83	0.38	2.58	0.54	0.69	0.33	0.40	0.37	0.44	0.35
Kurtosis	3.93	3.05	13.80	2.65	3.22	1.76	1.99	1.93	2.14	1.82
(b) High volatility (HIV) sub-period (1/2002–9/2003)										
Mean	0.83%	1.08%	0.75%	1.53%	0.98%	9.1%	9.6%	9.0%	9.2%	9.3%
Std	0.49%	0.37%	0.69%	0.73%	0.28%	0.8%	1.0%	0.9%	1.1%	0.9%
Max	2.15%	2.13%	3.92%	3.08%	1.87%	11.2%	12.6%	11.3%	12.0%	11.5%
Min	−0.38%	0.40%	−0.44%	0.12%	0.44%	7.7%	7.4%	7.6%	6.4%	7.6%
Skewness	−0.02	0.35	2.06	0.40	0.70	0.53	0.48	0.61	0.32	0.62
Kurtosis	3.27	2.86	9.45	2.54	3.70	3.01	3.59	2.73	3.30	3.48
(c) Low volatility (LIV) sub-period (10/2003–6/2006)										
Mean	0.50%	0.51%	0.26%	0.69%	0.41%	5.9%	6.1%	5.8%	5.8%	5.9%
Std	0.29%	0.50%	0.29%	0.64%	0.16%	0.6%	0.7%	0.7%	0.7%	0.6%
Max	1.76%	2.52%	1.37%	2.41%	0.88%	7.3%	7.5%	7.2%	7.4%	7.3%
Min	−0.08%	−0.41%	−0.20%	−0.38%	−0.22%	4.6%	4.4%	4.2%	3.9%	4.5%
Skewness	1.83	1.30	1.24	0.82	−0.43	0.12	0.02	−0.16	−0.27	−0.10
Kurtosis	7.98	5.83	5.31	3.05	5.51	2.62	2.47	2.76	2.65	2.53

This table presents basic statistics on BAS and IV of key players during the entire period (panel a), HIV period (panel b), and LIV period (panel c). The data in panel (a) include all transactions of all players during the sample period while the data in panels (a)–(c) are based on weekly means of daily data when all sectors were active. Corporates include also companies who are active in financial markets through daughter companies. BAS is calculated as IV_{ask}–IV_{bid} of all players in each group every trading day. Moneyness for call and put is defined in this study as the followings: for (plain vanila) call options $M_C = log(Se^{-r^{*}dt}/Xe^{-r\,dt})$ and for (plain vanila) puts $M_P = \log(Xe^{-r\,dt}/Se^{-r^{*}dt})$ where S is the spot rate, X is the excersize price, r^{*}, and r are the Libid and Makam rates, respectively, and dt is time to expiration in annual terms.

We divided the sample period into two sub-periods to analyze distinctions between relatively turbulent and tranquil times. During the first period, 1/2002 to 9/2003, the IV derived from all options was relatively high (HIV) while the second period was characterized by low IV (LIV). The mean HIV was 9.3% while mean LIV came to 5.9% and the IV for the entire period was 7.4%. The distinction between these two periods is based also on Chow's breakpoint test, which was significant at the 1% significance level.

4. THE BEHAVIOR OF KEY PLAYERS

We first examine the activity of key players in the FX options market. Table I outlines several significant distinctions between the major investor groups. Non-financial firms were the most active players, with 44% of all transactions, followed by financial companies (29%), foreign investors (17%), and households (10%). Differences between short and long transactions for each player category are relatively small. It can be seen that the long and short positions of the banks regarding financial companies and households are almost identical. This evidence which was also found in each bank's (market maker) reporting may indicate that usually banks serve solely as intermediaries between buyers and the sellers of these two sectors. In contrast, the extra short positions of foreign investors were partially offset by non-financial companies and in some periods the banks increased their exposure to FX as market makers do.[3] As a result, the net transactions number of all market makers (long minus short transactions) which can serve as proxy for the total exposure of all market makers was 479 out of 43,159 (1.2%).

Foreign investors typically trade options, written on large notional values, while other key players trade options written on smaller notional values. The DTE of non-financial firms (corporate) are the highest, while their IV is relatively low. There was a shift in the "market share" of key players during turbulent and tranquil periods. These sub-periods were determined by the IV derived from all options; reflecting two distinguished periods—a turbulent period (HIV) and a tranquil period (LIV). The proportion of transactions, conducted by financial companies, increased considerably during turbulent periods, while non-financial firms reduced activity in turbulent markets. The weight of financial companies was 36% in the turbulent period, but only 24% in the tranquil period while that of non-financial firms increased from 37% to 49% (not shown in Table I). Financial companies apparently take advantage of market uncertainty as their motivation is mainly driven by speculation. During the turbulent period, most players decreased DTE and traded more ATMF options. Generally, differences in DTE between key players may reflect differences in goals and motivations (Fig. 1).

[3]Examining the behavior of the banks across the sample period is beyond the scope of the paper as inter-dealer markets are quite different from client markets (see Vitale, 2007).

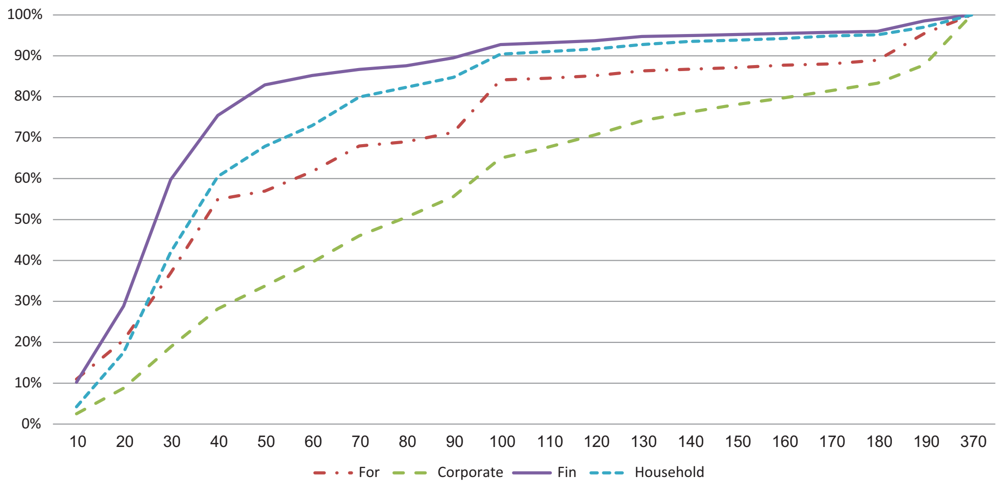

FIGURE 1
Comulative percentage of days-to-expiration (DTE) of the key players. This figure presents various shapes for different key players. The steeper curve of financial companies (FIN) represent more short term transactions while the 45° line of non-financial firms (CORPORATE) represents equal number of transactions across DTE. [Color figure can be viewed in the online issue, which is available at wileyonlinelibrary.com.]

As can be seen in the figure, there are substantial differences between the key players; the cumulative percentage of DTE of non-financial firms is uniformly distributed such that the cumulative percentage represents a straight line with an exception around 90 days. This little jump may reflect the common commercial credit length of 90 days. In comparison to other investor groups, non-financial firms usually remain active for longer periods, indicating the use of derivatives for hedging across financial market conditions (see Judge, 2006). This is also consistent with Warton's (1995) report documenting the use of derivatives in order to reduce the volatility of the firm's cash flow (see Bodnar et al., 2003). In contrast, the majority of financial companies use options whose DTE is much shorter, that is, more than 80% of the options expire in less than 50 days.

IV and BAS are simultaneously determined during the trading process thus, we expect that there are some relationships between them. The positive impact of volatility on BAS is well documented both theoretically and empirically (see George & Longstaff, 1993; Chong et al., 2003; Becker & Sy, 2005). However, the opposite impact of BAS on IV is surprisingly neglected in the current literature both theoretically and empirically. Neglecting this relation may cause bias and inefficiency in regression estimations—a phenomenon called "simultaneous equations bias."

The weekly means of BAS and IV in Table I show the differences between key players' IV and BAS. The largest BAS are those of households (1.06%), while the smallest correspond with foreign investors (0.47%). In contrast, the maximal difference between IV means is relatively negligible (0.5%); between 7.2% for foreigners and 7.7% for financial companies. The similarity among players' IV may reflect non-arbitrage opportunities concerning prices (which IVs are derived from) while the dissimilarity among players' BAS is explained in the literature by differences in trading volume, investor sophistication, contestability, and preferences/motivation. This is consistent with the fact that households usually pay higher transaction costs and use simple rather than sophisticated strategies. The differences in BAS are also consistent with Menkhoff et al. (2007) who found cross-subsidization between large and small transactions, namely FX dealers (local banks in our study) effectively subsidize spreads of large sophisticated clients, which usually carry useful information, on the expense of small and naive investors. Despite these basic differences between the key players, Table II shows the relations between the various BAS and IV based on 131 weeks.

Panel (a) presents the contemporaneous correlation coefficients between BAS and IV of the key players while panels (b) and (c) present Granger's causality tests of one and three lags, respectively. It can be seen that the correlation coefficients among the key players' IVs are very high (above 0.94) and significant (at the 0.01 level) while the correlation coefficients among the key players' BAS are relatively low (less than 0.46). Interestingly, the correlation of non-financial firms' BAS with the other key players is very low, reflecting their motivation to use options regardless of market conditions either turbulent or tranquil.

The correlation coefficients between the key players' IV and BAS are moderate while the correlation coefficient between all options' IV and BAS (not shown in Table I) is 0.785 ($p < 0.001$). As the latter indicates that contemporaneous relations exist, the question is whether IV Granger causes BAS or BAS Granger causes IV, or are they simultaneously determined? Panels (b) and (c) show that one can reject the null that IV does not Granger cause BAS for almost all key players (except financial companies with three lags). In contrast, one cannot reject the null that BAS does not Granger cause IV in most cases. These results support our argument that since IV and BAS are simultaneously determined in reality, they should run as a two-equation system rather than the common practice of regressing BAS on IV and other exogenous variables but not the other way around. We also examine the relations between BAS and IV of the key players across the surface namely, the MON and the DTE. This was done by dividing the dataset into three equal-size groups and examining the BAS and IV of the various players in the nine combinations of MON and DTE.

It can be seen that for all players (ALL) the BAS and IV are increasing across MON and DTE, that is, in-the-money-forward (ITMF) short-term options (small DTE) have the highest BAS and IV while out-the-money-forward (OTMF) Long-term options (large DTE) have the lowest BAS and IV. However, when examining the key players, one by one, different shapes of the surfaces revealed.

TABLE II
The Relationships Between Implied Volatility (IV) and Bid–Ask Spreads (BAS) of Key Players

	BAS_CORP	*BAS_FIN*	*BAS_FOR*	*BAS_HOUSE*	*IV_CORP*	*IV_FIN*	*IV_FOR*	*IV_HOUSE*
(a) Contemporanous correlation coefficients								
BAS_CORP	1							
BAS_FIN	0.14 (0.1132)	1						
BAS_FOR	0.02 (0.8186)	0.35 (0.0000)	1					
BAS_HOUSE	0.19 (0.0266)	0.33 (-0.0001)	0.45 (0.0000)	1				
IV_CORP	0.42 (0.0000)	0.51 (0.0000)	0.44 (0.0000)	0.56 (0.0000)	1			
IV_FIN	0.41 (0.0000)	0.57 (0.0000)	0.48 (0.0000)	0.59 (0.0000)	0.96 (0.0000)	1		
IV_FOR	0.41 (0.0000)	0.51 (0.0000)	0.49 (0.0000)	0.56 (0.0000)	0.97 (0.0000)	0.97 (0.0000)	1	
IV_HOUSE	0.39 (0.0000)	0.53 (0.0000)	0.44 (0.0000)	0.60 (0.0000)	0.95 (0.0000)	0.96 (0.0000)	0.96 (0.0000)	1

	IV does not Granger cause BAS			*BAS does not Granger cause IV*	
Null hypothesis	*F-statistic*	*Prob.*		*F-statistic*	*Prob.*
(b) Granger's causality test: one lag					
CORP	18.9	0.00	CORP	0.4	0.54
FIN	13.4	0.00	FIN	1.2	0.28
FOR	16.2	0.00	FOR	3.5	0.07
HOUSE	14.6	0.00	HOUSE	0.4	0.53
(c) Granger's causality test: three lags					
CORP	7.2	0.00	CORP	0.3	0.82
FIN	0.5	0.71	FIN	0.3	0.79
FOR	9.7	0.00	FOR	1.2	0.30
HOUSE	2.0	0.15	HOUSE	0.7	0.54

This table presents the relationships between the key players' IV and BAS using contemporaneous correlation coefficients and Granger's causality tests. The data consist of 131 weekly means when all key players were active in the OTC market. BAS were calculated as in Table I. It can be seen that the correlation coefficients among IVs are much higher and significant than the respective figures among BAS (panel a). In addition, the correlation coefficient between the same key players' BAS and IV is higher than the correlation between one key player's BAS and other player's IV. Panels (b) and (c) show a statistical causality between BAS and IV.
Usually, the null hypothesis of—IV does not cause BAS—is rejected by the Granger's test except for FIN and HOUSE with three lags. The opposite null (BAS does not cause IV) cannot be rejected by the 0.05 significance level. Granger's causality test examines the null running the 1st variable on the lags of the 2nd variable. Prob. under 0.05 means that we can reject the null.

For example, the BAS of foreign investors reflect a "smile" shape across MON and DTE, which is different from other key players' "skew" shape. This phenomenon repeats itself regarding IV; a "smile" shape across MON, which is again different from other key players. Menkhoff and Schmeling (2010) argue that informed traders tend to use larger trade sizes. This piece of evidence regarding the uniqueness and the big trade sizes of foreign investors point on their unique characteristics as informed trading investors, highly sophisticated, with large trading volumes, and very competitive compared to other key players. If the local banks follow "strategic dealing," that is, they can learn from the foreign investors useful information regarding future exchange rate behavior, they may subsidize these investors on the expense of other players; especially households. In contrast, the differences between players' IV are negligible due to the "no-arbitrage" argument. This means that over (under) priced IV may cause investors to replicating the relevant options by other assets and gaining arbitrage profits given these assets are liquid (see Akram, Rime, & Sarno, 2008).

5. WHICH VARIABLES AFFECT IV AND BAS?

The previous section described several parameters characterizing the microstructure of the OTC FX options market. In this section, we examine some variables affecting both BAS and IV. The explanatory variables were chosen based on earlier studies (see, e.g., Low & Zhang, 2005; Goncalves & Guidolin, 2006). We ran first the following two OLS regressions explaining BAS and IV for each key player (foreign investors, financial companies, non-financial (corporate) firms, and households) and for all players, as follows:

$$\mathrm{BAS} = \alpha + \beta_1 \mathrm{IV} + \beta_2 \mathrm{DTE} + \beta_3 \mathrm{MON} + \beta_4 \mathrm{MON}^2 + \varepsilon, \tag{1}$$

$$\mathrm{IV} = \alpha + \beta_1 \mathrm{BAS} + \beta_2 \mathrm{DTE} + \beta_3 \mathrm{MON} + \beta_4\, \#\mathrm{Trans} + \beta_5 \mathrm{Period1} + \varepsilon. \tag{2}$$

where #Trans is the number of transactions carried out by a key player, DTE and #Trans are in logs, ε represents "white noise," and Period1 is a dummy variable that takes on the value 1 during the turbulent period (1/2002–9/2003) and 0 otherwise (10/2003–6/2006). We added an AR(1) term in both equations in order to handle serial correlations (selected by Schwarz Information Criteria, see Low & Zhang, 2005). The data in both OLS regressions are based on matched data of 131 weekly means of daily data when all key players were active in the market. We hypothesize that IV and BAS will positively influence each other, MON positively and DTE negatively affect both BAS and IV (based on Table III and George & Longstaff, 1993), Period1 will positively affect BAS and IV, and #Trans which reflect to some extent the trading activity will negatively affect BAS but not the IV (see Christoffersen et al., 2011). The latter is explained by the fact that since

TABLE III

Bid–Ask Spreads (BAS) and Implied Volatilities (IV) Surfaces of the Key Players

	Bid–ask spreads (BAS)						*Implied volatility (IV)*					
Player	*MON/DTE*	*1*	*2*	*3*	*Total*	*Cutoff*	*MON/DTE*	*1*	*2*	*3*	*Total*	*Cutoff*
Non-financial firms (CORPORATE)	1	0.79%	0.59%	0.45%	0.61%	−0.92%	1	7.55%	6.43%	6.54%	6.84%	−0.92%
	2	0.68%	0.64%	0.69%	0.67%	0.01%	2	7.82%	6.30%	7.15%	7.09%	0.01%
	3	0.69%	0.73%	0.61%	0.68%	0.35%	3	8.68%	8.24%	7.40%	8.10%	0.35%
	Total	0.72%	0.65%	0.58%	0.65%		**Total**	8.02%	6.99%	7.03%	7.34%	
	Cutoff	44	84	100			**Cutoff**	44	84	100		
Financial Firms (FIN)	1	0.94%	0.67%	0.22%	0.61%	−2.43%	1	8.20%	7.60%	6.10%	7.30%	−2.43%
	2	0.87%	0.63%	0.75%	0.75%	0.12%	2	8.40%	7.27%	6.24%	7.30%	0.12%
	3	1.28%	1.01%	0.81%	1.03%	0.59%	3	9.59%	9.21%	6.98%	8.59%	0.59%
	Total	1.03%	0.77%	0.59%	0.80%		**Total**	8.73%	8.03%	6.44%	7.73%	
	Cutoff	17	34	45			**Cutoff**	17	34	45		
Foreign Investors (FOR)	1	0.58%	0.38%	0.56%	0.51%	−1.07%	1	6.99%	7.12%	6.70%	6.94%	−1.07%
	2	0.56%	0.17%	0.24%	0.33%	0.06%	2	6.94%	6.57%	6.77%	6.76%	0.06%
	3	0.75%	0.54%	0.41%	0.57%	0.32%	3	8.48%	8.47%	7.28%	8.08%	0.32%
	Total	0.63%	0.36%	0.40%	0.47%		**Total**	7.47%	7.39%	6.92%	7.26%	
	Cutoff	20	52	73			**Cutoff**	20	52	73		
Households (HOUSE)	1	1.04%	0.36%	0.91%	0.77%	−1.77%	1	6.35%	5.80%	6.51%	6.22%	−1.77%
	2	0.96%	0.94%	0.90%	0.93%	−0.38%	2	6.94%	6.98%	7.40%	7.11%	−0.38%
	3	1.73%	1.77%	0.81%	1.44%	0.30%	3	9.00%	8.95%	7.71%	8.55%	0.30%
	Total	1.24%	1.02%	0.88%	1.05%		**Total**	7.43%	7.24%	7.21%	7.29%	
	Cutoff	23	39	55			**Cutoff**	23	39	55		
All key players (ALL)	1	0.72%	0.51%	0.36%	0.53%	−1.17%	1	7.75%	6.28%	6.11%	6.72%	−1.17%
	2	0.69%	0.53%	0.43%	0.55%	0.06%	2	7.60%	6.62%	6.30%	6.84%	0.06%
	3	1.01%	0.85%	0.95%	0.93%	0.35%	3	9.55%	8.78%	8.56%	8.96%	0.35%
	Total	0.80%	0.63%	0.58%	0.67%		**Total**	8.30%	7.22%	6.99%	7.51%	
	Cutoff	35	60	74			**Cutoff**	35	60	74		

The data are based on weakly means. DTE is the days-to-expiration, MON is the moneyness (see a definition in Table I). Cutt-offs of the percentiles are based on options bought/sold by all key players of the particular sector (CORPORATE/FIN/FOR/HOUSEHOLD/ALL).
The differences between key players' BAS are substantial while negligible among key players' IVs.

larger trading activity decreases the inventory risk of market makers it enables them to reduce BAS in a competitive market.

The next step was running the above OLS equations as a two-equation system (GMM) for each key player:

$$\begin{aligned} &\mathrm{BAS} = \alpha_1 + \beta_{11}\mathrm{IV} + \beta_{12}\mathrm{DTE} + \beta_{13}\mathrm{MON} + \beta_{14}\mathrm{MON}^2 + \varepsilon_1, \\ &\mathrm{IV} = \alpha_2 + \beta_{21}\mathrm{BAS} + \beta_{22}\mathrm{DTE} + \beta_{23}\mathrm{MON} + \beta_{24}\,\#\mathrm{Trans} + \beta_{25}\mathrm{Period1} + \varepsilon_2. \end{aligned} \tag{3}$$

In (3) both BAS and IV are not exogenous any more as in (1) and (2) but endogenously determined.[4] This approach overcomes the "simultaneity bias" when an endogenous variable is treated as exogenous one. Particularly, the influence of BAS on IV is usually negligible in the literature although, in practice daily BAS and IV are simultaneously determined.[5] We ran the GMM procedure for the system in (3) using heteroskedasticity and autocorrelation consistent (HAC) matrix. The results of the OLS and the GMM regressions are presented in Table IV.

The upper panels (a) and (b) in Table IV present the results of the two OLS regressions while the lower panel (c) shows the results of the two-equation system run in GMM. All instrumental variables were taken as the variables in 1 week lag. Panels (a) and (b) show that BAS and IV are positively affecting each other, for all players however, IV usually explain BAS at the 1% significance level as expected but not the other way around. These results point to the need to run both variables, simultaneously. Yet, running these OLS regressions for each player yields different results. In panel (c) both equations were regressed as a two-equation system. As in panels (a) and (b), the Adjusted R^2 levels of IV equations were much higher than in the respective BAS equations. In contrast, the Adjusted R^2 levels of BAS equations (panel c) were higher than the respective figures in panel (a) although all the exogenous variables remained the same. Moreover, most endogenous variables, that is, IV and BAS positively and significantly influenced each other at the 1% significance level. The result regarding the contemporaneous influence of BAS on IV for all key players (except for corporate) is quite striking given the ignorance of the literature from this direction.

The coefficients of MON and DTE usually did not change their sign compared to the regressions in panels (a) and (b) although their significance level increased. The positive relation between MON and BAS and the negative relation

[4]Note that by the order condition this system is exactly identified as there is one exogenous variable that appears in the IV equation but not in the BAS equation and one exogenous variable that appears in the BAS equation but not in the IV equation (except for the dummy—Peroid1). Particularly, MON^2 is not affecting IV and #Trans is not affecting BAS.

[5]Christoffersen et al. (2011) explain option returns (equivalent to our IV) written on large stocks by the liquidity of the underlying stock (equivalent to ILS/USD exchange rate). Lately, Grover and Thomas (2012) found that BAS positively affected IV derived from options on the Nifty (NSE-50) index. However, to the best of our knowledge we are the first to run such a system where BAS and IV of the same underlying asset are run simultaneously focusing on clientele effects.

TABLE IV

OLS and GMM Regression Results of Bid–Ask Spread (BAS) and Implied Volatility (IV) of Key Players

Exogenous variable	*Non-financial firms (CORPORATE)*	*Financial companies (FIN)*	*Foreign investors (FOR)*	*Households (HOUS)*	*All players (ALL)*
(a) OLS—endogenous variable: bid–ask spread (BAS)					
Intercept	0.249**	0.127*	0.145**	0.277**	0.158**
IV	0.055	0.678**	0.696*	0.986	0.639**
MON	0.239	1.431	−1.745	0.390	1.821*
Log(DTE)	−0.037*	−0.023	−0.034**	−0.055*	−0.030**
MON^2	−103.188	−94.915	194.092	−49.564	−145.579*
AR(1)	0.147*	0.023	0.010	0.022	−0.009
Adj. R^2	0.04	0.12	0.09	0.04	0.27
D.W.	2.04	2.02	1.97	1.69	1.98
(b) OLS—endogenous variable: implied volatility (IV)					
Intercept	0.071**	0.057**	0.056**	0.047**	0.063**
BAS	−0.007	0.020**	−0.001	0.010	0.006
MON	−0.167*	−0.071	−0.305**	−0.130	−0.126
Log(DTE)	−0.001	−0.001	0.000	0.003	−0.002
Log(#Trans)	0.001*	0.002*	0.001	0.002	0.002**
Period1	0.008	0.030**	0.028**	0.026**	0.010*
AR(1)	0.949**	0.687**	0.773**	0.758**	0.945**
Adj. R^2	0.93	0.90	0.91	0.86	0.94
D.W.	2.11	2.10	2.03	2.50	2.03
(c) Generalized method of moments (GMM) regression results					
Equation (cl): endogenous variable: bid–ask spread (BAS)					
Intercept	0.011**	0.003	0.003	0.008*	0.005**
IV	0.102**	0.151**	0.121**	0.215**	0.128**
MON	0.046	0.062	−0.119	0.029	0.153**
Log(DTE)	−0.003**	−0.002**	−0.002**	−0.004**	−0.002**
MON^2	−9.349*	−0.113	7.469	−0.042	−9.577*
AR(1)	0.119**	0.007	0.050	0.044	−0.058
Adj. R^2	0.19	0.40	0.20	0.35	0.64
D.W.	2.01	2.00	2.02	1.85	1.97
Equation (c2): endogenous variable: implied volatility (IV)					
Intercept	0.068**	0.052**	0.057**	0.040**	0.058**
BAS	−0.017	0.494**	0.053**	0.268**	0.290**
MON	−0.144**	−0.087	−0.260**	−0.157	−0.095
Log(DTE)	−0.001	0.000	0.000	0.004**	−0.001
Log(#Trans)	0.001**	0.002**	0.000	0.002*	0.002**
Period1	0.006	0.028**	0.027**	0.024**	0.007*
AR(1)	0.952**	0.708**	0.769**	0.721**	0.944**
Adj. R^2	0.93	0.91	0.91	0.87	0.94
D.W.	2.11	2.07	2.02	2.33	2.03

The data are based on weakly means. DTE is the days-to-expiration, MON is the moneyness (see a definition in Table I), #Trans is the number of bought/sold options from/to the banks, and Period1 is a dummy variable for the high volatility period (takes on the value 1 for the period 1/2002–9/2003 and 0 otherwise). It can be seen that the significance of some coefficients in the GMM regressions are more robust than the respective OLS regressions, especially the simultaneously determined variables, that is, BAS and IV.

*Significance level of 5%.

**Significance level of 1%.

between DTE and BAS for all players (ALL) are consistent with George and Longstaff (1993). Period1 had a positive and significant effect on IV as expected, except for corporate. This may be explained by the different use corporates buy and sell options compared to other key players; the former trade options for hedging purposes whilst the latter trade options for speculation and investment. Additionally, the number of transactions (#Trans) positively and significantly influenced IV as more traded options reflect more uncertainty which result in higher option prices or higher IVs. As IV and BAS found more significant in the equations for all key players while other exogenous variables usually did not change their sign and found at least significant as in Equations (1) and (2), the usage of two-equation system rather than two separated OLS regressions is preferred (regardless of the "simultaneous equation bias").

So far, we examined the variables that influence each key player's BAS and IV but did not distinguish between the impact of common market variables and specific variables, that is, clientele effects. In order to isolate the "direct" clientele effect on BAS and IV we ran a pooled regression with the above exogenous variables as common explanatory variables and the four key players as specific (fixed effect) coefficients. We also added to both equations, BAS and IV, an exogenous specific variable representing the exposure of the banks to each key player. The exposure was calculated as Expos = |(#long − #short)/0.5(#long + # short)| where #short (#long) is the number of all bought (sold) options of all key players from (to) all banks. This assessment of inventory risk may reflect the "net demand effect" or "net buying pressure" of each key player on BAS and IV. The pooled (fixed effect) regressions for BAS and IV and a key player i $\{i = 1, \ldots, 4\}$, are the followings:

$$\mathrm{BAS}_{it} = \alpha_i + \phi_i \mathrm{Expos}_{it} + \beta_1 \mathrm{IV}_{it} + \beta_2 \mathrm{DTE}_{it} + \beta_3 \mathrm{Mon}_{it} + \beta_4 \mathrm{Mon}_{it}^2 + \varepsilon_{it}, \quad (4)$$

$$\mathrm{IV}_{it} = \alpha_i + \phi_i \mathrm{Expos}_{it} + \beta_1 \mathrm{BAS}_{it} + \beta_2 \mathrm{DTE}_{it} + \beta_3 \mathrm{Mon}_{it} + \beta_4 \mathrm{Period1} + \varepsilon_{it}. \quad (5)$$

Following Menkhoff et al. (2007) and Becker and Sy (2005), we hypothesize that Φ_i and β_1 will positively influence BAS as larger mismatch between short and long positions (Expos) and larger future uncertainty (IV) may increase the market makers' exposure to inventory and market price risks, which in turn may result in a larger BAS. Additionally, following Christoffersen et al. (2011) and Grover and Thomas (2012), we conjecture that BAS will positively influence IV for all key players as in Equation (3). Controlling for all of the above variables we also conjecture that $\alpha_i \neq \alpha_j$ in the BAS equations due the different characteristics of the key players, for example, foreign investors are large sophisticated players while households are small naive ones. In contrast, we hypothesize that $\alpha_i = \alpha_j$ in the IV equations due to the "no arbitrage opportunities" argument. The results of the pooled regressions are presented in Table V.

TABLE V

Pooled Regression Results of Bid–Ask Spread (BAS) and Implied Volatility (IV) of Key Players

				Tests for differences in specific intercept (α)		
				CORPORATE	*FIN*	*FOR*
(a) Endogenous variable: bid–ask spread (BAS)						
Common coefficients						
IV	0.1716**		FIN	−0.27		
MON	−0.0353		FOR	−2.96**	−2.97**	
Log(DTE)	−0.0021**		HOUS	1.55	1.95	4.60**
$MONA^2$	0.2706			**Tests for differences in specific expos (ϕ)**		
AR(1)	−0.0976**			CORPORATE	FIN	FOR
			FIN	−8.31**		
			FOR	7.47**	33.20**	
			HOUS	9.46**	47.83**	3.28**
				The variable Expos by period and Key player		
Specific coefficients (fixed effect)	**Intercept (α)**	**Expos (ϕ)**		All sample	HIV period	LIV period
Non-financial firms (CORPORATE)	0.0039**	0.0011*	CORPORATE	0.44	0.36	0.50
Financial companies (FIN)	0.0037**	−0.0029**	FIN	0.28	0.35	0.24
Foreign investors (FOR)	0.0012	0.0049**	FOR	0.15	0.14	0.15
Households (HOUS)	0.0055**	0.0057**	HOUS	0.13	0.15	0.11
Adj. R^2	0.59		ALL	1.00	1.00	1.00
D.W.	1.82					

continued

TABLE V
(Continued)

				Tests for differences in specific intercept (α)		
				CORPORATE	*FIN*	*FOR*
(b) Endogenous variable: implied volatility (IV)						
Common coefficients						
BAS	0.2577**		FIN	1.11		
MON	−0.0963**		FOR	0.35	−0.80	
Log(DTE)	0.0005		HOUS	0.49	−0.69	0.13
Log(#Trans)	0.0024**					
Period1	0.0067**			**Tests for differences in sepecific expos (ϕ)**		
AR(1)	1.0091**			CORPORATE	FIN	FOR
			FIN	−2.72*		
Specific coefficients (fixed effect)	**Intercept (α)**	**Expos (ϕ)**	FOR	0.63	3.10**	
Non-financial firms (corporate)	0.0032	−0.0012**	HOUS	4.54**	5.54**	4.37**
Financial companies (FIN)	0.0073**	−0.0028**				
Foreign investors (FOR)	0.0045	−0.0010**				
Households (HOUS)	0.0050*	0.0021**				
Adj. R^2	0.97					
D.W.	1.51					

The data are based on 131 weakly means of daily data only when all sectors were active in the market. The variables are the same as in Table IV except the specific coefficients of the pooled regressions (fixed effect). The intercepts reflect specific characteristics of each sector while all other common variables have the same coefficients. The specific variable, Expos, is defined as the number of bought options from banks of a particular sector minus the number of sold options to banks, divided by the total transactions: bought + sold. It reflects the exposure of the banks (market makers) to the players in a particular sector. Period1 is a dummy variable for the high volatility period—HIV (takes on the value 1 for the period 1/2002–9/2003 and 0 for the low volatility period (LIV), 10/2003–6/2006).

The table shows significant differences between the intercepts of key players in the BAS equation whilst similarities between the intercepts of key players in the IV equations. This can be seen by the tests for differences of the intercepts in the BAS regression. In contrast, the differences between Expos specific coefficients found significant in both BAS and IV equations, although the levels of significant differences in the BAS equation were higher.

Compared to the respective figures in the IV regression. The tests of differences check the hypothesis that the coefficients (intercepts) of two sectors are similar as follows: $t=(\mu_i-\mu_j)/(\sqrt{\sigma_i^2+\sigma_j^2})$ where $\mu_i, \mu_j\{i,j=1,\ldots,4, i<j\}$ are the coefficient of sector i and j, respectively, and σ_i, σ_j are the respective standard errors. The large/significant differences are the intercepts (a) of foreign investors and households in the BAS equation. *Significance level of $\alpha=5\%$. **Significance level of $\alpha=1\%$. These figures are before Šidàk's (1967) correction for multiple comparisons (six tests). Namely, the significance level corrected for six independent comparisons is: $\alpha_{\mathrm{Sidak}}=1-(1-\alpha)^{1/6}$.

The upper panel (a) presents the results of the BAS equation while panel (b) shows the results of the IV equation. In both pooled regressions, the coefficients of BAS and IV are positive and significant as hypothesized. Additionally, most common coefficients are similar to those presented in Table IV, both in their direction and in their significance levels. The intercepts (α) which are specific to the various key players are different in the BAS equation (panel a) while similar in the IV equation (panel b). The differences between the intercepts of foreign investors and households in the BAS equation appear significant by the test of differences (and Sidak's correction for multiple comparisons) while in the IV equation the differences found insignificant for all key players' intercepts. The similarity between the specific intercepts of the key players in the IV equation is explained by the "no arbitrage" argument. Namely, there are many possibilities to replicate options so their prices (IV) cannot deviate much from the theoretical values, which determined by Put-Call-Parity and the bid–ask band (see Akram et al., 2008). In contrast, differences between specific intercepts of various players in the BAS equation reflect, by the literature, player's sophistication, trading size, preferences, motivation, and contestability and are well documented in FX microstructure studies (see, e.g., Menkhoff et al., 2007). The ranking of the intercepts (α) are (lowest to highest): foreign investors, financial companies, non-financial firms (corporates), and households. This evidence is in line with Menkhoff et al. (2007) "strategic dealing" phenomenon that, FX dealers (the banks) effectively subsidize spreads to attract both informed investors and large transactions most likely to carry useful information on the expense of small naive investors. According to this argument, the foreigners are the most informed investors ($\alpha = 0.0012$) with the largest trade size (in terms of notional value, see Table I) while households are the most naive investors ($\alpha = 0.0055$).

In the IV equations (panel b), the specific intercept of nonfinancial firms (corporate) was the lowest ($\alpha = 0.003$), then foreign investors ($\alpha = 0.004$), households ($\alpha = 0.005$), and financial companies the highest ($\alpha = 0.007$). This evidence may be explained by the motivation of financial companies compared to other key players. As the former maximize financial and speculative profits, they are mainly active during turbulent periods (HIV), thus their intercept is the largest (see Table I for IVs of financial companies during HIV and LIV).

The other specific coefficients, Expos, reflect the influence of the net demand of a key player on BAS and on IV (all other things being equal). That influence found significant in both BAS and IV regressions reflecting the exposure of the banks to a particular key player. Moreover, in both regressions the differences between any two key players found robust in most cases by the tests of differences. The influence of Expos on BAS for financial companies found negative; contrarily to other key players' influences. This can be explained by the opposite revealed preferences and behavior of financial companies and other key players such as non-financial companies and foreign investors between LIV and HIV periods. As financial companies were more active during the HIV period their Expos increased from 0.24 in the LIV period to 0.35 in the HIV period (panel a). In contrast, the Expos of non-financial firms and foreign investors decreased from 0.5 and 0.15, respectively during the LIV period to 0.36 and 0.14, respectively in the HIV period. Following the "strategic dealing" argument of Menkhoff et al. (2007), the robust negative sign of the coefficient of financial companies may indicate that the latter are more informed during turbulent periods thus, their BAS is lower.

The coefficient of the common variable, #Trans., positively affected IV as in Equation (3) (see Table IV). The coefficient of the dummy variable, Period1, found positive and significant in the IV equation whilst insignificant in the BAS equation, as expected. This is reasonable as the decline in IV between the HIV period and the LIV period, was more substantial than the decline in BAS between these two sub-periods. This development can be seen in Figure 2.

As a robustness check we examined some alternatives to the definitions and regressions described above. We redefined BAS as follows, that is, $(IV_{ask} - IV_{bid})/0.5(IV_{ask} + IV_{bid})$ controlling for two regimes of volatility, examined non-matched

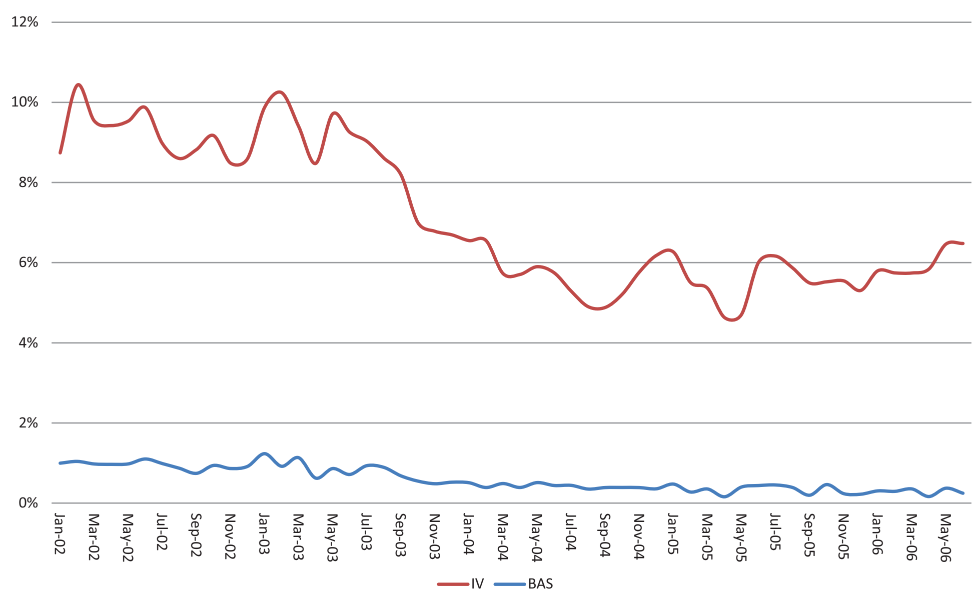

FIGURE 2

The developement of IV and BAS of All options across the sample period. The monthly IV and BAS are derived from all options. It can be seen that the drop in IV between HIV period (Period1) and the second period (LIV) is more substantial than the decline in BAS between these two sub-periods. Period1 lasts between 1/2002 and 9/2003 while the LIV period lasts between 10/2003 and 6/2006. [Color figure can be viewed in the online issue, which is available at wileyonlinelibrary.com.]

samples, that is, including all days although not all of the players were active in the market, ran 2SLS or 3SLS regressions rather than the GMM, and changed specifications in Equations (3)–(5). Under all these alternatives the obtained results were similar to those presented though, with lower significance levels, either in the alternative variables or in the Adj. R^2 of the regressions.

6. SUMMARY

This study examines the microstructure and the information embedded in Israel's OTC FX options market. We examine the behavior of key players (financial companies, households, non-financial local firms, and foreign investors) during turbulent and tranquil periods in order to reveal "clientele effects." As BAS and IV are simultaneously determined on a daily basis in FX option markets, we suggest a simultaneous estimate of BAS and IV where, BAS and IV contemporaneously affecting each other. This hypothesis is different from the current practice where BAS is regressed on IV and other exogenous variables but not the other way around. Despite the lack of a theoretical model contemporaneously connecting both BAS and IV on a daily basis, we found significant positive relations between BAS and IV in a two-equation system.

We also found substantial differences in BAS among key players and a significant impact of the key players' type on BAS. During the sample period of 1/2002–6/2006 foreign investors' BAS was the smallest while households' BAS the highest. These differences which reflect player's sophistication, trading size, preference/motivation, and contestability, found significant. This piece of evidence is in line with Menkhoff et al. (2007) "strategic dealing" as foreign investors are large sophisticated investors while households are small naive ones. We also found different impact of "net buying pressure" related to financial companies on their BAS, especially during turbulent periods.

In contrast to the differences in key players' BAS, the respective differences in IV were negligible. This is explained by the "no arbitrage" argument since options are replicable instruments thus, cannot deviate from equilibrium bid–ask bands.

In comparison to similar studies on OTC markets, ours is more comprehensive as it is based on a data set of detailed bank filings to the central bank on each transaction. The sample data contains information on *all* options sold/bought to/from the local banks, which served as market makers during the sample period.

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