Dealer Disagreement and Asset Prices in FX Markets *

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Keywords: Currency, Dealer, Disagreement, Heterogeneous Information, Heterogeneous Beliefs, Derivatives

JEL classification: C13, C14, G11, G12

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Abstract

We study the disagreement of major foreign exchange (FX) dealers using proprietary survey data on dealers' price quotes of short- and long-tenor currency derivatives. Dispersion among dealers is the highest at short tenors where heterogeneous information is of great relevance, and much lower at long tenors where heterogeneous beliefs dominate. This downward sloping term structure of dealer dispersion is most steep for risk reversals that capture asymmetric tail risk, and flattens considerably for forwards, strangles, and straddles that capture mean, symmetric tail risk, and volatility. Furthermore, dealer dispersion on risk reversals positively predicts currency returns in the cross section, with strong economic and statistical significance at short horizons but weak significance at long horizons. Dealer dispersion on the other three FX derivatives has no return predictive power.

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1 Introduction

The importance of disagreement among economic agents for asset prices has been greatly researched in the last few decades. Theoretical studies have analyzed various economic channels of disagreement, while empirical studies have tested the effects of disagreement on asset prices in different markets (see Basak (2005), Hong and Stein (2007), and Xiong (2013) for surveys). So far, most empirical studies use professional forecasts to measure investors' disagreement, e.g., the I/B/E/S analyst forecasts on firm earnings and the Survey of Professional Forecasters (SPF) and the Blue Chip surveys on aggregate economic and financial variables. Relatedly, such survey data are also used to study economic agents' belief formations in macroeconomics and finance.[1] However, various concerns are raised on these survey data. As Giglio, Maggiori, Stroebel, and Utkus (2021) summarize, "*critics have argued that survey data is often based on small and unrepresentative samples, that it is ridden with measurement error, that it asks qualitative questions that are not informative for models, and that it may not reveal those beliefs on which agents actually base their actions.*"[2]

In this paper, we provide new evidence on disagreement and asset prices using proprietary data from a survey that collects foreign exchange (FX) derivative price quotes from major FX dealers. Several features of this survey make our analysis likely to be free of the aforementioned prevailing criticisms. First, the survey respondents are major dealers in the FX market, where trading is over-the-counter and dealers serve as key intermediaries. Hence, information collected in this survey is highly representative of the FX market. Second, the variables reported are dealers' price quotes of FX derivatives, which are naturally quantitative. Third, the price quotes reported are those that dealers use to mark their books on FX portfolios and fulfill reg-

[1] See Coibion, Gorodnichenko, and Kamdar (2018) and Manski (2018) for comprehensive reviews and early studies of Frankel and Froot (1987), Ito (1990), and Froot and Ramadorai (2005) for tests of rational expectations using exchange rate survey data.

[2] See Cochrane (2011), Greenwood and Shleifer (2014), Cochrane (2017), and Adam, Matveev, and Nagel (2021) for more discussions of the concerns and debates on using these survey data to measure investors' expectations. For strategic behaviors of professional forecasters, see Trueman (1994), Hong, Kubik, and Solomon (2000), Welch (2000), and Lamont (2002).

ulatory requirements; that is, dealers' reported prices in the survey are tightly associated with their actions. Fourth, both reputation concerns and the data vendor's quality control ensure that strategic misreporting is unlikely.

In addition to these features that alleviate validity concerns, two further features of this FX dealer survey facilitate investigations into the economic channels of disagreement and asset prices. First, the survey covers FX derivatives of various maturities, which allows us to measure dealers' disagreement on exchange rate dynamics at varying forward horizons. This term structure of disagreement helps to distinguish between two primary sources of disagreement—heterogeneous information and heterogeneous beliefs (also known as heterogeneous models, different of opinion, or agree to disagree)—in that the former matters most at short horizons and the latter prevails at long horizons (Patton and Timmermann, 2010; Andrade, Crump, Eusepi, and Moench, 2016). Second, the various FX derivatives covered (forwards and three types of options including straddles, risk reversals, and strangles) allow for measurement of dealers' disagreement on different dimensions of exchange rate dynamics. In particular, forwards and straddles capture the mean and volatility of exchange rate dynamics, respectively, while risk reversals and strangles capture the tail risk in asymmetric and symmetric fashions, respectively.

We conduct two main sets of analyses on dealer disagreement and FX returns.

In the first set of analyses, we empirically measure and characterize the features of dealers' disagreement, which shed light on the economic sources of disagreement. Our baseline sample runs from January 2006 to December 2018, and contains price quotes on each of the four FX derivatives for each of 12 developed currencies. On average, about 16 dealers provide price quotes on each FX derivative with tenor ranging from one week to 24 months. We measure dealers' disagreement at each tenor τ for each product i of each currency j in each month t, denoted as $Dispersion_{t,j,i,\tau}$, as the across-dealer standard deviation of price quotes scaled by the absolute value of the consensus (calculated as the across-dealer average). We then take the average across currency and time to obtain the average term structure of dealer disagreement for each FX derivative.

We document two key features of dealer disagreement. First, the term structure of dealer disagreement is downward sloping, especially for risk reversals. Specifically, dealer disagreement on risk reversals is about 70% at the 1-week tenor, drops to about 20% at the 2-month tenor, and stays relatively flat beyond 2 months. Because heterogeneous information dominates at short horizons while heterogeneous beliefs prevail at long horizons, as mentioned above, the downward sloping term structure implies that the channel of heterogeneous information is a quantitatively major determinant of dealer disagreement. Second, the slope of the disagreement term structure is steepest for risk reversals, levels off considerably for forwards and strangles, and is almost flat for straddles. Hence, dealers' information heterogeneity on the asymmetric tail risk of exchange rates matters much more than those on the mean, symmetric tail risks, and volatility.

We conduct two additional analyses to provide further corroborative evidence for the importance of dealers' heterogeneous information on asymmetric tail risk we document. First, we measure the term structure of dealer disagreement for developing currencies and compare it to our baseline dealer disagreement measure for developed currencies. Because emerging markets are less transparent and more subject to regional economic shocks, we conjecture that dealers' access to information is more limited for developing currencies than for developed currencies, so dealers' information heterogeneity should be weaker for developing currencies. Consistent with our conjecture, we find that the disagreement term structure of risk reversals that is closely tied to dealers' heterogeneous information is much flatter for developing currencies than for developed currencies; in contrast, those of forwards, strangles, and straddles that are less about heterogeneous information are similar for developing and developed currencies.

Second, we compare dealer disagreement with the disagreement of professional forecasters using the Blue Chip Financial Forecast (BCFF). We find that in contrast to the downward sloping term structure of dealer disagreement, the disagreement of professional forecasters is upward sloping. In addition to providing further support for the importance of heterogeneous information in driving dealer disagreement, this finding highlights the potential difference between surveys of traders and surveys of professional forecasters.

In the second set of analyses, we turn to study the asset pricing effects of dealer disagreement. We consider how dealer disagreement affects FX returns in the cross section. From both theoretical and empirical studies on asset pricing with investor disagreement in the literature, there are at least three potential effects through which disagreement affects asset returns. First, if disagreement is driven by heterogeneous information, it would positively affect asset returns (Gârleanu and Pedersen, 2003; O'Hara, 2003; Easley and O'hara, 2004; Vayanos and Wang, 2012). Second, if disagreement is driven by the difference of opinion and short-sale constraints are not binding, asset returns are positively associated with disagreement in the market (Varian, 1985; Abel, 1989; Basak, 2005; David, 2008; Banerjee, 2011; Carlin, Longstaff, and Matoba, 2014). Third, if disagreement is driven by the difference of opinion and short-sale constraints are binding, disagreement would negatively affect asset returns (Miller, 1977; Chen, Hong, and Stein, 2002; Diether, Malloy, and Scherbina, 2002).

As heterogeneous information on asymmetric tail risk is the major determinant of FX dealers' disagreement, we first investigate how dealer disagreement of risk reversals, which is closely tied to dealers' heterogeneous information, affects FX returns. Specifically, we run Fama and MacBeth (1973) regressions of j-month-ahead FX returns on dealer disagreement of j-month risk reversals ($j = 1, 2, 3, 6, 9, 12$), controlling for standard covariates including exposures to the dollar and carry trade risk factors of Lustig, Roussanov, and Verdelhan (2011) in the baseline analyses, and exposures to the dollar and global FX volatility factors of Menkhoff, Sarno, Schmeling, and Schrimpf (2012) in the robustness check. We find that dealer disagreement affects FX returns *positively*, inconsistent with the channel of heterogeneous beliefs with short-sale constraints. Furthermore, both the statistical and economic significance of dealer disagreement on FX returns are strong at short horizons, but weak at long horizons. For example, a one-standard-deviation increase of dealer disagreement is associated with an increase in annualized return of about 7% at the one-month horizon but only about 2% at the 12-month horizon. Therefore, the effect of dealer disagreement on FX returns through the channel of heterogeneous beliefs is positive but weak, whereas the effect through the channel of heterogeneous information is positive and strong.

We then run similar Fama and MacBeth (1973) regressions of FX returns but on dealer disagreement of forwards, strangles, or straddles. We find some positive but statically and economically weak effects for strangles, and do not find any notable effects for forwards and straddles. Given that strangles have non-directional payoffs on tail risk, these findings further indicate the importance of heterogeneous information for dealers' disagreement on directional tail risk and the associated disagreement on FX returns.

We conduct several additional tests and robustness checks. First, we measure dealer dispersion using price range instead of standard deviation, and find that the range-based measure produces results quantitatively similar to those based on standard deviation. Second, we show that excluding the financial crisis period from December 2007 to June 2009 slightly improves the significance of dealer dispersion in predicting cross-sectional returns. Third, we find that the term structure of dealer disagreement is downward sloping for individual currencies, showing that the downward-sloping pattern is not due to the averaging across currencies.

Notwithstanding the great advantages in using surveys of dealers' price quotes of FX derivatives, like the availability of different tenors and of different products that capture different aspects of interest rate dynamics, challenges exist in using surveys of prices. For example, the price quotes do not solely reflect dealers' expectations of the exchange rate dynamics; they are also affected by economic channels that drive dealers' balance sheet capacity, portfolio constraints, and so on.[3] Moreover, using measures based on derivatives prices to test the effects of disagreement on FX returns is essentially testing an equilibrium condition that is part of a mar-

[3]Therefore, our analysis is related to the literature of intermediary-based asset pricing (Adrian, Etula, and Muir, 2014; He, Kelly, and Manela, 2017; Chen, Joslin, and Ni, 2019; Kargar, 2019; Ma, 2019).

ket with both FX returns and derivative prices determined jointly. That being said, our analysis serves as one of the first attempts in this direction and should be helpful for future investigations.

Related literature. Our paper contributes to both the literature that study what drives economic agents' disagreement and the literature that study how disagreement affects asset prices. The key deviation from most of the existing studies is our use of the novel survey data on FX dealers who are among the most important traders in FX markets, rather than professional forecasters. Moreover, the price quotes in the survey data are tightly associated with dealers' trading and portfolio adjustment. With this novel survey data, our analyses provide new findings on economic drivers of *traders*' disagreement and its effects on asset prices.

In particular, most studies on what drives economic agents' disagreement, including Lahiri and Sheng (2008), Patton and Timmermann (2010), Dominitz and Manski (2011), and Andrade, Crump, Eusepi, and Moench (2016), find that heterogeneous beliefs are an important channel using professional forecasts. We instead show that heterogeneous information is most important among the group of major FX traders. These results are consistent with the information-friction-based deviation from the full-information rational-expectation framework (see Mankiw and Reis (2010) and Woodford (2013) for recent surveys).[4]

Among the studies on how disagreement affects asset prices, most take the perspective of heterogeneous beliefs (Banerjee and Kremer, 2010; Beber, Breedon, and Buraschi, 2010; Dieckmann, 2011; Buraschi, Trojani, and Vedolin, 2014a,b; Hong and Sraer, 2016; Ehling, Gallmeyer, Heyerdahl-Larsen, and Illeditsch, 2018; Chen, Joslin, and Ni, 2019). Instead, our results highlight the effect of heterogeneous information on asset prices. A closely related study is Carlin, Longstaff, and Matoba (2014) who measure the disagreement of mortgage dealers about prepayment speeds and show that increased disagreement is associated with higher expected re-

[4]Some studies including Bordalo, Gennaioli, Ma, and Shleifer (2020) and Giacomini, Skreta, and Turen (2020) combine both heterogeneous information and heterogeneous beliefs in models of expectation formation.

turns of mortgage-backed securities over time. We complete their work in two ways. First, we are able to measure the term structure of disagreement, which helps to distinguish between heterogeneous information and heterogeneous beliefs as the source of disagreement. Second, we study how disagreement affects expected returns in the cross section. Third, we show that disagreement on tail risk is particularly important.

Our finding that dealer disagreement mainly reflects heterogeneous information, as well as its significant explanatory power for currency returns, adds to the literature that studies exchange rates with a microstructure approach, including Lyons (1995), Ito, Lyons, and Melvin (1998), Evans (2002), Evans and Lyons (2002), Bacchetta and Van Wincoop (2006), Evans and Lyons (2008), Burnside, Eichenbaum, and Rebelo (2009), Evans (2010), Rime, Sarno, and Sojli (2010), Michaelides, Milidonis, and Nishiotis (2019) among others (see e.g., Lyons, 2006, for a textbook treatment). Most of these studies focus on the strong explanatory power of order flow for exchange rate movements. We complement these studies by showing the importance of private information for exchange rate movements through the economic channel of heterogeneous information and disagreement.

2 FX Markets, Dealers, and Surveys

In this section, we briefly introduce the institutional background of FX markets and dealers (see King, Osler, and Rime (2012) and Schrimpf and Sushko (2019) among others for more comprehensive descriptions). We then discuss the surveys of dealers used for our analysis.

2.1 FX Markets and Dealers

The FX market, including spot and derivatives (forwards, swaps, and options), is the largest financial market in the world, with an average daily trading volume of \$6.6 trillion.[5] It is al-

[5] See the BIS survey for details at https://www.bis.org/statistics/rpfx19.htm.

most entirely an over-the-counter (OTC) market in which trading is fragmented and opaque. In particular, FX trades are conducted mostly via private, bilateral negotiations, as exposed to all-to-all trading mechanisms used by organized exchanges. Relatedly, there is little pre-trade transparency: price quote for a trade is usually indicative, up for negotiation, and specific to the investor who requests for it, so that no centralized dissemination of quotes is available.

Over the last few decades, a plethora of electronic and automated trading venues have been developed in the FX market, especially for spot and forwards. Some of these venues such as Electronic Broking Services (EBS) and Reuters Matching employ relatively centralized trading mechanisms like limit-order books. These developments have improved market quality in terms of transparency and transaction cost. However, because of the great variety of these trading venues, "*FX trading has become more complex and fragmented over the years*" (Schrimpf and Sushko, 2019). For example, there are more than 75 different FX venues available, which differ in terms of the pool of participants, latency, trading protocols and so on (Sinclair, 2018). Moreover, internalization of customer flow by dealer banks has increased significantly; such trades are not "visible" to the broad market. Hence, the FX market is still highly fragmented and opaque.

Because of the fragmentation and opaqueness, information in the FX market is naturally dispersed across various types of market participants. For example, as shown in a few empirical studies, large financial institutions often have information advantage over small individual traders, international trade trades, and even governments/central banks (Bjonnes and Rime, 2005; Osler, Mende, and Menkhoff, 2011; Osler, 2020). A special group of traders among these large financial institutions are dealer banks who intermediate trades of clients (such as international firms, commercial banks, public entities, and individuals) and also trade among themselves in an inter-dealer network to redistribute the inventory.

As the major traders, "*dealers are perhaps the best-informed agents in FX market*" (King, Osler, and Rime, 2012). Their information advantage can arise from both their extensive networks of financial customers who are informed and their own information production activities (Moore and Payne, 2011; Osler, 2020; Glode, Green, and Lowery, 2012; Li and Song, 2021). Further, market concentration among FX dealers is high, e.g., the top three dealer banks' share of FX trading is about 40%. Because of this great heterogeneity, a considerable degree of information heterogeneity can arise even among dealers, either from their differential access to customers' information or varying levels of expertise or skills of information production.

2.2 Surveys of FX Dealers

To capture dealers' heterogeneity, we use propriety data from a survey of major FX dealers by the Totem Vanilla FX valuation services of Markit (Markit Totem hereafter), which collects price quotes of FX forwards and options (straddles, risk reversals, and strangles). Markit Totem collects these quotes from FX dealers in an agreement that if a dealer provides her quote to Markit, she would receive a summary of the quotes Markit collects. Per our communications with Markit Totem, dealers participate in this survey to gauge market prices in order to mark their books on OTC derivatives and fulfill regulatory requirements. Hence, the price quotes in this survey are closely tied to dealers' business activities.[6] All the major FX dealers are constant participants, and due to relationship and reputation considerations, the price quotes collected are most likely authentic. In fact, Markit often back-tests historical quotes of a dealer and check whether her quotes are "abnormal."

The survey is conducted at each month-end before July 2014 and on a daily basis since July 2014. A typical timeline is as follows. The survey templates are distributed to each participating dealer at the close of the day before the reporting day. Markit Totem requires dealers to submit their "*best estimate of mid-market price quotes*" in the late afternoon of the reporting day. Markit Totem then checks and compares all submissions, and may reject a submission that looks "abnormally" different from others. Markit Totem then delivers a summary of the col-

[6] According to Markit, these prices are also used by regulators in evaluations of dealers' risk profiles.

lected quotes, including mean, range, standard deviation, and the number of accepted quotes, but not individual quotes, to the participating dealers' at the close of the reporting day.[7]

One may wonder whether dealers would update their own estimates using the mean or consensus of the quotes so that no dispersion exists anymore among them after they get information from Markit Totem. We find that this is not the case. In fact, using the daily data available from July 2014, we find that the dispersion of dealers' quotes persists from one day to the next day, implying that there is some generic disagreement among dealers. We now turn to characterize the FX dealer disagreement.

3 Characterization of Dealer Disagreement

We first discuss the data sample and measures, and then empirically characterize FX dealers' disagreement across tenors. To guide the economic interpretations, we provide a simple model in Appendix A to demonstrate how two different economic channels—heterogeneous beliefs and heterogeneous information—affect the term structure of disagreement.

3.1 Data Summary

As mentioned above, the Markit Totem survey collects price quotes on FX forwards, straddles, risk reversals, and strangles. These quotes capture various characteristics of the (risk-neutral) distribution and dynamics of future exchange rates. Roughly speaking, forwards capture the mean of the exchange rate dynamics, while straddles capture the volatility. Moreover, both risk reversals and strangles capture the non-normal features of exchange rate dynamics like tail probability; the difference is that risk reversals capture directional movements while strangles

[7] A minimum of three accepted quotes is required to produce the summary. When there are less than six accepted quotes, the summary statistics are calculated using all submitted quotes, and when there are six or more accepted quotes, the highest and lowest quotes are dropped before calculating the summary statistics. Moreover, the standard deviation is only calculated when there are six or more accepted quotes.

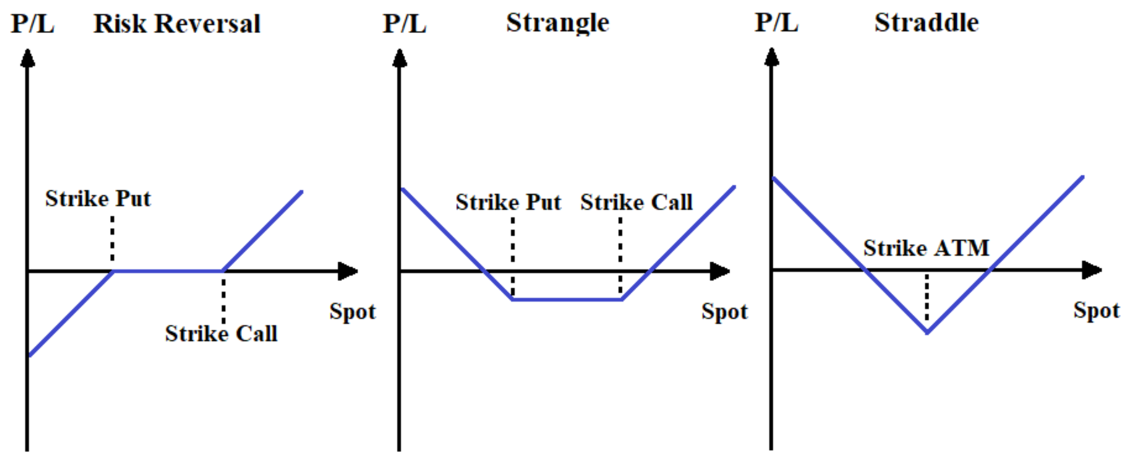

Figure 1. Profit/Loss of Risk Reversal, Strangle, and Straddle
This figure shows the profit or loss from taking long positions of risk reversal, strangle, and straddle as a function of spot price.

capture non-directional movements (Figure 1 provides a demonstration of the payoffs of risk reversals, strangles, and straddles.)[8] For example, investors who believe that the exchange rate will fluctuate considerably will prefer to buy a strangle, while investors who believe a significant weakening of the exchange rate is more likely than a substantial strengthening will prefer to purchase a risk-reversal.

For all FX contracts, tenors ranging from one week to 10 years are available. Moreover, straddles have ATM strikes by default, while risk reversals and strangles have moneyness of 10-delta and 25-delta as a market convention. For our baseline analysis, we use the surveys conducted at month ends from January 2006 to December 2018, covering 12 developed currencies, including Australia Dollar (AUD), Canada Dollar (CAD), Denmark Krone (DKK), Euro (EUR), Hong Kong Dollar (HKD), Japan Yen (JPY), New Zealand Dollar (NZD), Norway Krone (NOK), Singapore Dollar (SGD), Sweden Krona (SEK), Switzerland Franc (CHF) and United Kingdom Pound (GBP).

[8]The price of a straddle is equal to the sum of the prices of an ATM call and an ATM put. The price of a risk reversal is equal to the price difference of an OTM call and an OTM put. The price of a strangle is the sum of prices of an OTM call and an OTM put.

Table 1 provides a summary of the survey data, using the one-month forward, straddle, 10-delta risk reversal, and 10-delta strangle (results are similar using other tenors). We observe that the beginning month differs somewhat across currencies, but the ending month is all December 2018. On average, the number of dealer quotes in the survey is over 15 for most currencies except DKK, and reaches over 20 for a few currencies like AUD, EUR, JPY, and GBP. The number of dealer quotes is similar across different FX products, i.e., a dealer generally submits quotes for each product if she participates in the survey.

3.2 Term Structure of Dealer Disagreement

To measure dealer disagreement, for each product i of currency j in each month t of tenor τ, we use the across-dealer standard deviation of price quotes, scaled by the absolute value of the average, denoted as $Dispersion_{i,j,t,\tau}$. Figure 2 depicts the average (across months t and currencies j) dealer disagreement for tenor τ ranging from 1 week to 24 months and each of the four currency products i: forward, risk reversals, strangles, and straddles. Figure 3 depicts the monthly time series of 1-week and 12-month tenor dealer disagreement (averaged across currencies j) for risk reversals (Panel A), forwards (Panel B), strangles (Panel C), and straddles (Panel D), respectively. We observe two key findings.

First, from Figure 2, we observe that for all the four currency products broadly, the term structure of dealer disagreement is downward sloping. For example, dealer disagreement on risk reversals is about 70% at the 1-week tenor, drops to about 20% at the 2-month tenor, and stays relatively flat beyond 2 months. As illustrated by the model in Appendix A, the impact of heterogeneous information on disagreement decreases over the horizon, while the impact of heterogeneous prior belief increases. Therefore, the downward sloping term structure implies that heterogeneity in information signals is a major factor in explaining dealer disagreement on FX risks.

Table 1. Summary of the FX Dealer Survey: Developed Currencies

This table reports the sample period and the time-series quantiles of the number of dealers quotes on different currency option products with 1-month tenor for 12 developed currencies. Panels A to D report the statistics for risk reversals, forwards, strangles, and straddles, respectively.

	Panel A: Risk Reversals					*Panel B: Forwards*				
	Sample Period		Number of Dealer Quotes			Sample Period		Number of Dealer Quotes		
Currency	Begin	End	P25	Median	P75	Begin	End	P25	Median	P75
AUD	200601	201812	17	21	23	201001	201812	19	22	24
CAD	200601	201812	17	19	21	201001	201812	16	18	21
DKK	200802	201812	7	8	9	201007	201812	8	9	11
EUR	200601	201812	19	23	26	201001	201812	21	25	27
HKD	200707	201812	15	16	17	201001	201812	14	17	17
JPY	200601	201812	20	24	27	200909	201812	20	26	27
NZD	200604	201812	16	17	19	201001	201812	16	17	19
NOK	200703	201812	12	14	16	200909	201812	14	16	16
SGD	200706	201812	16	16	18	201001	201812	14	17	18
SEK	200608	201812	13	15	16	201001	201812	15	16	17
CHF	200601	201812	16	18	19	201001	201812	18	19	20
GBP	200601	201812	18	21	22	201001	201812	19	21	22
	Panel C: Strangles					*Panel D: Straddles*				
	Sample Period		Number of Dealer Quotes			Sample Period		Number of Dealer Quotes		
Currency	Begin	End	P25	Median	P75	Begin	End	P25	Median	P75
AUD	200802	201812	18	22	23	200601	201812	18	21	23
CAD	200802	201812	17	19	21	200601	201812	18	19	21
DKK	200802	201812	7	8	9	200802	201812	8	9	10
EUR	200802	201812	19	24	26	200601	201812	20	23	27
HKD	200802	201812	14	16	17	200707	201812	15	17	18
JPY	200704	201812	19	26	27	200601	201812	20	24	27
NZD	200802	201812	16	17	19	200603	201812	16	17	19
NOK	200802	201812	12	14	16	200702	201812	13	14	16
SGD	200802	201812	15	17	18	200612	201812	16	17	18
SEK	200802	201812	13	15	16	200608	201812	14	15	17
CHF	200802	201812	16	18	19	200601	201812	16	18	20
GBP	200802	201812	18	21	22	200601	201812	18	21	22

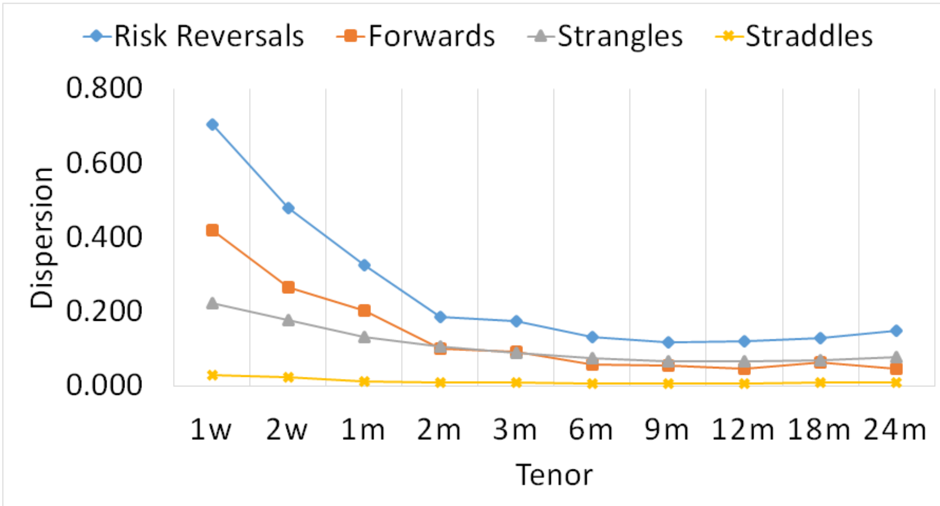

Figure 2. Term Structure of Dealer Disagreement

This figure presents the term structure of dealer disagreement (averaged across months and 12 developed currencies) on risk reversals, forwards, strangles, and straddles. The sample period is between January 2006 and December 2018 and the tenor ranges from one week to 24 months.

The time series plotted in Figure 3 further show that the downward sloping pattern is true for most of the months, i.e., 1-week tenor dispersion is consistently higher than 12-month tenor dispersion over time. Moreover, we also compute the time series correlations of the 1-week and 12-month dealer disagreement and find them to be much less than perfect (e.g., ranging from 0.07 for risk reversals to 0.562 for straddles). This is consistent with the rationale that differences in information signals are more tied to the short-horizon disagreement while differences in beliefs are more tied to the long-horizon disagreement.

Second, we observe that the magnitude of the (negative) slope of the disagreement term structure differs greatly across different FX products. In particular, the drop of dealer disagreement from 1 week to 2 months is the largest for risk reversals, while the term structure of dealer disagreement for straddles is totally flat. As risk reversals have a payoff that depends on the tail risk directionally, the larger slope of the disagreement term structure for risk reversals than for other FX products implies that dealers' heterogeneous information on dynamics of asymmetric tail risk is greatly important relative to other types of risks like time-varying volatility (see Equa-

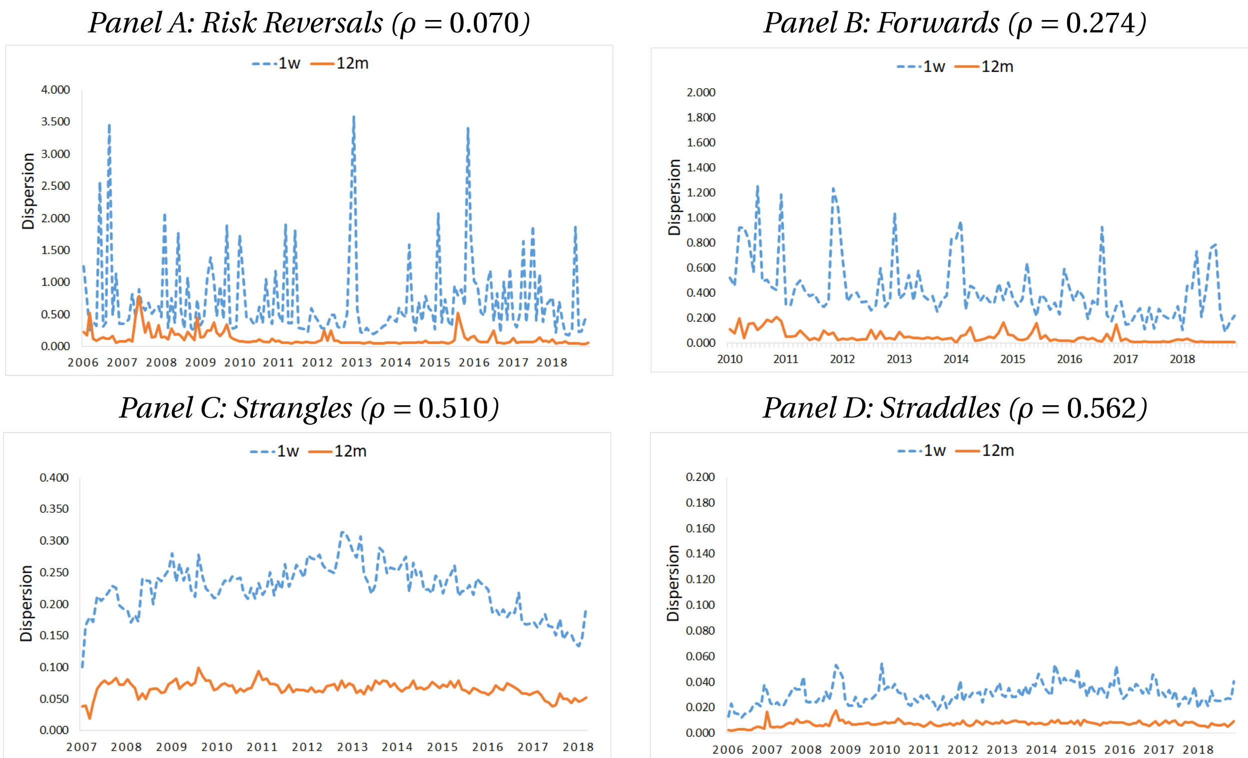

Figure 3. Time Series of Dealer Disagreement

This figure shows the time series of cross-currency mean of dealer dispersion on different currency option products with one-week (1w) or 12-month (12m) tenor for 12 developed currencies. The option products include risk reversals, forwards, strangles, and straddles. *Dispersion* is computed as the standard deviation of dealer price quotes on an option product with a given tenor divided by the absolute average price quote in that month.

tions (A.10) and (A.11) in Appendix A for the difference between disagreement on asymmetric tail risk related to risk reversals and disagreement on symmetric tail risk related to strangles.)

Overall, we find that the term structure of dealer disagreement on FX products is downward sloping, and the magnitude of the slope is strongest for risk reversals that are tied to asymmetric tail risks of exchange rate dynamics.

3.3 Developing Currencies and Professional Forecasters

In this section, we present two additional sets of analyses on FX dealer disagreement, which provide further supportive evidence for the channel of dealers' heterogeneous information.

First, we compare dealer disagreement on developed currencies used in our baseline analysis with that on developing currencies. Our conjecture is that dealers' access to information is more limited for developing currencies than for developed currencies, because emerging markets are less transparent, more subject to regional economic shocks, and so on. In consequence, dealers' information heterogeneity should be weaker for developing currencies. Given that dealers' heterogeneous information is mainly captured by the disagreement term structure for risk reversals, as shown above, we expect that the slope of the disagreement term structure will drop more for risk reversals than for other FX products.

Figure 4 compares the average (across months and currencies) dealer disagreement over tenor of 12 developed and 18 developing currencies for each of the four currency products.[9] We observe that the term structure of dealer disagreement for these developing currencies is also downward sloping, similar to that for developed currencies in Figure 2. Importantly, consistent with our conjecture, the disagreement term structure based on developing currencies flattens markedly for risk reversals, but those for forwards, strangles, and straddles remain roughly unchanged.

Second, we compare the disagreement of FX dealers our analysis focuses on with that of professional forecasters most existing studies in the literature rely on. In particular, we collect data from the Blue Chip Financial Forecasts (BCFF) survey, which provides monthly forecasts for a range of financial variables including exchange rates and has been used extensively in the literature (see Andrade, Crump, Eusepi, and Moench (2016), Bordalo, Gennaioli, Ma, and Shleifer (2020), and Giacoletti, Laursen, and Singleton (2021) among others). The BCFF survey only contains forecasts of future spot exchange rates 3, 6, and 12 months ahead, so the comparison will be conducted with dealer disagreement on forwards. For the sample period between November 2006 and February 2015, six out of the 12 developed currencies we use are covered

[9]The developing currencies include Brazil (BRL), Czech Republic (CZK), Hungary (HUF), India (INR), Indonesia (IDR), Israel (ILS), Poland (PLN), Russia (RUB), South Korea (KRW), Thailand (THB), Chile (CLP), Colombia (COP), Malaysia (MYR), Peru (PEN), South Africa (ZAR), Taiwan (TWD), Philippines (PHP), and Mexico (MXN).

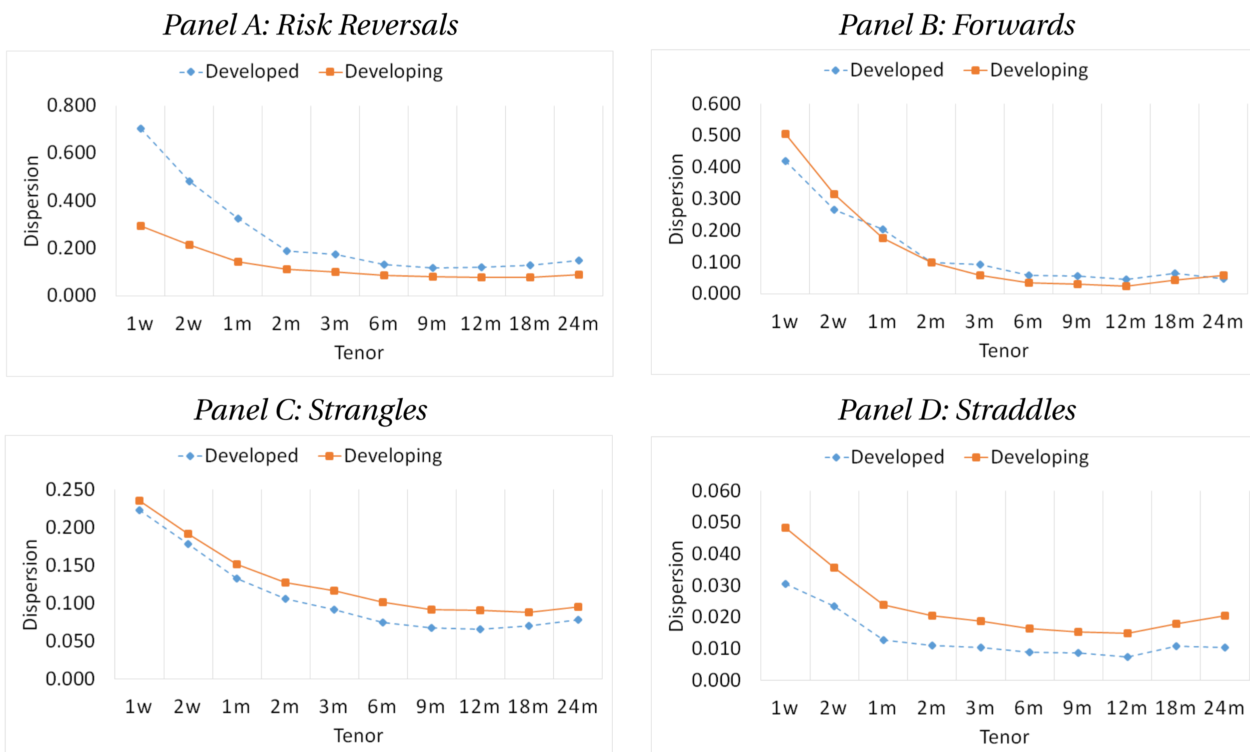

Figure 4. Dealer Disagreement: Developed vs. Developing Currencies

This figure shows the cross-currency mean of dealer dispersion (averaged over time) on different currency option products over tenor for 12 developed currencies and 18 developing currencies, respectively. The option products include risk reversals, forwards, strangles, and straddles. *Dispersion* is computed as the standard deviation of dealer price quotes on an option product with a given tenor divided by the absolute average price quote in that month.

by BCFF, including AUD, CAD, EUR, JPY, CHF, and GBP. In each month t, for a given currency i and a forecast horizon τ, we construct a disagreement measure of BCFF professional forecasters similar to our dealer disagreement measure—the across-forecaster standard deviation of the forecasts scaled by the consensus forecast.

Figure 5 presents the average (across months and currencies) BCFF disagreement term structure, together with the dealer disagreement term structure for the same sample period, the same six currencies, and the same tenors. We observe a sharp contrast: while the dealer disagreement is downward sloping, the professional forecaster disagreement is upward sloping. Notwithstanding other differences in the two series of disagreements, like future spot rate vs. forward rate, this striking contrast suggests that the main driver of disagreement among professional forecasters is heterogeneous beliefs, as opposed to heterogeneous information that is the main driver of dealer disagreement.[10]

4 Dealer Disagreement and FX Returns

In this section, we study whether dealer disagreement affects FX returns significantly. We first briefly discuss potential economic channels for the association between disagreement and asset returns drawing from the asset pricing literature with heterogeneous information and heterogeneous beliefs. We then present our findings on the effect of dealer disagreement on FX returns.

4.1 Economic Channels of Disagreement and Asset Returns

The existing literature on how disagreement affects asset returns is not fully conclusive. The effects depend on the specific driving forces of disagreement, and even under the same economic

[10] In addition, we also find that the time-series correlation between the dealer and professional disagreement is quite low at about 10%.

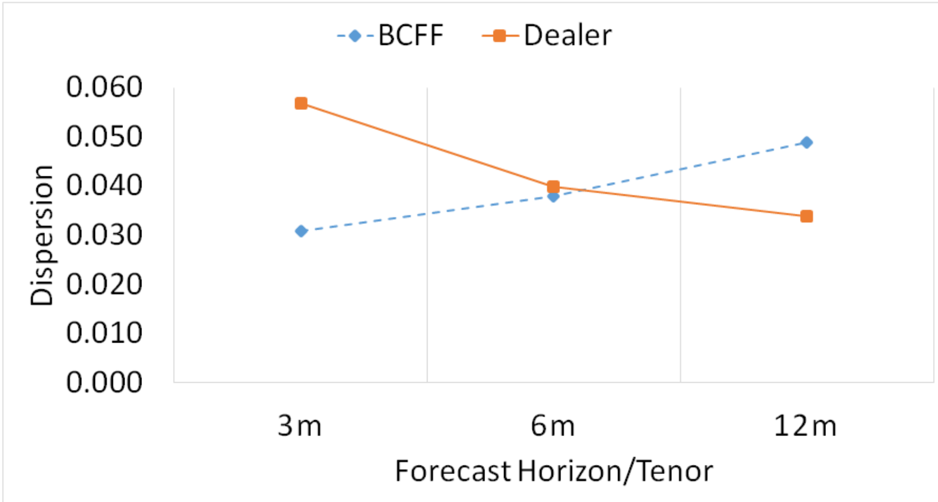

Figure 5. Professional Forecasters vs. Dealers
This figure displays cross-currency mean forecast dispersion (averaged over time) of Blue Chip financial forecasters (BCFF) on future exchange rates in 3 months, 6 months, and 12 months in comparison with dealer price dispersion on forward rates with tenor equal to the exchange rate forecast horizon. The sample consists of six developed currencies (AUD, CAD, CHF, EUR, GPB, and JPY) covered by both Blue Chip and Markit Totem for the period between November 2006 and February 2015. *BCFF Dispersion* is computed as the cross-currency standard deviation of forecasts from different forecasters scaled by the consensus forecast in that month. *Dealer Dispersion* is computed as the standard deviation of dealer price quotes on forward rates with a given tenor divided by the absolute average price quote in that month.

framework for disagreement, they depend on whether constraints on trading exist. We focus on the economic effects that have been employed extensively in the literature to explain empirical findings on the association between disagreement and asset returns.

First, if disagreement is driven by heterogeneous information, the literature largely reaches an agreement on a positive effect of disagreement on asset returns. For example, in the mode of Vayanos and Wang (2012), information asymmetry decreases liquidity and reduces risk-sharing among investors, which raises expected returns consequently. The models of Gârleanu and Pedersen (2003), O'Hara (2003), and Easley and O'hara (2004) also predict such a positive effect.

Second, if disagreement is driven by differences of opinion, the effect of disagreement on asset returns depends on whether short-sale constraints are binding in the market. When such constraints are not binding, many theoretical analyses find a positive risk premium should be associated with disagreement in the market (Varian, 1985; Abel, 1989; Basak, 2005; David, 2008). Other studies find that the relationship between disagreement and asset returns is time-varying. For example, Chen, Joslin, and Tran (2010) show that disagreement is negatively associated with risk premium in normal times but is positively associated with risk premium when disasters strike. Empirical studies like Carlin, Longstaff, and Matoba (2014) find a positive effect.

Further, when short-sale constraints are binding, the theoretical framework of Miller (1977) indicates a negative association between disagreement and asset returns. Intuitively, when pessimists are constrained, stock prices reflect the demand from optimists only, which causes prices to increase and returns to decrease. The empirical support for the prediction is mixed. A large empirical literature confirms this negative effect, including Chen, Hong, and Stein (2002), Diether, Malloy, and Scherbina (2002), Yu (2011), and so on. Yet, some studies such as Avramov, Chordia, Jostova, and Philipov (2009) and Boehme, Danielsen, Kumar, and Sorescu (2009) find the opposite.

4.2 Effects of Dealer Disagreement on FX Returns

Similar to the literature, we calculate currency returns using daily spot and one-month forward exchange rates provided by Barclays and Reuters through Datastream.[11] In particular, denote spot and forward rates in logarithms as s and f, respectively. The change in (log) spot rate is defined as $\Delta s_{t+1} = s_{t+1} - s_t$. A US investor who buys a foreign currency k in the forward market

[11] Both spot and forward exchange rates are based on midpoint quotes (i.e., the average of bid and ask rates). HKD is pegged to USD over our sample period; similar to Lustig, Roussanov, and Verdelhan (2011), we keep it in our developed sample because forward contracts are easily accessible to investors; our results remain unchanged if we exclude HKD.

and sells it in the spot market one month later will earn a monthly (log) excess return:

$$rx_{t+1}^{k} \equiv f_t^k - s_{t+1}^k. \tag{1}$$

This is also equal to the (log) forward discount minus the spot rate change:

$$rx_{t+1}^{k} = R_t^{f,k} - R_t^{f,US} - \Delta s_{t+1}^k,$$

where $R_t^{f,k}$ and $R_t^{f,US}$ are the one-month risk-free rates of the foreign country and the United States, respectively. [12]

As heterogeneous information on asymmetric tail risk is the major determinant of FX dealers' disagreement, we first investigate how dealer disagreement of risk reversals, which is closely tied to dealers' heterogeneous information, affects FX returns. Specifically, we run Fama and MacBeth (1973) regressions of h-month ahead currency returns on h-month tenor dealer disagreement of risk reversals, controlling for the exposure to the dollar risk factor β_{RX} and the exposure to the carry trade risk factor β_{HML}.[13] We consider horizons k of 1, 2, 3, 6, 9, and 12 months, and use the dealer disagreement of the same horizons.

Table 2 presents the estimated regression coefficients and t-statistics predicting annualized future currency returns using previous-month dealer disagreement of risk reversals. We observe that dealer disagreement positively affects currency returns across different horizons, inconsistent with the channel of heterogeneous beliefs with short-sale constraints. Furthermore, the statistical significance is strong at the 1-month horizon but weak at longer horizons. The magnitude of the regression coefficients across different horizons cannot be directly compared because variations of dealer disagreement differ significantly. Hence, to gauge economic significance, we calculate the change in return associated with a one-standard-derivation change in

[12]Table B.1 in the Appendix provides summary statistics of currency returns.

[13]β_{RX} and β_{HML} are estimated using 36-month rolling window with respect to the dollar risk factor *RX* and the carry trade risk factor *HML* from Lustig, Roussanov, and Verdelhan (2011).

Dispersion$_k$. The last two rows of Table 2 report the time-series average of cross-sectional standard deviation for dealer dispersion and the associated change in return. We observe that the magnitude is quite high, about 7% per annum (0.61×0.114) at one-month horizon, but drops to about 2% for horizons beyond one month. Table B.3 in the Appendix further presents the regression results controlling for exposures to the dollar risk factor and the global FX volatility factor in Menkhoff, Sarno, Schmeling, and Schrimpf (2012), and the conclusions are similar. Overall, dealer disagreement at short horizon that is tied to heterogeneous information has significant explanatory power for cross-sectional FX returns both statistically and economically. However, dealer disagreement at the long horizon that is tied to heterogeneous beliefs has weak explanatory power for currency returns.

We then run similar Fama and MacBeth (1973) regressions of FX returns but on the dealer disagreement of forwards, strangles, and straddles, which, as shown Section 3, are less associated with dealers' heterogeneous information. As reported in Table 3, dealer dispersion coefficients for strangles are positive across horizons with weak statistical significance, whereas no notable effects for forwards and straddles are observed. Given that strangles have non-directional payoffs on tail risk, these findings further indicate the importance of heterogeneous information for dealers' disagreement on directional tail risk and the associated disagreement on FX returns.

Finally, Table 4 presents results of similar Fama-MacBeth regressions for the sample of 18 developing currencies. We find that dealer dispersion on risk reversals is insignificant in predicting future currency returns, further corroborating the lower degree of information heterogeneity on directional tail risk captured by dealer risk reversal dispersion for developing currencies. In sum, the Fama-MacBeth regressions lend further support to the predictability of dealer risk reversal dispersion in future returns of developed currencies.

Table 2. Dealer Disagreement on Risk Reversals and FX Returns

This table reports the estimated regression coefficients and Newey-West t-statistics (in parentheses) from Fama and MacBeth (1973) cross-sectional regressions predicting *annualized* future currency returns using previous-month dealer dispersion on risk reversals. The sample is for 12 developed currencies from January 2006 to December 2018 and the horizon ranges from 1 month to 12 months. *Dispersion* is computed as the standard deviation of dealer price quotes on an option product with a given tenor divided by the absolute average price quote in that month. To forecast k-month returns, we use dealer dispersion with k-month tenor. β_{RX} and β_{HML} are the exposures to the dollar risk factor RX and the carry trade risk factor HML in Lustig, Roussanov, and Verdelhan (2011). SD(*Dispersion*) is the time-series average of cross-currency standard deviation of *Dispersion*. *Change in return* is the change in annualized future return associated with a one-standard-deviation change in *Dispersion*. For dependent variables at k-month horizon ($k > 1$), we use Newey-West robust standard errors with lag $k-1$.

Tenor & Ret Horizon	1m	2m	3m	6m	9m	12m
Intercept	-0.029	-0.029	-0.026	-0.029*	-0.029*	-0.023
	(-1.31)	(-1.45)	(-1.43)	(-1.72)	(-1.75)	(-1.55)
$Dispersion_k$	0.114**	0.097	0.082	0.160**	0.167*	0.157*
	(2.13)	(1.63)	(1.40)	(2.06)	(1.81)	(1.70)
β_{RX}	-0.001	0.005	0.007	0.007	0.008	0.004
	(-0.03)	(0.23)	(0.33)	(0.33)	(0.42)	(0.27)
β_{HML}	0.016	0.014	0.013	0.023	0.026	0.023
	(0.51)	(0.47)	(0.44)	(0.82)	(0.93)	(0.89)
R^2	49.3%	51.3%	51.1%	52.4%	49.3%	45.6%
# obs	1575	1572	1569	1530	1482	1449
SD($Dispersion_k$)	0.61	0.25	0.25	0.17	0.14	0.14
Change in return	7.0%	2.4%	2.1%	2.7%	2.3%	2.2%

Table 3. Dealer Disagreement on Forwards, Strangles, and Straddles, and FX Returns

This table reports the estimated regression coefficients and Newey-West t-statistics (in parentheses) from Fama and MacBeth (1973) cross-sectional regressions predicting *annualized* future currency returns using previous-month dealer dispersion on forwards, strangles, and straddles. The sample is for 12 developed currencies from January 2006 to December 2018 and the horizon ranges from 1 month to 12 months. *Dispersion* is computed as the standard deviation of dealer price quotes on an option product with a given tenor divided by the absolute average price quote in that month. To forecast k-month returns, we use dealer dispersion with k-month tenor. β_{RX} and β_{HML} are the exposures to the dollar risk factor RX and the carry trade risk factor HML in Lustig, Roussanov, and Verdelhan (2011). SD(*Dispersion*) is the time-series average of cross-currency standard deviation of *Dispersion*. *Change in return* is the change in annualized future return associated with a one-standard-deviation change in *Dispersion*. For dependent variables at k-month horizon ($k > 1$), we use Newey-West robust standard errors with lag $k-1$.

Tenor & Ret Horizon	1m	2m	3m	6m	9m	12m
			Panel A: Dispersion on Forwards			
Intercept	-0.027	-0.029	-0.023	-0.019	-0.019	-0.021*
	(-1.31)	(-1.54)	(-1.43)	(-1.27)	(-1.55)	(-1.78)
$Dispersion_k$	-0.121	-0.094	-0.082	-0.142	-0.044	0.200
	(-0.73)	(-0.36)	(-0.28)	(-0.55)	(-0.26)	(1.17)
β_{RX}	0.003	0.004	-0.003	-0.004	-0.003	-0.003
	(0.13)	(0.16)	(-0.13)	(-0.17)	(-0.15)	(-0.14)
β_{HML}	-0.006	-0.008	0.002	0.008	0.004	0.008
	(-0.20)	(-0.28)	(0.06)	(0.36)	(0.19)	(0.39)
R^2	48.1%	50.2%	50.6%	48.2%	43.7%	42.4%
# obs	1100	1100	1103	1077	1041	1012
			Panel B: Dispersion on Strangles			
Intercept	-0.026	-0.018	-0.025	-0.014	-0.015	-0.014
	(-0.78)	(-0.60)	(-0.99)	(-0.66)	(-0.81)	(-0.81)
$Dispersion_k$	0.108	0.083	0.085	0.007	0.046	0.073
	(0.75)	(0.51)	(0.56)	(0.05)	(0.29)	(0.55)
β_{RX}	-0.012	-0.015	-0.010	-0.012	-0.009	-0.005
	(-0.51)	(-0.62)	(-0.45)	(-0.52)	(-0.46)	(-0.30)
β_{HML}	-0.003	-0.005	-0.004	-0.003	-0.002	0.005
	(-0.11)	(-0.18)	(-0.14)	(-0.12)	(-0.11)	(0.28)
R^2	47.4%	49.5%	50.7%	48.9%	47.0%	42.9%
# obs	1383	1379	1375	1341	1296	1263
			Panel C: Dispersion on Straddles			
Intercept	-0.004	-0.023	-0.027	-0.018	-0.019	-0.014
	(-0.12)	(-1.09)	(-1.35)	(-1.08)	(-1.25)	(-0.95)
$Dispersion_k$	-1.281	0.126	1.468	-0.378	0.322	0.412
	(-0.78)	(0.18)	(1.03)	(-0.49)	(0.59)	(0.71)
β_{RX}	-0.004	0.008	0.008	0.004	0.003	-0.001
	(-0.16)	(0.34)	(0.36)	(0.20)	(0.14)	(-0.08)
β_{HML}	0.010	0.013	0.015	0.022	0.020	0.016
	(0.34)	(0.48)	(0.55)	(0.81)	(0.73)	(0.64)
R^2	47.1%	48.7%	49.5%	49.8%	47.4%	44.7%
# obs	1595	1591	1587	1553	1514	1479

Table 4. Dealer Disagreement on Risk Reversals and FX Returns for Developing Currencies
This table reports the estimated regression coefficients and Newey-West t-statistics (in parentheses) from Fama and MacBeth (1973) cross-sectional regressions predicting *annualized* future currency returns using previous-month dealer dispersion on risk reversals. The sample is for 18 developing currencies from January 2006 to December 2018 and the horizon ranges from 1 month to 12 months. *Dispersion* is computed as the standard deviation of dealer price quotes on an option product with a given tenor divided by the absolute average price quote in that month. To forecast k-month returns, we use dealer dispersion with k-month tenor. β_{RX} and β_{HML} are the exposures to the dollar risk factor RX and the carry trade risk factor HML in Lustig, Roussanov, and Verdelhan (2011). For dependent variables at k-month horizon ($k > 1$), we use Newey-West robust standard errors with lag $k-1$.

Tenor & Ret Horizon	1m	2m	3m	6m	9m	12m
Intercept	-0.004	0.043	0.076*	0.034	0.024	0.038
	(-0.10)	(1.64)	(1.68)	(1.24)	(0.80)	(1.43)
$Dispersion_k$	-0.116	-0.251	-0.341	-0.109	-0.037	-0.105
	(-1.01)	(-1.59)	(-1.57)	(-0.64)	(-0.13)	(-0.42)
β_{RX}	-0.097**	-0.066*	-0.053**	-0.054**	-0.047**	-0.052**
	(-2.17)	(-1.95)	(-2.41)	(-2.40)	(-2.39)	(-2.48)
β_{HML}	0.058	-0.037	-0.098	-0.060	-0.058	-0.066
	(0.89)	(-1.05)	(-1.14)	(-1.25)	(-1.20)	(-1.49)
R^2	44.5%	46.2%	47.3%	46.6%	51.1%	51.0%
# obs	2008	2001	1994	1928	1848	1796

5 Additional Results and Robustness Checks

In this section, we conduct additional checks to demonstrate the robustness of our key findings.

First, we present in Figure 6 the term structure of dealer disagreement over tenor for each currency product and each of the six developed currencies covered by both Blue Chip and Markit Totem. Consistent with the cross-currency term structure in Figure 2, the term structure of dealer disagreement is downward sloping, and risk reversals exhibit the steepest slope in four out of the six currencies. The pattern further emphasizes the importance of dealers' heterogeneous information in directional tail risk captured by risk reversals.

Second, we construct an alternative measure of dealer disagreement – computed as the

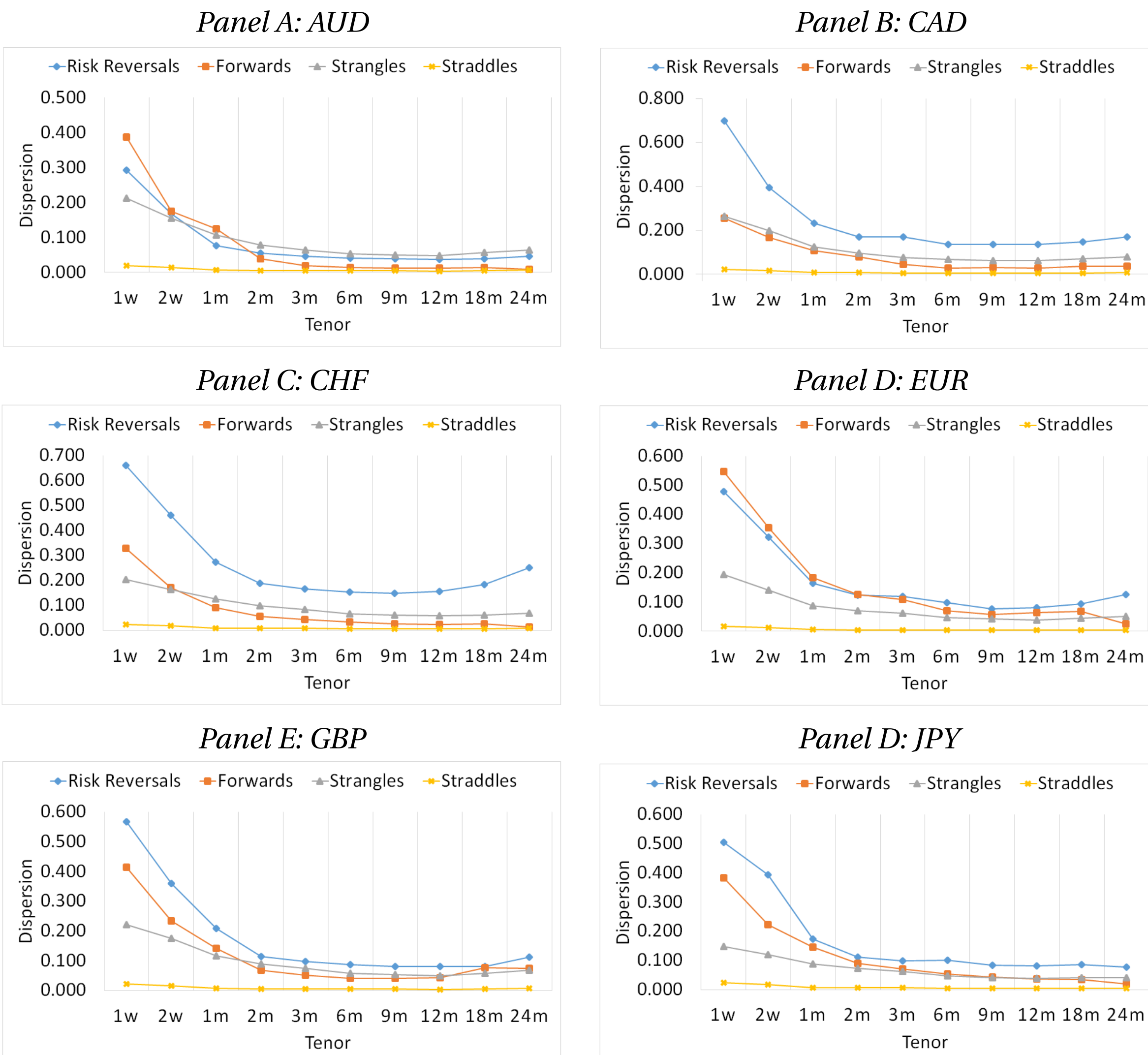

Figure 6. Dealer Dispersion over Tenor by Currency: Six Developed Currencies

This figure displays the time-series average of dealer dispersion on different currency option products over tenor for each of the six developed currencies (AUD, CAD, CHF, EUR, GBP, and JPY) covered by both Blue Chip and Markit Totem. The sample period is between January 2006 and December 2018, and the option products include risk reversals, forwards, strangles, and straddles with tenors between one week and 24 months. *Dispersion* is computed as the standard deviation of dealer price quotes on an option product with a given tenor divided by the absolute average price quote in that month.

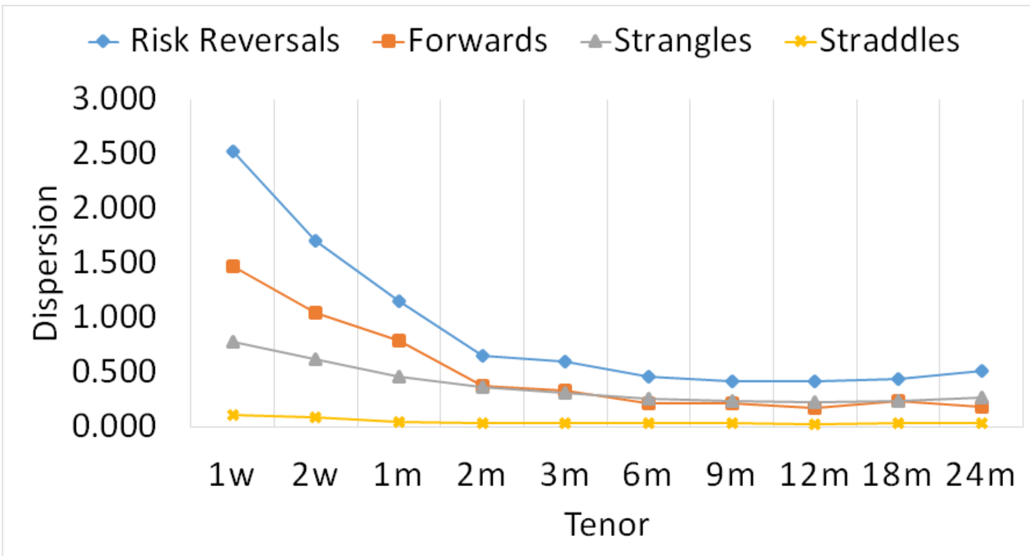

Figure 7. Dealer Dispersion over Tenor: Range-Based Dispersion

This figure displays the time-series average of cross-currency mean of range-based dealer dispersion on risk reversals, forwards, strangles, and straddles over tenor for 12 developed currencies. The sample period is between January 2006 and December 2018, and the option tenor for different products ranges from one week to 24 months. *Dispersion* is computed as the range of dealer price quotes on a given option product divided by the absolute average price quote.

range (max-min) of dealer price quotes on a given option product divided by the absolute average price quote. Figure 7 reports the term structure of range-based dealer disagreement over tenor for different option products, which largely mirrors the patterns in Figure 2 for standard-deviation-based (SD-based) dealer disagreement. Table 5 further reports the Fama-MacBeth regression results predicting forward currency returns using range-based dealer dispersion on risk reversals. The predictability is highly similar to the baseline findings using SD-based dealer disagreement.

Table 5. Range-Based Dealer Disagreement on Risk Reversals and FX Returns

This table reports the estimated regression coefficients and Newey-West t-statistics (in parentheses) from Fama and MacBeth (1973) cross-sectional regressions predicting *annualized* future currency returns using previous-month dealer dispersion on risk reversals measured using price range. The sample is for 12 developed currencies from January 2006 to December 2018 and the horizon ranges from 1 month to 12 months. *Dispersion* is computed as the range of dealer price quotes on 10-delta risk reversals divided by the absolute average price quote. To forecast k-month returns, we use dealer dispersion with k-month tenor. β_{RX} and β_{HML} are the exposures to the dollar risk factor RX and the carry trade risk factor HML in Lustig, Roussanov, and Verdelhan (2011). SD(*Dispersion*) is the time-series average of cross-currency standard deviation of *Dispersion*. *Change in return* is the change in annualized future return associated with a one-standard-deviation change in *Dispersion*. For dependent variables at k-month horizon ($k > 1$), we use Newey-West robust standard errors with lag $k-1$.

Tenor & Ret Horizon	1m	2m	3m	6m	9m	12m
Intercept	-0.031	-0.032	-0.031	-0.030*	-0.028*	-0.024
	(-1.34)	(-1.56)	(-1.62)	(-1.83)	(-1.73)	(-1.62)
$Dispersion_k$	0.032**	0.028	0.030*	0.046**	0.042*	0.041*
	(2.07)	(1.52)	(1.67)	(2.36)	(1.81)	(1.77)
β_{RX}	0.000	0.007	0.009	0.008	0.008	0.005
	0.00	(0.33)	(0.41)	(0.35)	(0.40)	(0.32)
β_{HML}	0.018	0.014	0.013	0.024	0.027	0.023
	(0.58)	(0.49)	(0.45)	(0.85)	(0.96)	(0.89)
R^2	49.1%	51.7%	51.5%	52.5%	49.1%	45.6%
# obs	1575	1572	1569	1530	1482	1449
SD($Dispersion_k$)	2.14	0.9	0.83	0.58	0.51	0.51
Change in return	6.8%	2.5%	2.5%	2.7%	2.1%	2.1%

Third, to understand how the financial crisis period affects the association between dealer risk reversal dispersion and FX returns, in Table 6 we redo the Fama and MacBeth (1973) re-

Table 6. Dealer Disagreement on Risk Reversals and FX Returns: Excluding the 2008 Crisis

This table reports the estimated regression coefficients and Newey-West t-statistics (in parentheses) from Fama and MacBeth (1973) cross-sectional regressions predicting *annualized* future currency returns using previous-month dealer dispersion on risk reversals after excluding the financial crisis period. The sample is for 12 developed currencies from January 2006 to December 2018 excluding December 2007 to June 2009, and the horizon ranges from 1 month to 12 months. *Dispersion* is computed as the standard deviation of dealer price quotes on an option product with a given tenor divided by the absolute average price quote in that month. To forecast k-month returns, we use dealer dispersion with k-month tenor. β_{RX} and β_{HML} are the exposures to the dollar risk factor RX and the carry trade risk factor HML in Lustig, Roussanov, and Verdelhan (2011). SD(*Dispersion*) is the time-series average of cross-currency standard deviation of *Dispersion*. *Change in return* is the change in annualized future return associated with a one-standard-deviation change in *Dispersion*. For dependent variables at k-month horizon ($k > 1$), we use Newey-West robust standard errors with lag $k-1$.

Tenor & Ret Horizon	1m	2m	3m	6m	9m	12m
Intercept	-0.034	-0.034	-0.030	-0.035*	-0.038**	-0.032**
	(-1.40)	(-1.57)	(-1.47)	(-1.88)	(-2.13)	(-2.06)
$Dispersion_k$	0.117**	0.117*	0.105	0.200**	0.214**	0.206**
	(2.08)	(1.82)	(1.64)	(2.34)	(2.15)	(2.09)
β_{RX}	0.006	0.011	0.012	0.013	0.016	0.010
	(0.27)	(0.48)	(0.55)	(0.59)	(0.80)	(0.58)
β_{HML}	0.031	0.027	0.026	0.036	0.038	0.030
	(0.96)	(0.99)	(1.00)	(1.34)	(1.42)	(1.20)
R^2	48.5%	50.0%	50.2%	50.7%	46.9%	44.0%
# obs	1349	1347	1344	1305	1258	1226
SD($Dispersion_k$)	0.61	0.25	0.23	0.14	0.12	0.12
Change in return	7.1%	2.9%	2.4%	2.8%	2.6%	2.5%

gressions excluding the financial crisis period between December 2007 and June 2009. During the non-crisis period, dealer dispersion becomes slightly more significant in predicting cross-sectional returns under most specifications.

6 Conclusion

In this paper, we provide one of the first analyses of disagreement of major FX dealers, using proprietary survey data on dispersion in dealers' price quotes of short- and long-tenor currency derivatives. Dispersion among dealers is highest at short tenors where heterogeneous information is of great relevance, and much lower at long tenors where heterogeneous beliefs dominate. This downward sloping term structure of dealer dispersion is most steep for risk reversals that capture asymmetric tail risk, and flattens considerably for forwards, strangles, and straddles that capture mean, symmetric tail risks, and volatility. Dealer dispersion on risk reversals positively predicts developed currency returns in the cross section, with strong economic and statistical significance at short horizons but weak significance at long horizons. In contrast, dealer dispersion on the other three FX derivatives have no return predictive power.

The use of this proprietary survey of dealers makes our analysis likely to be free of the prevailing validity and relevance criticisms on surveys of professional forecasters used in most studies of the literature. In fact, we find that dispersion among BCFF professional forecasters on future exchange rates is upward sloping, in contrast to the downward sloping pattern of the comparable dispersion among dealers on forward exchange rates. This finding, together with all of our baseline results, suggests that private information is an important economic factor for large institutional traders like dealers, but less likely so for professional forecasters. Comprehensive comparisons of expectations of actual traders and analyst forecasters would be an important venue for future research.

Appendices

A A Model of Dealer Disagreement on Tail Risk

In this appendix, we present a simple model characterizing dealer disagreement on exchange rate dynamics. Given the importance of dealer disagreement on risk reversals in our empirical findings, We focus on tail risk dynamics of currency returns (the analyses would be similar for dynamics of conditional mean and volatility.) The model is mainly to illustrate that dealers' heterogeneous beliefs are primarily identified from long-horizon disagreement, and heterogeneous private information has a more significant impact on the short end. The model also illustrates the difference in dealer disagreement on asymmetric and symmetric measures of tail risk.

A.1 Model Setup and Implications

Model Setup. We consider an infinite-horizon economy with dates $t = 0, \Delta t, 2\Delta t, \ldots$. Let rx_t represent the excess return of a US investor who buys foreign currency for the period from date t to $t + \Delta t$. It could be further decomposed into drift, diffusion, and tail risk components:

$$rx_t = \mu_t \Delta t + \sigma_t \Delta w_t + J_t^+ \Delta N_t^+ - J_t^- \Delta N_t^-. \tag{A.1}$$

$\mu_t \Delta t$ and $\sigma_t \Delta w_t$ are discrete-time analogues of drifts and Brownian motions, representing respectively the trend of small-scale changes in the currency market.

As mentioned above, we focus on infrequent and large adjustments of the exchange rate, represented by $J_t^+ \Delta N_t^+$ for changes with positive signs and $J_t^- \Delta N_t^-$ for changes with negative signs. J_t^+ and J_t^- represent the magnitudes of these tail risk components of return. ΔN_t^+ and ΔN_t^- are discrete-time analogues of Poisson shocks and satisfy Bernoulli distributions. The intensities of these shocks are represented by λ_t^+ and λ_t^-, respectively. ΔN_t^+ is equal to 1 with probability $\lambda_t^+ \Delta t$, and ΔN_t^- is equal to 1 with probability $\lambda_t^- \Delta t$.

$$\Delta N_t^+ = \begin{cases} 1, & \text{with probability } \lambda_t^+ \Delta t, \\ 0, & \text{with probability } 1 - \lambda_t^+ \Delta t. \end{cases} \qquad \Delta N_t^- = \begin{cases} 1, & \text{with probability } \lambda_t^- \Delta t, \\ 0, & \text{with probability } 1 - \lambda_t^- \Delta t. \end{cases} \tag{A.2}$$

The probabilities of these exchange rate jumps may change over time. The intensities of positive and negative jumps λ_t^+ and λ_t^- could take two levels, λ_H and λ_L ($< \lambda_H$). Positive and negative components of tail risks are assumed to be negatively correlated. When the probability of positive extreme returns are high (i.e., $\lambda_t^+ = \lambda_H$), negative extreme returns are unlikely to happen (i.e., $\lambda_t^- = \lambda_L$). The reverse is also true: when $\lambda_t^+ = \lambda_L$, λ_t^- is equal to λ_H. Henceforth we use λ_t^+ to characterize the state of tail risks.

Similar to Patton and Timmermann (2010), we consider both heterogeneous beliefs and heterogeneous information as drivers of dealers' disagreement on currency return dynamics.

Specifically, dealers have heterogeneous prior beliefs about how the state of the world would evolve between the two states $\lambda_t^+ = \lambda_H$ and $\lambda_t^+ = \lambda_L$. Dealer i believes that the current and next period positive component of tail risks λ_t^+ and $\lambda_{t+\Delta t}^+$ are linked by the following dynamics. If this risk is currently low, $\lambda_t^+ = \lambda_L$, in the next period, there is a probability $\nu_i \Delta t$ that the market switches into the other state $\lambda_{t+\Delta t}^+ = \lambda_H$.

$$\lambda_{t+\Delta t}^+ = \begin{cases} \lambda_L, & \text{with probability } 1 - \nu_i \Delta t, \\ \lambda_H, & \text{with probability } \nu_i \Delta t. \end{cases} \tag{A.3}$$

And similarly if the negative tail risk is currently high with $\lambda_t^+ = \lambda_H$, the market has a $(\nu - \nu_i)\Delta t$ probability to switch into the state $\lambda_{t+\Delta t}^+ = \lambda_H$.

$$\lambda_{t+\Delta t}^+ = \begin{cases} \lambda_L, & \text{with probability } (\nu - \nu_i)\Delta t, \\ \lambda_H, & \text{with probability } 1 - (\nu - \nu_i)\Delta t. \end{cases} \tag{A.4}$$

ν_i differs across dealers and represents the heterogeneous prior beliefs about the tail risk dynamics.

Furthermore, dealer i also has access to private signals Δz_{it}^+ and Δz_{it}^- about the current state. Δz_{it}^+ is similar to the tail risk realization ΔN_t^+, satisfies a Bernoulli distribution but is equal to 1 with a different probability $\tau \lambda_t^+ \Delta t$. Similarly, Δz_{it}^- is equal to 1 with probability $\tau \lambda_t^- \Delta t$. The parameter τ represents the precision of private signals, and a higher level of τ indicates that dealers learn more about the jump risk. A positive signal realization $\Delta z_{it}^+ = 1$ indicates that positive extreme returns are more likely to happen, and a negative signal realization $\Delta z_{it}^- = 1$ suggests the same about the negative component of tail risks.

Short-tenor and long-tenor beliefs. We now analyze dealers' beliefs on tail risk, at both the short and long tenors. For short tenor, let $p_t^i \equiv P_i(\lambda_t^+ = \lambda_H)$ represent dealer i's belief about the state at the beginning of date t before the realization of date t return and signal. When positive jumps realize $\Delta N_t^+ = 1$ or the dealer receives a signal indicating positive extreme returns are more likely $\Delta z_{it}^{+} = 1$, she adjusts this probability p_t^i upwards. When negative jumps realizes $\Delta N_t^{-} = 1$ or the dealer receives a signal indicating negative extreme returns are more likely $\Delta z_{it}^{-} = 1$, she adjusts this probability p_t^i downwards. The dynamics of dealer i's belief from date $t-\Delta t$ to the next date t are characterized in the following Lemma.

Lemma 1. *Suppose dealer i's belief about the state at date $t-\Delta t$ is represented by $p_{t-\Delta t}^i$. Her belief at date t is given by:*

$$
\begin{aligned}
p_t^i =& p_{t-\Delta t}^i + \left[\nu_i(1-p_{t-\Delta t}^i) - (\nu-\nu_i)p_{t-\Delta t}^i\right]\Delta t \\
&+ \frac{p_{t-\Delta t}^i(1-p_{t-\Delta t}^i)(\lambda_H-\lambda_L)}{p_{t-\Delta t}^i\lambda_H + (1-p_{t-\Delta t}^i)\lambda_L}\left(\Delta N_{t-\Delta t}^{+} + \Delta z_{i,t-\Delta t}^{+}\right) \\
&- \frac{p_{t-\Delta t}^i(1-p_{t-\Delta t}^i)(\lambda_H-\lambda_L)}{p_{t-\Delta t}^i\lambda_L + (1-p_{t-\Delta t}^i)\lambda_H}\left(\Delta N_{t-\Delta t}^{-} + \Delta z_{i,t-\Delta t}^{-}\right) + o(\Delta t).
\end{aligned}
\tag{A.5}
$$

For long tenor, the following result characterizes a dealer's belief on jump at a future date T:

Lemma 2. *At date t, dealer i's belief about the tail risk at a future date T is given by:*

$$
P_i(\lambda_T^{+} = \lambda_H | \mathscr{F}_t^i) = \frac{\nu_i}{\nu} + [1-\nu\Delta t]^{(T-t)/\Delta t}\left(p_t^i - \frac{\nu_i}{\nu}\right). \tag{A.6}
$$

The first term in the above expression represents dealer i's prior belief. As T goes to infinity, this probability converges to ν_i/ν. This limit comes from the tail-risk states' stationary distribution, which is specified by her prior. In the absence of any information and observation, dealer i believes that:

$$
\lambda_t^{+} = \begin{cases} \lambda_H, & \text{with probability} \quad \nu_i/\nu, \\ \lambda_L, & \text{with probability} \quad 1-\nu_i/\nu. \end{cases} \tag{A.7}
$$

$(\nu_i/\nu, 1-\nu_i/\nu)$ represent the distribution of λ_t^{+} that dealer i believes would converge to in the long run.

Term structure of disagreement. Based on the beliefs derived above, we can now analyze dealers' disagreement on tail risk.The following proposition summarizes disagreements about tail risks at both short and long horizons.

Proposition 1. *At short horizons, the disagreement between dealer i and j's beliefs $p_t^i - p_t^j$ comes from both prior and information heterogeneity, where p_t^i could be expressed as a function of her* *prior stationary level and all the news from the current date t back to the infinite past:*

$$p_t^i = \frac{\nu_i}{\nu} + \sum_{u=-\infty}^{t-\Delta t} \left[1 - \nu \Delta t\right]^{(t-u)/\Delta t - 1}$$
$$\left[\frac{p_u^i (1-p_u^i)(\lambda_H - \lambda_L)}{p_u^i \lambda_H + (1-p_u^i)\lambda_L} \left(\Delta N_u^+ + \Delta z_{iu}^+\right) - \frac{p_u^i (1-p_u^i)(\lambda_H - \lambda_L)}{p_u^i \lambda_L + (1-p_u^i)\lambda_H} \left(\Delta N_u^- + \Delta z_{iu}^-\right) \right] + o(1). \tag{A.8}$$

In the limit $T \to \infty$ at long horizons, the disagreement between dealers i and j's beliefs about future jump risks only comes from the difference in their priors:

$$\lim_{T\to\infty} P_i(\lambda_T^+ = \lambda_H | \mathscr{F}_t^i) - \lim_{T\to\infty} P_j(\lambda_T^+ = \lambda_H | \mathscr{F}_t^j) = \nu_i/\nu - \nu_j/\nu. \tag{A.9}$$

Note that the beliefs about the state in Equations (A.8) and (A.9) directly map to the beliefs about the jump intensities. In particular, Dealer i with belief p_t^i would believe that the probability of positive extreme returns in the next trading period $[t, t+\Delta t]$ is $(p_t^i \lambda_H + (1-p_t^i)\lambda_L)\Delta t$, and the probability of negative extreme returns is $(p_t^i \lambda_L + (1-p_t^i)\lambda_H)\Delta t$. Similarly, $P_i(\lambda_T^+ = \lambda_H | \mathscr{F}_t^i)$ maps into jump intensity $(P_i(\lambda_T^+ = \lambda_H|\mathscr{F}_t^i)\lambda_H + (1 - P_i(\lambda_T^+ = \lambda_H|\mathscr{F}_t^i))\lambda_L)\Delta t$ in the trading period $[T, T+\Delta t]$.

We illustrate the impacts of heterogeneous prior and heterogeneous information on dealer disagreements separately. First, we shut down the heterogeneous prior channel and only allow dealers to receive different information. ν_i is assumed to be the same for all dealers. Implication 1 summarizes the impact of heterogeneous information.

Implication 1. *Suppose dealers have homogeneous prior but receive heterogeneous information. In this situation, disagreement about the tail risk is strong at short horizons and dissipates at long horizons.*

Dealer i's belief (A.8) is affected by both publicly-observed tail risk realizations and her private signals. Tail risk realizations represent the common component of dealer's beliefs, while Δz_{iu}^+ and Δz_{iu}^- differ across dealers and create disagreement. Another dealer j would receive different signals Δz_{ju}^+ and Δz_{ju}^- and therefore come up with different beliefs about tail risk distributions. As the precision τ decreases from a moderate level, past signals form a more insignificant component of dealer i's belief. Dealers are equally ignorant about the actual state of the world and have to rely on the realizations of currency returns, which are commonly observed and publicly available to all dealers. Therefore, this decrease in heterogeneous information leads to a smaller dispersion of beliefs.

At long horizons, all disagreements dissipate. Tail risk realizations and private signals for the period $u \in (t, T]$ are not observed at date t and therefore not reflected in $P_i(\lambda_T^+ = \lambda_H | \mathscr{F}_t^i)$, dealer i's belief about the tail risk at a future date T. Therefore, differences in dealers' beliefs about future jump risks decrease as horizon increases. In the infinite horizon limit, these beliefs converge to the same stationary distribution level ν_i/ν specified by the homogeneous prior.

Second, we shut down the heterogeneous information channel and only allow dealers to hold different prior beliefs ν_i. Dealers now receive homogeneous information. Dealers i and j receive the same signal $\Delta z_{it}^+ = \Delta z_{jt}^+$, and $\Delta z_{it}^- = \Delta z_{jt}^-$. Implication 2 summarizes the impact of heterogeneous prior.

Implication 2. *Suppose dealers receive homogeneous information but have heterogeneous prior. In this situation, disagreement about the tail risk is stronger at long horizons.*

The effect of heterogeneous prior is most prominent at long horizons. In the limit $T \to \infty$, dealer i believes λ_t^+ has distribution $(\nu_i/\nu, 1 - \nu_i/\nu)$ while another dealer j would believe the correct distribution is $(\nu_j/\nu, 1 - \nu_j/\nu)$. This difference in prior belief thus give rise to disagreements in long horizon option quotes.

Heterogeneous prior has a smaller impact at short horizons because dealers observe the same set of information. Dealer i's belief p_t^i is an average of prior belief and all the information received in the past. Two dealers i and j would observe the same currency return realizations ΔN_u^+, ΔN_u^- and the same private signals Δz_{iu}^+, Δz_{iu}^-. Therefore the difference in their beliefs about the current state, $p_t^i - p_t^j$, would be smaller than the differences in priors $\nu_i/\nu - \nu_j/\nu$. Because jumps are infrequent, this disagreement would not converge to zero.

To summarize, the impact of heterogeneous information decreases over the horizon, while the impact of heterogeneous prior belief increases. At long horizons, heterogeneous information has no impact. Therefore disagreements at long horizons only measure the effect of heterogeneous prior. In contrast, disagreements at short horizons are affected by both heterogeneous information and heterogeneous prior. A downward-sloping term structure of dealer disagreement, as we find empirically, indicates that heterogeneous information plays a more significant role in shaping the term structure of disagreement.

Relation of option quotes to dealer beliefs. Although our model is not directed towards option pricing, it is conceivable that a dealer' belief on tail risk can be reflected in her option price quote. In particular, the short-tenor and long-tenor option price quotes of a dealer would reflect her short-tenor and long-tenor beliefs, respectively. In consequence, the dispersion in dealers' option price quotes can measure their disagreement on tail risk.

We consider two types of options. First, the expected payoff of risk reversal is strongly related to the expectation of the jump components of currency returns. Consider the short horizon from t and $t+\Delta t$, for example. A dealer's belief on tail risk p_t^i is reflected in

$$\begin{aligned}\mathbb{E}\left[J_t^+\Delta N_t^+ - J_t^-\Delta N_t^-\right] &= (p_t^i\lambda_H + (1-p_t^i)\lambda_L)\Delta t\,\mathbb{E}_t\left[J_t^+\right] - (p_t^i\lambda_L + (1-p_t^i)\lambda_H)\Delta t\,\mathbb{E}_t\left[J_t^-\right] \\ &= \lambda_L\Delta t\,\mathbb{E}_t\left[J_t^+\right] - \lambda_H\Delta t\,\mathbb{E}_t\left[J_t^-\right] + (\lambda_H-\lambda_L)\Delta t\big(\mathbb{E}_t\left[J_t^+\right]+\mathbb{E}_t\left[J_t^-\right]\big)\cdot p_t^i. \quad (A.10)\end{aligned}$$

Second, strangles capture tail risks in a symmetric fashion. The expected payoff of strangle is related to the expectation of the absolute value of currency return jumps. We still use short horizon from t and $t+\Delta t$ as an example. This expectation is

$$\begin{aligned}\mathbb{E}_t\left[J_t^+\Delta N_t^+ + J_t^-\Delta N_t^-\right] &= (p_t^i\lambda_H + (1-p_t^i)\lambda_L)\Delta t\,\mathbb{E}_t\left[J_t^+\right] + (p_t^i\lambda_L + (1-p_t^i)\lambda_H)\Delta t\,\mathbb{E}_t\left[J_t^-\right] \\ &= \lambda_L\Delta t\,\mathbb{E}_t\left[J_t^+\right] + \lambda_H\Delta t\,\mathbb{E}_t\left[J_t^-\right] + (\lambda_H-\lambda_L)\Delta t\big(\mathbb{E}_t\left[J_t^+\right]-\mathbb{E}_t\left[J_t^-\right]\big)\cdot p_t^i. \quad (A.11)\end{aligned}$$

Compared to the signed expectation of currency jumps (A.10), this unsigned expectation is less affected by dealers beliefs. The coefficient before p_t^i is $(\lambda_H-\lambda_L)\Delta t\big(\mathbb{E}_t\left[J_t^+\right]-\mathbb{E}_t\left[J_t^-\right]\big)$, smaller than $(\lambda_H-\lambda_L)\Delta t\big(\mathbb{E}_t\left[J_t^+\right]+\mathbb{E}_t\left[J_t^-\right]\big)$. Higher estimates of positive extreme returns and lower estimates of negative extreme returns tend to cancel out for strangle prices, and as a result strangle prices exhibit lower disagreements.

A.2 Proofs

We provide proofs of the results discussed above.

Proof of Lemma 1. The term $\left[\nu_i(1-p_{t-\Delta t}^i)-(\nu-\nu_i)p_{t-\Delta t}^i\right]\Delta t$ represents the impact of switching tail risk states. We look at the impact of different observations and signals separately.

Positive jumps of currency returns $\Delta N_{t-\Delta t}^+$ is equal to 1 with probability $\lambda_{t-\Delta t}^+\Delta t$ and 0 with probability $1-\lambda_{t-\Delta t}^+\Delta t$. If we assume other signals $\Delta N_{t-\Delta t}^-$, $\Delta z_{i,t-\Delta t}^+$ and $\Delta z_{i,t-\Delta t}^-$ and in addition the state are not switching between $\lambda_{t-\Delta t}^+$ and $\lambda_{t-\Delta t}^-$, dealer i's belief at date t is given by

$$p_t^i = \begin{cases} \dfrac{p_{t-\Delta t}^i\lambda_H}{p_{t-\Delta t}^i\lambda_H + (1-p_{t-\Delta t}^i)\lambda_L}, & \text{if} \quad \Delta N_{t-\Delta t}^+ = 1, \\ \dfrac{p_{t-\Delta t}^i(1-\lambda_H\Delta t)}{p_{t-\Delta t}^i(1-\lambda_H\Delta t)+(1-p_{t-\Delta t}^i)(1-\lambda_L\Delta t)}, & \text{if} \quad \Delta N_{t-\Delta t}^+ = 0. \end{cases} \quad (A.12)$$

The difference between $p^i_{t-\Delta t}$ and $p^i_t|_{\Delta N^+_{t-\Delta t}=1}$ is equal to

$$\frac{p^i_{t-\Delta t}\lambda_H}{p^i_{t-\Delta t}\lambda_H + (1-p^i_{t-\Delta t})\lambda_L} - p^i_{t-\Delta t} = \frac{p^i_{t-\Delta t}(1-p^i_{t-\Delta t})(\lambda_H-\lambda_L)}{p^i_{t-\Delta t}\lambda_H + (1-p^i_{t-\Delta t})\lambda_L}. \tag{A.13}$$

and this term is the coefficient before $\Delta N^+_{t-\Delta t} = 1$ in equation (A.5). This coefficient is the same for the shock $\Delta z^+_{i,t-\Delta t}$. For $\Delta N^-_{t-\Delta t}$ and $\Delta z^-_{i,t-\Delta t}$, the change in belief when the shock realizes is equal to

$$\frac{p^i_{t-\Delta t}(1-p^i_{t-\Delta t})(\lambda_H-\lambda_L)}{p^i_{t-\Delta t}\lambda_L + (1-p^i_{t-\Delta t})\lambda_H}. \tag{A.14}$$

Proof of Lemma 2. Suppose at date t, dealer i's belief about the tail risk at a future date u is $P_i(\lambda^+_u = \lambda_H|\mathscr{F}^i_t)$. The belief about the tail risk at $u+\Delta t$ is

$$P_i(\lambda^+_{u+\Delta t} = \lambda_H|\mathscr{F}^i_t) = P_i(\lambda^+_u = \lambda_H|\mathscr{F}^i_t)\Big(1-(\nu_i-\nu)\Delta t\Big) + \Big(1-P_i(\lambda^+_u = \lambda_H|\mathscr{F}^i_t)\Big)\nu_i\Delta t. \tag{A.15}$$

Therefore,

$$P_i(\lambda^+_{u+\Delta t} = \lambda_H|\mathscr{F}^i_t) - \frac{\nu_i}{\nu} = (1-\nu\Delta t)\Big(P_i(\lambda^+_u = \lambda_H|\mathscr{F}^i_t) - \frac{\nu_i}{\nu}\Big), \tag{A.16}$$

$$P_i(\lambda^+_T = \lambda_H|\mathscr{F}^i_t) - \frac{\nu_i}{\nu} = (1-\nu\Delta t)^{(T-t)/\Delta t}\Big(p^i_t - \frac{\nu_i}{\nu}\Big). \tag{A.17}$$

The above equation is equivalent to equation (A.6).

Proof of Proposition 1. Subtracting both sides of equation (A.5) by the long-run mean ν_i/ν, we obtain:

$$\begin{aligned} p^i_t - \frac{\nu_i}{\nu} =& (1-\nu\Delta t)\Big(p^i_{t-\Delta t} - \frac{\nu_i}{\nu}\Big) \\ &+ \frac{p^i_{t-\Delta t}(1-p^i_{t-\Delta t})(\lambda_H-\lambda_L)}{p^i_{t-\Delta t}\lambda_H + (1-p^i_{t-\Delta t})\lambda_L}\big(\Delta N^+_{t-\Delta t} + \Delta z^+_{i,t-\Delta t}\big) \\ &- \frac{p^i_{t-\Delta t}(1-p^i_{t-\Delta t})(\lambda_H-\lambda_L)}{p^i_{t-\Delta t}\lambda_L + (1-p^i_{t-\Delta t})\lambda_H}\big(\Delta N^-_{t-\Delta t} + \Delta z^-_{i,t-\Delta t}\big) + o(\Delta t). \end{aligned} \tag{A.18}$$

Thus,

$$
\begin{aligned}
p_t^i - \frac{\nu_i}{\nu} =& (1-\nu\Delta t)\left(p_{t-\Delta t}^i - \frac{\nu_i}{\nu}\right) \\
&+ \frac{p_{t-\Delta t}^i(1-p_{t-\Delta t}^i)(\lambda_H-\lambda_L)}{p_{t-\Delta t}^i\lambda_H+(1-p_{t-\Delta t}^i)\lambda_L}\left(\Delta N_t^+ + \Delta z_{it}^+\right) - \frac{p_{t-\Delta t}^i(1-p_{t-\Delta t}^i)(\lambda_H-\lambda_L)}{p_{t-\Delta t}^i\lambda_L+(1-p_{t-\Delta t}^i)\lambda_H}\left(\Delta N_t^- + \Delta z_{it}^-\right) + o(\Delta t) \\
=& \sum_{u=-\infty}^{t-\Delta t}\left[1-\nu\Delta t\right]^{(t-u)/\Delta t-1} \\
&\left[\frac{p_u^i(1-p_u^i)(\lambda_H-\lambda_L)}{p_u^i\lambda_H+(1-p_u^i)\lambda_L}\left(\Delta N_u^+ + \Delta z_u^+\right) - \frac{p_u^i(1-p_u^i)(\lambda_H-\lambda_L)}{p_u^i\lambda_L+(1-p_u^i)\lambda_H}\left(\Delta N_u^- + \Delta z_u^-\right)\right] + o(1).
\end{aligned}
\tag{A.19}
$$

Combining the impact of switching tail risk states and the impacts of different observations and signals, we obtain equation (A.8). The higher-order term $o(\Delta t)$ goes to 0 faster than Δt in the continuous-time limit $\Delta t \to 0$.

B Additional Results

We provide a number of results in this appendix. Figure B.1 compares BCFF professional forecasters' forecast dispersion on exchange rates with dealers' price dispersion on forward rates for each individual currency covered by both Blue Chip and Markit Totem, including AUD, CAD, CHF, EUR, GPB, and JPY, over the period between November 2006 and February 2015. Figure B.2 plots dealer dispersion over tenor for each option product and each of the six developing currencies, including HUF, INR, KRW, PLN, RUB, and ZAR. Table B.1 provides the summary statistics of the annualized monthly returns for each developed and developing currency in our sample over the period from January 2006 to December 2018 with dealers' price quote data. Table B.2 provides the summary of the dealer survey data for developing currencies. Table B.3 presents the Fama-MacBeth regression results predicting forward currency returns using dealer risk reversal dispersion controlling for exposures to the dollar risk factor and the global FX volatility factor.

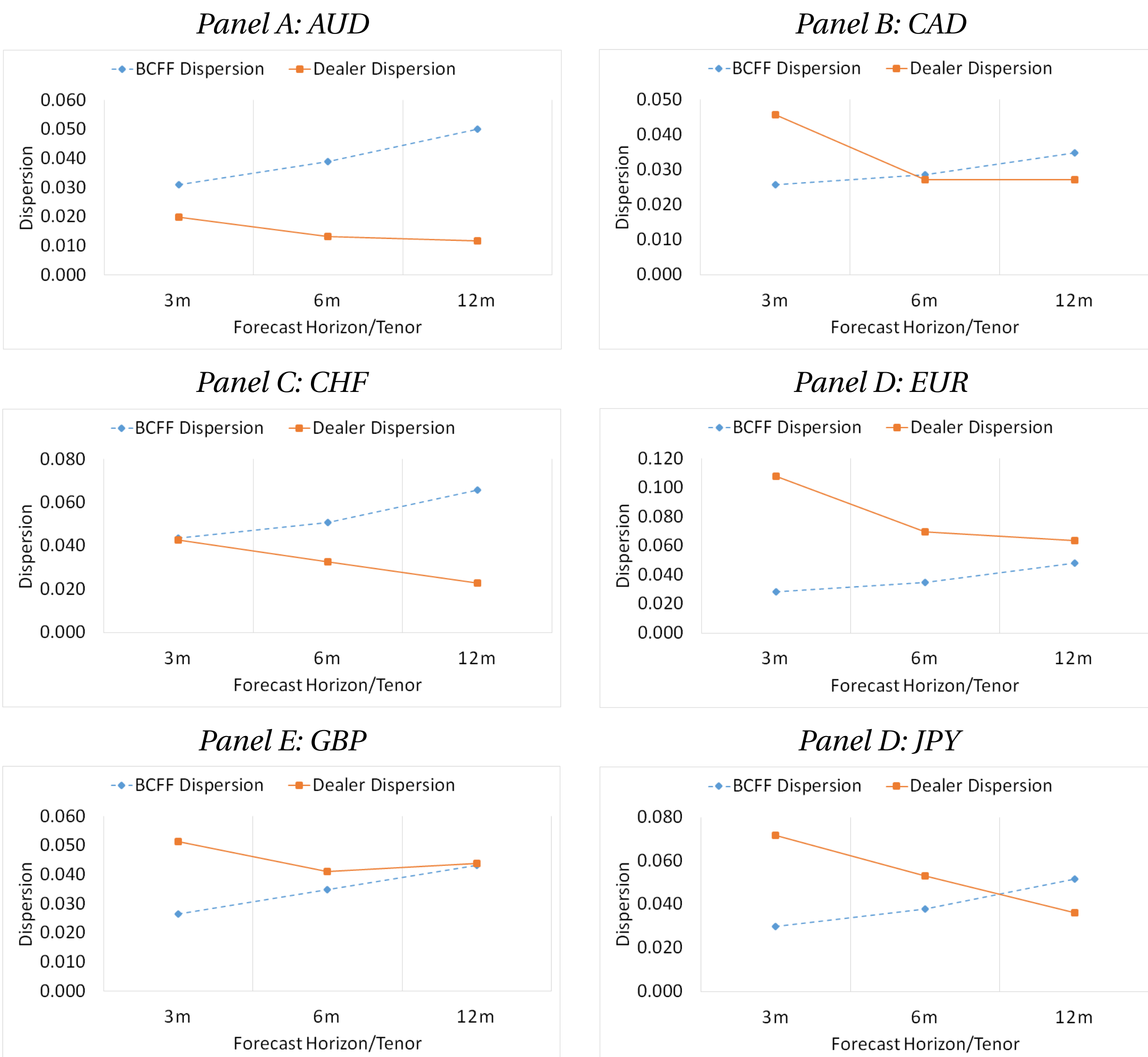

Figure B.1. BCFF Dispersion on Exchange Rates vs. Dealer Dispersion on Forward Rates by Currency

This figure displays the time-series average forecast dispersion of Blue Chip financial forecasters (BCFF) on future exchange rates in 3 months, 6 months, and 12 months in comparison with dealer price dispersion on forward rates with tenor equal to the exchange rate forecast horizon. The sample consists of six developed currencies (AUD, CAD, CHF, EUR, GPB, and JPY) covered by both Blue Chip and Markit Totem for the period between November 2006 and February 2015. *BCFF Dispersion* is computed as the cross-sectional standard deviation of forecasts from different forecasters scaled by the consensus forecast in that month. *Dealer Dispersion* is computed as the standard deviation of dealer price quotes on forward rates with a given tenor divided by the absolute average price quote in that month.

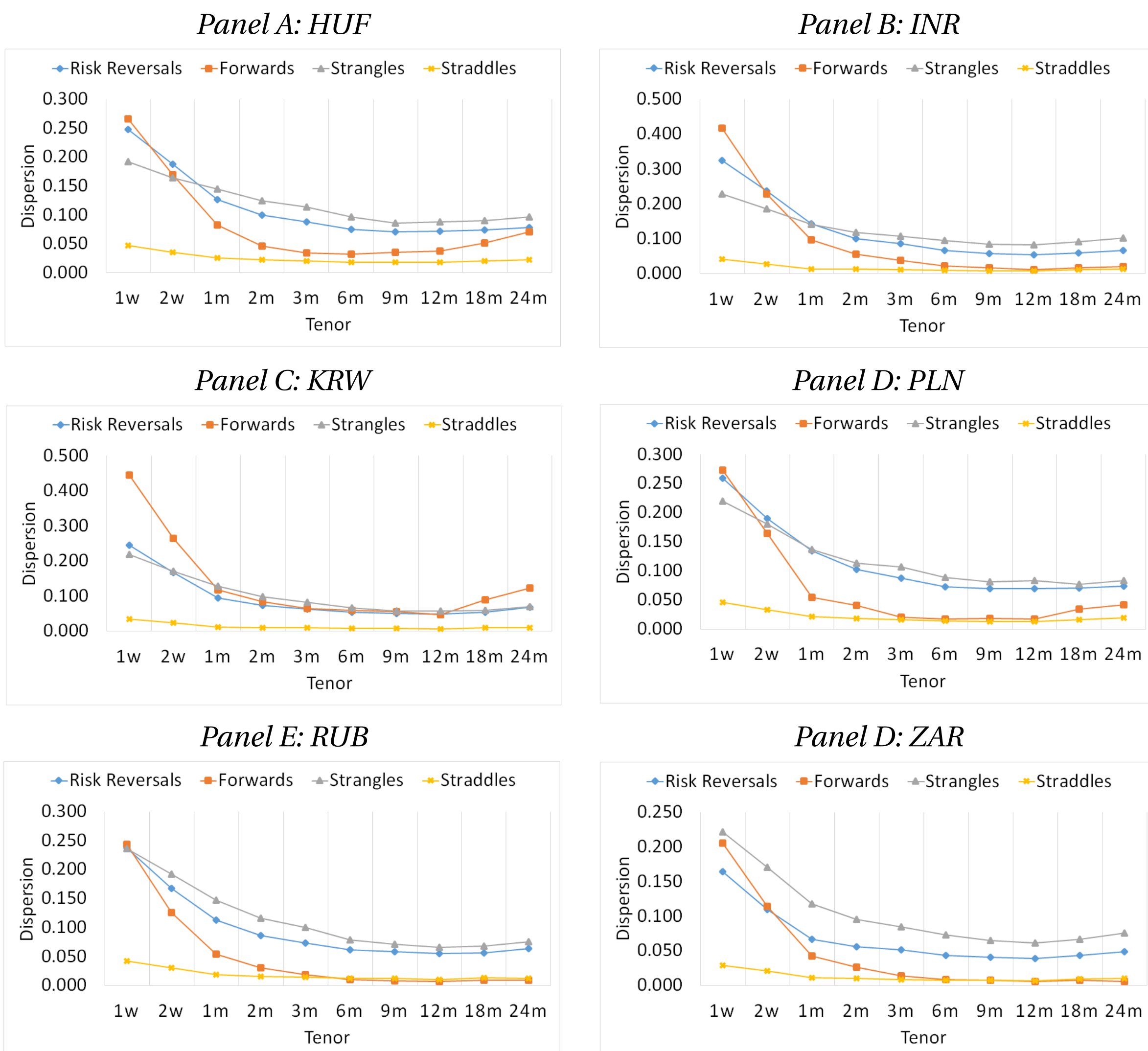

Figure B.2. Dealer Dispersion over Tenor by Currency: Six Developing Currencies

This figure displays the time-series average of dealer dispersion on different currency option products over tenor for six developing currencies, including HUF, INR, KRW, PLN, RUB, and ZAR. The sample period is between January 2006 and December 2018, and the option products include risk reversals, forwards, strangles, and straddles with tenors between one week and 24 months. *Dispersion* is computed as the standard deviation of dealer price quotes on an option product with a given tenor divided by the absolute average price quote in that month.

Table B.1. Summary Statistics of Annualized Currency Returns

This table reports the summary statistics of *annualized* and US-based currency returns for 12 developed currencies in Panel A and 18 developing currencies in Panel B. The sample period is between January 2006 and December 2018, and the statistics include the time-series mean, standard deviation, and quantiles. The last row reports cross-currency average of the statistics.

Panel A: Developed Currencies

Currency	Mean	SD	P1	P25	Median	P75	P99
AUD	0.003	0.465	-1.193	-0.234	0.000	0.280	1.020
CAD	-0.015	0.353	-1.079	-0.220	0.008	0.186	0.827
CHF	-0.002	0.393	-1.246	-0.207	-0.009	0.228	1.401
DKK	-0.036	0.381	-0.996	-0.253	-0.004	0.213	0.844
EUR	-0.016	0.424	-1.100	-0.227	0.003	0.219	1.287
GBP	-0.033	0.323	-1.089	-0.201	-0.002	0.180	0.672
HKD	-0.003	0.016	-0.061	-0.010	-0.002	0.003	0.038
JPY	-0.012	0.340	-1.061	-0.198	0.026	0.186	0.854
NOK	-0.035	0.403	-1.025	-0.317	-0.018	0.198	0.832
NZD	0.051	0.582	-1.610	-0.264	0.081	0.351	1.640
SEK	-0.027	0.412	-1.139	-0.235	-0.048	0.217	1.043
SGD	-0.003	0.229	-0.733	-0.114	-0.005	0.134	0.580
Average	-0.011	0.360	-1.027	-0.207	0.002	0.199	0.920

Panel B: Developing Currencies

Currency	Mean	SD	P1	P25	Median	P75	P99
BRL	0.021	0.570	-1.812	-0.325	0.079	0.399	1.412
CLP	-0.018	0.438	-1.404	-0.256	0.044	0.272	0.735
COP	-0.025	0.503	-1.228	-0.289	0.008	0.271	1.175
CZK	-0.045	0.460	-1.233	-0.294	-0.018	0.240	0.947
HUF	-0.035	0.569	-1.864	-0.308	0.002	0.274	1.223
IDR	0.017	0.338	-1.337	-0.107	0.018	0.169	1.154
ILS	-0.003	0.304	-0.875	-0.183	0.017	0.211	0.738
INR	0.008	0.344	-0.908	-0.155	0.037	0.198	0.841
KRW	-0.016	0.449	-1.415	-0.203	-0.004	0.245	1.302
MXN	-0.033	0.424	-1.610	-0.215	0.019	0.240	0.843
MYR	0.004	0.293	-0.778	-0.189	0.032	0.214	0.523
PEN	0.012	0.161	-0.349	-0.084	0.017	0.105	0.691
PHP	-0.003	0.208	-0.444	-0.148	0.016	0.127	0.433
PLN	-0.074	0.712	-1.822	-0.385	0.056	0.437	1.217
RUB	0.014	0.466	-1.290	-0.108	0.068	0.229	1.023
THB	0.018	0.217	-0.448	-0.126	0.011	0.174	0.429
TWD	0.001	0.194	-0.567	-0.102	-0.002	0.117	0.532
ZAR	-0.021	0.528	-1.568	-0.359	-0.009	0.322	1.053
Average	-0.010	0.399	-1.164	-0.213	0.022	0.236	0.904

Table B.2. Summary of the FX Dealer Survey: Developing Currencies

This table reports the sample period and the time-series quantiles of the number of dealers quotes on different currency option products with 1-month tenor for 18 developing currencies. Panels A to D report the statistics for risk reversals, forwards, strangles, and straddles, respectively.

	Panel A: Risk Reversals					*Panel B: Forwards*				
	Sample Period		Number of Dealer Quotes			Sample Period		Number of Dealer Quotes		
Currency	Begin	End	P25	Median	P75	Begin	End	P25	Median	P75
BRL	200601	201812	14	17	18	200905	201812	13	17	19
CLP	200707	201812	11	12	13	200909	201812	10	12	13
COP	200804	201812	9	10	11	200907	201812	9	11	12
CZK	200802	201812	8	10	12	200911	201812	11	13	14
HUF	200708	201812	11	12	14	200910	201812	13	14	15
IDR	200708	201812	14	15	16	200904	201812	12	14	16
ILS	200707	201812	11	12	14	201001	201812	13	14	15
INR	200708	201812	15	16	17	200904	201812	14	16	18
KRW	200706	201812	15	17	19	200904	201812	15	17	19
MXN	200601	201812	15	17	18	200905	201812	12.5	16.5	19
MYR	200802	201812	12	14	15	201001	201812	12	14	15
PEN	200910	201812	6	7	7	201002	201812	8	9	10
PHP	200802	201812	12	14	15	200904	201812	12	13	14
PLN	200705	201812	12	14	15	200910	201812	14	15	16
RUB	200702	201812	14	15	17	200910	201812	15	16	17
THB	200802	201812	9	10	11	200906	201812	9	10	11
TWD	200706	201812	15	16	18	200904	201812	14	16	18
ZAR	200605	201812	13.5	16	18	200909	201812	14	16.5	18

	Panel C: Strangles					*Panel D: Straddles*				
	Sample Period		Number of Dealer Quotes			Sample Period		Number of Dealer Quotes		
Currency	Begin	End	P25	Median	P75	Begin	End	P25	Median	P75
BRL	200802	201812	15	17	18	n.a.	n.a.	n.a.	n.a.	n.a.
CLP	200802	201812	11	12	13	n.a.	n.a.	n.a.	n.a.	n.a.
COP	200804	201812	9	10	11	n.a.	n.a.	n.a.	n.a.	n.a.
CZK	200802	201812	8	10	12	200802	201812	10	12	13
HUF	200802	201812	11	12	14	200708	201812	12	13	14
IDR	200802	201812	13	15	16	200707	201812	14	15	16
ILS	200802	201812	11	12	14	200707	201812	12	13	14
INR	200802	201812	15	16	17	200706	201812	16	16	18
KRW	200802	201812	14	18	19	200612	201812	15	17	19
MXN	200802	201812	15	16	18	n.a.	n.a.	n.a.	n.a.	n.a.
MYR	200802	201812	12	14	15	200802	201812	13	15	16
PEN	200910	201812	6	7	7	n.a.	n.a.	n.a.	n.a.	n.a.
PHP	200802	201812	12	13	15	200802	201812	12	14	15
PLN	200802	201812	12	14	15	200705	201812	13	14.5	16
RUB	200802	201812	14	15	16	200702	201812	15	16	17
THB	200802	201812	8	9	10	200801	201812	9	10	11
TWD	200802	201812	14	16	18	200612	201812	15	16	18
ZAR	200802	201812	14	16	18	200605	201812	14	16	18

Table B.3. Dealer Disagreement on Risk Reversals and FX Returns: Different Controls

This table reports the estimated regression coefficients and Newey-West t-statistics (in parentheses) from Fama and MacBeth (1973) cross-sectional regressions predicting *annualized* future currency returns using previous-month dealer dispersion on risk reversals with different controls. The sample is for 12 developed currencies from January 2006 to December 2018 and forecast horizon ranges from 1 month to 12 months. *Dispersion* is computed as the standard deviation of dealer price quotes on an option product with a given tenor divided by the absolute average price quote in that month. To forecast k-month returns, we use dealer dispersion with k-month tenor. β_{RX} and β_{VOL} are the exposures to the dollar risk factor RX and the global foreign exchange volatility factor VOL in Menkhoff, Sarno, Schmeling, and Schrimpf (2012). SD(*Dispersion*) is the time-series average of cross-currency standard deviation of *Dispersion*. *Change in return* is the change in annualized future return associated with a one-standard-deviation change in *Dispersion*. For dependent variables at k-month horizon ($k > 1$), we use Newey-West robust standard errors with lag $k-1$.

Tenor & Ret Horizon	1m	2m	3m	6m	9m	12m
Intercept	-0.034	-0.037*	-0.036*	-0.039**	-0.037*	-0.031*
	(-1.51)	(-1.91)	(-1.96)	(-2.15)	(-1.89)	(-1.67)
$Dispersion_k$	0.108**	0.106*	0.099	0.159*	0.185	0.177
	(2.01)	(1.71)	(1.56)	(1.94)	(1.60)	(1.57)
β_{RX}	0.002	0.012	0.015	0.019	0.018	0.015
	(0.08)	(0.57)	(0.71)	(0.83)	(0.87)	(0.85)
β_{VOL}	-0.099	0.041	0.042	0.085	0.088	0.121
	(-0.56)	(0.27)	(0.29)	(0.67)	(0.69)	(0.87)
R^2	47.3%	49.5%	50.4%	51.8%	48.4%	45.0%
# obs	1575	1572	1569	1530	1482	1449
SD($Dispersion_k$)	0.61	0.25	0.25	0.17	0.14	0.14
Change in return	6.6%	2.7%	2.5%	2.7%	2.6%	2.5%

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