

FX Options-Implied Probability Densities and Macroeconomic Surprises

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Motivation and Preview

- How do macroeconomic surprises affect market-implied expectations of the USD/JPY exchange rate?
 - Use options-implied risk-neutral probability density functions (PDFs)
- I expect that...
 - Corollaries to interest rate parity hold
 - Ederington and Lee [4]: implied variance should decrease following an event
 - Brunnermeier et al. [2]: the Japanese yen should be skewed towards appreciation



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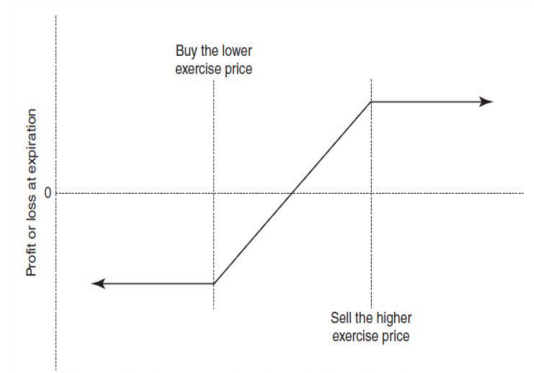
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Theory and Intuition

- Breeden and Litzenberger [1] showed that we can extract risk-neutral PDFs from options
- Shimko [8] proposed a method to do this by interpolating between call prices
- For the intuition, think of a "vertical spread" structure



Source: Natenberg [7]



Empirical Studies and Applications

- Central banks & markets professionals monitor these PDFs
- Campa et al. [3]: used options on the Brazilian real to evaluate the credibility of Brazil's crawling-peg exchange rate regime
- Kitsul and Wright [6]: used inflation caps and floors (essentially options on inflation) to assess how inflation expectations change in response to macroeconomic news announcements



Data

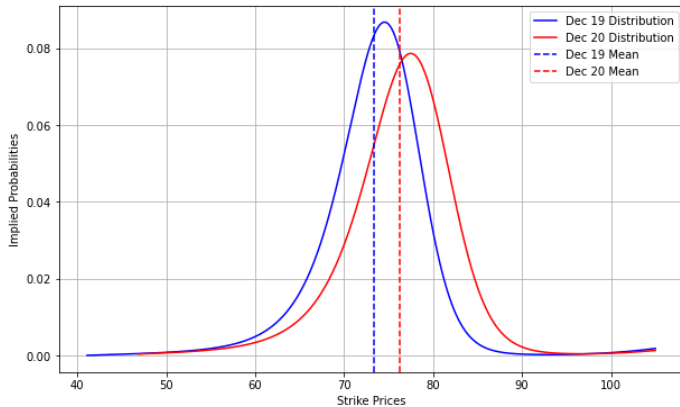
- Options prices came from CME via Bloomberg, speculator positions (important later) came from CFTC, and all other data came from Bloomberg
- I use the method of Shimko [8] to extract daily PDFs from 2018-2024
- Ten types of macroeconomic surprises; surprise components calculated as actual minus expected
 - Central bank policy rate decisions, CPI, PPI, GDP, and Unemployment for the U.S. and Japan



Example

- Mean: 73.4 \rightarrow 76.24
- Variance: 39.96 \rightarrow 40.20
- Skew: 0.06 \rightarrow -0.34
- Kurtosis: 7.76 \rightarrow 5.65

3-Mo. PDF for JPY/USD on 12/19/2022 and 12/20/2022





Model Specification

- Regression to quantify the effect of a surprise on the PDF moments:

$$\Delta Y_t = \beta_0 + \beta_1 X_{1t} D_{1t} + \beta_2 X_{2t} D_{2t} + \dots + \beta_{10} X_{10t} D_{10t} + \epsilon_t$$

- Regression to quantify the effect of the passing of an event on the variance:

$$\Delta Y_t = \beta_0 + \beta_1 D_{1t} + \beta_2 D_{2t} + \dots + \beta_{10} D_{10t} + \epsilon_t$$



Interest Rate Parity

1-Month Regression Results

Release Type	Mean	Variance	Skewness	Kurtosis
FOMC Meetings	-7.59*** (2.78)	-15.31* (8.45)	1.15 (2.10)	18.10 (12.46)
BOJ Meetings	33.30 (56.89)	290.64** (124.95)	13.14 (13.53)	15.41 (132.10)
U.S. CPI	-110.11** (54.14)	-88.13 (115.95)	-49.18 (40.04)	25.30 (156.96)
Japanese CPI	-52.13 (47.56)	168.34 (180.76)	12.20 (75.02)	282.66 (368.81)
U.S. PPI	-8.72 (15.81)	29.51 (42.45)	4.84 (22.93)	19.10 (82.58)
Japanese PPI	-10.04 (18.36)	17.19 (53.35)	-2.10 (10.38)	26.66 (54.37)
U.S. GDP	0.60 (16.01)	-89.42*** (34.78)	43.27** (18.01)	237.16*** (83.56)
Japanese GDP	-2.58 (4.35)	-10.07 (11.90)	-0.31 (5.02)	8.04 (16.21)
U.S. Unemployment	-64.07 (90.38)	7.26 (18.39)	-1.26 (5.97)	-6.11 (41.73)
Japanese Unemployment	49.12 (44.17)	-195.53* (113.61)	114.22 (80.46)	451.06 (345.99)
Intercept	-0.14 (0.17)	-0.03 (0.07)	0.03 (0.02)	0.21* (0.12)

Notes: Statistical significance at the ten, five, and one percent levels are denoted by one, two, and three asterisks, respectively.

3-Month Regression Results

Release Type	Mean	Variance	Skewness	Kurtosis
FOMC Meetings	-8.48*** (2.47)	-10.88 (11.09)	-0.33 (0.945)	0.72 (2.63)
BOJ Meetings	403.41 (450.68)	-58.60 (157.67)	-1.73 (8.86)	56.47 (62.38)
U.S. CPI	-151.28*** (58.67)	42.82 (169.27)	12.90 (14.27)	24.58 (48.75)
Japanese CPI	79.73 (76.32)	116.89 (139.04)	13.66 (14.89)	113.83*** (38.53)
U.S. PPI	-20.73 (17.33)	2.30 (57.75)	-1.81 (4.00)	-6.13 (11.71)
Japanese PPI	-33.3 (23.20)	-155.16** (77.56)	-4.53* (2.66)	-5.30 (12.91)
U.S. GDP	-21.36 (31.99)	-52.07* (27.13)	-1.79 (3.54)	6.60 (9.96)
Japanese GDP	-2.96 (4.86)	-11.74 (19.47)	1.97* (1.06)	4.37 (4.14)
U.S. Unemployment	12.43 (7.88)	43.96*** (11.27)	-0.01 (1.32)	-2.33 (3.67)
Japanese Unemployment	-666.02 (730.77)	-60.37 (144.47)	-14.22 (14.21)	-89.07 (71.21)
Intercept	0.15 (0.26)	0.04 (0.10)	0.00 (0.01)	0.06** (0.03)

Notes: Statistical significance at the ten, five, and one percent levels are denoted by one, two, and three asterisks, respectively.



The Passing of an Event

- Find no evidence that the passing of an event lowers the implied variance
- Ederington and Lee [4]: stronger evidence for this in interest rate markets rather than currency markets
- Lots of events occur over life of option

Dummy-Only Regression Results

Release Type	1m Var	1m $P_{90} - P_{10}$	3m Var	3m $P_{90} - P_{10}$
FOMC Meetings	0.37 (0.41)	0.09 (0.14)	-0.01 (0.61)	-0.07 (0.15)
BOJ Meetings	0.19 (0.29)	0.03 (0.09)	0.54 (0.44)	0.06 (0.14)
U.S. CPI	0.20 (0.29)	0.04 (0.08)	0.27 (0.57)	-0.06 (0.13)
Japanese CPI	-0.33 (0.26)	-0.04 (0.07)	0.22 (0.39)	-0.02 (0.10)
U.S. PPI	0.01 (0.22)	-0.01 (0.07)	0.45 (0.33)	-0.01 (0.08)
Japanese PPI	-0.04 (0.27)	-0.03 (0.08)	-0.02 (0.51)	-0.07 (0.11)
U.S. GDP	0.06 (0.24)	-0.04 (0.07)	0.11 (0.33)	-0.08 (0.10)
Japanese GDP	0.26 (0.27)	0.06 (0.08)	0.16 (0.43)	-0.02 (0.11)
U.S. Unemployment	0.34 (0.35)	0.12 (0.13)	0.29 (0.50)	-0.11 (0.15)
Japanese Unemployment	0.51** (0.26)	0.14 (0.08)	0.20 (0.36)	0.07 (0.12)
Intercept	-0.18 (0.24)	-0.09 (0.07)	-0.23 (0.39)	0.03 (0.10)

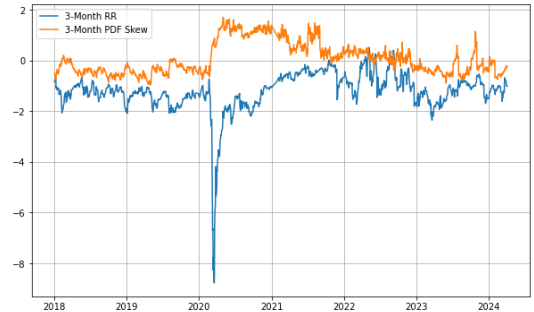
Notes: $P_{90} - P_{10}$ is the ninetyth percentile of the distribution minus the tenth percentile of the distribution. Statistical significance at the ten, five, and one percent levels are denoted by one, two, and three asterisks, respectively.



The Carry Trade (I)

- Surprisingly, yen frequently skewed towards depreciation
- The PDF measure is likely more accurate

3-Month PDF Skew and 25 Δ RR

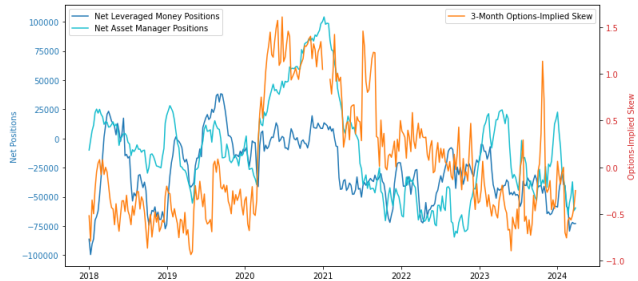




The Carry Trade (II)

- Skew closely tracks fast money positions in futures contracts
- Indicates that yen skew highly related to magnitude of carry trade

Yen Futures Positions and 3-Month PDF Skewness



Source: Author's calculations and the Commodity Futures Trading Commission.

The 'net positions' are the number of futures contracts of JPY/USD 12,500,000.

Negative values indicate that money managers are net short JPY/USD, or equivalently net long USD/JPY.



Concluding Thoughts

- Friedman [5]: "A hypothesis is important if it "explains" much by little, that is, if it abstracts the common and crucial elements from the mass of complex and detailed circumstances surrounding the phenomena to be explained and permits valid predictions on the basis of them alone."



References I

- [1] Douglas T. Breeden and Robert H. Litzenberger. Prices of state-contingent claims implicit in option prices. *The Journal of Business*, 51(4):621–651, 1978.
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- [4] Louis H. Ederington and Jae Ha Lee. The creation and resolution of market uncertainty: The impact of information releases on implied volatility. *The Journal of Financial and Quantitative Analysis*, 31(4):513–539, 1996.



References II

- [5] Milton Friedman. The methodology of positive economics. In *Essays in Positive Economics*, pages 3–43. University of Chicago Press, Chicago, 1953.
- [6] Yuriy Kitsul and Jonathan H. Wright. The economics of options-implied inflation probability density functions. *Journal of Financial Economics*, 110(3):696–711, 2013.
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- [8] David Shimko. Bounds of probability. *Risk*, 6(4):33–37, 1993.

Questions?