Crash Risk in Currency Markets

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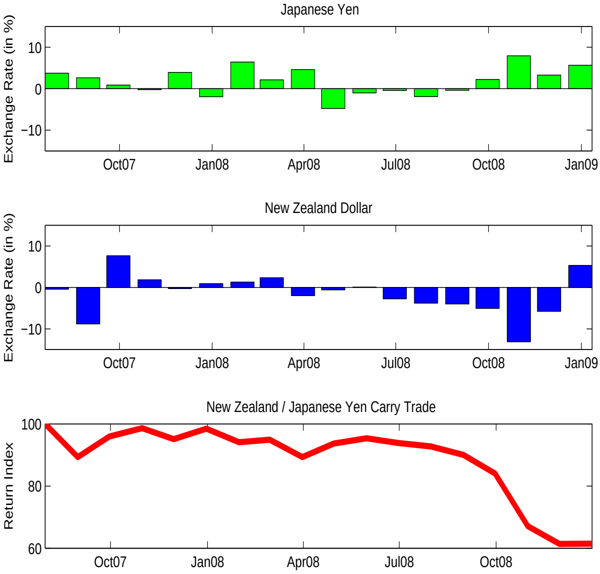
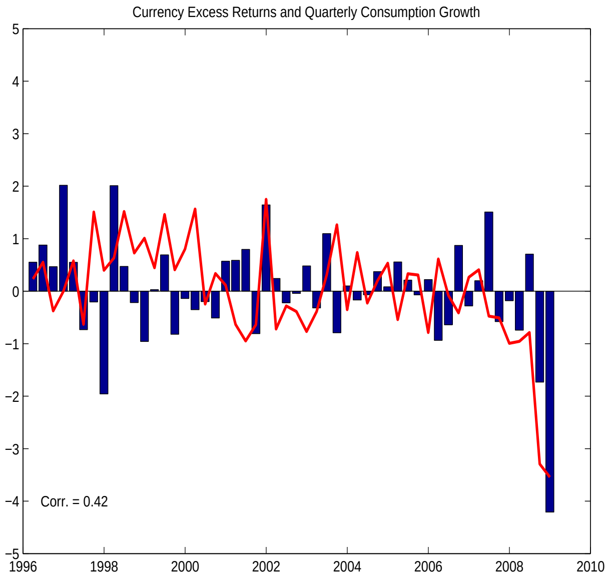
I. INTRODUCTION

- Carry trade:
  - borrow in low interest rate currencies
  - invest in high interest rate currencies
  - risk: depreciation of investment currency / appreciation of funding currency
- Large expected returns:
  - inconsistent with UIP
  - risk-based explanation?
- Folk wisdom:
  - 'up the stairs, down the elevator', 'picking dimes in front of a steamroller'
  - akin to **disaster risk** $\longrightarrow$ low returns in large, rare events with high SDF

Example: New Zealand Dollar and Japanese Yen



Carry Returns (blue) and Consumption Growth (red)



Question

- **How much** compensation for disaster risk in carry-trade returns?
- Idea: hedge carry trade with currency options:
    - no more disaster risk
    - less ‘normal times’ / Gaussian risk
    - need a method to assess how much Gaussian risk is left

Option Market Lexicon

- Black and Sholes (B&S)

- Out of the Money, At the Money, In the Money

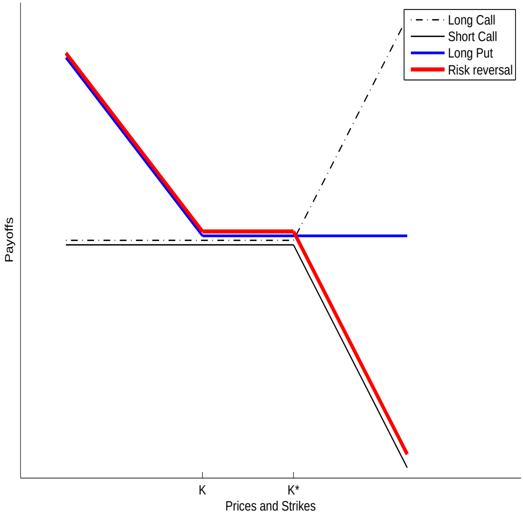
- Delta: sensitivity of Option Price to Price of Underlying

- Delta: 10, 25, 50, 75, 95.

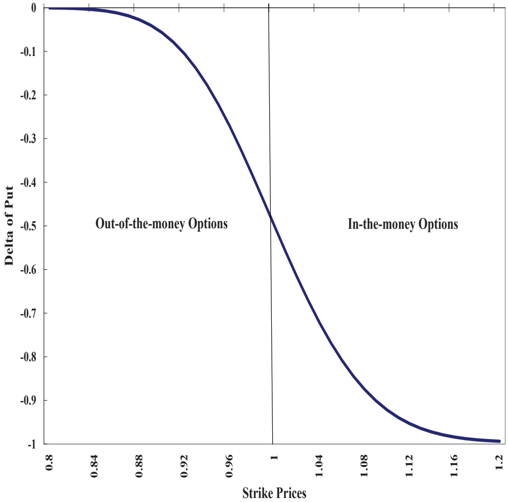
- Delta Intepretation: Delta 10, 10% change of enterning the money (B&S)

- Implied Volatility (B&S implied)
- Smile (symmetric or assymetric)
- Risk Reversal: Price OTM put - Price OTM Call
- Risk-Neutral Density (State-Price Density)
- Risk-Reversal, Excess Downside Risk, Skewness of Risk-Neutral Distribution, Assymetric Smile

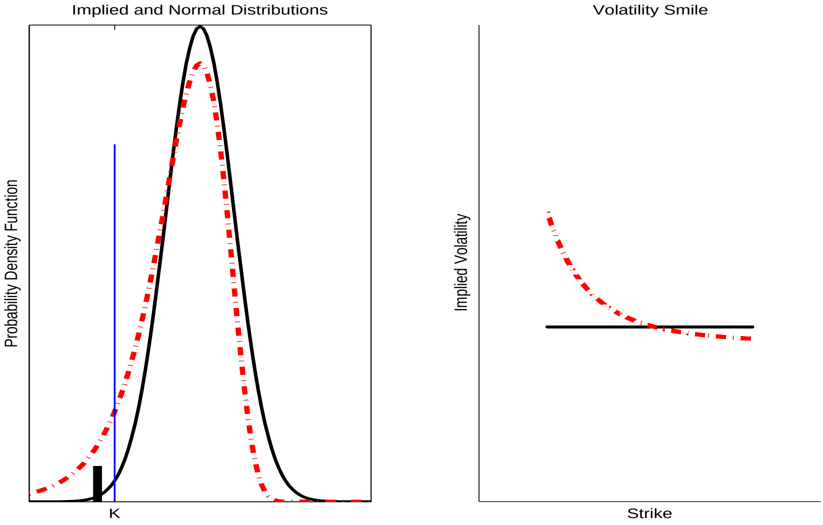
Option Payoffs



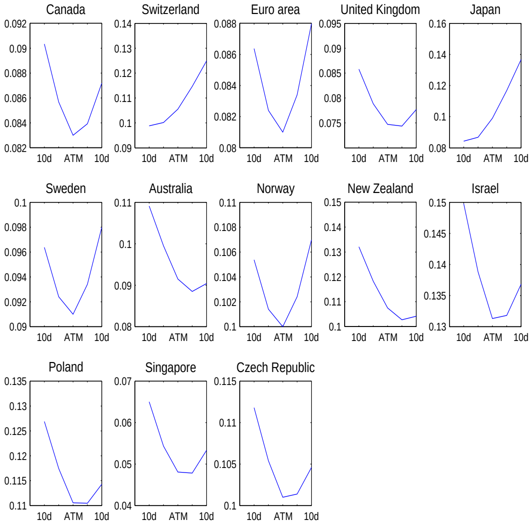
Deltas of Put Options



Implied Distributions and Volatility Smiles

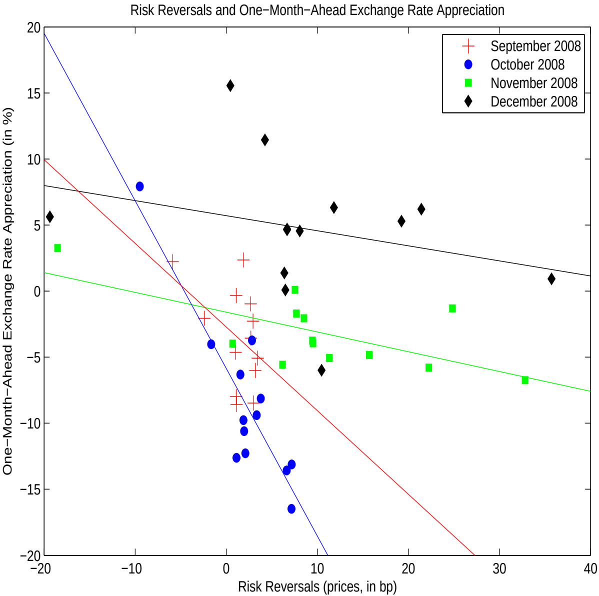


Implied Volatility Smiles - August 2008



Implied volatilities are in percentages. Strike prices are scaled by spot rates.

Risk Reversals and Changes in Exchange Rates



This paper

- Simple structural model:
  - Gaussian risk + disaster risk
  - option prices in closed form
  - carry trade returns and hedged carry trade returns in closed form
- Simple decomposition:
  - carry trade returns $\pi^G + \pi^D$
  - hedged carry trade returns $(1 + \Delta)\pi^G$
- Key advantage: structural estimation, can use wide range of option strikes
  - very liquid at the money options
  - less liquid out of the money options

Preview of our main results

- Build portfolios using JPMorgan data $\longrightarrow$ developed countries, 1996-2008
- Exclude fall 2008 from sample $\longrightarrow$ disaster
- **Sizeable** contribution of disasters:
  - $\pi^D/(\pi^G+\pi^D) \simeq 1/5$
  - large standard errors, but π^D significant
- Robustness:
  - transaction costs $\Rightarrow$ $\pi^D/(\pi^G+\pi^D) \simeq$ **1/4**
  - options that are not default-free: may increase estimate
  - include developing countries or focus on smaller set of countries
  - portfolios formed on risk-reversals
- Back of the envelope:
  - case study of Fall 2008 as a disaster
  - roughly consistent with Barro (2006), Barro and Ursua (2008)

Preview of our results

- More with options
  - risk-reversals positively correlated with interest rates
  - change in risk-reversals correlated with change in exchange rates
  - match volatility smile

Related literature

- Most closely related:
  - Brunermeier, Nagel and Pedersen (2008)
  - Bhansali (2007)
  - Burnside, Eichenbaum, Kleshchelski and Rebelo (2008)
  - Jurek (2008)
- Options:
  - Bates (1996)
  - Carr and Wu (2007)

Related literature

- Microstructure, information, behavioral:
  - microstructure: Lyons (2001), Burnside, Eichenbaum, Kleshchelski and Rebelo (2006, 2008)
  - information: Bacchetta and van Wincoop (2006)
  - sentiment: Froot and Thaler (1990)
- Risk:
  - consumption: Lustig and Verdelhan (2007)
  - segmentation: Alvarez, Atkeson and Kehoe (2002, 2007)
  - habit preferences: Verdelhan (2006)
  - long term risk: Colacito and Croce (2006), Bansal and Shaliastovich (2007)
  - peso: Kaminsky (1993), Evans and Lewis (1995), Lewis (2008)
  - disaster: Farhi and Gabaix (2008)
  - preference-free: Lustig, Roussanov and Verdelhan (2008)

Outline

1. Introduction
2. Model
3. Estimation
4. Conclusion

II. MODEL

- Nominal SDF for Home and Foreign (**conditional** on state Ω_t):

$$\log M_{t,t+\tau} = -g\tau + \varepsilon\sqrt{\tau} - \frac{1}{2}\operatorname{var}(\varepsilon)\,\tau + \left\{ \begin{array}{ll} 0 & \text{if there is no disaster at time } t+\tau \\ \log(J) & \text{if there is a disaster at time } t+\tau \end{array} \right\}.$$

$$\log M^{\star}_{t,t+\tau} = -g\tau + \varepsilon^{\star}\sqrt{\tau} - \frac{1}{2}\operatorname{var}(\varepsilon^{\star})\,\tau + \left\{ \begin{array}{ll} 0 & \text{if there is no disaster at time } t+\tau \\ \log(J^{\star}) & \text{if there is a disaster at time } t+\tau \end{array} \right\}.$$

- **Gaussian** risk $\rightarrow$ $(\varepsilon, \varepsilon^{\star})$ normal, mean zero, any correlation
- **Disaster** risk
  - (J, J^{*}) impact of **world** disaster on country's SDF
  - realization of a disaster: probability $= p\tau$
- **Independence** of $(\varepsilon, \varepsilon^{\star})$, (J, J^{*}) and realization of disasters

World disasters

- Disasters:
  - rare
  - high SDF
  - large asset price movements
- Two views:
  - macroeconomic drop in aggregate consumption as in Rietz (1988) and Barro (2006), from war or global economic crisis
  - financial crisis, stress, liquidity shortage

Interest rates and exchange rates

Nominal exchange rate: $S_{t+\tau} / S_t = M^{\star}_{t,t+\tau} / M_{t,t+\tau}$

- $S_{t+\tau} / S_t > 1 \longrightarrow$ appreciation of foreign currency
- movements in $S_{t+\tau} / S_t$:
  - normal times $\longrightarrow \underset{-}{\varepsilon}, \underset{+}{\varepsilon^*}$
  - disasters $\longrightarrow \underset{-}{J}, \underset{+}{J^*}$

Interest rate: $r = g - pE\left[J - 1\right]$

- limit of short maturities $\tau \longrightarrow 0$
- increases with disaster risk $-pE\left[J - 1\right]$
- compensation for holding currency that depreciates in disasters

Hedging

- Assume for exposition:
  - $r < r^*$ (home is funding currency)
  - $J > J^*$ a.s.
- Carry trade payoff:

$$X_{t,t+\tau} = e^{r^\star \tau} \frac{S_{t+\tau}}{S_t} - e^{r\tau}$$

- Hedged carry trade payoff:

$$\begin{aligned} X_{t,t+\tau}(K) &= \left(1 - \lambda^P_{t,t+\tau}(K) \, P_{t,t+\tau}(K)\right) e^{r^\star \tau} \frac{S_{t+\tau}}{S_t} \\ &\quad + \lambda^P_{t,t+\tau}(K) \left(K - \frac{S_{t+\tau}}{S_t}\right)^+ - e^{r\tau} \end{aligned}$$

  where hedge ratio chosen to eliminate tail risk

$$\lambda^P_{t,t+\tau}(K) = e^{r^\star \tau} / \left(1 + P(K) \, e^{r^\star \tau}\right)$$

Carry Trades

- Limit of short maturities:

$$X^e = \lim_{\tau \to 0} E^{ND}\left[X_{t,t+\tau}\right] / \tau$$
$$X^e(\kappa) = \lim_{\tau \to 0} E^{ND}\left[X_{t,t+\tau}\left(e^{\kappa\sqrt{\tau}}\right)\right] / \tau$$

- Key objects:
  - delta $\Delta^P_{BS}(\kappa) = -\mathbb{N}(\kappa/\sigma)$
  - disaster risk premium $\pi^D = pE\left[J - J^\star\right]$
  - Gaussian risk premium $\pi^G = \text{cov}\left(\varepsilon, \varepsilon - \varepsilon^\star\right)$

Carry trade: $X^e = \pi^D + \pi^G$

Hedged carry trade: $X^e\left(\kappa\right) = \left(1 + \Delta^P_{BS}(\kappa)\right)\pi^G$

Hedged Carry Trades

- Unhedged return: $X^e = \pi^D + \pi^G$
- In practice:
  - ATM: $X^e(\kappa) = 0.5\pi^G$
  - at 25-delta: $X^e(\kappa) = 0.75\pi^G$
  - at 10-delta: $X^e(\kappa) = 0.9\pi^G$
- Intuition for ATM $X^e(\kappa) = 0.5\pi^G$
  - eliminate all disaster risk
  - eliminate half- Gaussian risk
  - SDF puts more weight on depreciations...
  - ...but risk adjustment of order τ with Gaussian distribution $\sigma\sqrt{\tau}$

Implied volatilities

- Implied volatility , $\hat{\sigma}_{t,t+\tau}(K)$

$$P_{t,t+\tau}(K) = e^{-r^*\tau} V_{BS}^{P}\left(1, Ke^{(r^\star - r)\tau}, \hat{\sigma}_{t,t+\tau}(K)\sqrt{\tau}\right).$$

Implied vol $\lim_{\tau\to 0} \hat{\sigma}_{t,t+\tau}\left(e^{\kappa\sqrt{\tau}}\right) = \text{var}\left(\varepsilon^\star - \varepsilon\right)^{1/2}$

- Valid if contribution from disaster to option price $p(J^* - J)\tau$ small compared to contribution from normal volatility $\xi(\kappa)\sigma\sqrt{\tau}$ or $\tau \ll \left(\xi\sigma/\left(p\left|J - J^\star\right|\right)\right)^2$
- With our estimates, rewrite as $\tau \ll 44\xi(\kappa)^2$
- In practice **valid ATM** $\xi = 1/\sqrt{2\pi} \to \tau = 1$ month$\ll 6.9$ years
- **Away from money** $\to$ **negliglible adjustments**. Typically, implied vol away from money less than 20% higher than ATM
  - $(1+\Delta)$ of 10-delta options from 0.9 to 0.94
  - $(1+\Delta)$ of 25-delta options from 0.75 to 0.79
  - **bias towards less disaster risk**

Risk reversals

- Forward $\mathcal{F} = e^{(r-r^{\star})\tau}$
- Risk reversal
  - $RR(\mathcal{F}k) = P\left(\mathcal{F}k^{-1}\right) - k^{-1}C\left(\mathcal{F}k\right)$
  - $RR(\mathcal{F}k) = 0$ if no disaster risk

$$\lim_{\tau\to 0} RR(\mathcal{F}e^{\kappa\sqrt{\tau}})/\tau = (1 + 2\Delta_{BS}^{P}(\kappa))pE\left[(J^{\star} - J)\right]$$

$\lim_{\tau\to 0} RR(\mathcal{F}e^{\kappa\sqrt{\tau}})/\tau$ and r^{*} increase with J^{*}

- Can also be used for direct inference of π^{D}

III. Estimation

- Main estimates
  - with transaction costs
- Robustness checks:
  - defaults
  - risk-reversals
- Case study: Fall 2008
- Implied volatility smile

Estimation

- Focus on one month currency options and returns
- Build portfolios of currency excess returns by sorting on interest rates, rebalancing every month
- Countries are indexed by $i \in I$
- State variable Ω_t: arbitrary stationary stochastic process
- Parameters of the model are arbitrary functions of Ω_t
- Portfolio sets $I_1(\Omega_t)$, $I_2(\Omega_t)$, and $I_3(\Omega_t)$.
- High interest rates r_i: high g^i or low $pE[J_i - 1]$.
- Disaster risk important determinant of cross-country variations in interest rates $\implies$ portfolio formed by selecting countries with high interest rates will on average select countries that feature high disaster risk, $-E[J_i]$.

Estimation Procedure

- Zero-investment strategy: long portfolio 3, short portfolio 1 $\rightarrow$ usual carry trades
- Estimation of $\overline{\pi}^G$ and $\overline{\pi}^D$:
  - Recall that $\overline{X}^e = \overline{\pi}^G + \overline{\pi}^D$ and $\overline{X}^e(\kappa) = (1 + \Delta_\kappa)\overline{\pi}^G$
  - GMM using $\widetilde{X^e(\kappa)}$ and $\overline{X^e}$, where

$$\widetilde{X^e(\kappa)} = \overline{X}^e(\kappa)/(1 + \Delta_\kappa)$$

- Summary:

$$\begin{aligned} \overline{\pi}^G &= \frac{\sum_{\kappa \in I} \widetilde{X^e(\kappa)}}{\# I} \\ \overline{\pi}^D &= \overline{X^e} - \overline{\pi}^G \end{aligned}$$

- Small sample size $\rightarrow$ Bootstrap standard errors.

Sample

- January 1996 - December 2008
  - Focus on January 1996 - August 2008
  - Fall 2008 $\rightarrow$ disaster
- JP Morgan, 32 currencies: Argentina, Australia, Brazil, Canada, Switzerland, Chile, China, Columbia, Czech Republic, Denmark, Euro Area, United Kingdom, China Hong Kong, Indonesia, Israel, India, Japan, South Korea, Mexico, Malaysia, Norway, New Zealand, Peru, Philippines, Poland, Sweden, Singapore, Thailand, Turkey, Taiwan, Venezuela, and South Africa.
- Focus on developed countries: Australia, Canada, Switzerland, Czech Republic, Euro Area, United Kingdom, Israel, Japan, South Korea, Norway, New Zealand, Poland, Sweden and Singapore.
  - more liquid options
  - normal returns (except South Korea $\rightarrow$ out)

Normality of returns

- Developed countries 01/96-08/08:
  - bootstrapping skewness and kurtosis → not significantly different from Gaussian
  - Lilliefors test → same conclusion
  - Jarque-Berra test → rejects more often (UK, Japan) but known to over-reject in short samples
  - Heteroscedasticity → GARCH(1,1) before normality tests
- Striking difference with developing countries (mostly high kurtosis)
- Including Fall 2008 → reject normal for many developed countries

Portfolio Characteristics

- Average return increases from portfolio 1 to 3
- Hedging reduces returns: the closer to the money is the hedge, the lower the average returns

Excess Returns: Countries sorted on Interest Rates

Portfolios	1	2	3	1	2	3
		Going Long			Going Short	
			Panel I: Unhedged			
Mean	−1.37	1.45	5.13	1.37	−1.45	−5.13
	[2.08]	[2.25]	[2.08]	[2.02]	[2.14]	[1.99]
Sharpe Ratio	−0.19	0.19	0.71	0.19	−0.19	−0.71
			Panel II: Hedged at 10-delta			
Mean	−2.30	0.65	4.06	0.74	−1.58	−5.33
	[1.93]	[1.99]	[1.90]	[1.86]	[1.94]	[1.87]
Sharpe Ratio	−0.33	0.09	0.60	0.11	−0.23	−0.81
			Panel III: Hedged at 25-delta			
Mean	−2.14	0.59	3.03	0.62	−1.21	−4.68
	[1.72]	[1.82]	[1.66]	[1.48]	[1.59]	[1.53]
Sharpe Ratio	−0.36	0.09	0.51	0.12	−0.21	−0.86
			Panel IV: Hedged ATM			
Mean	−1.33	0.61	1.68	0.02	−0.86	−3.47
	[1.27]	[1.40]	[1.26]	[1.07]	[1.13]	[1.10]
Sharpe Ratio	−0.31	0.13	0.39	0.00	−0.21	−0.91

Disaster Risk Premia - Developed Countries

	Panel I: Carry Excess Returns				
	Unh. Carry	H. at 10 δ	H. at 25 δ	H. ATM	
Mean	6.50	4.80	3.65	1.70	
	[1.88]	[1.59]	[1.41]	[1.12]	
Mean Spread		1.70	2.85	4.80	
		[0.41]	[0.85]	[1.32]	
	Panel II: Estimations				
	10δ	25δ	ATM	10δ, 25δ, and ATM	GMM 2^{nd} $Stage$
$\overline{\pi}^D$	1.16	1.63	3.10	1.96	1.01
	[0.41]	[0.87]	[1.68]	[0.93]	[0.36]
$\overline{\pi}^G$	5.33	4.87	3.40	4.53	4.77
	[1.79]	[1.87]	[2.21]	[1.87]	[1.92]
$\overline{\pi}^D - \overline{\pi}^G$	-4.17	-3.23	-0.30	-2.57	-3.76
	[1.90]	[2.31]	[3.51]	[2.35]	[2.02]

Countries sorted on interest rates. Data are monthly, from JP Morgan. The sample period is 1/1996 - 8/2008.

Disaster risk premia

$\overline{\pi}^D \simeq$ **1/5 of** $\overline{\pi}^G + \overline{\pi}^D$

- Large standard errors, but $\overline{\pi}^D$ significant
- Two conclusions:
  - **disaster risk priced** in currency markets
  - **significant differences** in amount of disaster risk across countries
- $\overline{\pi}^D$ higher using ATM options than out of the money options:
  - differences not significant
  - illiquidity
- **Model misspecification?**
  - small disasters to increase risk neutral probability of small depreciations
  - specification test: GMM estimation 4 moments for 2 parameters $\rightarrow$ J test of model pricing errors $\rightarrow$ p-value of 0.18 $\rightarrow$ **model not rejected**

Transaction costs

- Bid-ask spreads for spots and forwards: Reuters $\rightarrow \approx 8$ bp
- Impact on unhedged carry trade:
  - assuming 12 trades per year, reduces unhedged carry trade by 100bp
  - Gilmore and Hayashi $\rightarrow$ overestimate if position rolled over $\rightarrow$ estimate 13bp (but assumes stays in portfolio for 5 years)
  - We assume something in between: 25bp
- Bid-ask spreads for currency options:
  - Bank of France for bid-ask spreads for different currency pairs
  - November 10 2008 $\rightarrow$ 30% of mid-point
  - January 20 2009 $\rightarrow$ 10% of mid-point
  - market participants$\rightarrow$ larger than usual
  - we assume 5% of implied volatility $\rightarrow$ time-varying spreads

$\pi^D \simeq$ **1/4 of** $\pi^G + \pi^D$

Disaster Risk Premia - With Transaction Costs

	Unh. Carry	H. at 10 δ	H. at 25 δ	H. ATM	
Mean	6.25	4.21	2.83	0.78	
	[1.83]	[1.67]	[1.44]	[1.14]	
Mean Spread		2.04	3.42	5.47	
		[0.43]	[0.85]	[1.34]	
			Panel II: Estimations		
	10δ	25δ	*ATM*	10δ, 25δ, *and ATM*	*GMM* 2^{nd} *Stage*
$\overline{\pi}^D$	1.57	2.47	4.69	2.91	1.28
	[0.41]	[0.87]	[1.68]	[0.93]	[0.37]
$\overline{\pi}^G$	4.67	3.78	1.56	3.34	4.02
	[1.81]	[1.91]	[2.29]	[1.91]	[1.96]
$\overline{\pi}^D - \overline{\pi}^G$	−3.10	−1.31	3.14	−0.42	-2.74
	[1.91]	[2.35]	[3.60]	[2.41]	[2.04]

Countries sorted on interest rates. Data are monthly, from JP Morgan. The sample period is 1/1996 - 8/2008.

If options are not default-free

- Suppose that the party selling the options defaults in disasters with probability ϕ
- Then, agent engaging in hedged carry trade still bears ϕ of the disaster risk premium. So:

$$X^e_{\text{hedged}} = (1+\Delta)\pi^G + \phi\pi^D.$$

- This implies, for our estimation:

$$\overline{\pi}^D = \frac{\overline{X}^e - \overline{X}^e(\kappa)/(1+\Delta_\kappa)}{1-\phi/(1+\Delta_\kappa)}$$

- For instance, with ATM options ($\Delta = -0.5$), our estimate is multiplied by 1.25 when $\phi = 0.1$, by 2 when $\phi = 0.25$.
- So counterparty risk could be quite important.

Risk-Reversals: Developed Countries

Portfolios	1	2	3
	Units: Implied Volatilities		
Mean RR10	−0.73	0.05	1.12
	[0.06]	[0.05]	[0.06]
Mean RR25	−0.40	0.01	0.58
	[0.03]	[0.03]	[0.03]
	Units: Prices		
Mean RR10	−0.62	0.43	1.96
	[0.08]	[0.07]	[0.08]
Mean RR25	−0.46	1.28	3.95
	[0.14]	[0.13]	[0.15]

Countries sorted on interest rates. Data are monthly, from JP Morgan. The sample period is 1/1996 - 8/2008.

Interest Rate Differential and Risk Reversal

- Country set: advanced
- Maturity: One month
- Fixed Effects

Risk-Reversal (Vol, Delta 10)	0.4484*** [0.0544]	
(Vol, Delta 10 - Vol, ATM)		0.8763*** [0.0991]
Observations	1828	1828
R-squared	0.47	0.479

Excess Returns: Developed Countries, sorted on RR

Portfolios	1	2	3	1	2	3
Panel I: Unhedged						
Mean	0.48	1.22	3.70	−0.48	−1.22	−3.70
	[2.10]	[2.11]	[1.95]	[2.06]	[2.05]	[1.87]
Sharpe Ratio	0.06	0.16	0.54	−0.06	−0.16	−0.54
Panel II: Hedged at 10-delta						
Mean	−0.38	0.47	2.57	−1.00	−1.39	−3.96
	[2.02]	[2.05]	[1.83]	[1.98]	[1.90]	[1.76]
Sharpe Ratio	−0.05	0.07	0.39	−0.14	−0.20	−0.62
Panel III: Hedged at 25-delta						
Mean	−0.21	0.05	1.83	−0.68	−1.29	−3.45
	[1.68]	[1.70]	[1.51]	[1.66]	[1.61]	[1.45]
Sharpe Ratio	−0.03	0.01	0.33	−0.12	−0.23	−0.65
Panel IV: Hedged ATM						
Mean	−0.03	−0.09	1.17	−0.53	−1.33	−2.55
	[1.28]	[1.31]	[1.10]	[1.12]	[1.16]	[1.06]
Sharpe Ratio	−0.01	−0.02	0.29	−0.13	−0.32	−0.69

Data are monthly, from JP Morgan. The sample period is 1/1996 - 8/2008.

Disaster Risk Premia - Countries Sorted on RR

	Unh. Carry	H. at 10 δ	H. at 25 δ	H. ATM	
Mean	3.22	1.57	1.15	0.64	
	[1.66]	[1.53]	[1.29]	[1.14]	
Mean Spread		1.65	2.07	2.58	
		[0.36]	[0.80]	[1.32]	
			Panel II: Estimations		
	10δ	25δ	ATM	10δ, 25δ, $and\ ATM$	GMM 2^{nd} $Stage$
$\overline{\pi}^D$	1.48	1.68	1.94	1.70	1.41
	[0.36]	[0.87]	[1.72]	[0.94]	[0.32]
$\overline{\pi}^G$	1.74	1.54	1.28	1.52	1.67
	[1.67]	[1.74]	[2.11]	[1.74]	[1.78]
$\overline{\pi}^D - \overline{\pi}^G$	−0.26	0.14	0.66	0.18	−0.27
	[1.79]	[2.22]	[3.49]	[2.28]	[1.90]

Countries sorted on risk reversals. Data are monthly, from JP Morgan. The sample period is 1/1996 - 8/2008.

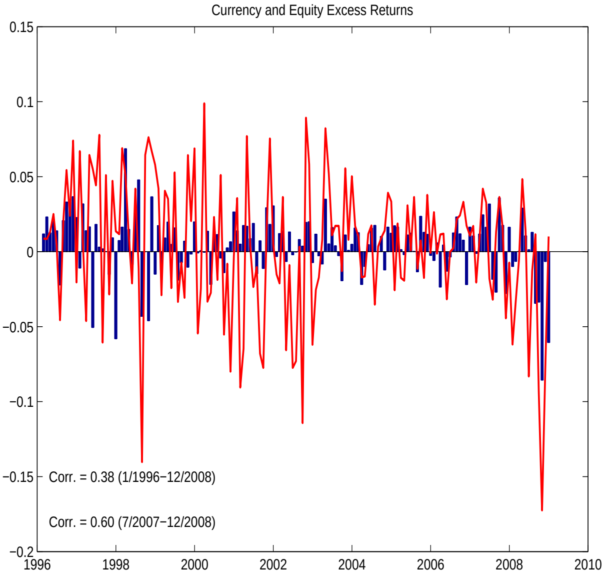
Changes in Risk Reversals and Exchange Rates: Contemporaneous Specifications

Dependant Variable:	Exchange Rates							
	Panel I: Raw Variables				Panel II: Demeaned Variables			
Risk Reversals Strike: Forward +/- 10%	-49.95 [9.47]***				-41.02 [6.24]***			
Risk Reversals Strike: Forward +/- 5%		-32.78 [2.21]***				-26.22 [2.47]***		
Risk Reversals Strike: Delta 10			-102.65 [7.03]***				-41.02 [6.24]***	
Risk Reversals Strike: Delta 25				-63.14 [3.99]***				-30.69 [3.95]***
Observations	1667	1759	1776	1776	1667	1759	1776	1776
R^2	0.08	0.21	0.23	0.23	0.04	0.05	0.04	0.05

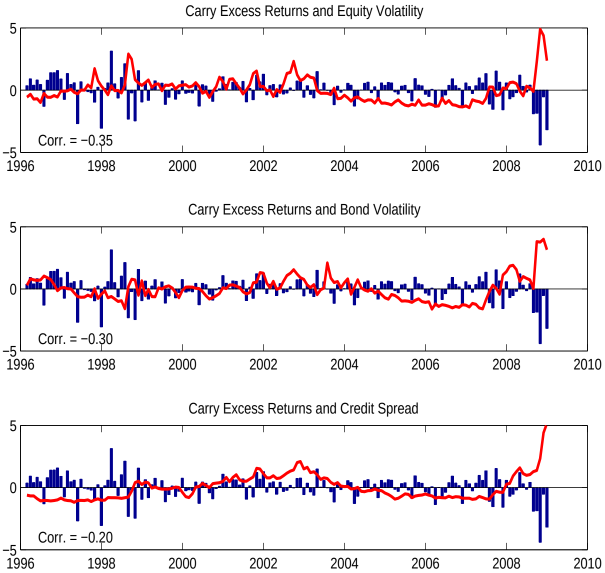
Fall 2008

- We take the view that Fall 2008 is a disaster
- **Very low carry trade returns**:
  - average monthly return of our carry trade strategy is -4.6 percent $\rightarrow$ large drop (monthly std=2%)
  - cumulative decline from September to December amounts to 17.8 percent
  - almost all due to losses on sharp depreciations of high interest rate currencies
  - large number of options triggered
- **Bad times** as measured by most risk factors:
  - stock market, VIX, MOVE, credit spreads, aggregate consumption
  - up to five standard deviations
- Negative relation: risk-reversals and subsequent depreciations

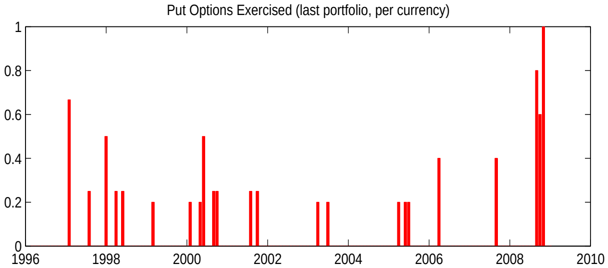
Currency Carry Trades and Equity Returns

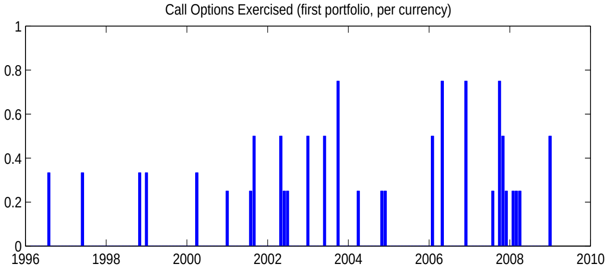


Carry Returns and Risk Measures



Options Exercised





Comparison with Barro and Ursua (2008)

- Barro and Ursua (2008)
  - $p = 3.63\%$
  - $E\left[B^{-\gamma}\right] = 3.88$
  - $pE[B^{-\gamma}] = 14\%$
- In our model
  - $J = B^{-\gamma}F$
  - based on Fall 2008 $\rightarrow$ assume $E[F - F^{\star}] = 20\%$
  - assume no correlation between $F - F^{*}$ and B
  - leads to $\pi^{D} = pE[B^{-\gamma}(F - F^{*})] = 2.8\%$
  - higher than our estimate of 1.1%
- Broadly **consistent** with Barro

Implied volatilities in the model

- Price of a put is

$$\begin{aligned} P_{t,t+\tau}(K) &= (1-p\tau)\, e^{-g^*\tau} V_{BS}^{P}\left(1, Ke^{-(g-g^*)\tau}, \sigma\sqrt{\tau}\right) \\ &+ p\tau e^{-g^*\tau} E\left[J^* V_{BS}^{P}\left(1, Ke^{-(g-g^*)\tau} J/J^*, \sigma_{t,t+\tau}\sqrt{\tau}\right)\right], \end{aligned}$$

- We use that to compute the implied volatility of the option
- Calibration
  - $J = B^{-\gamma} = 3.88$, $p = 3.63\%$ from Barro and Ursua (2008)
  - J^* to match estimate of π^D (i.e. $J^* = J\left(1 - \pi^D/\left(pB^{-\gamma}\right)\right)$)
  - $\sigma_{t,t+\tau}$ to match implied volatility at the money in portfolio 3 of 10% (i.e. $\sigma_{t,t+\tau} = 9.6\%$).
  - we want $r = 3\%$, $r^* = 5.8\%$, so we take $g = 13.4$ and $g^* = 14.6\%$.

Implied Volatilities: Portfolio 3 vs Model

	Portfolio 3	Model
10δ−Put	11.50 [0.20]	11.5
25δ−Put	10.60 [0.17]	10.6
ATM	10.0 [0.17]	10.0
25δ-Call	10.02 [0.15]	9.9
10δ-Call	10.39 [0.16]	9.8

Countries sorted on interest rates. Data are monthly, from JP Morgan. The sample period is 1/1996 - 8/2008.

IV. CONCLUSION

- This paper:
    - Simple methodology to disentangle disaster and Gaussian risk premia
    - Significant estimate of disaster risk premia on currency markets.

Options: Black-Scholes background (I/II)

- Black-Scholes formula extended to exchange rates by Garman and Kohlhagen (1983)

$$V^P_{BS}(S, K, \sigma, r, r^\star, \tau) = Ke^{-r\tau}\mathbb{N}(-d_2) - Se^{-r^\star\tau}\mathbb{N}(-d_1)$$

where

$$d_1 = \frac{\log(S/K) + (r - r^\star + \sigma^2/2)\tau}{\sigma\sqrt{\tau}}, \qquad d_2 = d_1 - \sigma\sqrt{\tau}$$

- Scaling

$$V^P_{BS}(S, K, \sigma, r, r^\star, \tau) = V^P_{BS}(Se^{-r^\star\tau}, Ke^{-r\tau}, \sigma\sqrt{\tau}, 0, 0, 1)$$

- Notation

$$V^P_{BS}(S, K, \sigma) \equiv V^P_{BS}(S, K, \sigma, 0, 0, 1)$$

Options: Black-Scholes background (II/II)

- Delta of a put:

$$\partial V_{BS}^{P}(S, K, \sigma, r, r^{\star}, \tau)/\partial S = -e^{-r^{\star}\tau}\mathbb{N}(-d_1)$$

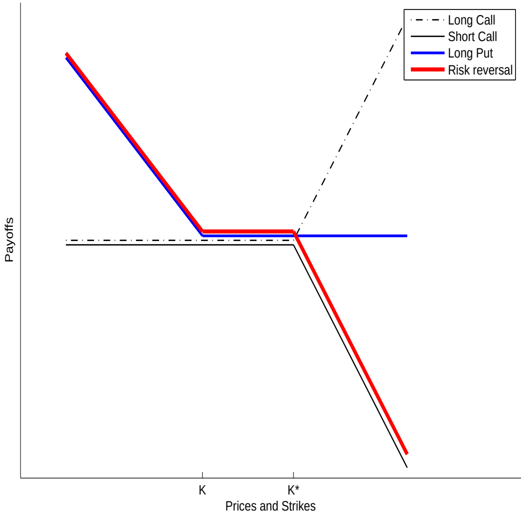
- Limit of short maturities $\rightarrow$ delta of a put option with time to maturity τ and strike $Se^{\kappa\sqrt{\tau}}$:

$$\Delta_{BS}^{P}(\kappa) \equiv \lim_{\tau \to 0} \partial V_{BS}^{P}(S, Se^{\kappa\sqrt{\tau}}, \sigma, r, r^{\star}, \tau)/\partial S = -\mathbb{N}(\kappa/\sigma)$$

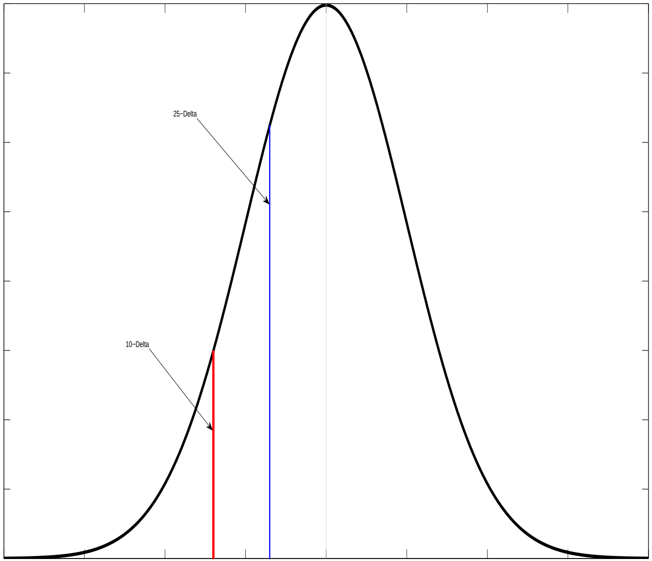
- Example, ATM:

$$\Delta_{BS}^{P}(0) = -0.5$$

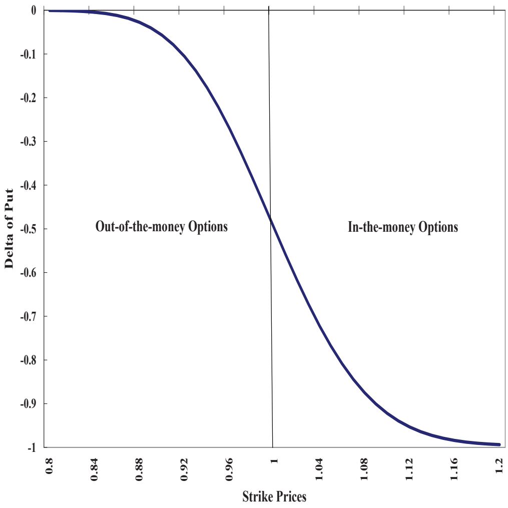
Option Payoffs



Deltas and Strikes



Deltas of Put Options



Implied Volatilities: Developed Countries

Portfolios	1	2	3
10δ−Put	9.78	10.09	11.50
	[0.14]	[0.17]	[0.20]
25δ−Put	9.38	9.56	10.60
	[0.15]	[0.16]	[0.17]
ATM	9.33	9.31	10.02
	[0.14]	[0.16]	[0.17]
25δ-Call	9.78	9.55	10.02
	[0.15]	[0.16]	[0.15]
10δ-Call	10.51	10.05	10.39
	[0.16]	[0.17]	[0.16]

Countries sorted on interest rates. Data are monthly, from JP Morgan. The sample period is 1/1996 - 8/2008.