Demand Propagation Through Traded Risk Factors

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Motivation

- Defining feature of modern financial markets: tight interlinkages.
  - Shocks rapidly propagate across the globe (e.g., Allen and Gale, 2000; Pavlova and Rigobon, 2008).
- An important class of shocks: demand shocks not motivated by fundamentals.
  - Nonetheless move prices powerfully (e.g., Lee, Shleifer, and Thaler, 1991; Froot and Ramadorai, 2008; Koijen and Yogo, 2019).
- Demand shocks rarely affect one asset in isolation.
  - Consider a currency intervention by a central bank: the exchange rate of the target currency may move, but so can many other currencies.
- **Q: How do demand shocks propagate across financial assets?**

A risk-driven framework

- **A: Demand shocks propagate through traded risk factors because intermediaries are averse to absorbing non-diversifiable risk.**

$$\textit{Asset A demand changes} \xrightarrow{\text{equivalent}} \textit{Risk factor demand changes} \xrightarrow{\text{interm. risk aversion}}$$

$$\textit{Risk factor price changes} \xrightarrow{\text{law of one price}} \textit{Asset B price changes}$$

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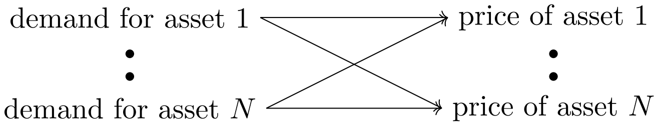

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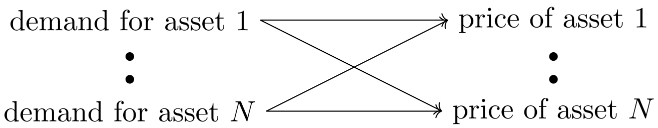

  - N assets requires $N(N-1)$ coef + rare asset-spec demand variation = need structure.
  - Main driver of co-movements in asset prices are non-diversifiable risks, or risk factors (e.g., Markowitz, 1952; Ross, 1976; Kozak, Nagel, and Santosh, 2018).
  - Risk factor price can be sensitive to demand (e.g., Gabaix and Koijen, 2021).

Operationalize the framework

- Which non-diversifiable risks are traded?
  - Risk factors proposed to explain returns (e.g., Ross, 1976): ignores quantities, may not be actually traded.
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  - Solution: recover traded risk factors by jointly analyzing price and quantity data.

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  - Solution: recover traded risk factors by jointly analyzing price and quantity data.
- How propagation works when multiple factors are at play?
  - Even with $K \ll N$ factors, if a shock to one factor could reprice other factors, still K^2 difficult-to-estimate parameters.
  - Solution: construct traded risk factors to have uncorrelated returns *and* uncorrelated flows.
    - Each factor is an independent source of risk that is also traded independently.
    - K parameters directly linked to agent's risk-bearing capacity for each factor.
    - Factor construction enables IV estimation of price sensitivity factor-by-factor.

The FX market

- Our setting is foreign exchange (FX) market.
- The needs:
  - Frequently affected by demand shocks.
  - No isolated or independent currency market: triangular arbitrage held.
- The advantages:
  - Deep and liquid trading among FX intermediaries facilitates arbitrage.
    - All customer trades go through intermediaries, who absorb imbalance.
    - Returns exhibit strong factor structure (Lustig, Roussanov, and Verdelhan, 2011).
  - Novel data on aggregate net trading flows facing FX intermediaries.
    - Data from the CLS group, jointly owned by 70+ largest FX intermediaries.
    - Global coverage of trading between 17 currencies, largest single source of FX data.

Key results

- **In FX, just 3 traded risk factors matter...**
  - Dollar, Carry, and Euro-Yen Residual jointly explain 90% of non-diversifiable risk in FX trading, reveal unobserved sector-wide risk exposures.
- **... and because intermediaries have limited risk-bearing capacity to absorb these risk...**
  - IV-estimated price sensitivity to risk, even higher than U.S. equity.
- **... demand shocks propagate across (17) currencies and even (5) non-FX asset classes.**
  - Propagation is strong among some ("substitutes") but muted among others ("complements"), highlighting integrated yet complex financial markets.

Roadmap

- Model.
  - Standard equilibrium optimization at currency vs. factor level.
  - Key improvement: heterogeneous price sensitivity.
  - Quantifying demand propagation.
  - Key necessity: most traded independent sources of risks.
- Empirics.
  - What non-diversifiable risks matter in FX trading?
  - What is each factor's price sensitivity to trading-induced risk?
  - What is the strength of demand propagation across currencies and assets?

Model sketch

- Two-period N-foreign-currency model.
  - Trading between any two currencies, record as net flow against the USD.
- r_n: excess return of investing in currency n from $t = 0$ to $t = 1$.
- A mass μ of competitive intermediaries, CARA with risk aversion γ, absorb customer FX trades and clear market.

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- A mass μ of competitive intermediaries, CARA with risk aversion γ, absorb customer FX trades and clear market.
- Demand shocks ΔQ_n at $t = 0 \Rightarrow$ price moves from P_n to $P_n (1 + \Delta p_n)$.
- Standard equilibrium optimization:

$$\Delta p_n = \lambda \left[\text{cov}(r_n, r_1)\Delta Q_1 + \text{cov}(r_n, r_2)\Delta Q_2 + \cdots + \text{cov}(r_n, r_N)\Delta Q_N\right],$$

where $\lambda := \gamma/(\mu R_F)$ (per-capita risk aversion).

Optimization

Model generalization

- Can always find factors with uncorrelated return to restate the solution as:

$$\Delta p_k^{\text{factor}} = \lambda \text{var}\left(r_k^{\text{factor}}\right) \underbrace{\left[\beta_{1,k}\Delta Q_1 + \cdots + \beta_{N,k}\Delta Q_N\right]}_{\textbf{factor demand } \Delta Q_k^{\textbf{factor}}}.$$

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- BUT: same λ for all factors.

$$\frac{\Delta p_k^{\text{factor}}}{\text{var}\left(r_k^{\text{factor}}\right)\Delta Q_k^{\text{factor}}} = \lambda = \frac{\gamma}{\mu R_F}.$$

  - Factors don't have the same unconditional risk-return tradeoffs (Fama and MacBeth, 1973).
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- Relaxation: $\frac{\Delta p_k^{\text{factor}}}{\text{var}\left(r_k^{\text{factor}}\right)\Delta Q_k^{\text{factor}}} = \lambda_k.$
  - Possibly different γ_k but more likely different μ_k.
  - Justifies estimating λ_k factor-by-factor when each factor's price responds only to its own demand shock.

Demand propagation through risk exposure

$$\frac{\partial \text{ ccy-}n \text{ price}}{\partial \text{ ccy-}m \text{ demand}} = \sum_{k=1}^{K} \frac{\partial \text{ factor-}k \text{ demand}}{\partial \text{ ccy-}m \text{ demand}} \times \frac{\partial \text{ factor-}k \text{ price}}{\partial \text{ factor-}k \text{ demand}} \times \frac{\partial \text{ ccy-}n \text{ price}}{\partial \text{ factor-}k \text{ price}}$$
$$= \sum_{k=1}^{K} \beta_{m,k} \times \lambda_k \operatorname{var}\left(r_k^{\text{factor}}\right) \times \beta_{n,k}$$

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- Recall that $\Delta Q_k^{\text{factor}} = \beta_{1,k}\Delta Q_1 + \cdots + \beta_{N,k}\Delta Q_N$.
- Features:
  - Own price-multiplier never negative as long as $\lambda_k > 0$.
  - Cross-multiplier easily generates complementarity: $\beta_{m,k}\beta_{n,k} < 0$.
  - Consistent with risk exposure and no-arbitrage.

Novel construction to ensure uncorrelated factors

- Theoretically: under standard static risk-based model, uncorrelated returns generate no cross-impact.

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- Solution: modified PCA applied *jointly* to currency returns and trading.
  - PCA on returns only: $\text{cov}\big(r_k^{\text{factor}}, r_j^{\text{factor}}\big) = 0$.
  - PCA on flows only: $\text{cov}\big(\Delta Q_k^{\text{factor}}, \Delta Q_j^{\text{factor}}\big) = 0$.
  - Our approach: $\text{cov}\big(r_k^{\text{factor}}, r_j^{\text{factor}}\big) = 0$ and $\text{cov}\big(\Delta Q_k^{\text{factor}}, \Delta Q_j^{\text{factor}}\big) = 0$.

Data

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- Daily FX return data from Bloomberg.
  - Spot and forward rates at London closing.
  - Exchange rate: USD / FGN.
  - Currency return: $r_{t+1,n} = f_t - s_{t+1} = s_t - s_{t+1} + i^{CCY} - i^{USD} - x_t$.
- We aggregate both flow and return to weekly level for analysis.

Top 3 traded FX factors

Currency	Factor 1	Factor 2	Factor 3
AUD	-0.08	0.14	-0.08
CAD	-0.15	0.56	-0.87
CHF	-0.03	-0.07	-0.02
DKK	-0.01	0	0.02
EUR	-0.5	-0.43	1.16
GBP	-0.11	0.18	0.09
HKD	0	-0.01	0.02
ILS	0	0	0
JPY	-0.07	-0.49	-1
KRW	-0.01	0.01	-0.01
MXN	-0.01	0.02	-0.03
NOK	-0.01	0.02	-0.01
NZD	-0.01	0.02	-0.01
SEK	-0.01	0.01	-0.01
SGD	-0.01	0	0.02
ZAR	-0.01	0.01	-0.01
USD	1	0.03	0.74
Var explained	65%	16%	9%

Robustness

Economic risk factors

- Factor 1: Dollar factor.
  - -1/6 on AUD, CAD, CHF, EUR, GBP, JPY v.s. 1 on USD.
- Factor 2: Carry factor.
  - -1/3 on CHF, EUR, JPY vs. 1/3 on AUD, CAD, GBP.
- Factor 3: Euro-Yen Residual factor.
  - -1 on JPY vs. 1 on EUR.

Only flow OR return

Unconditional return

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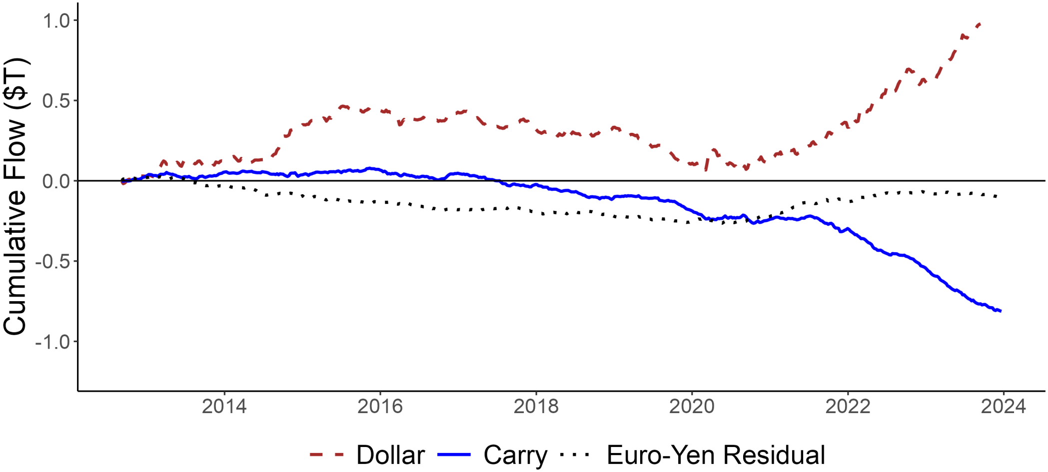
Correlation Between Economics Factors and PC Factors

	Factor 1	Factor 2	Factor 3
Return	0.98	0.95	0.92
Flow	1.00	0.99	0.95
Var explained by Econ Factors	63%	15%	8%

Customer flow to traded FX factors



- Intermediaries' exposures are the negative of customer'.
- Intermediaries have been providing Dollar and gaining exposure to Carry.

Estimating factor price sensitivity

- We want to identify λ_k associated with Δ quantity of risk, as induced by demand shocks.

$$r_{k,t}^{\text{factor}}/\text{var}(r_{k,t}^{\text{factor}}) = \lambda_k \Delta \hat{Q}_{k,t}^{\text{factor}} + \epsilon_{k,t}, \text{ where}$$

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- Ideal instrument: induces trading, carries no information, affect a factor's price only though demand for that factor.
    - Typically, an instrument that shifts demand for one asset is likely to shift demand for others that are not included in the regression.
    - Our traded risk factors are orthogonalized: return by construction responds only to own demand shocks.

Instrumental variable

- Candidate instruments: week-ahead announcements of the offering amount at upcoming sovereign bond auctions.
    - Relevance: foreigners exchange for local currency to participate in auctions.
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- Estimation details:
  - Auctions: US for Dollar; AU, CA, GP, JP for Carry; DE, FR, IT for Euro-Yen.
  - Sample: weekly observations from Sep 2012 to Dec 2023 excluding the first half of 2020 (COVID).

Economic magnitude of price sensitivity (I)

	Price sensitivity to trading-induced risk λ_k	Return volatility (annualized) $\sigma(r_{k,t}^{\text{factor}})$	Price impact per $B shock to factor $\lambda_k \sigma^2(r_{k,t}^{\text{factor}})$
Dollar	0.11	6.9%	5.0 bps
Carry	0.14	8.2%	9.3 bps
Euro-Yen Residual	0.34	9.4%	29.3 bps

Shock reversion

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- Price impacts revert in a month:
  - Trading volatility explains about 10–35% of the 1-week return, but only 5–15% of the 1-month return.
  - Sharpe ratios from exploiting return predictability are 0.04 (Dollar), 0.05 (Carry), and 0.09 (Euro-Yen Residual).

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- Higher price sensitivity ⇔ more limited risk-bearing capacity.
    - Possibly limited FX arbitrage capital due to specialized nature.
    - Available arb capital may be even less for less traded factors such as Euro-Yen.

Time-varying λ and the role of risk

	Weekly Return of Dollar Factor					
	(1)	(2)	(3)	(4)	(5)	(6)
Intermed. ret	-0.490***	-0.109				
	(0.119)	(0.204)				
Flow × Intermed. ret		-0.091***				
		(0.033)				
S&P ret			-0.148	-0.077		
			(0.096)	(0.314)		
Flow × S&P ret				0.006		
				(0.074)		
CIP deviation					0.081	0.182
					(0.060)	(0.177)
Flow × CIP deviation						0.063
						(0.129)
Factor flow		0.096***		0.106***		0.160*
		(0.037)		(0.040)		(0.093)
Observations	559	385	559	385	559	385

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Intermed. ret	-0.490***	-0.109				
	(0.119)	(0.204)				
Flow × Intermed. ret		-0.091***				
		(0.033)				
S&P ret			-0.148	-0.077		
			(0.096)	(0.314)		
Flow × S&P ret				0.006		
				(0.074)		
CIP deviation					0.081	0.182
					(0.060)	(0.177)
Flow × CIP deviation						0.063
						(0.129)
Factor flow		0.096***		0.106***		0.160*
		(0.037)		(0.040)		(0.093)
Observations	559	385	559	385	559	385

Time-varying λ and the role of risk

	Weekly Return of Dollar Factor					
	(1)	(2)	(3)	(4)	(5)	(6)
Intermed. ret	-0.490***	-0.109				
	(0.119)	(0.204)				
Flow × Intermed. ret		-0.091***				
		(0.033)				
S&P ret			-0.148	-0.077		
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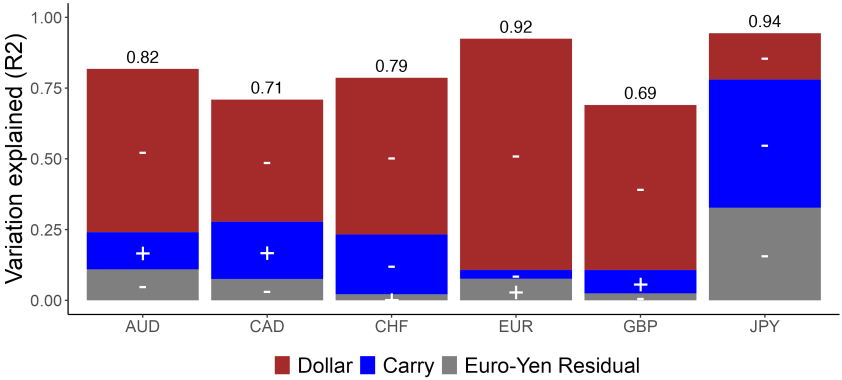
Factor flow		0.096***		0.106***		0.160*
		(0.037)		(0.040)		(0.093)
Observations	559	385	559	385	559	385

Currency's exposure to traded FX factors



- Individual currency's risk exposure determines:
  - If a demand shock hits one currency, how the demand for risks change.
  - If prices of risks change, how the price of one currency changes.

Price impact (in bps) per $1B demand shock

	CAD	GBP	CHF	EUR	JPY	HKD
AUD	7.9	9.0	2.1	2.8	5.9	0.2
CAD		5.9	0.7	1.6	2.6	0.1
GBP			3.1	4.0	3.2	0.1
CHF				7.3	4.1	0.0
EUR					0.2	0.1
JPY						0.0

- All positive because loading on Dollar factors.

Price impact (in bps) per $1B demand shock

	CAD	GBP	CHF	EUR	JPY	HKD
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- All positive because loading on Dollar factors.
- Low cross-multiplier between long and short Carry legs (complementarity).

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- Low cross-multiplier between EUR and JPY because of Euro-Yen Residual factor.

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- All positive because loading on Dollar factors.
- Low cross-multiplier between long and short Carry legs (complementarity).
- Low cross-multiplier between EUR and JPY because of Euro-Yen Residual factor.
- HKD as sanity check.

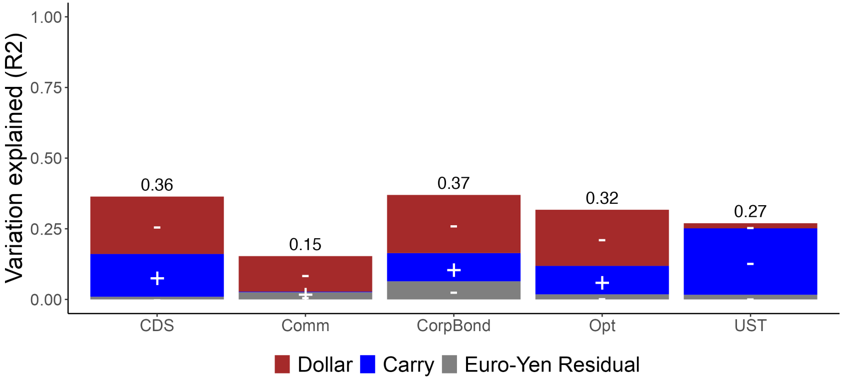
Demand propagation across asset classes

$$\frac{\partial \text{ asset-}n \text{ price}}{\partial \text{ asset-}m \text{ demand}} = \sum_{k=1}^{K} \frac{\partial \text{ factor-}k \text{ demand}}{\partial \text{ asset-}m \text{ demand}} \times \frac{\partial \text{ factor-}k \text{ price}}{\partial \text{ factor-}k \text{ demand}} \times \frac{\partial \text{ asset-}n \text{ price}}{\partial \text{ factor-}k \text{ price}}$$

$$= \sum_{k=1}^{K} \beta_{m,k} \times \lambda_k \text{var}(r_{k,t}^{\text{factor}}) \times \beta_{n,k}$$

- Can also quantify the cross-multiplier between asset classes if other asset classes are exposed to risks captured by the traded FX factors.
- Demand shocks to one asset increase demand for the traded FX factors, affecting factor prices and (other) asset prices.

Other asset classes load on traded FX factors



- All negative on Dollar factor.
- UST negative on Carry factor, but other assets load positively.
- CorpBond loads on Euro-Yen Residual.

Demand propagation across asset classes through traded FX factors

	Comm	CorpBond	Opt	UST
CDS	3.5	3.2	4.7	-0.5
Comm		6.0	7.7	0.7
CorpBond			6.5	-0.2
Opt				-0.6

- UST: "safe-haven asset" $\leftrightarrow$ only asset class that loads negatively on Carry.
- Note: our cross-multiplier captures what is *channeled via traded FX factors*.

Conclusion

- Q: How do demand shocks propagate through financial assets?
- A: Demand shocks propagate through traded risk factors because of intermediaries' aversion to non-diversifiable risks.
  - Jointly analyzing flow and return data to identify Dollar, Carry, Euro-Yen Residual: account for 90% of the non-diversifiable risks in FX trading.
  - IV analysis finds low risk-bearing capacity: price must rise by 5 to 30 bps for intermediaries to absorb $1B demand shock to traded FX factors.
  - Quantifies demand propagation across 17 currencies and 6 asset classes: a literature first.
- Overall, our findings highlight an integrated-market and a portfolio (rather than asset-by-asset) view when studying demand shock propagation.

Supplementary materials

Elasticity in Koijen and Yogo (2019)

$$\underbrace{\frac{w_{i,t}(n)}{w_{i,t}(0)}}_{\text{Quantity}} = \exp\{\underbrace{\beta_{0,i,t}\text{me}_t(n)}_{\text{Price}} + \underbrace{\sum_{k=1}^{K-1} \beta_{k,i,t} x_{k,t}(n)}_{\text{Risk}} + \beta_{K,i,t}\} \underbrace{\epsilon_{i,t}(n)}_{\text{Latent demand}} \tag{10}$$

- $\beta_{0,i,t}$: quantity elasticity to price at stock level.
- $\beta_{k,i,t}$: quantity elasticity to the stock's characteristics (factor risk exposures).
- Our λ_k: price elasticity to risk induced by quantity change at factor level.

Details of intermediary optimization

- The equilibrium price impacts Δp_n are set such that each intermediary finds it optimal to buy $y_n = -\Delta Q_n/\mu$ dollars of currency n.

$$\{-\Delta Q_1/\mu, \ldots, -\Delta Q_N/\mu\} = \arg \max_{\{y_1,\ldots,y_N\}} \mathbb{E}\left[-\exp\left(-\gamma \sum_{n=1}^{N} y_n(r_n - R_F \Delta p_n)\right)\right].$$

- The equilibrium λ is not a function of intermediaries' pre-existing holdings at time 0, as we do not model nonlinear constraints (e.g., position limits).
  - Also because of CARA utility, though we can re-cast the absolute risk aversion as a function of intermediary wealth to mimic a CRRA preference.

Back

Robustness of FX factors

		Factor 1	Factor 2	Factor 3
Return	Pre 2020	0.97	0.83	0.83
	Post 2020	1.00	0.97	0.89
Flow	Pre 2020	0.98	0.82	0.81
	Post 2020	0.99	0.96	0.81

- The underlying data are well-behaved.
- In particular, the flow and return covariance structures are rather stable over time.

Back

Factors from only return or flow

Currency	Return PCA			Flow PCA		
	PC 1	PC 2	PC 3	PC 1	PC 2	PC 3
AUD	-0.08	0.04	0.27	-0.03	0.03	0.12
CAD	-0.05	0.05	0.32	-0.04	1	-0.06
CHF	-0.05	-0.21	-0.51	-0.01	-0.02	-0.06
DKK	-0.06	-0.15	-0.12	0	0	0.01
EUR	-0.06	-0.15	-0.13	-1	-0.03	0.03
GBP	-0.07	-0.08	0.47	-0.02	-0.01	0.26
HKD	0	0	0	0	-0.02	0
ILS	-0.04	-0.03	0.24	0	-0.01	0
JPY	-0.03	-0.17	-1	-0.04	-0.06	-0.95
KRW	-0.06	0.02	-0.15	0	0.01	0
MXN	-0.08	0.22	0.71	-0.01	0.01	0
NOK	-0.1	-0.05	0.72	0	0.01	0.01
NZD	-0.08	0.01	0.13	-0.01	0.01	0.01
SEK	-0.08	-0.13	0.22	0.01	0	0
SGD	-0.04	-0.03	-0.12	-0.01	-0.01	0.01
ZAR	-0.11	0.29	-1.35	-0.01	0	0.01
USD	1	0.37	0.29	1.17	-0.92	0.62

Back

Unconditional returns of traded FX factors

Panel A: Sep 2012 to Dec 2023			
	Dollar	Carry	Euro-Yen
Mean return (annualized %)	2.38	2.15	5.26
Sharpe ratio (annualized)	0.35	0.26	0.56
Fama-MacBeth premium (annualized %)	2.42	3.34	3.58
t-stats	(1.15)	(1.22)	(1.12)
Panel B: Jan 2000 to Dec 2023			
	Dollar	Carry	Euro-Yen
Mean return (annualized %)	-0.16	2.09	1.99
Sharpe ratio (annualized)	-0.02	0.23	0.20
Fama-MacBeth premium (annualized %)	-0.07	3.02	1.00
t-stats	(-0.04)	(1.41)	(0.40)

Back

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Mean return (annualized %)	-0.16	2.09	1.99
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Back

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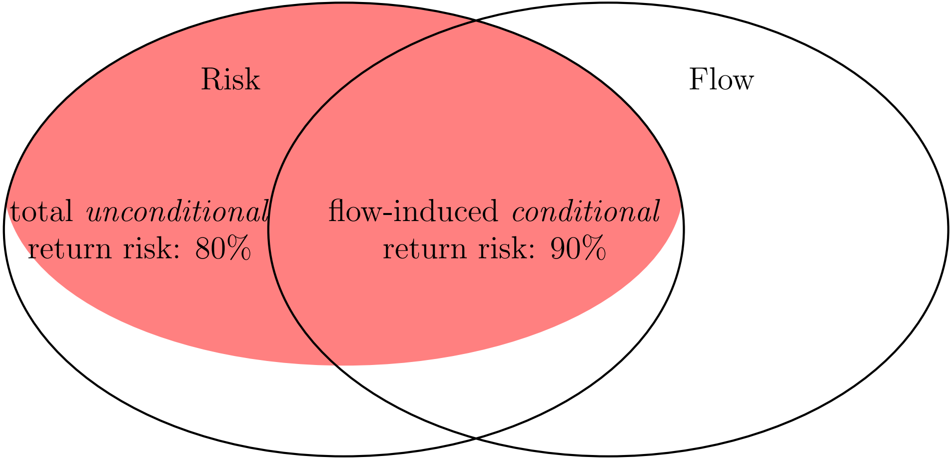
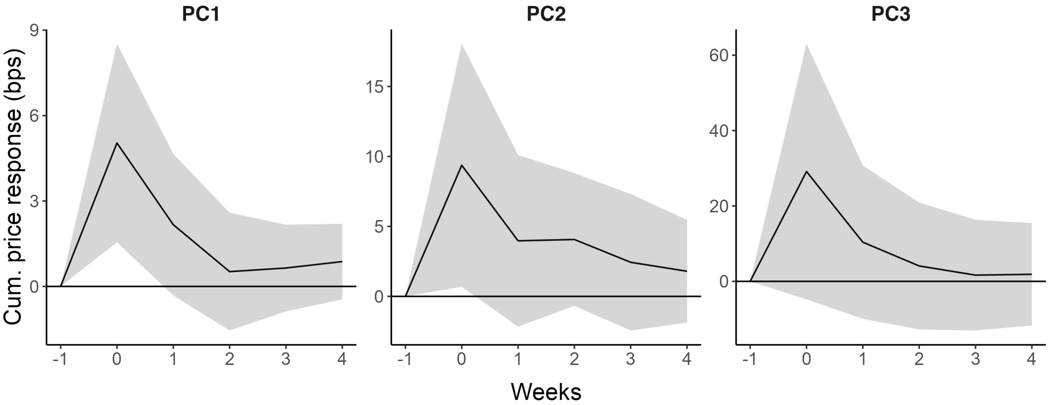
Back

Unconditional v.s. Conditional Risk: % Explained



Back

Reversion of instrumented shocks



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