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Smooth Sailing? A Finite Gaussian Mixture Factor Model of What Makes Safe Haven Currencies

Economics in Practice 2021, Foreign Exchange: Safe Haven Currencies

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Jonas Paul Schmitten, MA Quantitative Economics and Finance

Noah Julian Angara, MA Quantitative Economics and Finance

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- How to identify FX regimes
  - Finite Gaussian Mixture Models
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- Results
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  - What makes a safe haven currency
  - Are the results stable over time
  - Can we predict switches
- Policy Implications
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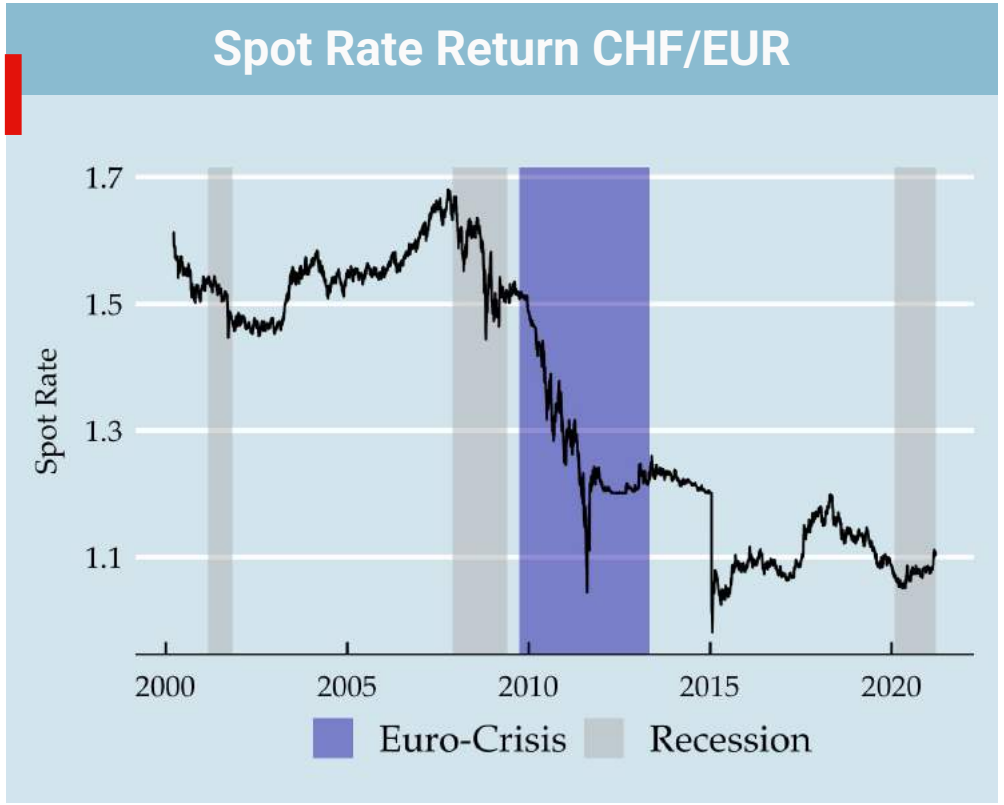
What are Safe Haven Currencies?

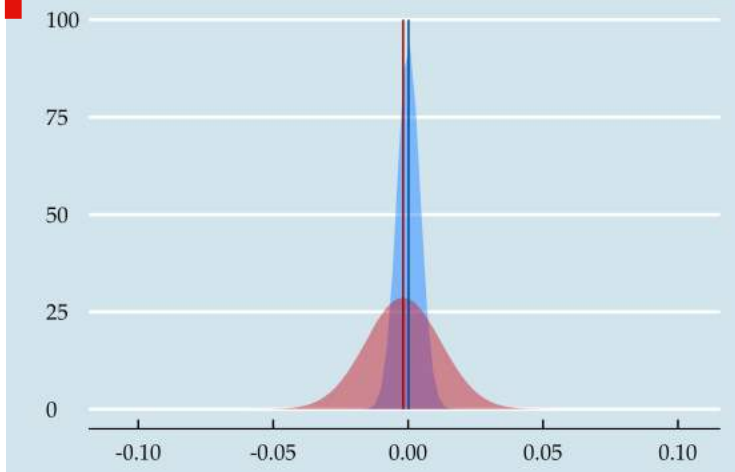
- Low correlation with traditional risk factors and not too sensitive to volatility in markets or liquidity squeezes (Ranaldo & Söderlind, 2010)
  - Provide hedging benefits against a reference asset, both in times of stress and on average
- Kugler & Weder (2002) put forward the hypothesis that Switzerland suffers from a reverse peso problem



Finite Gaussian Mixture Models

- Idea – Separate spot rate returns into two distributions:
  - 1st component: ”Crisis"
  - 2nd component: ”Non-Crisis"
- Why? – Identify safe haven periods and detect **non-linearities** in response to risk factors
- How? – EM-Algorithm to numerically get MLE estimates of latent variables (μ, σ)

Two Regimes CHF/NOK



Univariate Mixture Model

$$p(x) = \sum_{i=1}^{K} \phi_i \mathcal{N}(x \mid \mu_i, \sigma_i)$$

$$\mathcal{N}(x \mid \mu_i, \sigma_i) = \frac{1}{\sqrt{2\pi}\sigma_i} \exp\left(-\frac{(x-\mu_i)^2}{2\sigma_i^2}\right)$$

$$\sum_{i=1}^{K} \phi_i = 1$$

Full Derivation of Gaussian Mixture with EM-Algorithm in Appendix

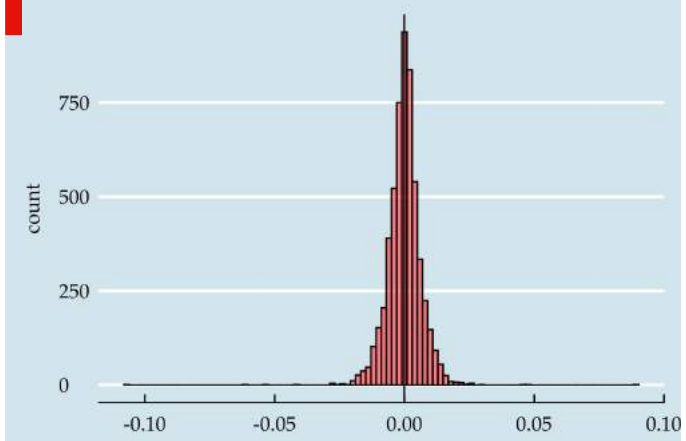
Data

- Currency Pairs: Focus on "safer" currencies such as CHF, EUR, USD, GBP & JPY

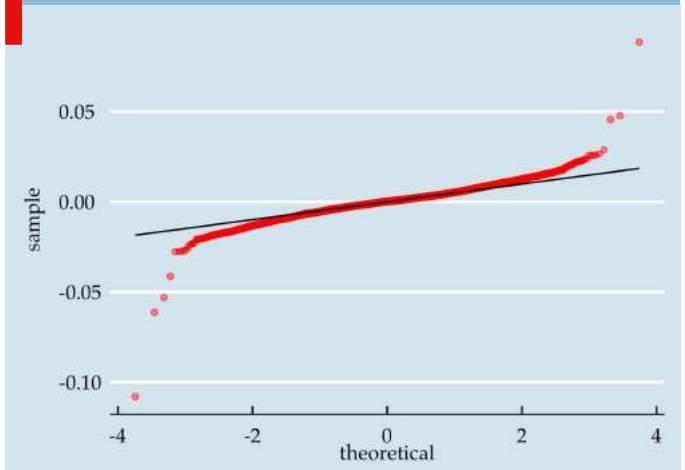
- Broad range of risk factors:
  - Equity Markets: MSCI World
  - Market Volatility: VIX & VSTOXX
  - Investor Sentiment: CBOE Put-Call Ratio
  - Credit Risk: TED-Spread
  - FX Volatility: JPM Global FX Vola Index

- Take simple returns of spot rates and risk factors

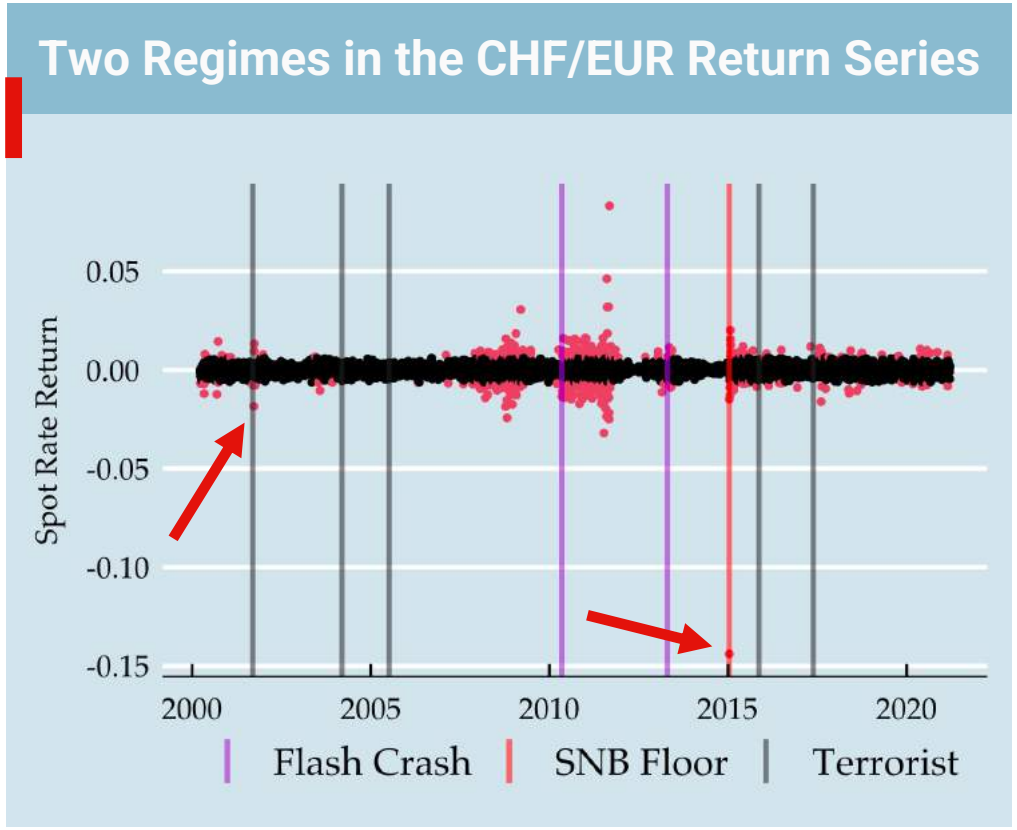
Histogram CHF/USD

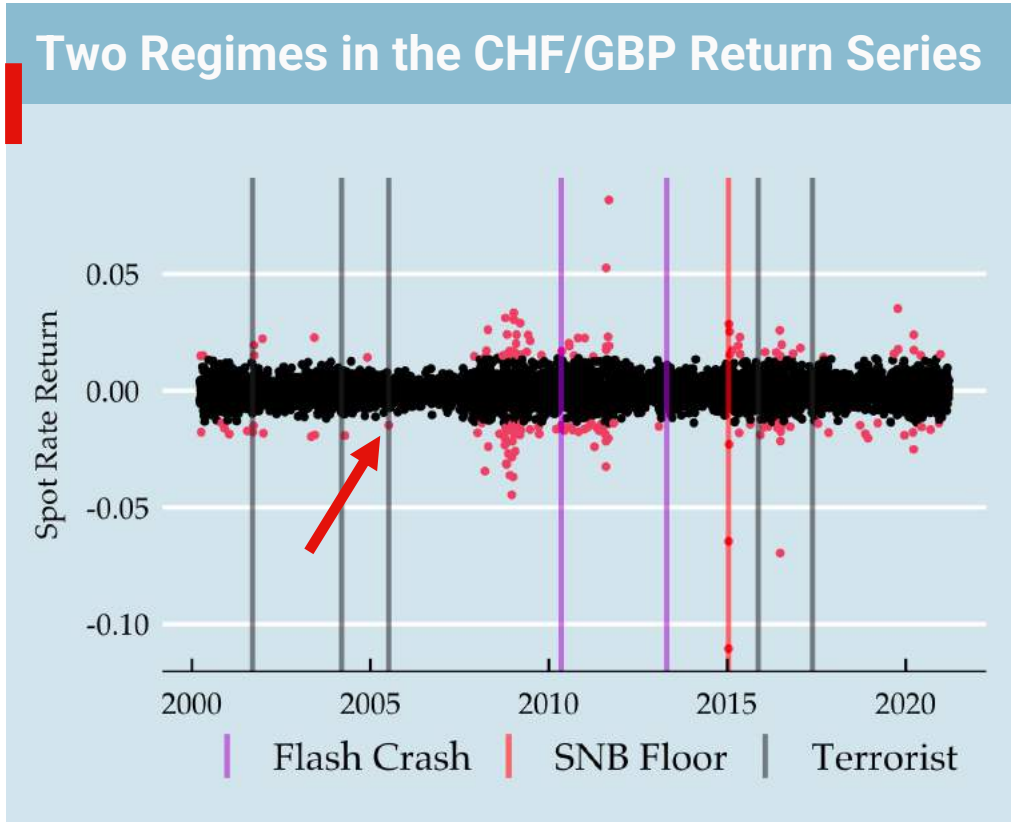


QQ-Plot CHF/USD



Does the Mixture detect FX regimes?





Results Crisis Regime

- Magnitude of coefficients larger than non-crisis
- Small sample size problematic
- ϕ_1 smaller and σ_1 larger than non-crisis

Table 2: Results Gaussian Mixture and Regression Crisis Component

	Dependent variable:								
	CHF/EUR	CHF/GBP	CHF/USD	CHF/JPY	CHF/BRL	CHF/INR	CHF/NOK	JPY/USD	BRL/USD
ϕ_1	0.094	0.036	0.065	0.105	0.126	0.036	0.149	0.206	0.204
σ_1	0.011	0.019	0.017	0.015	0.014	0.020	0.023	0.010	0.019
MSCI	0.129*	0.183	0.066	−0.358***	0.162	0.210	0.259***	0.015	−0.348***
	(0.068)	(0.112)	(0.333)	(0.123)	(0.116)	(0.263)	(0.067)	(0.051)	(0.081)
Put-Call Ratio	−0.004	−0.012	−0.013	0.004	−0.018**	−0.005	−0.006	−0.012***	0.011**
	(0.005)	(0.009)	(0.016)	(0.009)	(0.008)	(0.021)	(0.006)	(0.003)	(0.006)
MOVE 3-months	0.018	0.064	0.057	−0.007	0.088**	−0.069	0.011	0.046***	−0.024
	(0.021)	(0.046)	(0.090)	(0.036)	(0.043)	(0.095)	(0.022)	(0.014)	(0.026)
VIX	0.013	0.040**	0.005	−0.038*	0.029	0.019	0.026**	0.009	−0.042***
	(0.011)	(0.020)	(0.047)	(0.021)	(0.021)	(0.045)	(0.012)	(0.008)	(0.014)
VSTOXX	−0.018	−0.033	−0.020	0.031	−0.094***	−0.061	−0.042***	−0.041***	0.051***
	(0.012)	(0.025)	(0.054)	(0.021)	(0.020)	(0.054)	(0.012)	(0.008)	(0.014)
TED Spread	0.019*	0.025	0.018	0.008	0.003	0.045	0.015	−0.006	−0.001
	(0.011)	(0.018)	(0.030)	(0.015)	(0.011)	(0.035)	(0.010)	(0.005)	(0.007)
Gold	−0.101**	−0.244***	−0.748***	−0.183**	−0.241***	−0.720***	0.025	−0.352***	−0.180***
	(0.051)	(0.086)	(0.170)	(0.080)	(0.087)	(0.188)	(0.056)	(0.033)	(0.055)
Global FX Vola	−0.124***	−0.199***	−0.147*	0.047	−0.192***	−0.197**	−0.047*	−0.105***	0.139***
	(0.024)	(0.046)	(0.084)	(0.037)	(0.041)	(0.089)	(0.024)	(0.017)	(0.030)
10-year Breakeven Inflation	−0.003	0.009	0.008	−0.009	0.004	−0.016	0.003	0.007	−0.007**
	(0.010)	(0.011)	(0.014)	(0.013)	(0.004)	(0.022)	(0.002)	(0.005)	(0.003)
US 10-year HY Index	0.005	−0.019	0.143	−0.013	−0.110*	0.203	−0.065*	−0.015	0.075*
	(0.034)	(0.064)	(0.160)	(0.061)	(0.057)	(0.143)	(0.033)	(0.024)	(0.041)
Bid-Ask Spread	−0.978	−2.712	−5.672*	0.901	0.673	−0.038	−0.035		
	(0.752)	(1.943)	(3.145)	(1.141)	(0.446)	(0.084)	(0.031)		
Constant	0.001	0.001	0.005	−0.002	−0.0005	0.002	−0.001	0.0003	0.001
	(0.001)	(0.002)	(0.004)	(0.002)	(0.002)	(0.006)	(0.001)	(0.001)	(0.001)
Observations	326	165	71	246	374	67	341	479	573
R^2	0.241	0.391	0.449	0.213	0.362	0.443	0.355	0.444	0.330
Adjusted R^2	0.214	0.348	0.346	0.176	0.342	0.331	0.333	0.432	0.318
Residual Std. Error	0.013	0.019	0.023	0.020	0.026	0.025	0.015	0.011	0.021
F Statistic	9.047***	8.942***	4.367***	5.751***	18.658***	3.969***	16.449***	37.352***	27.644***

Notes: This table shows the results for Gaussian Mixture model and regression for the crisis component. The data covers the period of 20-03-2000 until 18-03-2021. The figures are in percentage. Statistical significance is given by *p<0.1; **p<0.05; ***p<0.01. ϕ_1 indicates the mixture proportion for the crisis component while σ_1 indicates the daily volatility of the spot rate returns. Spot rates are reported as CHF/EUR, i.e., Swiss franc per Euro.

Results Non-Crisis Regime

- The franc appreciates with increases in various risk factors
- Results are more pronounced for the VSTOXX than the VIX
- Yen is a safer currency when risks are idiosyncratic to the FX market

Table 3: Results Gaussian Mixture and Regression Non-Crisis Component

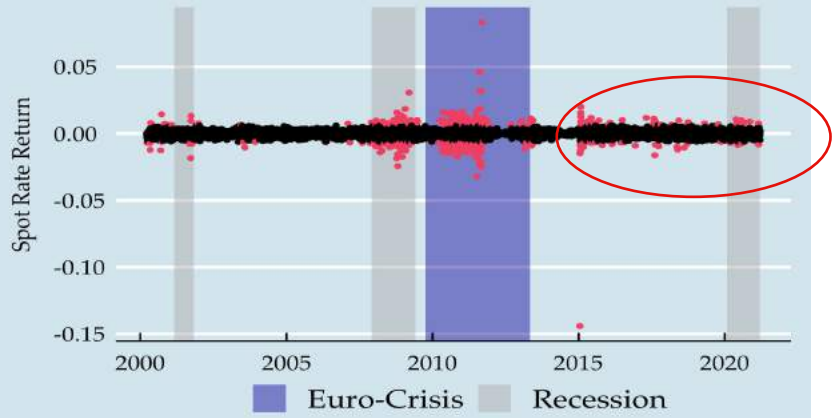
	Dependent variable:								
	CHF/EUR	CHF/GBP	CHF/USD	CHF/JPY	CHF/BRL	CHF/INR	CHF/NOK	JPY/USD	BRL/USD
ϕ_2	0.906	0.964	0.935	0.895	0.874	0.964	0.851	0.794	0.796
σ_2	0.002	0.006	0.005	0.005	0.004	0.006	0.008	0.004	0.006
MSCI	0.023***	0.011	−0.149***	−0.065***	0.027	−0.096***	0.069***	−0.058***	−0.180***
	(0.005)	(0.010)	(0.010)	(0.011)	(0.018)	(0.012)	(0.009)	(0.009)	(0.015)
Put-Call Ratio	0.0001	−0.001*	−0.002***	−0.001**	−0.003***	−0.001***	−0.001	−0.001***	0.0002
	(0.0002)	(0.0004)	(0.0004)	(0.0004)	(0.001)	(0.0005)	(0.0003)	(0.0004)	(0.001)
MOVE 3-months	0.001	0.003	0.002	−0.013***	0.0005	0.007**	0.001	0.012***	0.003
	(0.001)	(0.002)	(0.003)	(0.003)	(0.004)	(0.003)	(0.002)	(0.002)	(0.003)
VIX	0.002***	0.0003	−0.008***	−0.003**	0.003	−0.004***	0.005***	−0.004***	−0.008***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.002)	(0.001)	(0.001)	(0.001)	(0.002)
VSTOXX	−0.003***	−0.009***	−0.014***	−0.0002	−0.026***	−0.018***	−0.009***	−0.012***	0.012***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.002)	(0.002)	(0.001)	(0.001)	(0.002)
TED Spread	−0.001**	−0.001	−0.001	−0.0002	−0.003**	−0.001	−0.001	−0.001	0.0004
	(0.0003)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Gold	−0.006*	−0.061***	−0.195***	−0.044***	−0.068***	−0.147***	0.003	−0.092***	−0.072***
	(0.003)	(0.006)	(0.007)	(0.007)	(0.011)	(0.008)	(0.006)	(0.006)	(0.009)
Global FX Vola	−0.012***	−0.019***	−0.001	0.039***	−0.044***	−0.023***	−0.033***	−0.023***	0.032***
	(0.002)	(0.003)	(0.004)	(0.004)	(0.006)	(0.004)	(0.003)	(0.003)	(0.005)
10-year Breakeven Inflation	−0.001***	−0.001	−0.002***	−0.001*	0.004	−0.001	0.002	−0.0003	0.001
	(0.0003)	(0.001)	(0.001)	(0.001)	(0.004)	(0.001)	(0.002)	(0.001)	(0.003)
US 10-year HY Index	−0.004**	−0.016***	−0.021***	0.017***	−0.028***	−0.040***	−0.026***	−0.031***	0.008
	(0.002)	(0.004)	(0.004)	(0.004)	(0.007)	(0.005)	(0.004)	(0.003)	(0.005)
Bid-Ask Spread	−0.027	−0.084	−0.096	0.041	−0.004	−0.00004	−0.002		
	(0.047)	(0.082)	(0.085)	(0.105)	(0.007)	(0.001)	(0.004)		
Constant	−0.00002	0.0001	0.0002**	−0.0001	−0.0001	−0.00001	0.0001*	0.0003***	0.00004
	(0.00004)	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0001)
Observations	5,153	5,314	5,408	5,233	5,105	5,412	5,138	5,000	4,906
R^2	0.054	0.066	0.195	0.064	0.117	0.141	0.130	0.131	0.132
Adjusted R^2	0.052	0.064	0.193	0.062	0.115	0.139	0.128	0.129	0.130
Residual Std. Error	0.002	0.005	0.005	0.005	0.007	0.006	0.004	0.004	0.006
F Statistic	26.484***	34.141***	118.857***	32.676***	61.456***	80.251***	69.790***	74.999***	74.400***

Notes: This table shows the results for Gaussian Mixture model and regression for the non-crisis component. The data covers the period of 20-03-2000 until 18-03-2021. The figures are in percentage. Statistical significance is given by *p<0.1; **p<0.05; ***p<0.01. ϕ_2 indicates the mixture proportion for the non-crisis component while σ_2 indicates the daily volatility of the spot rate returns. Spot rates are reported as CHF/EUR, i.e., Swiss franc per Euro.

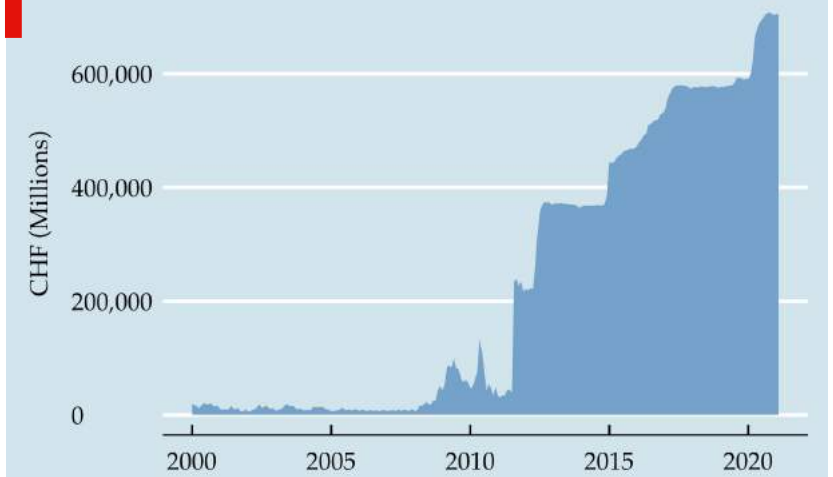
Are the Results Stable Over Time?

- Less extreme swings but consistently higher level of volatility post-SNB CHF/EUR floor removal in early 2015
- Safe haven status of CHF less clear due to additional noise in the data
  - Which appreciation as a result of safe haven status?
- Coincides with massive increase in FX interventions by the SNB post-2015

Two Regimes for CHF/EUR



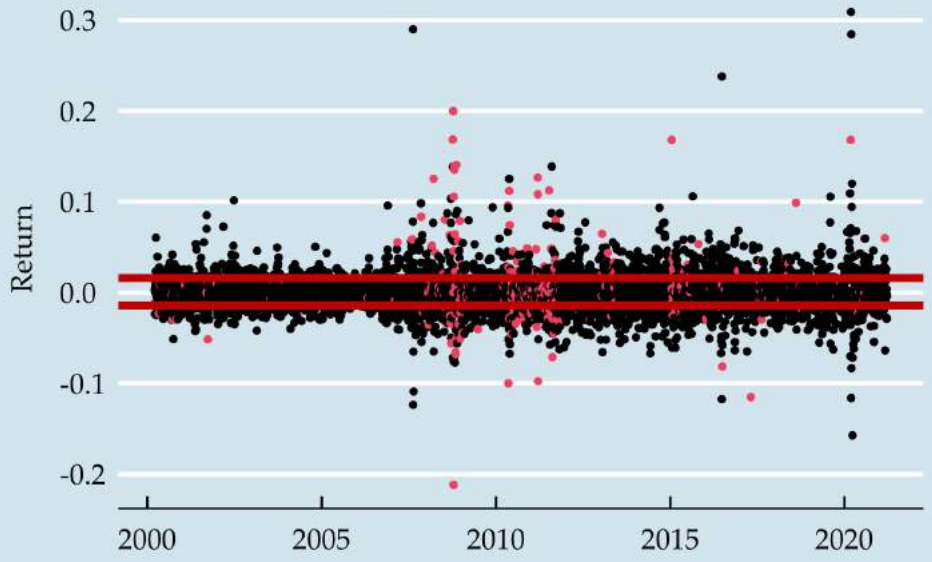
SNB Sight Deposits



Regime Switch Detection – Thresholds

- Idea – Calculate threshold values to see if risk factors are distinct between the two regimes and which values separate the two
- Threshold values have some power as **early warning indicators**
- Proportion of deviations higher in crisis period vs non-crisis period

Threshold Values JPM Global FX Volatility (CHF/EUR)

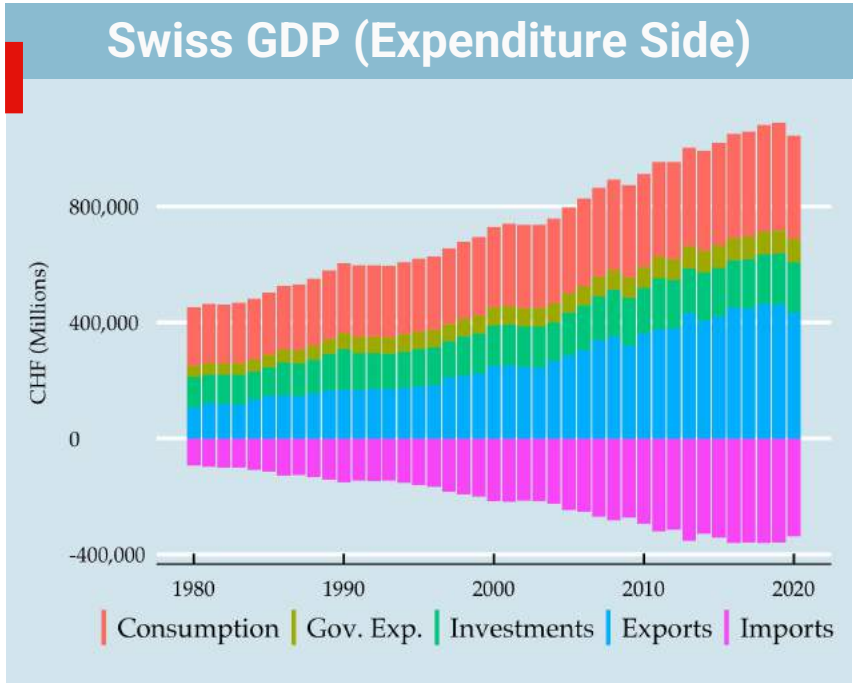


Threshold Value Formula

$$x_i = \begin{cases} \varphi, & \text{if } \gamma > 0.5 \\ x_i, & \text{otherwise} \end{cases}$$

Policy Implications

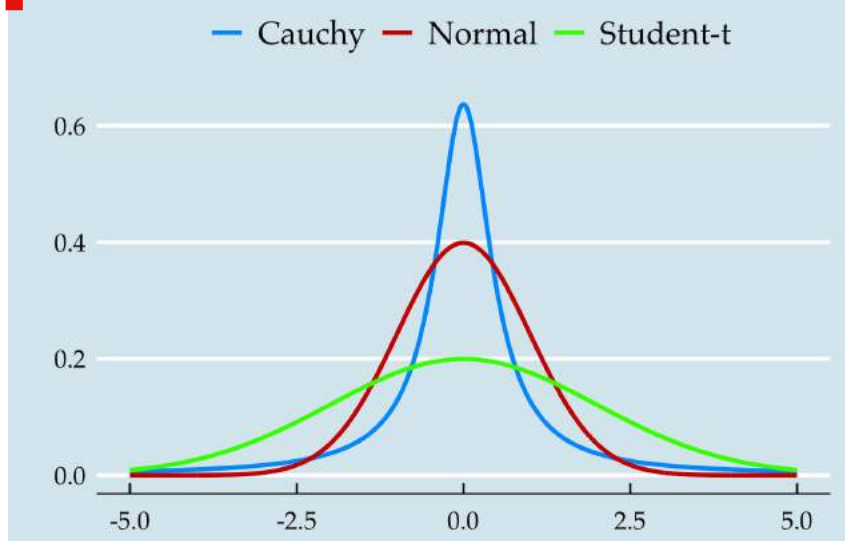
- Switzerland's **high export dependency** coupled with safe haven status is problematic for monetary policy
- Monitor developments in **gold market** and European risk factors such as VSTOXX
- Safe haven status not problematic vis-à-vis all currencies (e.g. BRL)
- **Changing role** of CHF safe haven status post-2015 may alleviate reverse peso problem
- Monitor capital flows generated by switch into and out of CHF



Future Research

- Use different distributions in mixture model
- Extend results to include weekly/monthly variables with Reverse MIDAS
- Fine-tune threshold value selection with ML
- Add lagged variables in probabilistic ML model to narrow down predictability

Different Distributions for Mixtures



Q&A

Appendix

(1) $$p(x) = \sum_{i=1}^{K} \phi_i \mathcal{N}(x \mid \mu_i, \sigma_i)$$

(2) $$\mathcal{N}(x \mid \mu_i, \sigma_i) = \frac{1}{\sqrt{2\pi}\sigma_i} \exp\left(-\frac{(x-\mu_i)^2}{2\sigma_i^2}\right)$$

(3) $$\sum_{i=1}^{K} \phi_i = 1$$

(4) $$\hat{\gamma}_{ik} = \frac{\hat{\phi}_k \mathcal{N}(x_i \mid \hat{\mu}_k, \hat{\sigma}_k)}{\sum_{j=1}^{K} \hat{\phi}_j \mathcal{N}(x_i \mid \hat{\mu}_j, \hat{\sigma}_j)}$$

(5) $$\hat{\phi}_k = \sum_{i=1}^{N} \frac{\hat{\gamma}_{ik}}{N}$$

(6) $$\hat{\mu}_k = \frac{\sum_{i=1}^{N} \hat{\gamma}_{ik} x_i}{\sum_{i=1}^{N} \hat{\gamma}_{ik}}$$

(7) $$\hat{\sigma}_k^2 = \frac{\sum_{i=1}^{N} \hat{\gamma}_{ik} (x_i - \hat{\mu}_k)^2}{\sum_{i=1}^{N} \hat{\gamma}_{ik}}$$

Following the methodology laid out by Dempster, Laird, & Rubin (1977), we use the two-step expectation-maximizing (EM) algorithm for a parametric mixture.

The one-dimensional model with K = 2 states is given by equations 1-3. p(x) is the a-priori posterior probability, the probability that an observed x is generated by component K, and ϕ are the component weights constrained to 1 for the probability distribution to not exceed 1. x are the spot returns, μ and σ the mean and standard deviation of spot returns, respectively.

In the E step (equation 4), we estimate the expected values of the latent variables, i.e., the probability weights, also referred to as membership probabilities or component assignments, by means of Bayes' theorem.

Using γ from equation 4 in the M-step (equations 5-7), E- and M-steps are then iteratively changed and repeated until the difference for parameters θ_t at iteration t | $\theta_t - \theta_{t-1}$ |≤ ε is arbitrarily small and does not change anymore.

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