A Model of Procyclical Exchange Rates

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Motivation

International Puzzles

Exchange rates present some of the most challenging puzzles in macroeconomics and macro-finance.

- Cyclicality puzzle (Backus and Smith (1993))
  - Risk-sharing implies that consumption growth should negative correlated with exchange rate appreciation.
  - Recession $\rightarrow$ marginal utility $\uparrow$ $\rightarrow$ real exchange rate $\uparrow$
- UIP puzzle
  - low interest rate currency should appreciate
- Volatility puzzle (Brandt et al. (2006))
  - real exchange rates are not sufficiently volatile when confronted with the evidence from asset prices

International Puzzles

- Several studies introduce asset market frictions to rationalize these anomalies, usually address one puzzle at a time at the expense of aggravating others — Lustig and Verdelhan (2019) and Jiang et al. (2023)

Our approach

- Conceptually: benefits of growth/innovation are not evenly distributed
  - limited risk sharing of innovator: can not contract to share the economic rents of ideas
- A dynamic general equilibrium model: exchange rate can be potentially pro-cyclical.

Findings

- Real exchange rates — marginal utility – can rise even when macro-fundamental improves.
  - Heterogeneity: the majority of households are displaced
- Produce positive correlation between capital flows and exchange rate
  - Innovation at home $\uparrow$, foreign investors buy shares of new firms, the share of the home in the world market $\uparrow$, home receives net capital inflows.
- Link to the potential source of “dollar factor”
- One possible channel through which Balassa-Samuelson hypothesis operates.

Relation to the literature

- Exchange rate in general equilibrium: Chari et al. (2002); Alvarez et al. (2002); Corsetti et al. (2008); Pavlova and Rigobon (2007); Alvarez et al. (2009); Colacito and Croce (2011, 2013); Colacito et al. (2018)
- Capital flows and exchange rates: Hau and Rey (2006), Camanho et al. (2020)
- Common risk factor in exchange rates: Lustig et al. (2011); Verdelhan (2018); Jiang (2023). Richmond (2019); Lustig and Richmond (2019); Jiang and Richmond (2019)
- Displacement risks and asset pricing: Gârleanu et al. (2016), Kogan et al. (2020), Huang et al. (2023), Kogan et al. (2020)

Facts

Exchange rate and Consumption

	Consumption growth	R^2(%)	Observations
Panel	0.011**	14.85	476
	(0.004)		
Australia	0.000	12.46	49
	(0.014)		
Canada	0.021*	16.88	49
	(0.012)		
France	0.025	20.82	28
	(0.022)		
Germany	-0.004	17.75	28
	(0.016)		
Italy	0.010	15.05	28
	(0.017)		
Japan	-0.018	17.53	49
	(0.014)		
New Zealand	0.020	16.26	49
	(0.015)		
Norway	0.029*	21.00	49
	(0.016)		
Sweden	0.009	6.19	49
	(0.019)		
Switzerland	0.008	21.55	49
	(0.021)		
United Kingdom	0.005	19.62	49
	(0.01)		

The table reports regression results of the growth of log exchange rate on log consumption growth ratio. Panel regression includes country fixed effects. 1971-2019. [Output]

Exchange rate and stock market

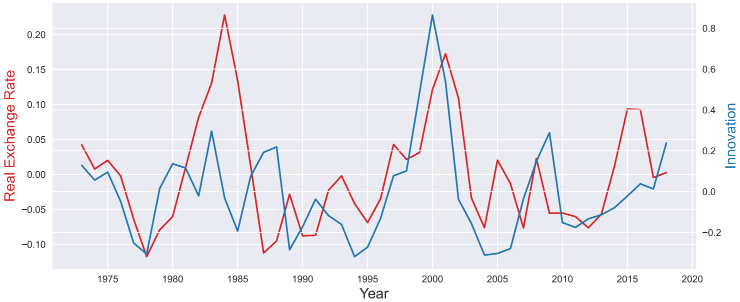
	Consumption growth	Stock market returns	$R^2(\%)$	Observations
Panel	0.010*	-0.016**	15.60	460
	(0.005)	(0.007)		
Australia	0.000	-0.011	13.40	49
	(0.014)	(0.016)		
Canada	0.021*	0.001	16.89	49
	(0.012)	(0.009)		
France	0.020	-0.012	21.67	28
	(0.025)	(0.03)		
Germany	-0.011	-0.039*	26.86	28
	(0.014)	(0.02)		
Italy	0.012	-0.019	17.72	28
	(0.015)	(0.019)		
Japan	-0.018	-0.010	18.17	49
	(0.014)	(0.017)		
New Zealand	0.033*	-0.023	21.75	42
	(0.019)	(0.022)		
Norway	0.034**	0.018	23.41	49
	(0.017)	(0.014)		
Sweden	0.016	-0.042***	17.25	49
	(0.016)	(0.012)		
Switzerland	-0.007	-0.051***	32.68	40
	(0.024)	(0.013)		
United Kingdom	0.002	-0.023	23.40	49
	(0.01)	(0.023)		

The table reports regression results of the growth of log exchange rate on consumption growth and stock market returns. Panel regression includes country fixed effects. 1971-2019.

In summary

- Macro fundamental $\uparrow$ — real exchange rate $\uparrow$
- Stock market $\downarrow$ — real exchange rate $\uparrow$
- Displacive innovation shocks?
    - consumption/output growth $\uparrow$
    - incumbents are displaced $\rightarrow$ marginal utility $\uparrow$

Exchange rate and innovation



The dollar index in red is the traded-weighted real advanced foreign economy dollar (AFE) indexes, calculated by the Fed. The US innovation series in blue plots the average real value per patent each year (adjusted using CPI, in logs), using methodology in Kogan et al. (2017). Both series are HP-filtered to remove the trend. [Future $ Index] [KPSS/GDP] [KPSS/GDP vs Future $ Index]

A simple model

Model ingredients

1. Two countries, home (H) and foreign (F). Two goods, X and Y. Time is discrete and is indexed by t.
    - Firms in each respective country only produce the local good. That is, the firms in the home country only produce the X good, while foreign firms only produce the Y good.
2. Innovation shocks
    - Innovation reallocates market share from incumbents to new entrants.
3. Incomplete markets
    - Small measure of households obtain shares in new firms, cannot sell their future endowment in financial markets.

Firms

- A continuum of productive units in each country.
- Firm varies by country $c \in \{H, F\}$, cohort s; and index within cohort i. Firm characterized by (i, s, H) produce output at time t

$$x_{t,s}^{i,H} = a_{t,s}^{i,H} X_t \qquad \text{where} \qquad \sum_{s \le t} \int_{i \in [0,1]} a_{t,s}^{i,H} = 1$$

- Aggregate output evolves exogenously according to

$$\Delta \ln X_{t+1} = \mu + \varepsilon_{t+1}^{H} + \delta u_{t+1}^{H}; \qquad \Delta \ln Y_{t+1} \quad = \mu + \varepsilon_{t+1}^{F} + \delta u_{t+1}^{F}$$

- New firms born at t: "steal" market share of existing firms

$$\int_{i \in [0,1]} X_{t,t}^{i} = \left(1 - e^{-u_{H,t}}\right) X_t$$

$$a_{t,s}^{i,c} = a_{s,s}^{i,c} e^{-\sum_{n=s+1}^{t} u_n^c}.$$

- Innovation shock u reallocates market share from existing to new firms.

Households

- Allocation of new firms (projects):
  - New firms is allocated to a measure $\zeta \in [0,1]$ of inventors; allocation is in proportion to their wealth (enables aggregation).
- Incomplete markets:
  - Can trade securities contingent on aggregate shocks;
  - Cannot sell claims against future endowment in new firms.
- Log preferences over composite good

$$E_t \left[\sum_{s=t}^{\infty} \hat{\beta}^s \ln \left(C_t^c \right) \right]$$

where

$$C_t^H = (x_t^H)^{\alpha} (y_t^H)^{1-\alpha}$$
$$C_t^F = (x_t^F)^{1-\alpha} (y_t^F)^{\alpha}$$

Competitive equilibrium

Equilibrium:

- Firms and households optimize.
- Markets clear and all resource constraints are satisfied.

Cross-sectional distribution of wealth within countries irrelevant for prices:

- Households in each country make identical saving and investment decisions.
- Existing households differ only in their level of wealth.

Equilibrium can be described as a central planner's problem:

$$\max_{x_t^H, y_t^H, x_t^F, y_t^F} \mathrm{E}_0 \left[\sum_{t=0}^{\infty} \hat{\beta}^t (\ln C_t^H + \lambda_t \ln C_t^F) \right]$$

λ_t is the ratio of Pareto-Neigishi weights Λ_t^* / Λ_t.

Real exchange rate

- Real exchange rate growth is a function of λ_t

$$\begin{aligned}\Delta e_t &= \ln M^H_{t,t+1} - \ln M^F_{t,t+1} \\ &= \Delta \ln C^F_t - \Delta \ln C^H_t - \Delta \ln \lambda_t\end{aligned}$$

- Dynamics of utility weights λ_t

$$\Delta \ln \lambda_{t+1} = \ln \Omega^*_{t+1} - \ln \Omega_{t+1}$$

  If markets are complete, $\Delta \ln \lambda_t = 0$ (Backus-Smith).

- Next: characterize SDF

Equilibrium SDF

- At each point in time, split households into two groups: those who receive new firms (with measure ζ) and those who do not (with measure $1-\zeta$).
- Consumption is proportional to wealth, so the SDF can be written as

$$M_{t,t+1} = \hat{\beta}\left(\frac{C_{t+1}}{C_t}\right)^{-1} \overbrace{\left(\underbrace{(1-\zeta)b_{t+1}^{-1}}_{\text{displacement}} + \underbrace{\zeta\left(\frac{1-(1-\zeta)b_{t+1}}{\zeta}\right)^{-1}}_{\text{receiving new firms}} \right)}^{\Omega_{t+1}}$$

- b_{t+1} is the wealth share of households in the country who do not receive new firms.

$$b_{H,t+1} = \frac{\int_{i\in[0,1],a_{t+1,t+1}^{i,H}=0} w_{t+1}^{i,H}}{\int_{i\in[0,1]} w_t^{i,H}}$$

Autarchy

- Consider a simplified case where households have extreme home-bias ($\alpha = 1$).
- Equilibrium SDF is

$$M_{t,t+1} = \hat{\beta}\left(\frac{C_{t+1}}{C_t}\right)^{-1}\left((1-\zeta)e^{u_{t+1}} + \zeta\left(\frac{1-e^{-u_{t+1}}}{\zeta}\right)^{-1}\right)$$

- In the limit of $\zeta \to 0$

$$M_{t,t+1} = \hat{\beta}\left(\frac{C_{t+1}}{C_t}\right)^{-1} \underbrace{e^{u_{t+1}}}_{\text{displacement effect}}$$

- Real exchange rate growth

$$\Delta e_t = \ln M_{t,t+1} - \ln M^F_{t,t+1} = \Delta \ln C^F_t - \Delta \ln C^H_t + (u^H_t - u^F_t)$$

- Next: $\alpha < 1$

General case

- Real exchange rate growth around the symmetric steady state

$$\begin{aligned}\Delta e_{t+1} &\approx \Delta c^F_{t+1} - \Delta c^H_{t+1} + u^H_{t+1} - u^F_{t+1} \\ &\approx \underbrace{(2\alpha - 1)(1-\delta)}_{>0}(u^H_{t+1} - u^F_{t+1}) + (1-2\alpha)(\varepsilon^H_{t+1} - \varepsilon^F_{t+1})\end{aligned}$$

- Relative output

$$\Delta x_{t+1} - \Delta y_{t+1} = \delta(u^H_{t+1} - u^F_{t+1}) + \varepsilon^H_{t+1} - \varepsilon^F_{t+1}$$

- Relative consumption

$$\Delta c^H_{t+1} - \Delta c^F_{t+1} \approx (1-2\alpha)(1+\delta-2\alpha)(u^H_{t+1} - u^F_{t+1}) + (2\alpha-1)\varepsilon^H_{t+1} - \varepsilon^F_{t+1}$$

- Assuming $\delta < 2\alpha - 1$,
  - displacement shock u: pro-cyclical
  - neutral shock ε: counter-cyclical

Model implications: stock market

- The log return of holding the market portfolio is

$$r^H_{t+1} = \underbrace{\mu + \delta u^H_{t+1} + \varepsilon^H_{t+1}}_{\text{Aggregate dividend growth}} - u^H_{t+1} + \ln\left(\frac{1 + pd^H_{t+1}}{pd^H_t}\right)$$

- Investing in the stock market at time t only generate $X_{t+1} e^{-u^H_{t+1}}$ dividends at $t+1$. Because displacement shocks
  - introduce new firms: $X_{t+1} \uparrow$
  - dilute existing shares: $e^{-u^H_{t+1}} < 1$

Model implications: income inequality

- Recall that the value of new firms $\eta S(1-e^{-u_t})$ is distributed to a small measure ζ of the population.
- Some of these entrepreneurs or inventors are part of the top 1%.
- The model implies a positive correlation between income inequality growth and the local price level.

Exchange rate and Inequality

	Inequality growth	R^2(%)	Observations
Panel	0.012**	14.26	406
	(0.005)		
Australia	0.023	15.52	49
	(0.015)		
Canada	-0.007	10.04	49
	(0.007)		
France	0.016	18.42	28
	(0.022)		
Germany	0.030	19.48	18
	(0.028)		
Italy	0.065**	36.11	18
	(0.024)		
Japan	0.005	7.28	39
	(0.013)		
New Zealand	0.019	16.01	49
	(0.014)		
Norway	-0.012	14.05	39
	(0.016)		
Sweden	0.015	13.24	39
	(0.021)		
Switzerland	0.014	14.50	39
	(0.011)		
United Kingdom	0.029*	29.29	39
	(0.015)		

The table reports regression results of the growth of log exchange rate on growth of top 1% income share.

Panel regression includes country fixed effects.

The Full Model

General setup

1. Epstein-Zin preferences

$$U_{i,t}^{c} = \left[(1-\beta)\left(\hat{C}_{i,t}^{c}\right)^{1-\frac{1}{\psi}} + \beta \mathrm{E}_t\left[(U_{i,t+1}^{c})^{1-\gamma}\right]^{\frac{1-1/\psi}{1-\gamma}}\right]^{\frac{1}{1-1/\psi}}$$

2. Allow innovation to spillover across countries:

$$u_{t+1}^{H} = (1-\rho_u)\,\tilde{u}_{t+1}^{H} + \rho_u\,\tilde{u}_{t+1}^{F}$$
$$u_{t+1}^{F} = (1-\rho_u)\,\tilde{u}_{t+1}^{F} + \rho_u\,\tilde{u}_{t+1}^{H}$$

3. Neutral shocks are i.i.d. and jointly normally distributed $[\varepsilon^h, \varepsilon^f] \in N(0, \Sigma)$, where

$$\Sigma = \begin{bmatrix} \sigma_e^2 & \rho_e\sigma_e^2 \\ \rho_e\sigma_e^2 & \sigma_e^2 \end{bmatrix}$$

Estimation: moments

- Estimate the model using indirect inference (SMM)

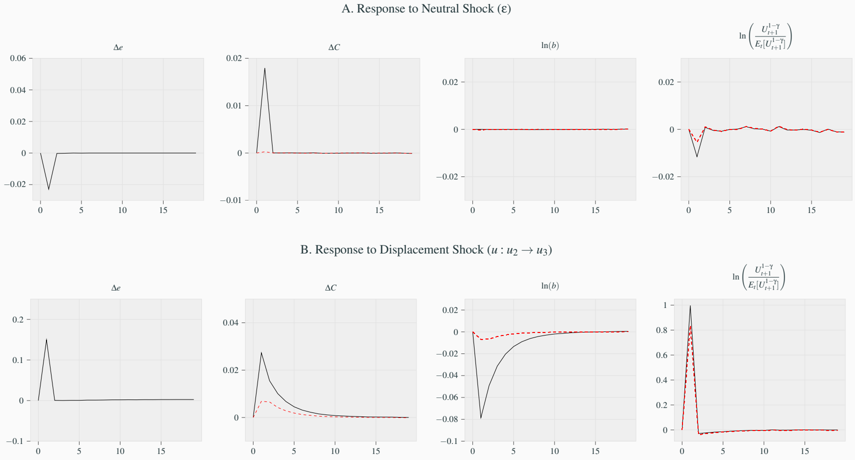
	Data	Model		
		Median	5%	95%
Aggregate Quantities				
Consumption growth, mean	0.016	0.015	0.008	0.022
Consumption growth, volatility	0.022	0.020	0.018	0.035
Output growth, mean	0.016	0.015	0.008	0.021
Output growth, volatility	0.021	0.021	0.018	0.023
Mean top 1% income share	0.158	0.216	0.150	0.289
Asset prices				
Risk-free rate, mean	0.014	0.025	-0.005	0.033
Risk-free rate, volatility	0.033	0.011	0.004	0.046
Excess stock returns, mean	0.049	0.035	0.013	0.095
Excess stock returns, volatility	0.232	0.111	0.058	0.246
Exchange rate, volatility	0.104	0.077	0.036	0.182
Correlations (regression slopes)				
Exchange rate and				
—relative consumption growth	0.011	0.038	-0.005	0.155
—relative output growth	0.011	0.005	-0.035	0.049
Bi-variate correlations (regression slopes)				
Exchange rate and				
—relative c-growth	0.014	0.022	-0.009	0.126
—relative growth in top 1% income shares	0.014	0.038	0.000	0.076
Exchange rate and				
—relative c-growth	0.010	0.015	-0.006	0.124
—relative difference in stock returns	-0.016	-0.036	-0.084	0.000
Correlations				
Consumption growth (H and F)	0.337	0.804	0.333	0.923
Output growth (H and F)	0.449	0.862	0.735	0.954
Stock Returns (H and F)	0.541	0.275	-0.087	0.646
Trade surplus (as % of output) growth and c-growth	-0.472	-0.148	-0.852	0.267
Uncovered Interest Parity				
UIP slope	-0.572	-0.506	-6.104	2.225

Estimation: parameters

Description	Symbol	Value	SE
Preferences:			
Home bias	α	0.990	0.149
Preference for own consumption	h	0.174	0.728
Subjective discount rate	β	1.057	0.064
Risk aversion	γ	6.501	6.325
Elasticity of intertemporal substitution	ψ	1.762	2.568
Death	ξ	0.078	0.035
Endowments:			
Displacement shock productivity	δ	0.269	0.758
Measure of projects-receiver	π	0.086	0.423
Mean of output growth	μ	0.012	0.007
Displacement shock low state	u_1	0.001	0.018
Displacement shock high state	u_3	0.137	0.096
Persistence of displacement shock			
— low state persistence	p	0.930	0.098
— high state persistence	q	0.830	0.417
Volatility of neutral shock	σ_e	0.019	0.015
Technology spillover	ρ_u	0.698	0.221
Correlation of neutral shock	ρ_e	0.872	0.253

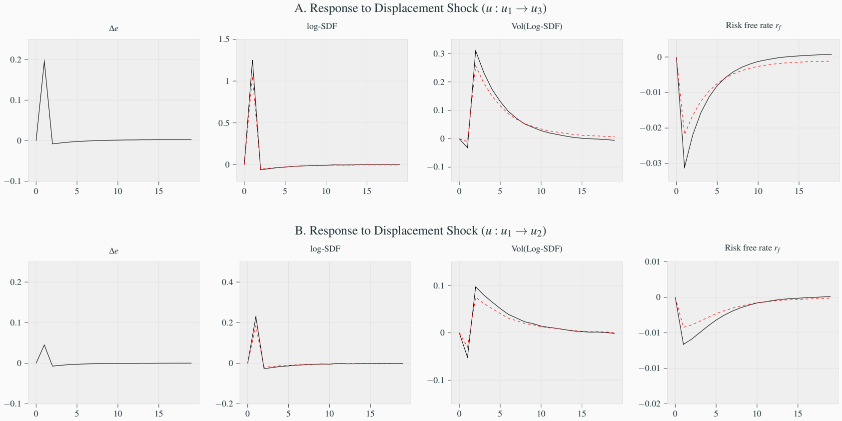
[Numerical]

Impulse responses: cyclicality



Black = Home, Red = Foreign

Impulse responses: UIP



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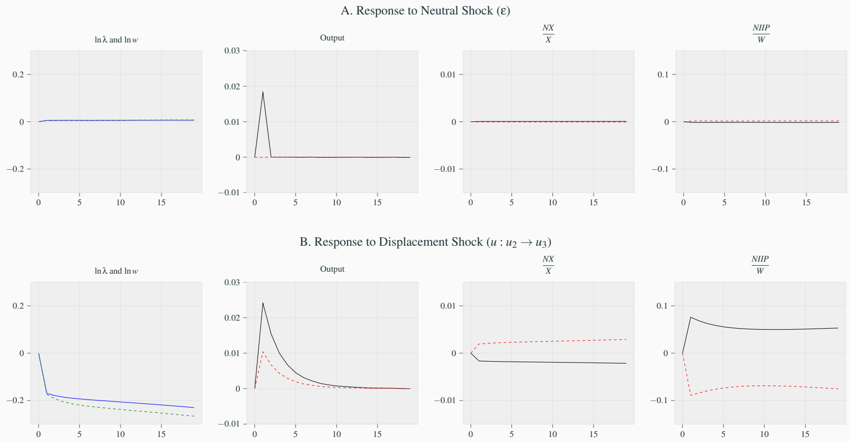
Trade and capital flows

In the model, the net export as a fraction of total output is

$$\frac{NX_t^H}{X_t} = \frac{p_{x,t}X_t - p_{x,t}x_t^H - p_{y,t}y_t^H}{p_{x,t}X_t} = 1 - \frac{1}{\alpha + (1-\alpha)\lambda_t}$$

$$\frac{NX_t^F}{Y_t} = \frac{p_{y,t}Y_t - p_{y,t}Y_t^F - p_{y,t}x_t^H}{p_{y,t}Y_t} = 1 - \frac{\lambda_t}{1-\alpha+\alpha\lambda_t}$$

Trade and capital flows



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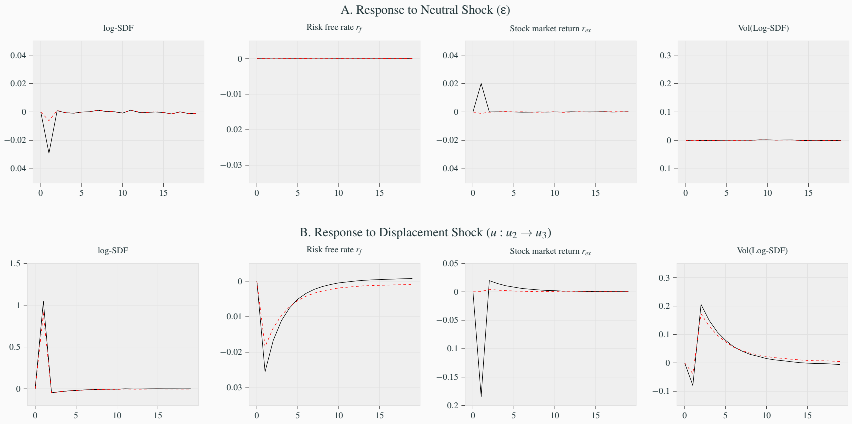
Conclusion

Conclusion

- A quantitative general equilibrium model that replicates the dynamics of exchange rates, consumption, stock returns and trade flows.
- Displacive shocks can help resolve international finance puzzles
  - Backus-smith puzzle
  - UIP puzzle
  - Volatility puzzle
- Link to the fundamentals of the “dollar factor”

Additional slides

Stock market returns



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Numerical

- A number of simplifying restrictions on the dynamics of u shocks: $u \in \{u_1, u_2, u_3\}$
- First, we assume that $u_1 = u_2$. Hence, a transition from u_1 to u_2 only affects the future distribution of u (as the transition probabilities change) rather than the current level of displacement.
- Second, we assume that the matrix T corresponds to transition matrix of a discretized AR(1) process, so that it could be parameterized by only two parameters—the corresponding autocorrelation parameter p and q.

$$T = \begin{bmatrix} p^2 & 2p(1-p) & (1-p)^2 \\ p(1-q) & pq+(1-p)(1-q) & q(1-p) \\ (1-q)^2 & 2q(1-q) & q^2 \end{bmatrix}$$

Back

Exchange rate and Output

	GDP growth	$R^2(\%)$	Observations
Panel	0.011**	14.86	476
	(0.004)		
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	(0.011)		
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Germany	0.026	21.76	28
	(0.018)		
Italy	0.022	17.92	28
	(0.021)		
Japan	-0.011	16.20	49
	(0.015)		
New Zealand	0.015	15.21	49
	(0.017)		
Norway	0.009	15.18	49
	(0.011)		
Sweden	0.005	5.83	49
	(0.017)		
Switzerland	0.006	21.44	49
	(0.021)		
United Kingdom	0.026	24.03	49
	(0.018)		

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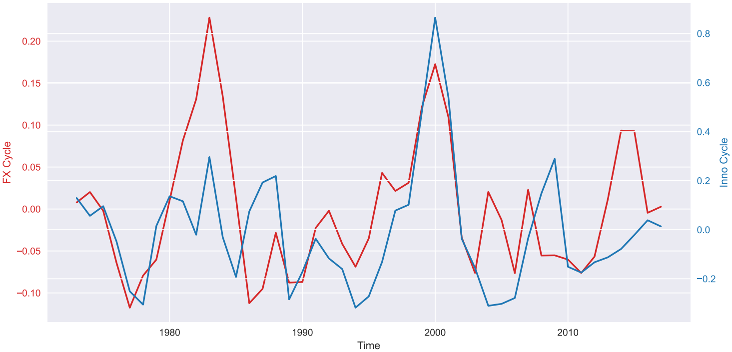
Exchange rate and innovation



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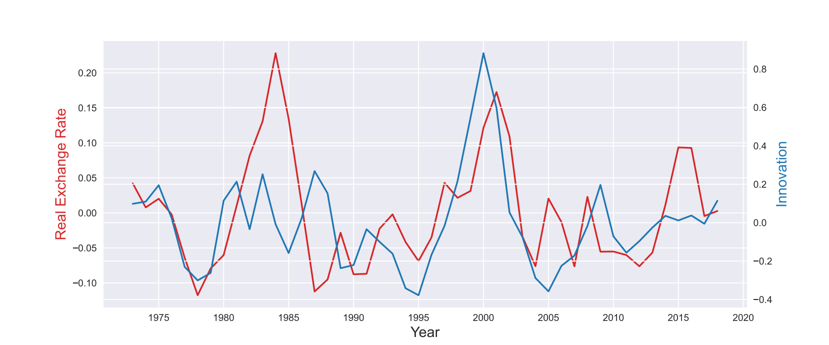
Exchange rate and innovation



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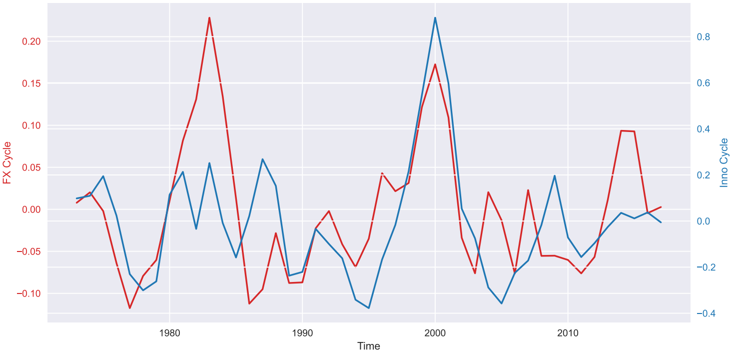
Exchange rate and innovation



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