M2 Financial Economics Thesis Proposal – Stage 3

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Reference Repo: https://github.com/EliaLand/PVAR_japan_endogenous_money

STAGE 3

Monetary Endogeneity Theory Stress-Testing in the context of Yield Curve Control (YCC): A **Panel VAR** Stress-Test of Yield Curve Control Long-term Sustainability: A Lens on Japan

H01: 2 REGIMES UNDER PRESSURE

As according to the **endogenous money hypothesis**, credit creation is the primary driver of money supply, i.e., banks create deposits (broad money) when they extend loans and, in this context, the central bank (BoJ) accommodates reserves to maintain the target policy rate.

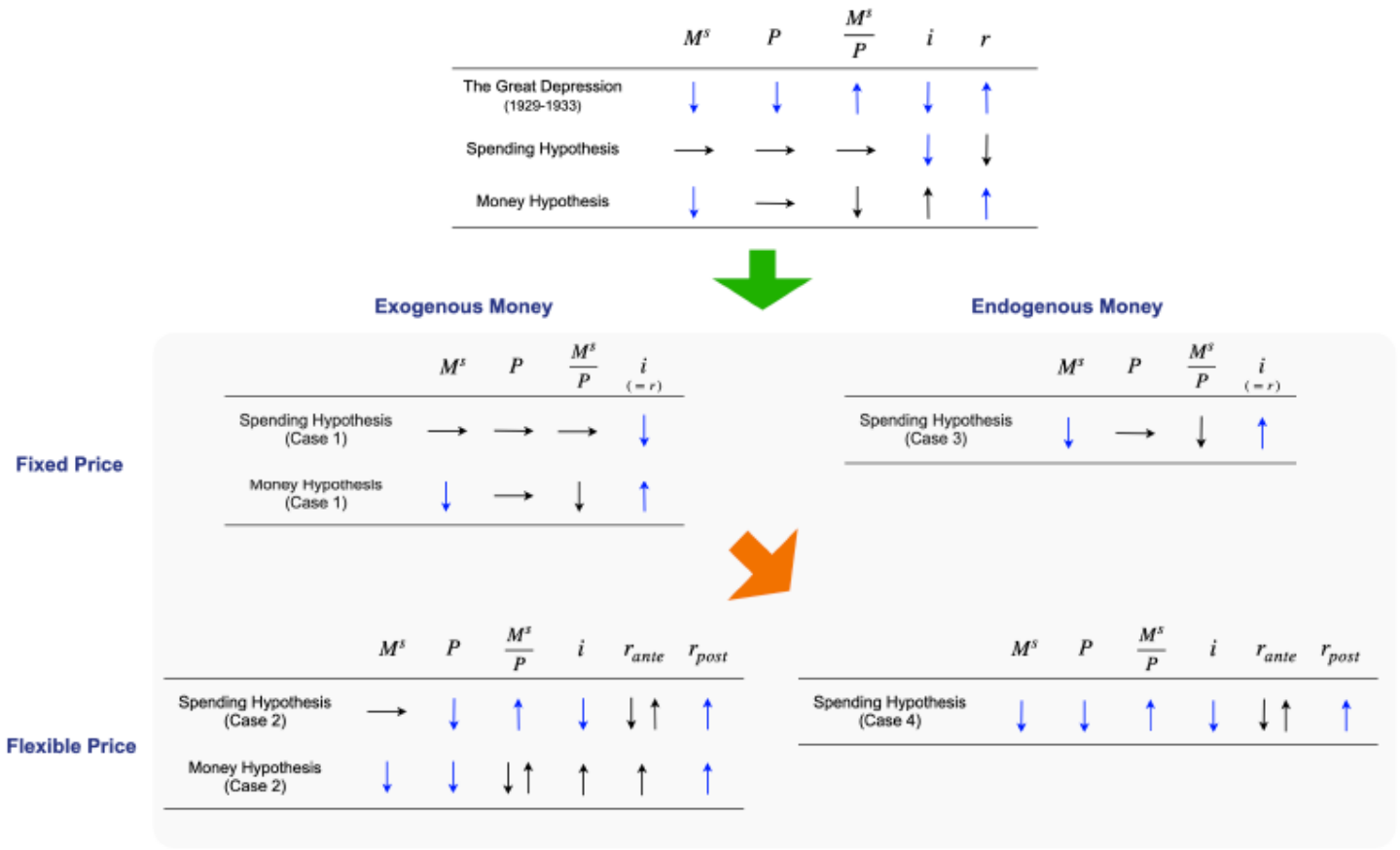
$$Y_t = [L_t, M_t, R_t, y_t \pi_t],$$

$$H_{01}^{(endogenous)}: A_{L,M}(1) = A_{L,M}(2) = \cdots = A_{L,M}(p) = 0$$

Therefore, **credit demand leads money**, **not the other way around**.

Past values of broad money do **not Granger-cause credit**, meaning that credit (L) is *not predicted by* money (M). Lending decisions originate from **credit demand and profitability**, and not from prior money supply.

ENDOGENOUS vs EXOGENOUS MONEY



Source: Yamaguchi et al. (2022)

H02: IS THE BOJ ACCOMODATING RESERVE DEMAND?

We inquire whether the Bank of Japan actually accommodates reserve demand generated by bank lending, which is the direct result of the tandem between loans expansion and reserves rises. This concept if true would imply one of the pillar at the root of the endogenous money theory: **credit-induced liquidity creation**. While, in the opposite scenario, if reserves are unaffected by lending, liquidity remains **centrally controlled,** providing evidence of the validity of the exogenous regime.

$$H_{02}^{(endogenous)} : R_t \text{ driven by } L_t$$

$$H_{02}^{(endogenous)} \; valid \; if \;\; \gamma_1 > 0 \text{ in } R_t = \gamma_0 + \gamma_1 L_t + \ldots$$

- Persistent reserve accommodation may **inflate the BoJ's balance sheet**, increasing vulnerability to mark-to-market losses or future exit challenges
- A valid $H_{02}^{(endogenous)}$ would imply stronger **monetary control** by the BoJ (comparison with FED and ECB)
- A valid $H_{02}^{(endogenous)}$ supports the endogenous-money mechanism where the Bank of Japan, mandate by the Ministry of Finance, adjusts reserves to maintain interest rate stability under YCC

H03: INFLATION & GDP REACTIVITY TO LIQUIDITY SHOCKS

We are all widely aware about the ramping HICP in Japan nowadays, and in this framework, we want to test whether this inflationary trend can be caused **by credit-driven liquidity under YCC**. And more generally whether liquidity can lead to macroeconomic feedback effects. According to the endogenous framework, endogenous credit growth should stimulate aggregate demand (**rGDP**) and, over time, price levels (**HICP**). In other words, if this assumption of endogeneity holds true, we expect to observe a significant feedback from loans to HICP/rGDP, indicating that **money creation via credit channels** translates into real and nominal growth.

$$H_{03}^{(endogenous)} : y_t, \pi_t \; responsive \; to \; L_t \; shocks$$
$$H_{03}^{(endogenous)} \; valid \; if \; IRFs \; L \rightarrow y, L \rightarrow \pi > 0$$

- A valid $H_{03}^{(endogenous)}$ reveals that **YCC amplifies** the macro impact of credit-driven liquidity

→ **Effective stimulus**, but risk of overheating or asset-price inflation

H04: YCC CHALLENGING TRADITIONS

Japan is also famous for its peculiar approach to monetary policy, which significantly differs from the Western approach adopted by the FED and ECB. One of the famous trademarks of the Japanese modern monetary philosophy is the YCC. In this section, we attempt to assess whether the **monetary transmission mechanism** fundamentally changed after the introduction of YCC in 2016 (still present). In a regime of pegged long-term yields like the one boasted by the YCC, the deduce that the central bank's reaction function alters from the classic theory, leading to a reinforcement of the endogenous behaviour as it must absorb liquidity fluctuations to maintain the yield target.

$$H_{04}: A_j^{(YCC)} = A_j^{(pre-YCC)}$$

$$H_{04}\ valid\ if\ the\ coefficients\ do\ not\ differ\ heavily\ between\ the\ 2\ regimes\ of\ YCC$$

Rejecting H_{04} indicates a **structural break** and hence, Japan's monetary regime must have moved toward credit-driven liquidity creation, confirming the assumption of regime dependence of endogeneity.

Leading to a transformation of the BoJ from a **rate setter to a balance-sheet accommodator,** caused by the introduction of the YCC

H05: A WIDELY DEBATED TOPIC: YCC SUSTAINABILITY

What we try to investigate here is whether the BoJ, as dummy of the Ministry of Finance, can **elastically supply reserves** to meet credit-driven liquidity demand **without losing price or yield control**. The concept of sustainability here implies that liquidity adjustments are **mean-reverting**, or in other words that reserves, inflation, and yields eventually stabilize after shocks. Unsustainability occurs when money creation leads to **persistent balance-sheet growth**, inflation drift, or yield volatility.

$$H_{05}: \textit{Reserve accommodation does not destabilize inflation or the policy rate}$$

Failing to reject H_{05} means that **YCC is sustainable** in the long-run and consequently, the BoJ can accommodate credit growth while maintaining inflation and rate stability. The opposite scenario happens when reserve accommodation becomes **destabilizing** with continuous balance-sheet expansion that undermines policy control. However, the robustness of these findings are subjected to the validity of the original assumption of endogeneity.

MODEL FRAMEWORK

The **PVAR model** is already setup for hosting multiple countries, and consequently, a panel data framework, but for the moment we will focus only on Japan, despite the plan is to extend the analysis to both Australia, which enacted a proxy YCC for a short period (1998), and the EU as robustness control framework to the test whether our assumptions also hold outside the Japanese landscape.

$$Y_{c,t} = \begin{bmatrix} L_{c,t} \\ M_{c,t} \\ R_{c,t} \\ y_{c,t} \\ \pi_{c,t} \\ i^{S}_{c,t} \\ i^{10}_{c,t} \end{bmatrix}, X_{c,t} = \begin{bmatrix} YCC_{c,t} \\ global_{c,t} \end{bmatrix}$$

$$Y_{c,t} = \sum_{j=1}^{p} A_j \; Y_{c,t-j} + \Gamma X_{c,t} + \mu_c + \tau_t + \varepsilon_{c,t}, p \in \{2, 3\}$$

$$Y_{c,t} = \sum_{j=1}^{p} (A_j^{(0)} + A_j^{(1)} \cdot YCC_{c,t}) Y_{c,t-j} + \Gamma X_{c,t} + \mu_c + \tau_t + \varepsilon_{c,t}$$

Where L is (log) bank credit to private sector, M (log) broad money (M2/M3), R (log) bank reserves at BoJ, y (log) real GDP, π inflation (indexed), i^S :short policy rate (shadow rate), i^{10} the 10-year government bond yields, YCC the regime dummy, global controls (Crude Oil Price Brent, Broad USD Index, CBOE VIX, 10-year T-bills).

DATA FETCHING (via API and manual import)

- **Real Effective Exchange Rates**: CPI Based for Japan (monthly, Index 2015=100, non-seasonally adjusted, 1970-01, 2025-09) [https://fred.stlouisfed.org/series/CCRETT01JPM661N]
- **Consumer prices (HICP),** all items (whole country), NSA, Japan (monthly, Index April 2025=111.5, non-seasonally adjusted, 1970-01, 2025-04) [https://data.ecb.europa.eu/data/datasets/RTD/RTD.M.JP.N.P_C_OV.X]
- **Japanese Yen to U.S. Dollar Spot Exchange Rate** (monthly, non-seasonally adjusted, 1971-01, 2025-09) [https://fred.stlouisfed.org/series/EXJPUS]
- **Monthly price and volume of Japan's stock indices and bond-related instruments** (monthly, log, number of securities traded, 2015-01, 2025-10) [Nikkei 225, NYSE Arca Japan Index, iShares 7-10 Year Japan Government Bond ETF, iShares Core Japan Government Bond ETF]
- **Total Reserves excluding Gold for Japan** (monthly, millions USD, non-seasonally adjusted, 1950-01, 2025-07) [https://fred.stlouisfed.org/series/TRESEGJPM052N]
- **Monetary Aggregates and Their Components**: Broad Money and Components: **M3** for Japan (monthly, YPJ , seasonally adjusted, 1980-01, 2023-11) [https://fred.stlouisfed.org/series/MABMM301JPM189S]
- **Monetary Aggregates and Their Components:** Broad Money and Components: **M2** for Japan (monthly, YPJ, seasonally adjusted, 1955-01, 2013-12) [https://fred.stlouisfed.org/series/MABMM201JPM189S]
- **Total Credit to Private Non-Financial Sector**, Adjusted for Breaks, for Japan (quarterly, percentage of GDP, breaks adjusted, 1964-01, 2025-01) [https://fred.stlouisfed.org/series/QJPPAM770A]
- **Total Credit to General Government**, Adjusted for Breaks, for Japan (quarterly, percentage of GDP, breaks adjusted, 1997-01, 2025-01) [https://fred.stlouisfed.org/series/QJPGAM770A]
- **Total Credit to households and NPISHs**, Adjusted for Breaks, for Japan (quarterly, percentage of GDP, breaks adjusted, 1964-01, 2025-01) [https://fred.stlouisfed.org/series/QJPHAM770A]
- **Real Gross Domestic Product for Japan** (quarterly, billions of chained 2015 JPY, seasonally adjusted, 1994-01, 2025-04) [https://fred.stlouisfed.org/series/JPNRGDPEXP]
- **Interest Rates: Long-Term Government Bond Yields: 10-Year**: Main (Including Benchmark) for Japan (monthly, percent, non-seasonally adjusted, 1989-01, 2025-09) [https://fred.stlouisfed.org/series/IRLTLT01JPM156N]
- **Interest Rates: Immediate Rates (< 24 Hours): Call Money/Interbank Rate**: Total for Japan (monthly, percent, non-seasonally adjusted, 1985-01, 2025-09) [https://fred.stlouisfed.org/series/IRSTCI01JPM156N]

METRICS CLUSTERS

$$\textbf{Monetary Aggregates} = \{M1_{JPY},\ M2_{JPY},\ M3_{JPY}\}$$

$$\textbf{Credit Metrics} = \{\text{Credit}_{Gov}/GDP,\ \text{Credit}_{HH+NPISH}/GDP,\ \text{Credit}_{Private\,NF}/GDP\}$$

$$\textbf{Reserves} = \{\text{Treasury Reserves}_{ex\ Gold}\}$$

$$\textbf{Monetary Policy Proxies (Yields)} = \{Y_{Gov}^{10y},\ r_{Interbank},\ r_{1y}^{*},\ r_{10y}^{*}\}$$

$$\textbf{Exchange Rate} = \{REER_{USD/JPY}^{CPI},\ S_{JPY/USD}\}$$

$$\textbf{Output \& Trends} = \{GDP_{2015\,JPY}^{Real}\}$$

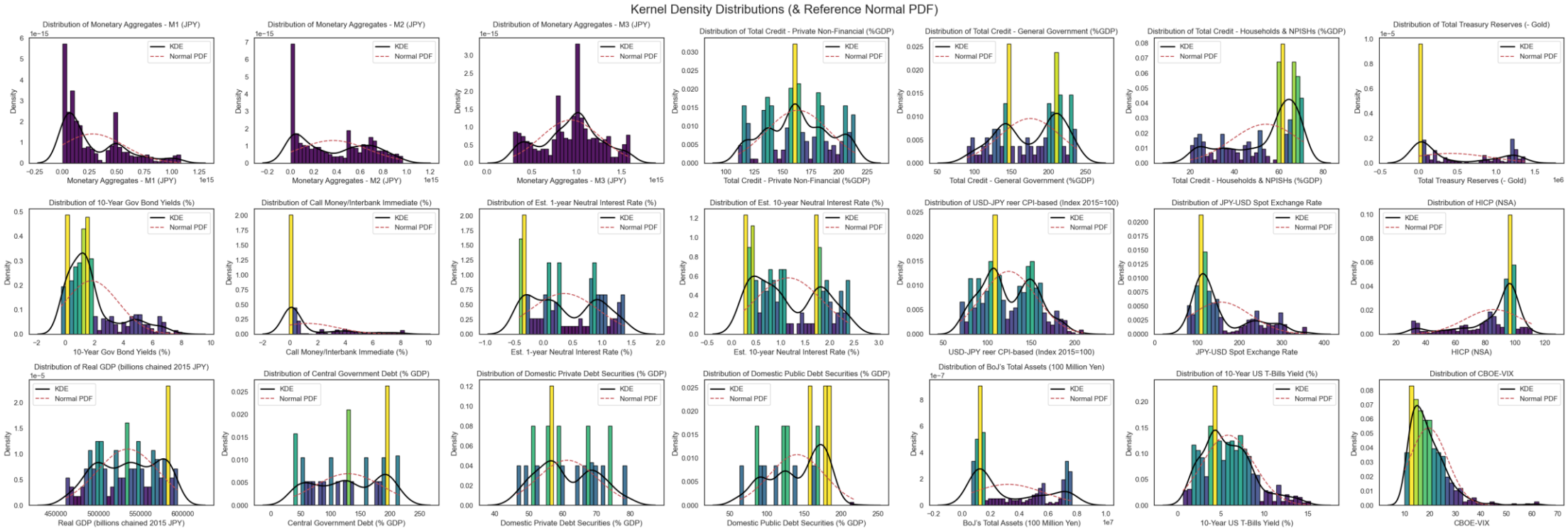
$$\textbf{Consumption Prices} = \{HICP_{NSA}\}$$

$$\textbf{Debt Metrics} = \{Debt_{Gov}/GDP,\ DebtSec_{Private}/GDP,\ DebtSec_{Public}/GDP\}$$

$$\textbf{Controls} = \{Y_{US}^{10y},\ VIX\}$$

$$\textbf{BoJ Balance Sheet} = \{Assets_{BoJ}\}$$

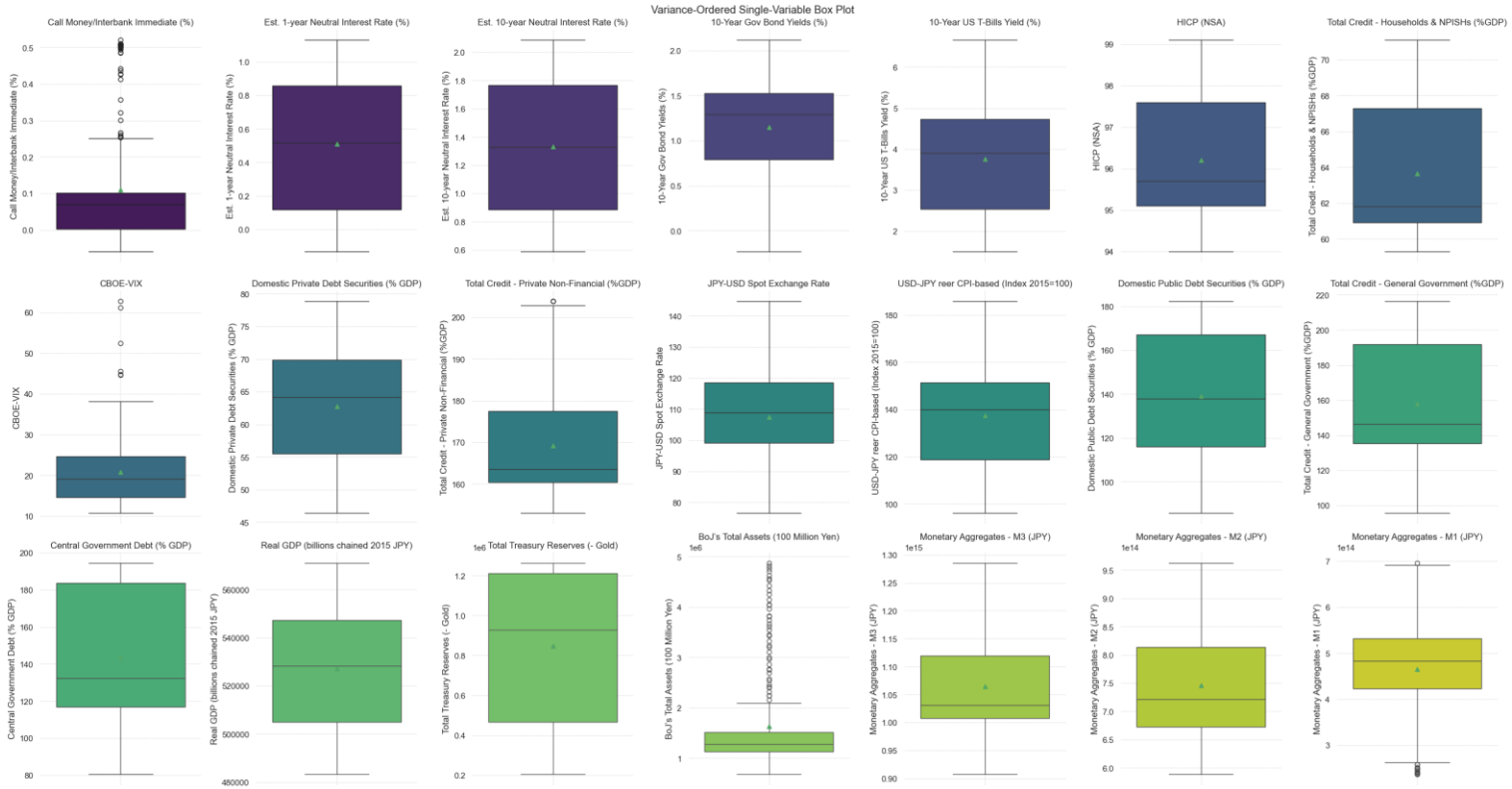
KDE DISTRIBUTIONS (& NORMAL PDF)



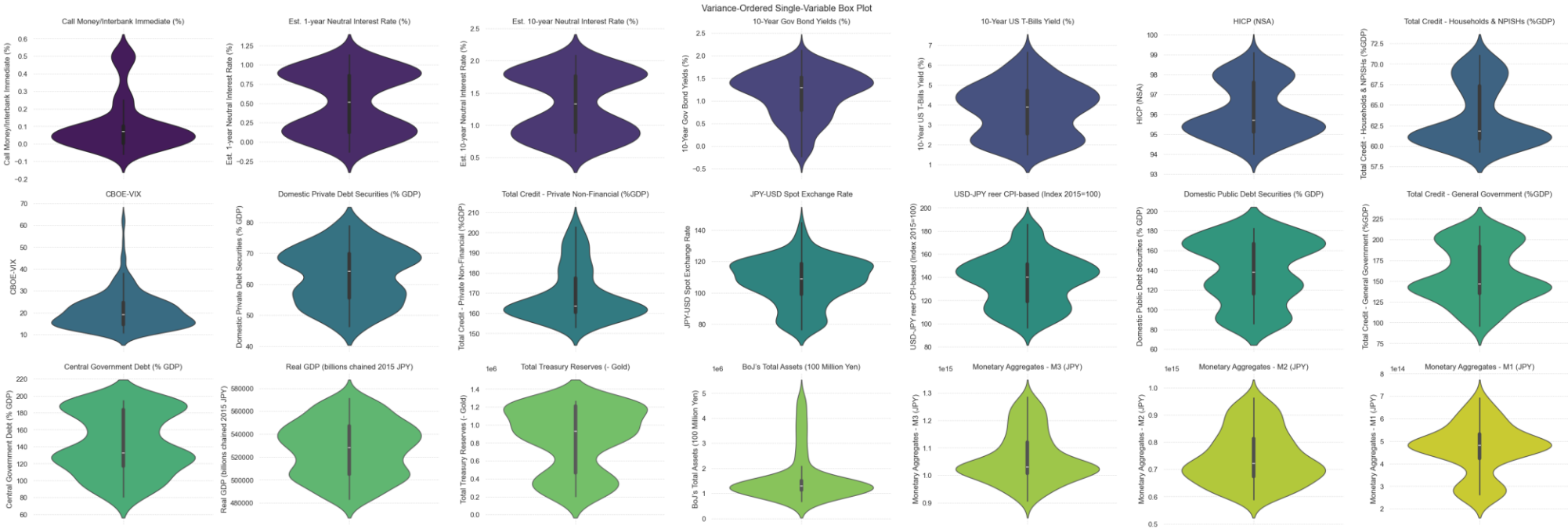
We note that monetary aggregates, credit measures, and interest rates, **deviate significantly from normality**, displaying skewness, kurtosis, and in several cases, multimodality. This non-normal behaviour is particularly pronounced in **bond yields, call money rates, and exchange rates**, suggesting the presence of structural breaks, regime shifts, or policy-driven discontinuities.

VARIANCE-ORDERED BOX PLOTS

From the boxplots we observe that monetary aggregates and total credit measures exhibit **wide interquartile ranges** and positive skewness, suggesting persistent growth and structural shifts over time. Government bond yields and interbank rates boast a **notable asymmetry** with numerous outliers, probably the result of market volatility and policy-driven rate interventions. In contrast, GDP and HICP display **more stable medians** but still exhibit variability consistent with cyclical and inflationary dynamics.



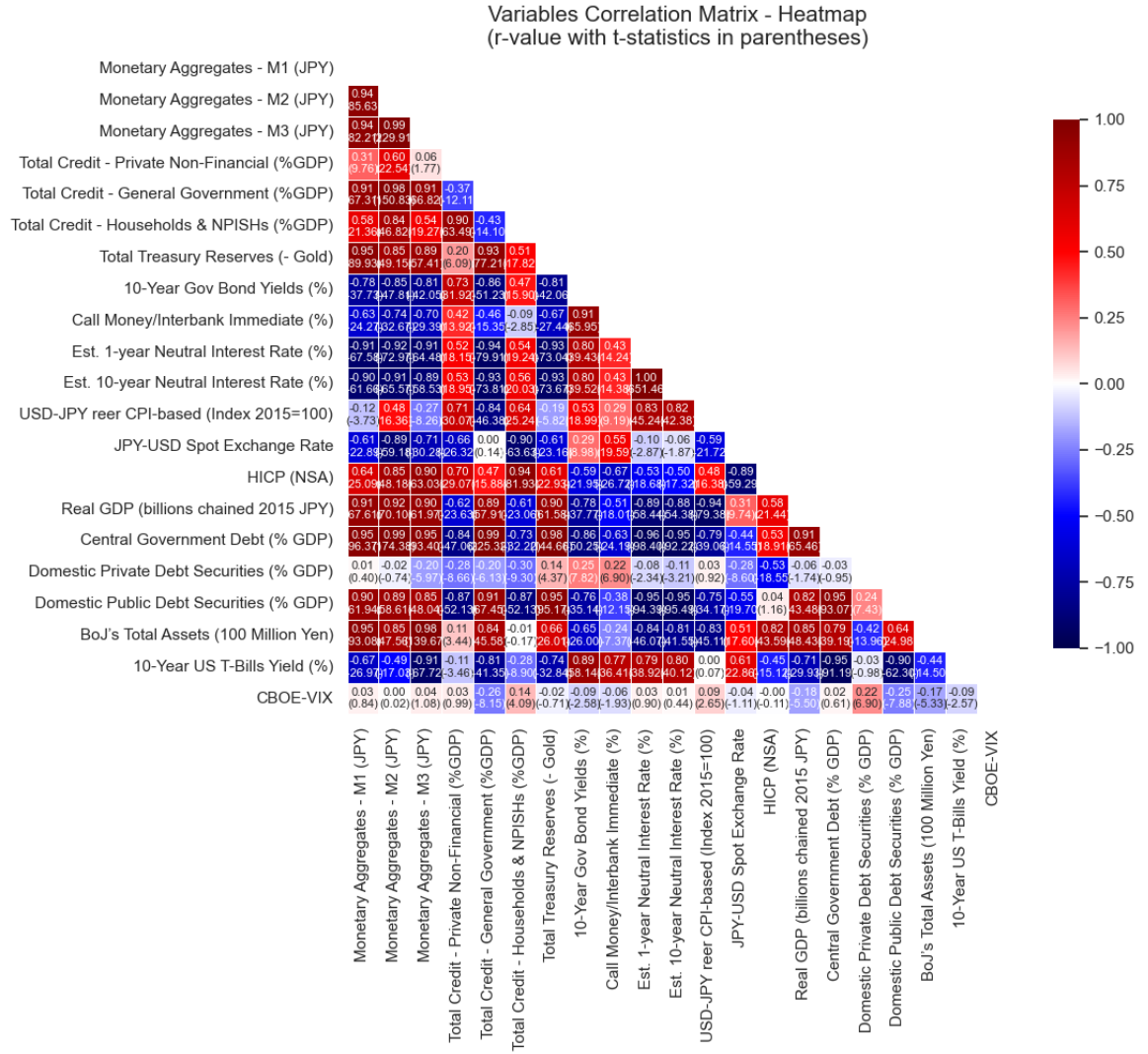
VIOLIN PLOTS (stock volume & price excl.)



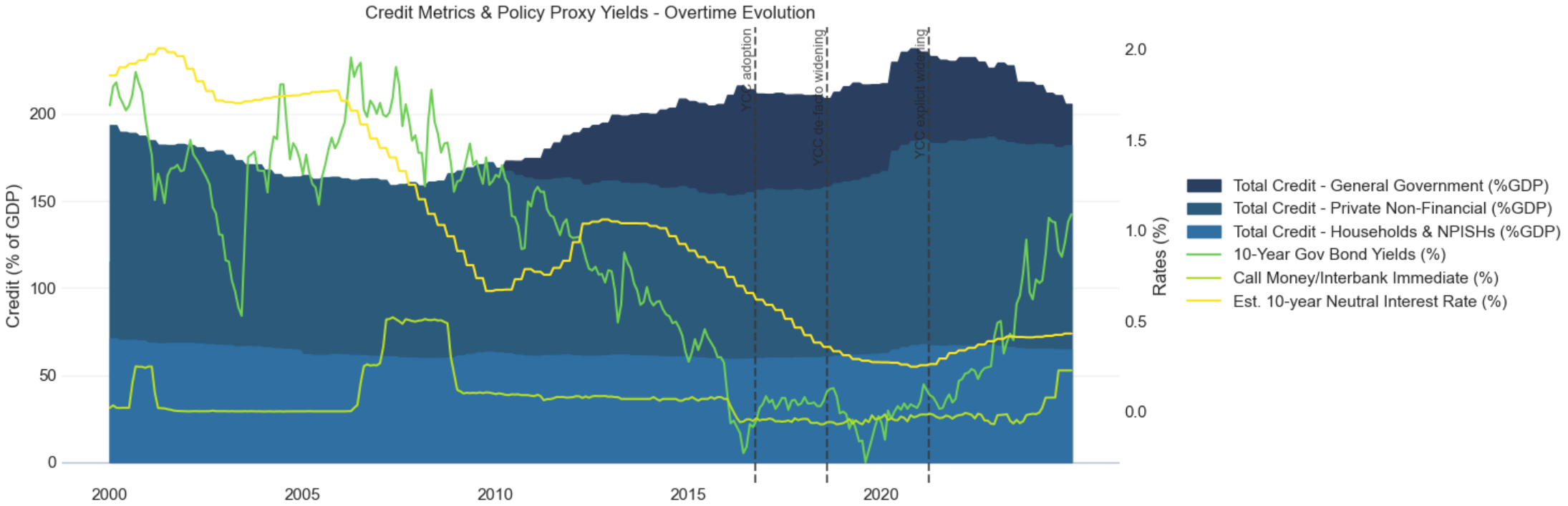
With respect to the boxplots, violin plots reveal distributional patterns that were not displayed by the standard boxplot layout. Monetary aggregates, credit measures, and exchange rates show **multiple peaks**, indicating regime shifts or structural changes, while bond yields and call money rates cluster **sharply near zero**, reflecting Japan's prolonged low-rate environment. In contrast, GDP and HICP display smoother, centred distributions.

BIVARIATE CORRELATION MATRIX

The correlation heat map shows **highly positive correlation** between monetary aggregates (M2 and M3) and total credit variables, mirroring synchronized monetary and credit expansion. Real GDP and inflation (HICP) also show a **notable positive correlation**, consistent with cyclical demand effects. Conversely, interest rate variables such as the 10-year bond yields, or call money rates, exhibit **weak or negative correlations** with most aggregates. A moderate positive correlation is instead found between exchange rate and macro-measures (inflation and GDP).

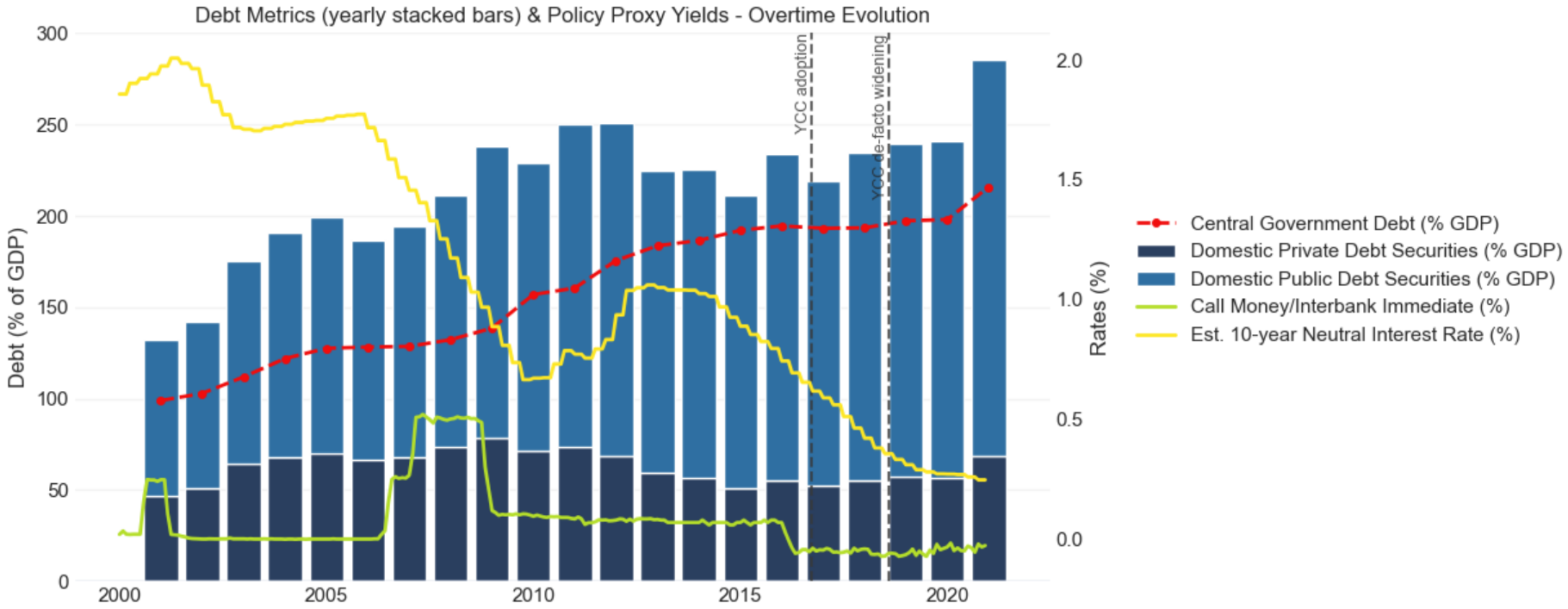


JOINT PLOTS OF OVERTIME EVOLUTION



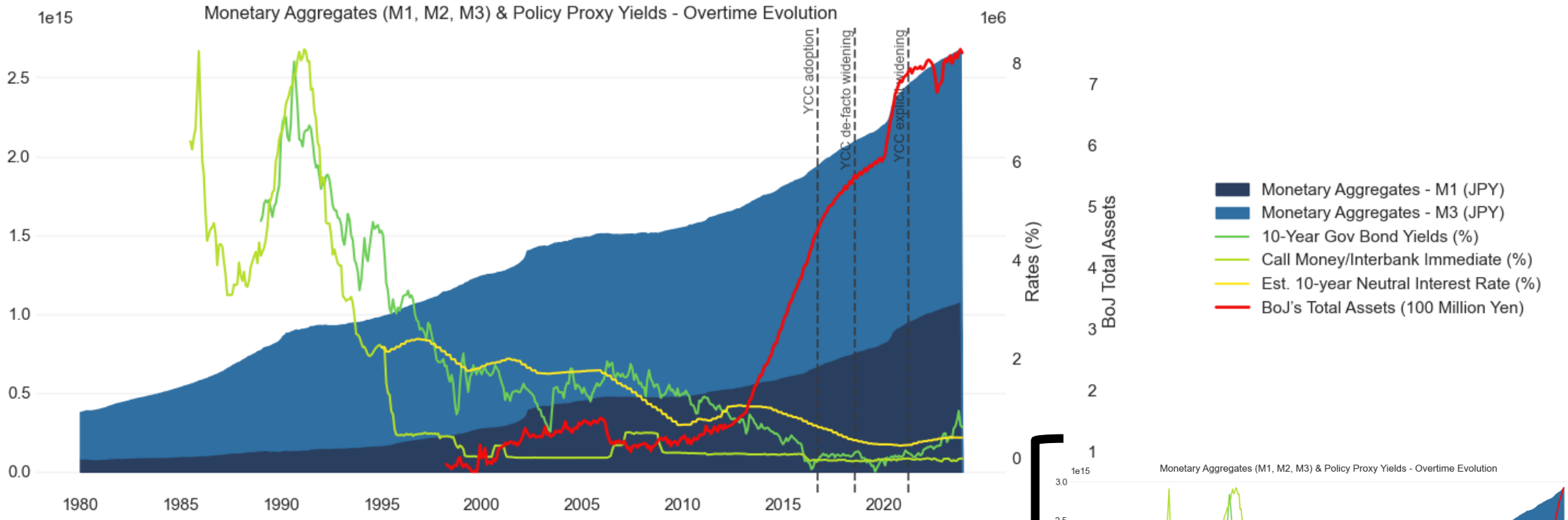
Under YCC, falling and stabilized yields coincide with **rising government credit** but muted private-sector credit expansion. It is worth noticing that this divergence may lead to conclude that yield compression primarily facilitates **public-sector borrowing**, while **private credit demand** and **transmission** remain subdued, pointing to an asymmetric credit channel under the YCC regime.

JOINT PLOTS OF OVERTIME EVOLUTION

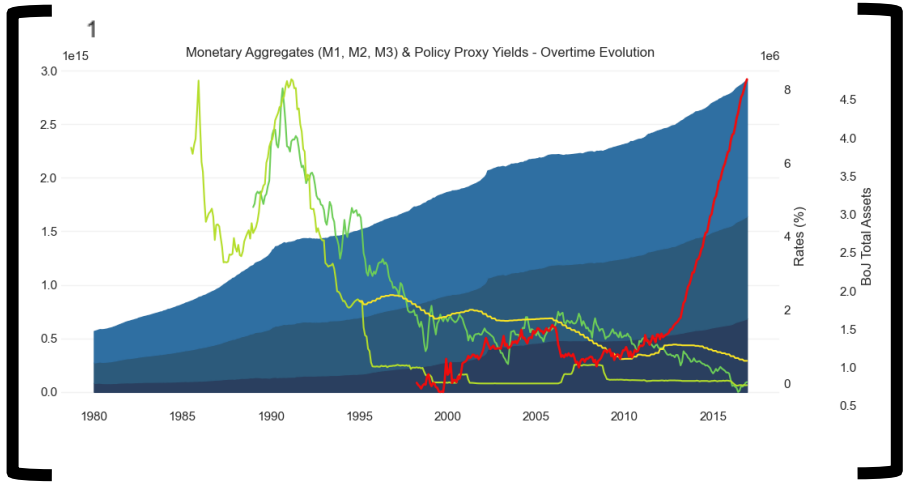


Public debt rises steadily and is increasingly held in the form of **domestic public debt securities**, while private debt remains broadly contained, and at the introduction of the YCC, short- and long-term rates become effectively anchored, despite, however, **persistent debt accumulation**. From this pattern we deduce that YCC alters the debt-rate relationship by decoupling government financing costs from debt dynamics, allowing **higher public debt levels** to be sustained under a tightly managed yield environment.

JOINT PLOTS OF OVERTIME EVOLUTION



The **expansion of monetary aggregates** and the BoJ balance sheet intensifies following **YCC adoption**, while policy and market rates compress toward the lower bound (**0 bound**), which is coherent with the shift we observe from rate-based to balance-sheet-based monetary policy transmission.



AUTOCORRELATION COEFFICIENTS AR(1)

From the AR(1) test summary we note that most variables, particularly monetary aggregates, credit measures, and real GDP, exhibit coefficients above 0.99, indicating highly persistent or near-unit-root behaviour. Financial variables such as bond yields, call money rates, and exchange rates show slightly lower but still high coefficients (around 0.93–0.98). The reason of such high degrees of autocorrelation might be found in the fact that Japan's macro-financial variables **evolve slowly over time**, with strong path dependence and limited short-run volatility, as it happens typically in developed, **low-inflation economies under extended accommodative monetary policy.**

Series	AR(1)
Monetary Aggregates - M1 (JPY)	0.999 652 075 933 588 2
Monetary Aggregates - M2 (JPY)	0.999 928 545 931 436 5
Monetary Aggregates - M3 (JPY)	0.999 880 832 684 501 5
Total Credit - Private Non-Financial (%GDP)	0.996 947 922 043 862 3
Total Credit - General Government (%GDP)	0.998 993 930 014 430 4
Total Credit - Households & NPISHs (%GDP)	0.996 775 746 108 487 2
Total Treasury Reserves (- Gold)	0.999 309 923 407 074 1
10-Year Gov Bond Yields (%)	0.972 351 693 054 378 2
Call Money/Interbank Immediate (%)	0.979 436 997 975 610 1
Est. 1-year Neutral Interest Rate (%)	0.998 564 223 556 686 0
Est. 10-year Neutral Interest Rate (%)	0.998 338 685 437 727 4
USD-JPY reer CPI-based (Index 2015=100)	0.987 458 544 766 510 8
JPY-USD Spot Exchange Rate	0.981 407 049 410 759 8
HICP (NSA)	0.974 266 434 558 893 2
Real GDP (billions chained 2015 JPY)	0.991 435 329 396 725 7
Central Government Debt (% GDP)	0.998 133 328 338 786 3
Domestic Private Debt Securities (% GDP)	0.980 880 843 072 420 8
Domestic Public Debt Securities (% GDP)	0.993 757 208 647 266 1
BoJ's Total Assets (100 Million Yen)	0.998 230 767 383 182 3
10-Year US T-Bills Yield (%)	0.985 768 589 475 486 4
CBOE-VIX	0.879 406 880 972 562 9

UNIT-ROOT TESTING
ADFULLER Test

Out of the 12 macro-financial variables, only **HICP (NSA) – Japan** appear to be stationary (5% confidence level), while the remaining eleven exhibit non-stationary behaviour with the potential presence of a unit root. The series of high AR(1) coefficients, the majority exceeding 0.93, and large p-values failing to reject the null hypothesis, lead to the assume the absence of stationarity. The persistence observed across variables such as monetary aggregates, credit aggregates, and interest rates indicates strong temporal dependence and slow mean reversion dynamics.

Variable	AR(1)	ADF Statistic	p-value	Stationary
Monetary Aggregates - M1 (JPY)	0.999 652 075 933 588 2	3.117 286 140 354 423 0	1.000 000 000 000 000 0	No
Monetary Aggregates - M2 (JPY)	0.999 928 545 931 436 5	3.305 054 911 373 038 5	1.000 000 000 000 000 0	No
Monetary Aggregates - M3 (JPY)	0.999 880 832 684 501 5	2.149 086 366 352 039 0	0.998 837 931 061 396 0	No
Total Credit - Private Non-Financial (%GDP)	0.996 947 922 043 862 3	−3.192 805 084 517 362 3	0.020 404 944 830 173 3	Yes
Total Credit - General Government (%GDP)	0.998 993 930 014 430 4	−0.577 265 246 772 323 6	0.876 036 845 873 562 6	No
Total Credit - Households & NPISHs (%GDP)	0.996 775 746 108 487 2	−1.360 899 601 774 618 4	0.600 871 263 084 541 3	No
Total Treasury Reserves (- Gold)	0.999 309 923 407 074 1	−1.874 189 393 090 866 6	0.344 298 929 510 238 3	No
10-Year Gov Bond Yields (%)	0.972 351 693 054 378 2	−0.569 896 703 491 348 4	0.877 640 097 160 985 6	No
Call Money/Interbank Immediate (%)	0.979 436 997 975 610 1	−2.879 303 429 940 336 0	0.047 808 204 230 074 2	Yes
Est. 1-year Neutral Interest Rate (%)	0.998 564 223 556 686 0	−0.844 657 620 464 449 7	0.805 651 121 247 658 5	No
Est. 10-year Neutral Interest Rate (%)	0.998 338 685 437 727 4	−1.030 354 615 305 180 6	0.742 032 813 580 144 0	No
USD-JPY reer CPI-based (Index 2015=100)	0.987 458 544 766 510 8	−1.682 819 455 104 376 0	0.439 985 439 162 005 7	No
JPY-USD Spot Exchange Rate	0.981 407 049 410 759 8	−2.325 773 247 054 351 0	0.163 790 257 142 598 8	No
HICP (NSA)	0.974 266 434 558 893 2	−2.521 680 486 189 486 0	0.110 287 944 458 925 5	No
Real GDP (billions chained 2015 JPY)	0.991 435 329 396 725 7	−1.173 264 501 320 503 4	0.684 989 638 793 812 6	No
Central Government Debt (% GDP)	0.998 133 328 338 786 3	−1.013 853 958 844 214 0	0.748 177 910 507 935 6	No
Domestic Private Debt Securities (% GDP)	0.980 880 843 072 420 8	−1.376 770 954 563 675 3	0.593 360 371 200 060 8	No
Domestic Public Debt Securities (% GDP)	0.993 757 208 647 266 1	−1.169 644 718 625 212 0	0.686 515 624 997 281 8	No
BoJ's Total Assets (100 Million Yen)	0.998 230 767 383 182 3	0.263 173 528 169 470 5	0.975 590 370 460 869 2	No
10-Year US T-Bills Yield (%)	0.985 768 589 475 486 4	−1.508 710 317 506 401 4	0.529 198 153 151 328 8	No
CBOE-VIX	0.879 406 880 972 562 9	−3.447 138 242 294 566 0	0.009 453 127 842 882 7	Yes

Table 1: AR(1), ADF statistics, p-values, and stationarity results

UNIT-ROOT TESTING
Phillips-Perron Test

The Phillips-Perron (PP) test results confirm the findings from the Augmented DickeyFuller (ADF) test, showing that nearly all variables remain **non-stationary**. Compared to ADF, here none of the twelve series reject the null hypothesis of a unit root, as all p-values are well above 0.05. Even variables close to the threshold in the ADF test, such as **Total Credit – Private Non-Financial**, fail to reach significance under the PP specification. This reinforces the evidence of strong persistence and shared stochastic trends across Japan's monetary, credit, and real-sector indicators and corroborates the need for variable transformations.

Variable	PP Statistic	p-value	Stationary
Monetary Aggregates - M1 (JPY)	4.307 841 720 665 766 0	1.000 000 000 000 000 0	No
Monetary Aggregates - M2 (JPY)	12.177 730 937 058 532 0	1.000 000 000 000 000 0	No
Monetary Aggregates - M3 (JPY)	6.908 405 754 936 050 0	1.000 000 000 000 000 0	No
Total Credit - Private Non-Financial (%GDP)	−2.943 800 868 272 618 7	0.040 486 511 947 893 9	Yes
Total Credit - General Government (%GDP)	−0.995 610 996 103 472 1	0.754 861 721 496 778 3	No
Total Credit - Households & NPISHs (%GDP)	−1.213 292 838 133 352 5	0.667 851 488 507 546 4	No
Total Treasury Reserves (- Gold)	−1.826 515 343 627 227 5	0.367 379 269 748 613 0	No
10-Year Gov Bond Yields (%)	−1.095 042 541 959 175 0	0.717 044 827 544 698 1	No
Call Money/Interbank Immediate (%)	−2.817 121 639 358 980 0	0.055 869 378 496 365 4	No
Est. 1-year Neutral Interest Rate (%)	−0.617 291 673 636 796 8	0.867 026 752 489 751 9	No
Est. 10-year Neutral Interest Rate (%)	−0.785 981 948 285 380 4	0.823 205 124 595 734 4	No
USD-JPY reer CPI-based (Index 2015=100)	−1.177 173 927 624 208 0	0.683 337 041 442 736 3	No
JPY-USD Spot Exchange Rate	−2.188 564 440 905 504 5	0.210 422 054 122 470 7	No
HICP (NSA)	−1.921 281 383 224 749 7	0.322 116 849 974 943 7	No
Real GDP (billions chained 2015 JPY)	−0.973 277 857 772 920 9	0.762 885 409 603 963 0	No
Central Government Debt (% GDP)	−1.199 153 646 769 970 4	0.673 959 685 709 936 5	No
Domestic Private Debt Securities (% GDP)	−1.507 516 785 338 708 0	0.529 789 669 632 439 6	No
Domestic Public Debt Securities (% GDP)	−1.121 446 324 413 878 4	0.706 444 028 536 542 2	No
BoJ's Total Assets (100 Million Yen)	5.245 876 224 701 488 0	1.000 000 000 000 000 0	No
10-Year US T-Bills Yield (%)	−1.440 302 312 224 741 0	0.562 809 552 306 307 9	No
CBOE-VIX	−3.593 314 653 465 371 0	0.005 890 130 997 301 7	Yes

Table 1: Phillips–Perron (PP) test results, p-values, and stationarity flag by variable

STATIONARITY CORRECTIONS
Log-Difference Transformations

Basically we need a detrending transformation for all the variables as expected, given the undisputable presence of unit-root root and so non-stationarity. Autocorrelation is also evident, suggesting a marked time-dependent component, and so a trend, so we'll opt for both log transformations as well as first differences

Transformations:

- Monetary Aggregates: I(1) nominal levels (levels non-stationary, but first-differences are I(0), stationary)
- Reserves: I(1), level series of policy shocks
- Exchange Rate: Log-difference (returns)
- Consumption Prices: Log-difference (inflation)
- BoJ's Total Assets: CA smoothing

$$\Delta \log(X_t) = \log(X_t) - \log(X_{t-1})$$

$$X_t \sim I(1) \quad \Rightarrow \quad \Delta \log(X_t) \sim I(0)$$

STATIONARITY CORRECTIONS

AR(1) Detrending

Now here instead we want to remove persistence while preserving medium-term cyclical dynamics. We avoid first differences for **credit variables**, as they are overly aggressive and tend to destroy medium-term cyclical information, reducing the signal-to-noise ratio. Credit variables are typically highly persistent and near-unit-root stationary: while they may appear non-stationary in levels, they are slowly mean-reverting. AR(1) detrending preserves cyclical dynamics while removing mechanical persistence.

$$X_t = \alpha + \rho X_{t-1} + \varepsilon_t$$

$$\widetilde{X}_t = X_t - (\alpha + \rho X_{t-1}) = \varepsilon_t$$

$$X_t \sim \text{persistent / near-unit-root} \quad \Rightarrow \quad \widetilde{X}_t \sim I(0)$$

The same AR(1) detrending approach is applied to **monetary policy proxies**, which exhibit persistence but are not genuinely I(1), and to **debt metrics**, as well as for some **global controls**, such as VIX and US 10-Year T-Bills Yields.

STATIONARITY CORRECTIONS
Hodrick–Prescott Filter

Last, with the HP filter, we want to separate trend and cyclical components of real economic activity. And this is the case for **Real GDP dynamics**:

$$\log(Y_t) = \tau_t + c_t$$

$$\min_{\{\tau_t\}} \sum_t (\log Y_t - \tau_t)^2 \; + \; \lambda \sum_t (\Delta^2 \tau_t)^2$$

$$\lambda = 1600$$

$$c_t^{GDP} = HP\text{-cycle}\left(\log(\text{Real GDP}_t)\right)$$

The cyclical component captures medium-term fluctuations in economic activity around potential output, abstracting from long-run growth and low-frequency movements. We set the smoothing parameter to 1600, as it is the conventional choice for quarterly/monthly macroeconomic data (GDP is extended to monthly frequency but it is imported in quarterly data raw), for comparability with standard business-cycle analyses.

TRANSFORMED VARS – RE-TESTING

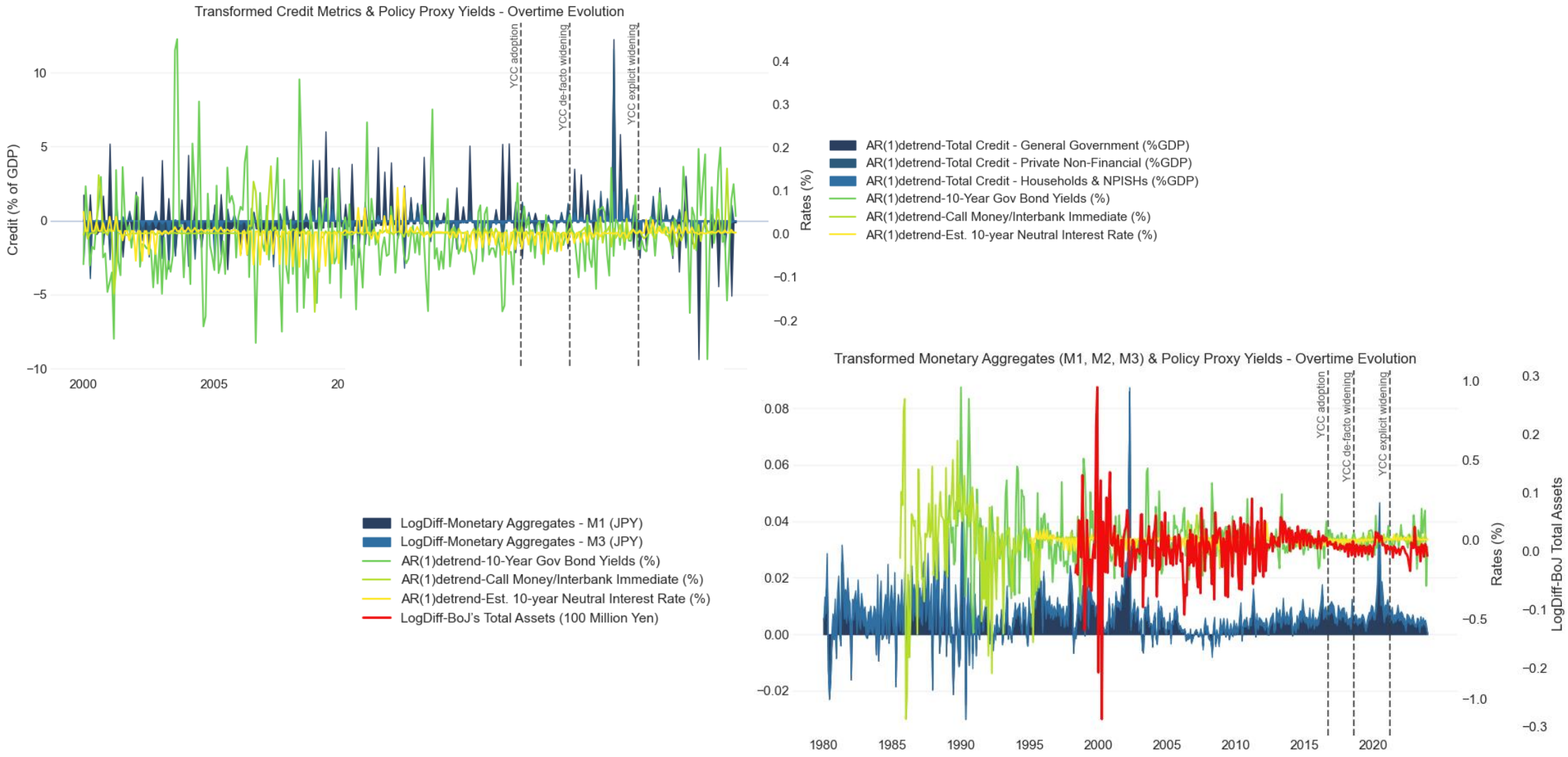
Variable	AR(1)	ADF Statistic	p-value	Stationary
LogDiff-Monetary Aggregates - M1 (JPY)	0.501 148 780 075 075 4	−4.115 769 383 211 295 0	0.000 912 000 249 426 8	Yes
LogDiff-Monetary Aggregates - M2 (JPY)	0.145 686 917 948 031 1	−3.560 424 608 750 540 0	0.006 563 902 615 522 9	Yes
LogDiff-Monetary Aggregates - M3 (JPY)	0.436 827 389 892 173 3	−2.566 713 576 133 240 0	0.100 699 906 897 349 0	No
LogDiff-Total Treasury Reserves (- Gold)	0.285 307 819 784 613 1	−3.105 381 465 374 654 0	0.026 157 490 780 971 0	Yes
LogDiff-USD-JPY reer CPI-based (Index 2015=100)	0.280 190 671 513 562 3	−1.198 618 223 714 567 0	0.272 329 451 750 686 0	No
LogDiff-JPY-USD Spot Exchange Rate	0.276 983 954 910 708 3	−11.253 497 676 279 500 0	1.689 229 146 356 424 0	Yes
LogDiff-HICP (NSA)	0.221 840 831 081 120 9	−2.804 428 053 987 980 0	0.057 644 030 831 734 5	No
LogDiff-BoJ's Total Assets (100 Million Yen)	−0.106 853 225 294 313 4	−2.337 405 261 492 757 0	0.160 187 592 105 568 3	No
AR(1)detrend-Total Credit - General Government (%GDP)	−0.107 351 930 527 895 4	−2.681 102 675 052 324 0	0.070 735 684 203 144 2	No
AR(1)detrend-Total Credit - Households & NPISHs (%GDP)	−0.020 726 435 568 634 6	−5.601 803 742 410 476 0	1.221 035 995 772 990 0	Yes
AR(1)detrend-Total Credit - Private Non-Financial (%GDP)	−0.050 671 869 750 416 5	−6.362 846 490 546 280 0	2.450 529 665 936 170 0	Yes
AR(1)detrend-10-Year Gov Bond Yields (%)	0.220 920 121 921 964 1	−9.907 063 721 661 940 0	3.242 351 926 194 520 0	Yes
AR(1)detrend-Call Money/Interbank Immediate (%)	0.457 391 746 757 935 7	−9.113 806 316 532 270 0	3.343 074 073 501 436 0	Yes
AR(1)detrend-Est. 1-year Neutral Interest Rate (%)	−0.069 039 960 449 427 0	−2.034 651 553 528 350 0	0.271 589 415 036 826 4	No
AR(1)detrend-Est. 10-year Neutral Interest Rate (%)	−0.057 052 068 474 823 9	−2.033 017 403 831 670 0	0.272 286 330 769 744 6	No
AR(1)detrend-Central Government Debt (%GDP)	−0.052 412 203 548 926 3	−2.874 613 781 775 420 0	0.048 387 063 995 191 0	Yes
AR(1)detrend-Domestic Private Debt Securities (%GDP)	0.016 755 483 193 565 7	−14.648 472 815 572 360 0	3.115 845 019 296 153 0	Yes
AR(1)detrend-Domestic Public Debt Securities (%GDP)	−0.012 818 415 853 741 2	−15.127 750 842 210 600 0	7.317 524 186 892 630 0	Yes
AR(1)detrend-10-Year US T-Bills Yield (%)	0.193 723 076 016 503 7	−10.674 208 661 685 450 0	4.093 340 075 998 061 0	Yes
AR(1)detrend-CBOE-VIX	0.212 138 264 208 581 7	−11.317 159 733 612 000 0	1.199 027 309 351 724 0	Yes
HPfilter-Real GDP (billions chained 2015 JPY)	0.782 128 534 487 075 3	−5.656 437 189 586 576 0	9.597 026 738 804 120 0	Yes

Table 1: AR(1) coefficients and Augmented Dickey–Fuller test results for transformed series

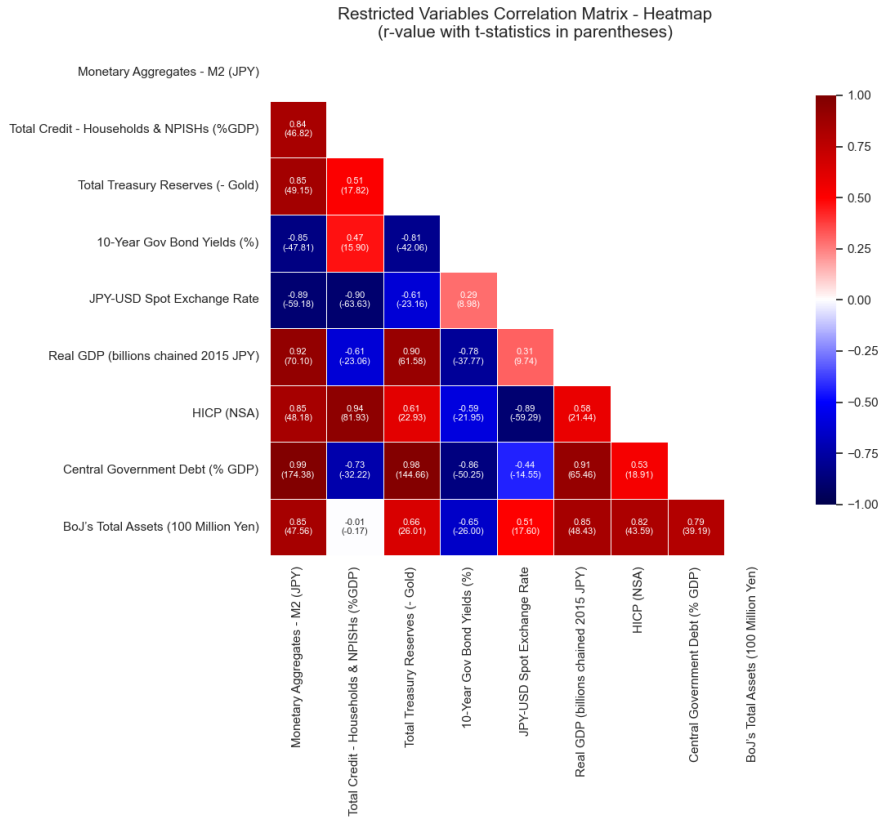
Variable	PP Statistic	p-value	Stationary
LogDiff-Monetary Aggregates - M1 (JPY)	−10.297 478 223 568 850 0	3.440 941 676 301 480 0	Yes
LogDiff-Monetary Aggregates - M2 (JPY)	−14.515 998 816 425 200 0	5.625 586 184 645 620 0	Yes
LogDiff-Monetary Aggregates - M3 (JPY)	−12.271 784 581 607 700 0	8.286 240 348 222 920 0	Yes
LogDiff-Total Treasury Reserves (- Gold)	−12.993 841 312 915 800 0	5.860 435 343 406 420 0	Yes
LogDiff-USD-JPY reer CPI-based (Index 2015=100)	−11.004 297 963 000 700 0	6.704 013 045 129 010 0	Yes
LogDiff-JPY-USD Spot Exchange Rate	−11.252 805 041 222 000 0	1.695 360 457 901 520 0	Yes
LogDiff-HICP (NSA)	−11.651 993 987 472 000 0	2.026 901 587 346 910 0	Yes
LogDiff-BoJ's Total Assets (100 Million Yen)	−16.444 526 744 092 700 0	1.241 181 486 428 260 0	Yes
AR(1)detrend-Total Credit - General Government (%GDP)	−16.711 860 799 234 200 0	1.541 741 867 637 220 0	Yes
AR(1)detrend-Total Credit - Households & NPISHs (%GDP)	−15.731 897 271 633 600 0	1.286 771 802 219 970 0	Yes
AR(1)detrend-Total Credit - Private Non-Financial (%GDP)	−15.899 860 371 597 700 0	8.353 224 078 200 160 0	Yes
AR(1)detrend-10-Year Gov Bond Yields (%)	−12.172 028 438 861 900 0	1.418 612 167 059 880 0	Yes
AR(1)detrend-Call Money/Interbank Immediate (%)	−9.037 790 748 361 300 0	5.231 997 472 105 140 0	Yes
AR(1)detrend-Est. 1-year Neutral Interest Rate (%)	−18.452 633 380 816 900 0	2.152 663 712 158 130 0	Yes
AR(1)detrend-Est. 10-year Neutral Interest Rate (%)	−18.467 884 573 366 000 0	2.187 642 937 416 150 0	Yes
AR(1)detrend-Central Government Debt (%GDP)	−16.419 377 455 792 700 0	2.539 019 804 770 120 0	Yes
AR(1)detrend-Domestic Private Debt Securities (%GDP)	−14.802 569 153 293 800 0	2.388 623 892 102 860 0	Yes
AR(1)detrend-Domestic Public Debt Securities (%GDP)	−15.326 272 553 849 500 0	5.233 036 809 215 810 0	Yes
AR(1)detrend-10-Year US T-Bills Yield (%)	−12.940 054 327 477 000 0	2.623 492 937 129 320 0	Yes
AR(1)detrend-CBOE-VIX	−11.873 946 543 067 000 0	6.425 308 336 688 770 0	Yes
HPfilter-Real GDP (billions chained 2015 JPY)	−4.592 931 176 931 620 0	9.597 026 738 804 120 0	Yes

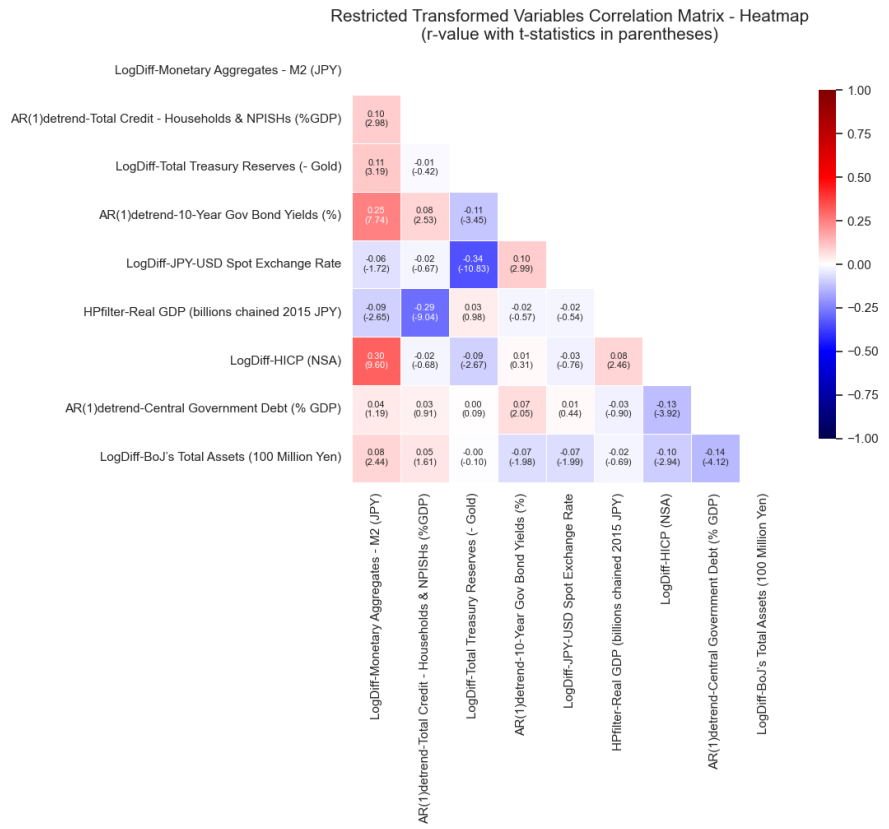
Table 1: Phillips–Perron test results for transformed macroeconomic series

TRANSFORMED VARS – PLOTTING



BIVARIATE CORRELATION





In **levels**, we observe strong and widespread co-movement across variables, which could attribute to by shared **stochastic trends**, **scale effects**, and **high persistence** rather than structural economic linkages. After applying **log-differencing**, **AR(1) detrending**, and **HP filtering**, the correlation structure weakens markedly and becomes more sparse. We can say that transformations effectively remove common trends and mechanical autocorrelation.

BASELINE VAR MODEL

For each estimation window, the following **VAR(p)** is estimated:

$$\mathbf{y}_t = \mathbf{A}_1 \mathbf{y}_{t-1} + \mathbf{A}_2 \mathbf{y}_{t-2} + \cdots + \mathbf{A}_p \mathbf{y}_{t-p} + \boldsymbol{\varepsilon}_t$$

with:

- $\mathbf{A}_i \in \mathbb{R}^{K \times K}$,
- $\boldsymbol{\varepsilon}_t \sim \mathcal{N}(0, \boldsymbol{\Sigma})$,
- $K = 2 + \dim(\mathbf{x}_t)$.

Endogenous Vector → $\mathbf{y}_t = \begin{pmatrix} m_t \\ c_t \\ \boldsymbol{z}_t \end{pmatrix}$ Control Vector → $\boldsymbol{z}_t = \begin{pmatrix} \pi_t \\ y_t \\ r_t^{\text{call}} \\ r_t^{10y} \\ e_t \\ b_t \\ \text{res}_t \end{pmatrix}$

MONEY

$$\boxed{m_t = \Delta \log\left(\text{M1}_t^{\text{JPY}}\right)}$$

CREDIT

$$\boxed{c_t = \varepsilon_t^{(c)}} \quad \text{with} \quad \varepsilon_t^{(c)} = c_t^{\text{raw}} - \hat{\phi} c_{t-1}^{\text{raw}}$$

$$c_t^{\text{raw}} = \text{Total Private Non-Financial Credit}_t \ (\% \text{ of GDP})$$

VAR ORDER SELECTION & FIT

	coefficient	std. error	t-stat	prob
const	0.002660	0.000436	6.097	0.000
L1.LogDiff-Monetary Aggregates - M1 (JPY)	0.489728	0.050800	9.640	0.000
L1.AR(1)detrend-Total Credit - Private Non-Financial (%GDP)	0.000097	0.000315	0.309	0.757
L1.LogDiff-HICP (NSA)	-0.116173	0.110972	-1.047	0.295
L1.HPfilter-Real GDP (billions chained 2015 JPY)	-0.074476	0.035894	-2.075	0.038
L1.AR(1)detrend-Call Money/Interbank Immediate (%)	-0.010465	0.012660	-0.827	0.408
L1.AR(1)detrend-10-Year Gov Bond Yields (%)	0.002786	0.003145	0.886	0.376
L1.LogDiff-JPY-USD Spot Exchange Rate	-0.012358	0.015043	-0.822	0.411
L1.LogDiff-BoJ's Total Assets (100 Million Yen)	0.001629	0.007799	0.209	0.835
L1.LogDiff-Total Treasury Reserves (- Gold)	-0.011721	0.020536	-0.571	0.568

Results for equation AR(1)detrend-Total Credit - Private Non-Financial (%GDP)

	coefficient	std. error	t-stat	prob
const	-0.132247	0.087812	-1.506	0.132
L1.LogDiff-Monetary Aggregates - M1 (JPY)	13.397391	10.224850	1.310	0.190
L1.AR(1)detrend-Total Credit - Private Non-Financial (%GDP)	-0.032516	0.063306	-0.514	0.608
L1.LogDiff-HICP (NSA)	-37.399507	22.336315	-1.674	0.094
L1.HPfilter-Real GDP (billions chained 2015 JPY)	-4.688288	7.224584	-0.649	0.516
L1.AR(1)detrend-Call Money/Interbank Immediate (%)	-0.061049	2.548211	-0.024	0.981
L1.AR(1)detrend-10-Year Gov Bond Yields (%)	0.385050	0.633040	0.608	0.543
L1.LogDiff-JPY-USD Spot Exchange Rate	-4.381618	3.027802	-1.447	0.148
L1.LogDiff-BoJ's Total Assets (100 Million Yen)	-2.264303	1.569816	-1.442	0.149
L1.LogDiff-Total Treasury Reserves (- Gold)	-8.599943	4.133371	-2.081	0.037

	AIC	BIC	FPE	HQIC
0	-64.68	-64.57	8.125e-29	-64.64
1	-66.11*	-64.98*	1.949e-29*	-65.66*
2	-65.95	-63.81	2.286e-29	-65.09
3	-66.03	-62.88	2.121e-29	-64.77
4	-65.91	-61.75	2.393e-29	-64.25
5	-65.86	-60.69	2.545e-29	-63.79
6	-65.71	-59.52	3.020e-29	-63.23
7	-65.63	-58.43	3.334e-29	-62.75
8	-65.64	-57.42	3.435e-29	-62.35
9	-65.51	-56.28	4.074e-29	-61.81
10	-65.40	-55.16	4.791e-29	-61.30
11	-65.23	-53.98	6.018e-29	-60.73
12	-65.40	-53.14	5.506e-29	-60.49

Selected lags - AIC : 1
Selected lags - BIC : 1
Selected lags - HQIC: 1
Using p = 1

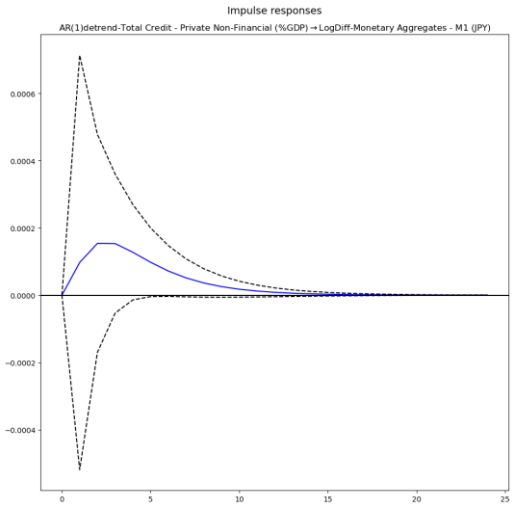
Eigenvalues of VAR(1) rep
0.6877880273498864
0.5238537497958115
0.4443682840911205
0.3779016701217786
0.22339075259235394
0.12881447017654102
0.10115502562340381
0.08319244770030643
0.043601038732037786

IRFs & GRANGER CAUSALITY

Test statistic	Critical value	p-value	df
0.095 57	3.841 00	0.757 00	1.000 00

Table 1: Walt-Test Results

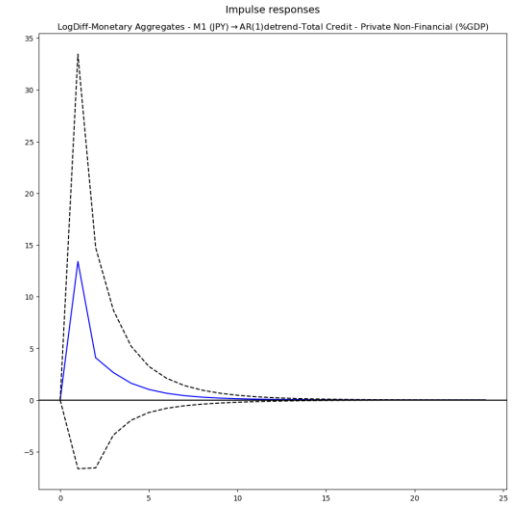
AR(1)detrend-Total Credit - Private Non-Financial (%GDP) on LogDiff-Monetary Aggregates - M1 (JPY)



Test statistic	Critical value	p-value	df
1.717	3.841	0.190	1.000

Table 1: Walt-test Results

LogDiff-Monetary Aggregates - M1 (JPY) on AR(1)detrend-Total Credit - Private Non-Financial (%GDP)



The Granger causality tests indicate no statistically significant predictive relationship between money and credit in **either direction**. Specifically, we fail to reject the null hypothesis that private non-financial credit does not Granger-cause M1, and likewise fail to reject the null that M1 does not Granger-cause private credit at the 5% significance level.

ROLLING WINDOW VAR MODEL

That idea behind is that we assume the endogenous vector *y* to be **not globally time-invariant**, but instead follows a **locally stationary VAR.** For each rolling window $\mathcal{W}_\tau$,estimate a VAR(p):

$$\mathbf{y}_t = \sum^{p} \mathbf{A}_i \mathbf{y}_{t-i} + \boldsymbol{\varepsilon}_t$$

$$\begin{pmatrix} m_t \\ c_t \\ \boldsymbol{z}_t \end{pmatrix} = \sum_{i=1}^{p} \begin{pmatrix} A_{mm}^{(i)} & A_{mc}^{(i)} & A_{mz}^{(i)} \\ A_{cm}^{(i)} & A_{cc}^{(i)} & A_{cz}^{(i)} \\ A_{zm}^{(i)} & A_{zc}^{(i)} & A_{zz}^{(i)} \end{pmatrix} \begin{pmatrix} m_{t-i} \\ c_{t-i} \\ \boldsymbol{z}_{t-i} \end{pmatrix} + \boldsymbol{\varepsilon}_t$$

So, we fix a window length L (in our case 120 months). For each terminal date τ, we define the estimation window:

$$\boxed{\mathcal{W}_\tau = \{ t \mid \tau - L + 1 \leq t \leq \tau \}}$$

$$\mathbf{A}_i(t) \approx \mathbf{A}_i^{(\tau)} \quad \forall t \in \mathcal{W}_\tau \longrightarrow$$

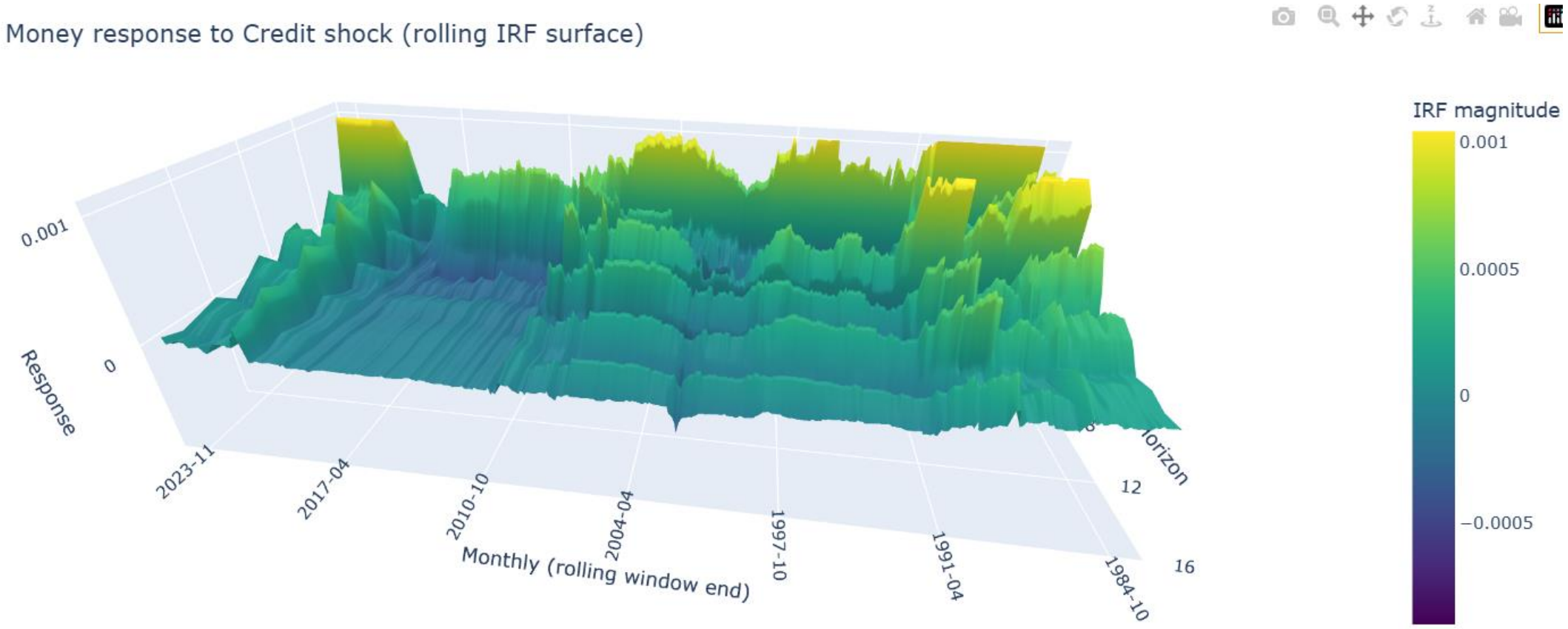
Locally constant coefficients, within the window

$$\mathcal{A}^{(\tau)} = \begin{pmatrix} \mathbf{A}_1^{(\tau)} & \cdots & \mathbf{A}_p^{(\tau)} \\ \mathbf{I} & \cdots & \mathbf{0} \end{pmatrix} \qquad \boxed{\max \left| \lambda\left(\mathcal{A}^{(\tau)}\right) \right| < 1 \quad \forall \tau} \longleftarrow$$

ROLLING STABILITY CONDITION

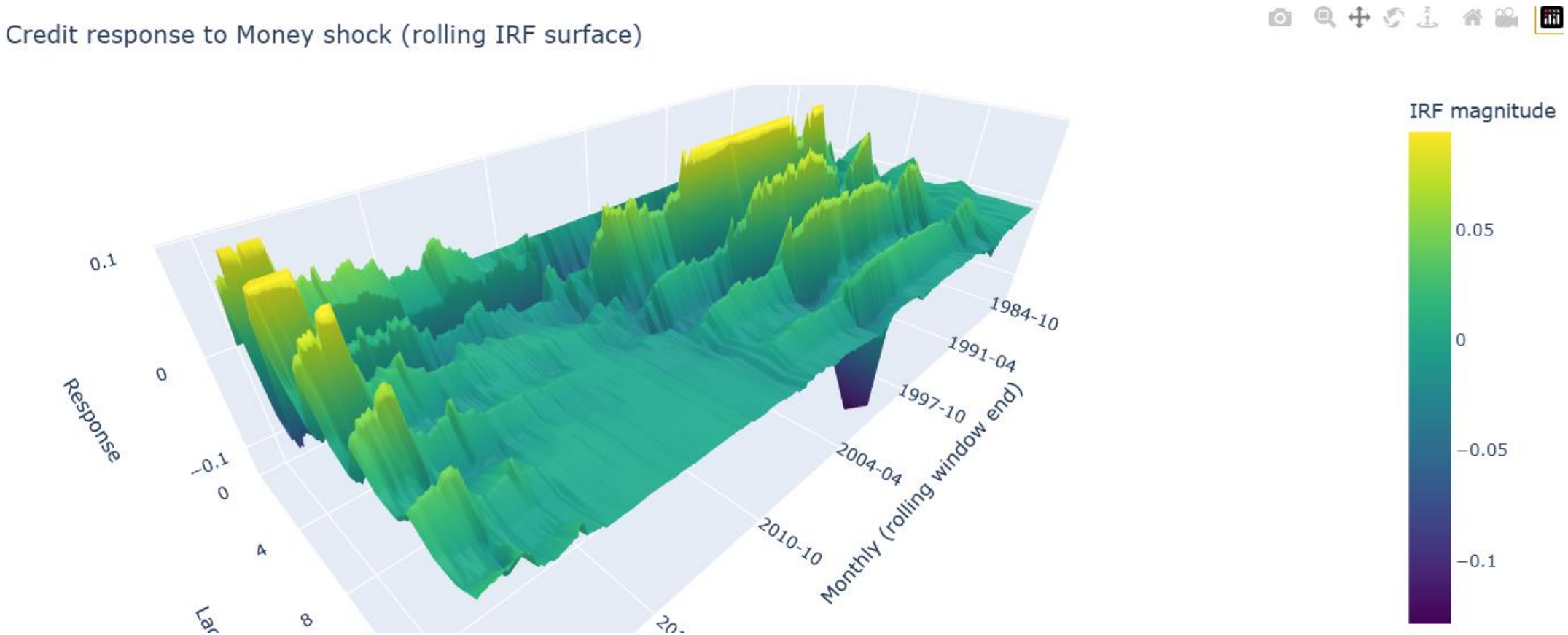
ROLLING WINDOW VAR MODEL

Money Response to Credit Shock



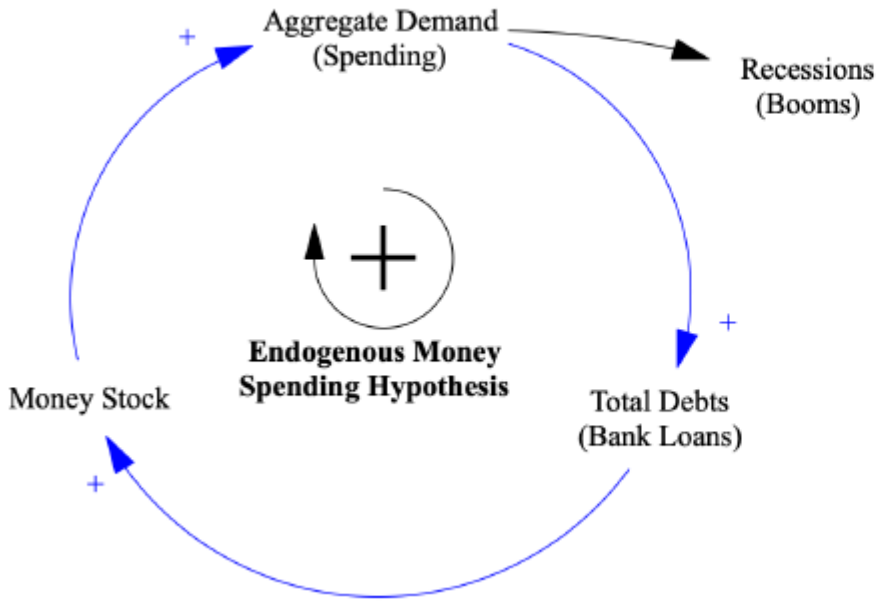
ROLLING WINDOW VAR MODEL

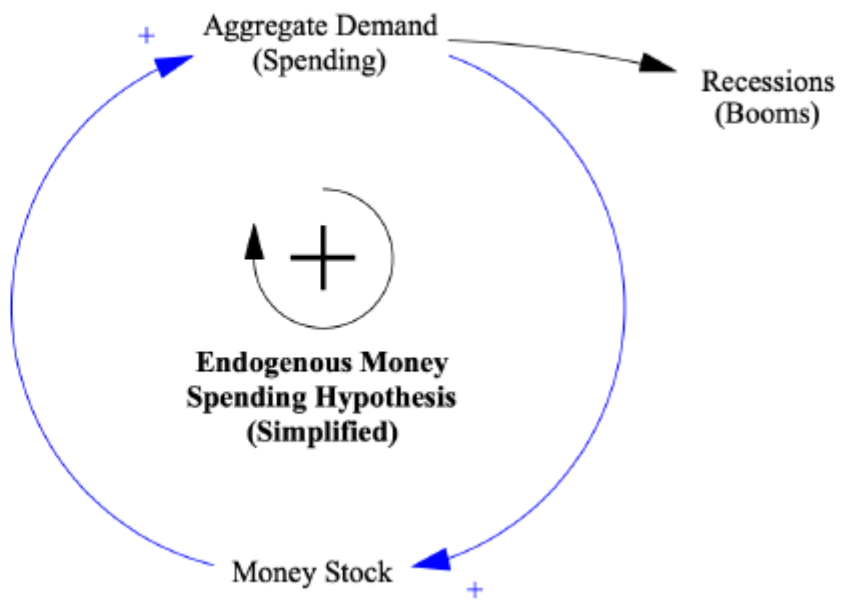
Credit Response to Money Shock



ENDOGENOUS MONEY IS-LM

The core idea behind is to demonstrate that **recessions** are not caused by IS *or* LM shifts, but by **endogenous contraction of bank-created money** through debt repayment, transmitted via deflation and real interest rates.





ENDOGENOUS MONEY IS-LM

STANDARD IS-LM → **DYNAMIC IS-LM** → **FLEXIBLE PRICE IS-LM**

→ **ENDOGENOUS MONEY IS-LM**

In this set up we require price and inflation dynamics (**to close Fisher loop**):

$$\frac{dP}{dt} = \frac{P^* - P}{\tau_P} \quad \text{with} \quad P^* = P\left(\frac{Inv}{Inv^*}\right)^{\varepsilon_P}$$

→ Inflation:

$$\pi = \frac{d\ln P}{dt}$$

→ Adaptive Expected Inflation:

$$\frac{d\pi^e}{dt} = \frac{\pi - \pi^e}{\tau_\pi}$$

→ Endogenous Money Block:

$$M \equiv D$$

$$\begin{cases} Y = C(Y-T) + I(r) + G \\ r = i - \pi^e \\ \dot{M} = L_{new}(Y,r) - Repay(Y,r) - Default(Y) \\ \frac{M}{P} = L^d(Y,i)/V \\ \dot{P} = g(Inv - Inv^*) \\ \dot{\pi}^e = \pi - \pi^e \end{cases}$$

→ Net Money Dynamics:

$$\frac{dM}{dt} = L_{new} - Repay - Default$$

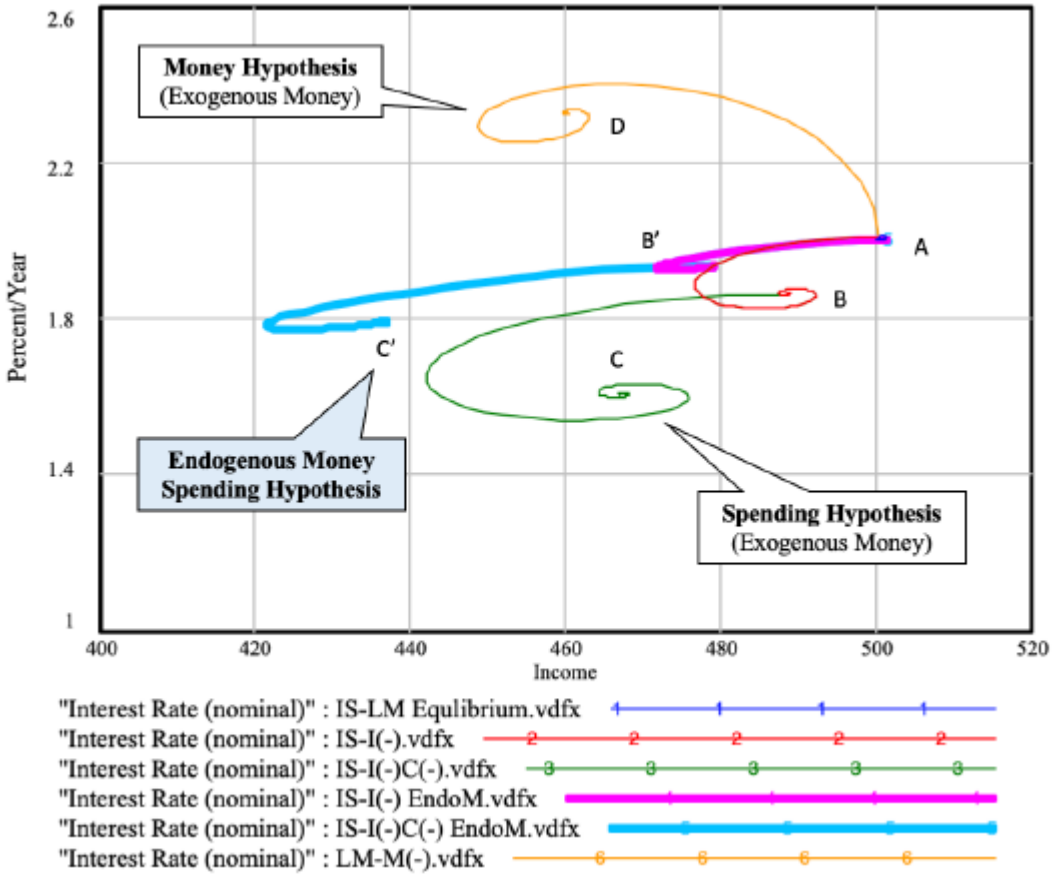
REPLACING

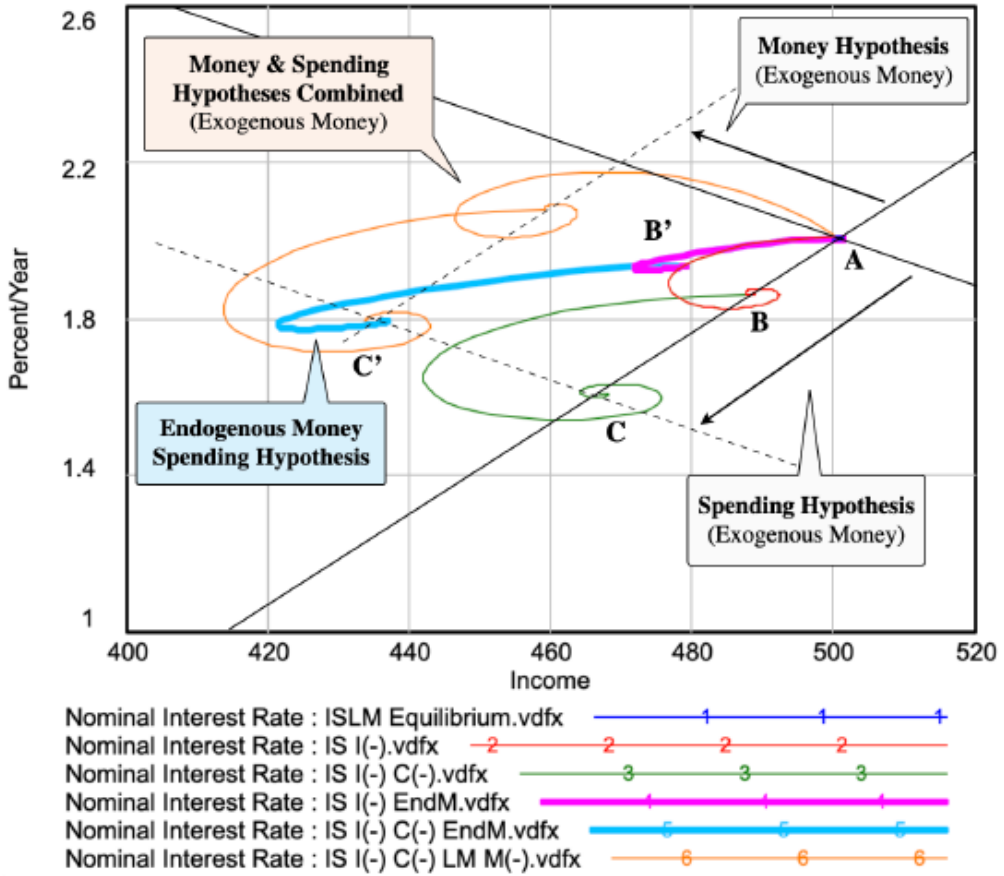
$$M = \bar{M} \quad \text{(exogenous money)}$$

→ Money Market (now endogenous):

$$i^* = i\left(\frac{L^d}{M/P \cdot V}\right)^{\varepsilon_i}$$

HYPOTHETICAL EXPECTED BEHAVIOUR





Source: Yamaguchi et al. (2022)