Quantitative Easing and Local Banking Systems in the Euro Area

Riksbank Conference

September 1, 2022

Motivation

- Asset Purchases: key ECB monetary policy tool in recent years
  - Purchasing of assets, financed by issuing new safe assets: reserves
- Direct effect on balance sheet of Euro Area banking sector
  - Changes composition of bank assets held (new reserves)
- **This Paper**: Quantitative impact of asset purchases on real economy through *liquidity services* offered by banks
  - Liquidity Services: bank deposits valuable for liquidity
  - Source of heterogeneity: segmented deposit markets?

Message

Role of Banking

- supplies money $\equiv$ deposits
- uses money raised to buy assets to back deposits
    - safer and more liquid assets $\rightarrow$ more deposits supplied

Euro Area Bank Balance Sheets

- Deposit sector fragmented across countries
- Asset held by banks in more integrated Euro Area capital markets

Quantitative Easing has powerful, harmonized effect across union

- scarcity of deposit supply matters for consumption
- QE raises supply of union-wide collateral to back deposits
- Integrated bank collateral market (via reserves) implies pass-through is broadly harmonised across countries
- Agg. effects bolstered by less responsive Taylor rule in recent years

Preview of Results

Stylized Facts of Country-Level Banking Structure in Euro Area

- Bank assets and liabilities: foreign vs. domestic

Introduce two-region New-Keynesian model with banks

- Households attach convenience yield on bank deposits
- Bank deposit issuance limited by leverage constraint
  - backed by reserves, firm loans, other private collateral assets
- Bayesian estimation of parameters / structural shocks

Questions

- What impact did asset purchases have on output/inflation?
  - Do segmented deposit markets induce heterogeneous responses?
- What happens if QE coincided with less aggressive Taylor rule?

Related Literature

1. **ECB Asset Purchases within DSGE Framework** :
   Coenen-Karadi-Schmidt-Warne 18, Christoffel-Coenen-Warne 08, Andrade-Breckenfelder-De Fiore-Karadi-Tristani 18, De Fiore-Hoerova-Uhlig 19, Burlon-Geraali-Notarpietro-Pisani 16, Gertler-Karadi 13

2. **NK Models with Financial Frictions and Banking** :
   Bernanke-Gertler-Gilchrist (1999), Gertler-Karadi (2011), Christiano-Motto-Rostagno (2012), Diba-Loisel (2017), Bocola (2016), Wang (2018)

3. **Cost Channel and Interest Rates** :
   Christiano-Eichenbaum-Evans (2001), Ravenna-Walsh (2006)

4. **Convenience yield on assets that back medium of exchange** :
   Kiyotaki-Moore (2005), Williamson (2012), Piazzesi-Rogers-Schneider (2020), Lenel-Piazzesi-Schneider (2019)

Outline of Talk

1. Stylized facts of banking sector
2. Model Setup
   - Households
   - Banking sector
   - Firms
3. Model Estimation
   - Outline of Estimation Strategy
   - Calibrated and Estimated Parameters
   - Contribution of Structural Shocks
   - Counterfactual Exercises

Data Sources and Facts

Data Sources

1. Balance Sheet Indicators Database
   - monthly breakdown bank assets/liabilities at country level in EU
   - reported at individual institution (not banking group) level
   - assets/liabilities split by residency, counterparty

2. Bureau van Dyke (BvD) Orbis
   - detailed annual snapshots of customer deposits at bank level
   - ability to observe unconsolidated balance sheet data

Fact 1: Deposit market fragmented across countries

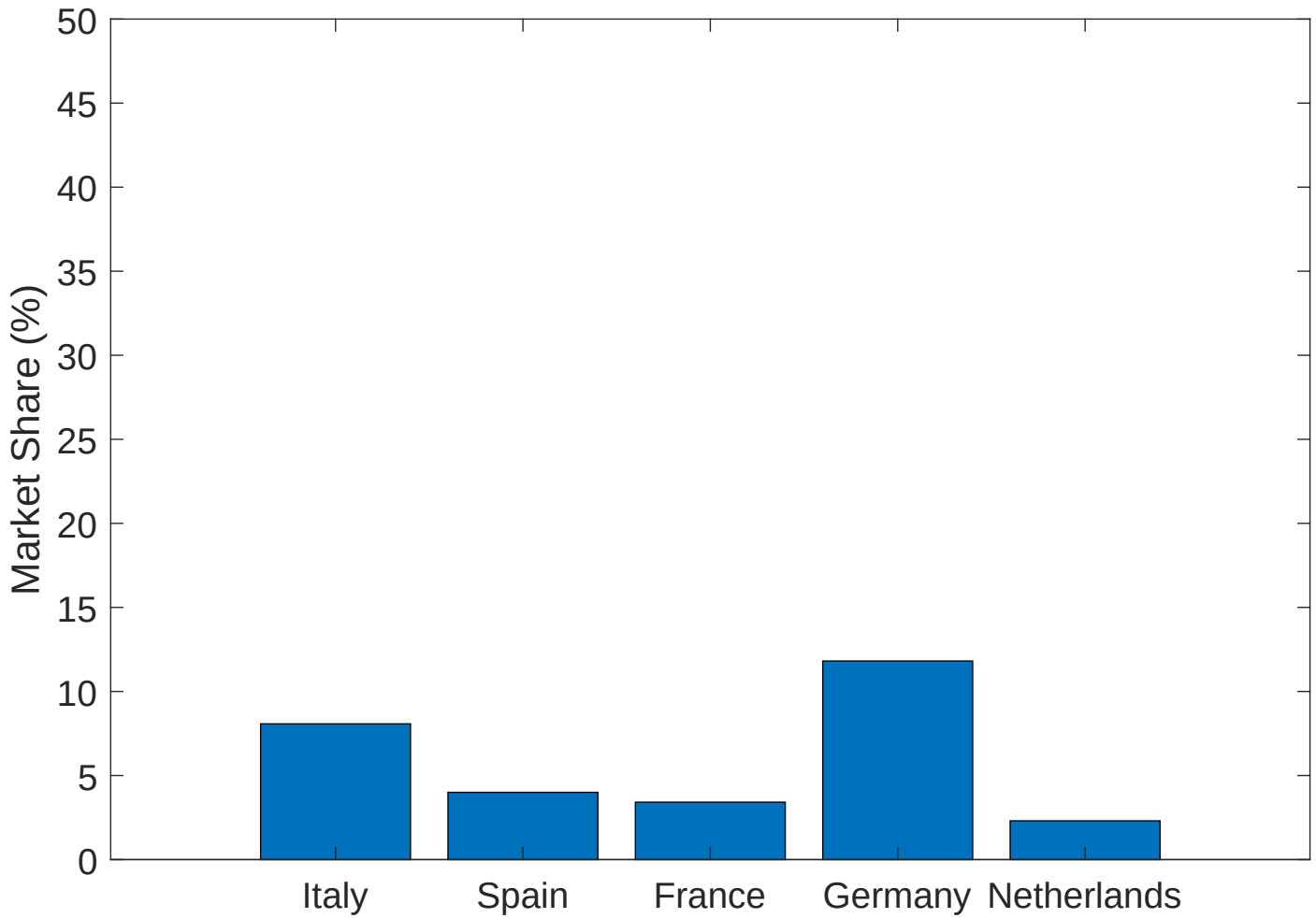


Figure 1: Customer Deposits: Foreign Bank Market Share, 2019 (Source: Orbis + BSI) Details

Fact 2: Assets backing deposits are more integrated

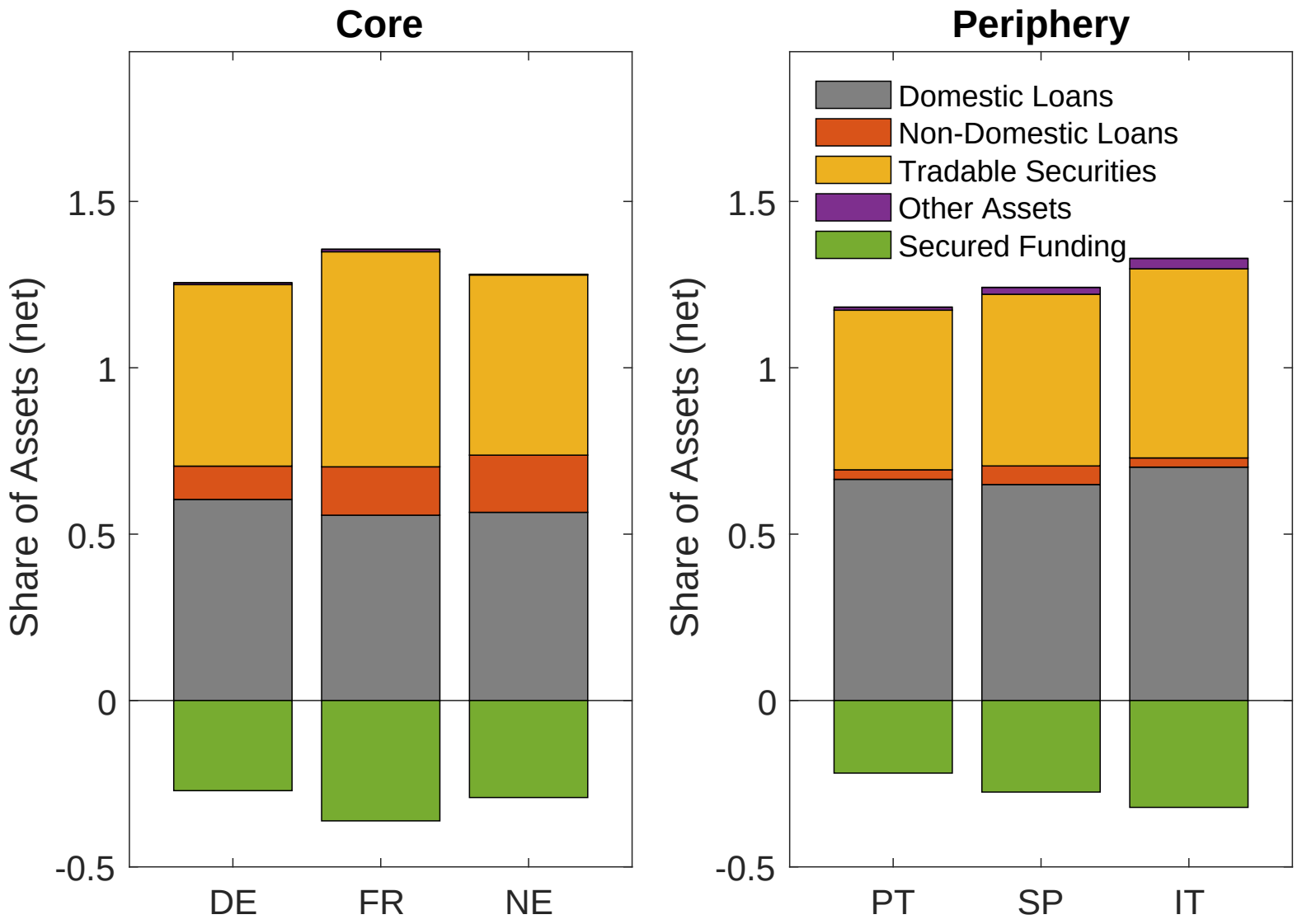


Figure 2: Composition of Assets Backing Deposits, 2019 (Source: BSI) Details

Model

Model: Setup + Household + Firm Sectors

Summary: Two-region (I, J) variant of New Keynesian Model

Representative Household Details

- Utility separable in labour + CES bundle of consumption + deposits

$$\frac{1}{1-1/\sigma}\left(C_t^{1-1/\eta} + \omega(D_t/P_t)^{1-1/\eta}\right)^{\frac{1-1/\sigma}{1-1/\eta}}$$

- IES consumption (σ), interest elasticity money demand (η); $(\eta < \sigma)$
- Access to bonds, deposits for savings, at interest (i_t^S, i_t^D)
- Consumption CES bundle of home, foreign tradable, home bias (a_H)
- Discount factor (β_t) subject to persistent local demand shocks
- Complete markets: access to full set of state-contingent assets B-S

Firms Details

- Own Tradable final good = CES aggregate of local intermediates
- Intermediate goods made 1-1 from labour, Calvo price setting
  - Labour productivity Z_t stochastic, subject to persistent shocks
- Assumption: Law of One Price for final tradable goods

Banking Sector

- Balance sheet

Assets		Liabilities	
R_t	Reserves	Deposits	D_t
A_t	Other assets	Equity	

- Assuming zero equity adjustment costs, shareholders solve

$$\max_{\{D^i_{t+1}, R^i_{t+1}, A^i_{t+1}\}} E_t \sum_{s \geq 0} M_{t+s} \mathrm{CF}^i_{t+s}$$

$$CF^i_{t+1} = R_t(1 + i^R_t) + A_t(1 + i^A_t) - D_t(1 + i^D_t) - R_{t+1} - A_{t+1} + D_{t+1}$$

- Leverage constraint: $D_t \leq \ell_t \left(R_t + \rho_{A,t} A_t\right)$
  - ℓ^i_t reflects leverage, subject to persistent shocks
  - reserves, other assets valuable as sources of collateral
    - $\rho_{A,t} < 1$ other assets are lower quality collateral
- A_t consists of firm loans (L_t) + other exogenous assets (X_t)

Bank Optimization

Equilibrium: Required nominal rate of return on equity is i_t^S

- Intuition: Nominal return net asset portfolio predetermined at time t $\rightarrow$ in equilibrium, portfolio returns set equal to short rate i_t^S

Asset Holdings

- Optimal portfolio choice: assets valued as collateral (lagrange γ_t)
- Banks equate return on assets to cost of capital i_t^S

$$i_t^S = i_t^R + \ell_t^I \gamma_t \left(1 + i_t^S\right)$$
$$i_t^S = i_t^A + \rho_{A,t} \ell_t \gamma_t \left(1 + i_t^S\right)$$

Deposit Issuance Bank FOC

- Issuance requires leverage: priced at mark-up over marginal cost

$$i_t^S - i_t^D = \underbrace{\left(\frac{\eta_b}{\eta_b - 1}\right)}_{\text{mark-up}} \underbrace{\left(\frac{1}{\ell_t}\right)\left(i_t^S - i_t^R\right)}_{\text{marginal cost}}$$

Intermediate Firm Sector

- Face demand for own intermediate variety from final goods firm
- Can issue one-period loans ($L_{j,t}$), subject to the following constraint:

$$L_{j,t+1} \leq \gamma_L p_{jt} y_{jt} \quad \text{(Lagrange } \lambda_t^{BC}\text{)}$$

Motivation: Majority of debt tied to firm cash flow, not assets (Ma, 2020)

Key First Order Condition (L_{t+1}):

$$\lambda_t^{BC} = \underbrace{\frac{i_t^S - i_t^L}{1 + i_t^S}}_{\text{collateral premium}} > 0$$

Intuition: Firms also productive in supplying collateral to banks

Implication: Loan supply endogenous and tied to aggregate output

- $L_{t+1} = \int_0^1 L_{j,t+1} = \int_0^1 \gamma_L p_{jt} y_{jt} = \gamma P_t Y_t$

Government

Government

- Taylor rule for policy rate i_t^R

$$i_t^R = r^R + \rho_R \left(i_{t-1}^R - r^R\right) + (1-\rho_R)\left(\phi_\pi \hat{\pi}_t^{\text{UNION}} + \phi_y \hat{y}_t^{\text{UNION}}\right) + \phi_{\Delta\pi}\left(\hat{\pi}_t^{\text{UNION}} - \hat{\pi}_{t-1}^{\text{UNION}}\right) + \phi_{\Delta Y}\left(\hat{y}_t^{\text{UNION}} - \hat{y}_{t-1}^{\text{UNION}}\right) + v_t^{MPS}$$

- Lump-sum taxes adjust to satisfy budget constraint

Central Bank Operating System

- *Ample Regime* (2015 - Present)
  - reserve supply ample - no marginal liquidity benefit
  - reserves supply (R_t^S) independent policy instrument
- *Scarce Regime* (1999 - 2014)
  - reserves hold liquidity benefit (manage liquidity shocks)
  - reserves supply chosen to implement target interbank rate

Result: Scarce $\equiv$ Ample with **endogenous** reserve supply process Proof

Collateral Market and Equilibrium

Collateral Market: Banks have three sources of collateral

- Central Bank Reserves (R_t)
- Loans issued to intermediate firms (L_t)
- Claims sold by household to banks (X_t)
    - Assumed to follow an exogenous process

Equilibrium: Sequence of prices and allocations such that:

- 2 tradable goods markets clear: $Y_t^K = C_{Ht}^K + C_{Ft}^K$ for $K \in \{I, J\}$
- 2 local labour, deposit markets clear
- 1 Reserves market clears: $R_t^S = R_t^I + R_t^J$
- 2 intermediate firm loans markets clear
- 1 union-wide household claims market clears
- 1 government bond market clears: $B_t^S = B_t^I + B_t^J$
- Full set of state-contingent assets markets clear

QE Shock Description

Reserves (R_t^S): separate policy instrument. Exhibits log-linear process:

$$\hat{r}_t^S = \hat{r}_{t-1}^S + v_t^{QE}$$

QE Shock (v_t^{QE}): issuance of new reserves to finance asset purchases

- *Financing*: issuance of reserves, all held by private banks
- *Purchases*: majority (80%) against non-bank counterparties

  $\rightarrow$ outright new collateral supply for banks, not just collateral swap

QE Mechanism: increases quantity of collateral available to banks

$$\begin{aligned} \uparrow \epsilon_t^{QE} \quad &\rightarrow \quad \uparrow \text{collateral supply} \\ &\rightarrow \quad \downarrow \text{collateral premium} \\ &\rightarrow \quad \downarrow \text{deposit spread (bank optimality condition)} \\ &\rightarrow \quad \uparrow \text{deposits} \rightarrow \quad \uparrow \textbf{consumption} \end{aligned}$$

Outline of Estimation and Counterfactuals

Estimation

- Bayesian strategy
- Data Sources
- Calibrated parameters Calibration
- Estimation results
- Contribution of Shocks Figure

Counterfactual Policy Exercises

- Counterfactual 2: Impact of lower ϕ_π

Estimation Strategy

Strategy: Bayesian estimation

Full Information: Select a set of structural shocks that has model exactly match target variables $\rightarrow$ model fully explains empirical outcomes

Macro Targets: $(\pi_t^I,\ \pi_t^J,\ y_t^I,\ y_t^J,\ i_t^R)$ Figure

- Local Productivity Shock - identified by negative (y, π) comovement
- Local Demand Shock - identified by positive (y, π) comovement
- Monetary Policy Shock - identified by policy rate

Banking Sector Targets: $(i_t^R - i_t^{D,I},\ i_t^R - i_t^{D,J},\ \rho_{A,t}^{UNION},\ R_t^S)$

- Local bank leverage shocks - identified by deposit spreads
- Private Collateral Supply Shock - identified by collateral quality
- QE Shocks - identified by reserve supply

Shock Processes u_t:

- AR(1): $u_t = \rho_u u_{t-1} + \sigma_u \epsilon_{t,u}$
- Cross Correlations: prod., demand, leverage shocks across regions
- Priors: Diffuse ρ_u priors with mean 0.8

Outline of Estimation and Counterfactuals

Estimation

- Bayesian strategy
- Data Sources
- **Calibrated parameters**
- Estimation results
- Contribution of Shocks Figure

Counterfactual Policy Exercises

- Counterfactual 2: Impact of lower ϕ_π

Calibrated Parameters

Step 1: Assets Purchased by ECB Remaining Parameters

- 80% purchases against non-bank held assets: *firm equity holdings*

Step 2: Bank Leverage

- Leverage (ℓ^I): units of deposits issued per unit of new collateral

$$\ell^I = \frac{\text{Deposits}}{\text{Deposits} + \text{Equity}}$$

- *"Equity"*: includes liabilities lying explicitly junior to deposits
- *"Deposits"*: all non-MFI counterparties

Step 3: Interest Elasticity of Money Demand (η) Details Figure

- Estimate the deposit demand FOC at the region level

$$\underbrace{\log\left(\frac{GDP_t}{M1_t}\right)}_{\text{Velocity}} = \alpha + \underbrace{\frac{\eta}{r^S - r^D}}_{\epsilon_d} \underbrace{\left(i_t^S - i_t^D\right)}_{\text{Deposit Spread}} + u_t$$

Estimated Parameters

Estimated Parameters Results

- Intertemporal elasticity of substitution (σ)
- Taylor rule parameters: $(\rho_T, \phi_\pi, \phi_y, \phi_{\Delta\pi}, \phi_{\Delta y})$
- Parameters governing structural shock processes

Split Sample: Observation period split into two sub-samples

1. Sub-Sample 1: Q1 1999 - Q4 2014 (**Scarce Regime**)
   - estimate all parameters except for QE shock process
2. Sub-Sample 2: Q1 2015 - Q1 2020 (**Ample Regime**)
   - estimate parameters of QE shock process alone
   - all others parameters set to posterior mean

Contribution of Collateral Shocks

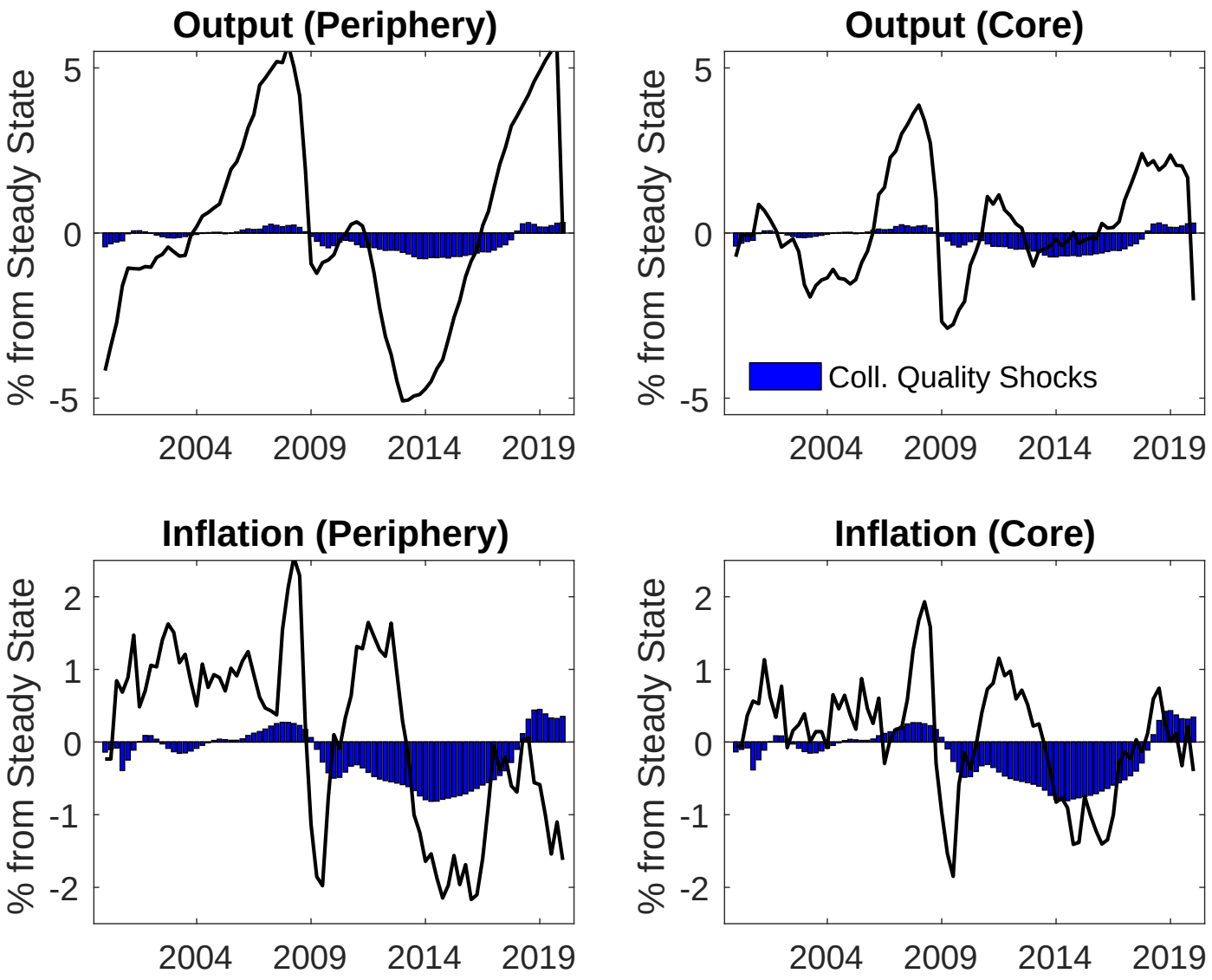


Figure 3: Contribution of Collateral Quality Shocks

Core Macro

Contribution of Collateral Shocks

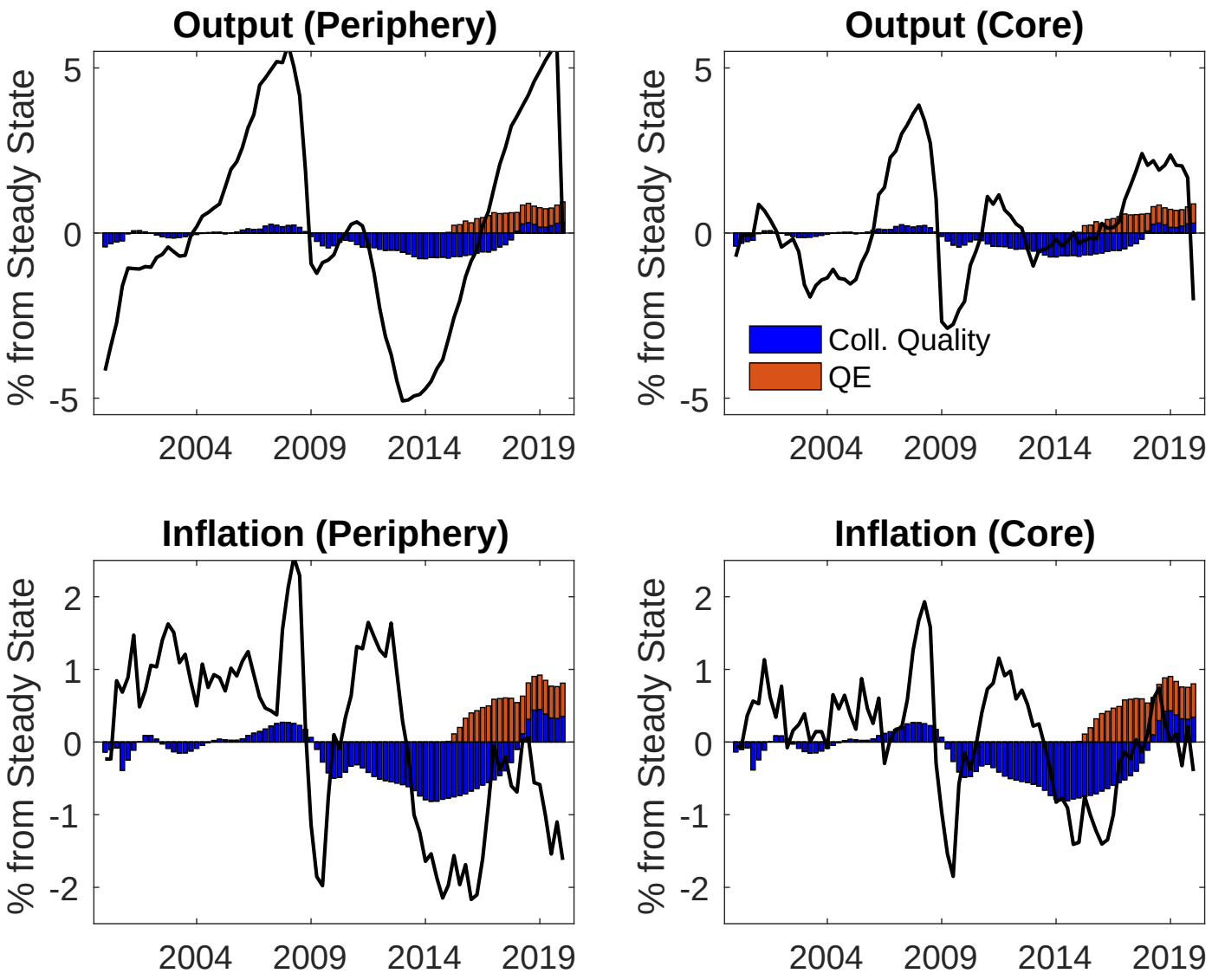


Figure 4: Contribution of Collateral Quality Shocks + QE Shocks

Core Macro

Counterfactual 2: Role of Lower ϕ_π

Motivation

- ϕ_π estimated within scarce reserves regime
- BUT QE policy implemented amidst ZLB i.e. lower ϕ_π to first order
- In ample regime, Taylor rule can be set independently from QE policy

Counterfactual 2: Reduce ϕ_π from mode (1.87) to 5% C.I. (1.35) of posterior distribution

- Evaluate additional impact caused by same realizations of QE shocks

Result: Impact of QE on inflation rises from 60bps to 110bps

- Inflation itself replaces Taylor rule as stabilization tool
- QE $\equiv$ shock to nominal reserves

$$\uparrow \text{inflation} \rightarrow \quad \downarrow \frac{\partial(\text{Real Reserves})}{\partial(\text{QE})} \rightarrow \quad \downarrow \frac{\partial(\text{Coll. Supply})}{\partial(\text{QE})} \rightarrow \quad \downarrow \frac{\partial(\text{Deposits})}{\partial(\text{QE})}$$

Counterfactual 2: Role of Lower ϕ_π

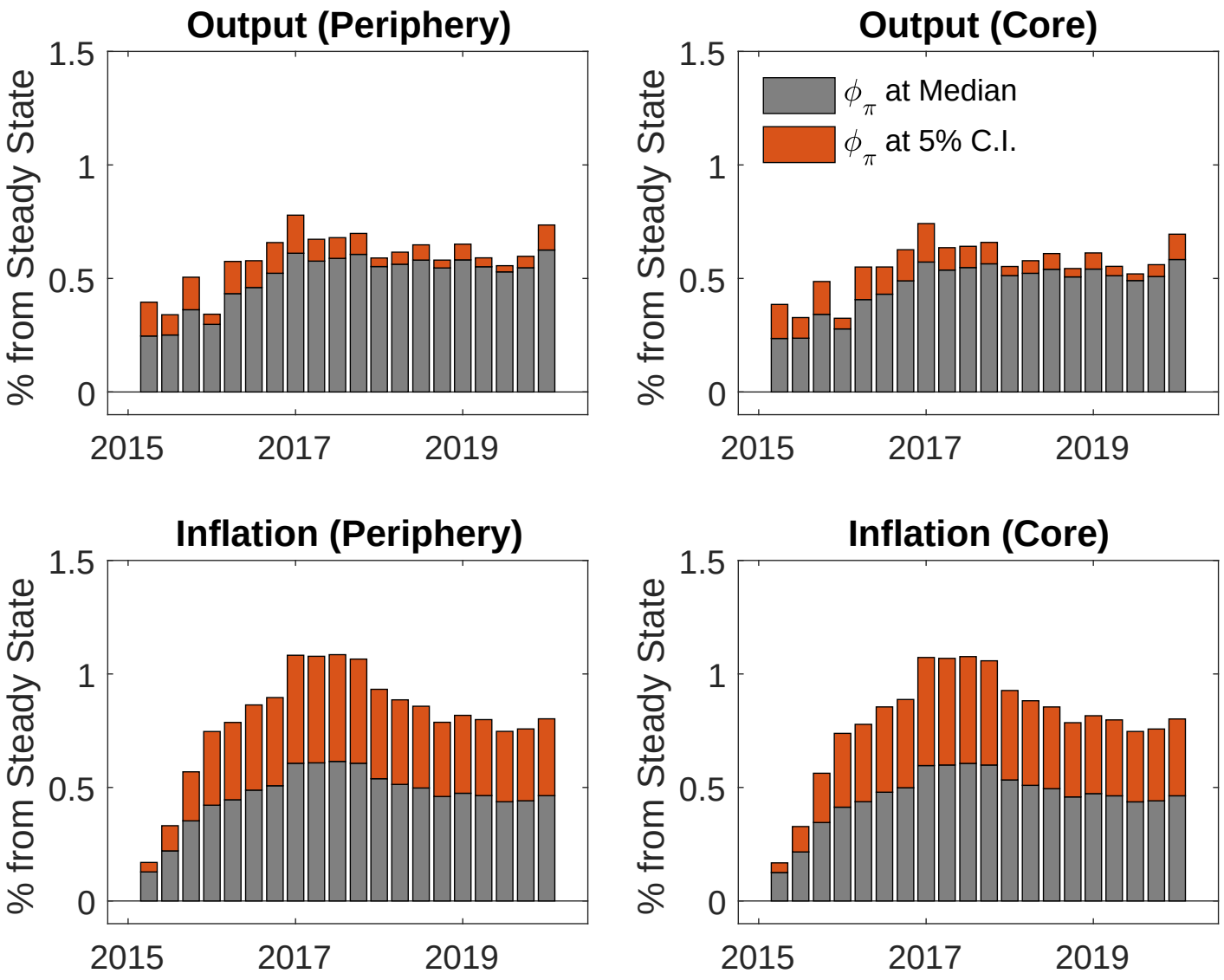


Figure 5: Role of ϕ_π for Propagation of QE Shocks Prod. Shock

Conclusion

Stylized Facts of Country-Level Banking Structure in Euro Area

- Fact 1: Deposit sector fragmented across countries
- Fact 2: Assets held by banks in more integrated markets

Introduce framework of ample regime within currency union (Euro)

- Households attach convenience yield on bank deposits
- Bank deposit issuance limited by leverage constraint
  - backed by reserves, firm loans, other private collateral assets
- Central bank controls interest rate on and supply of reserves

Quantitative Easing has powerful, harmonized effect across union

- scarcity of deposit supply matters for consumption
- QE raises supply of union-wide collateral to back deposits
- Integrated bank collateral market (via reserves) implies pass-through is broadly harmonised across countries
- Agg. effects bolstered by less responsive Taylor rule in recent years

Appendix

Breakdown of Tradable Securities

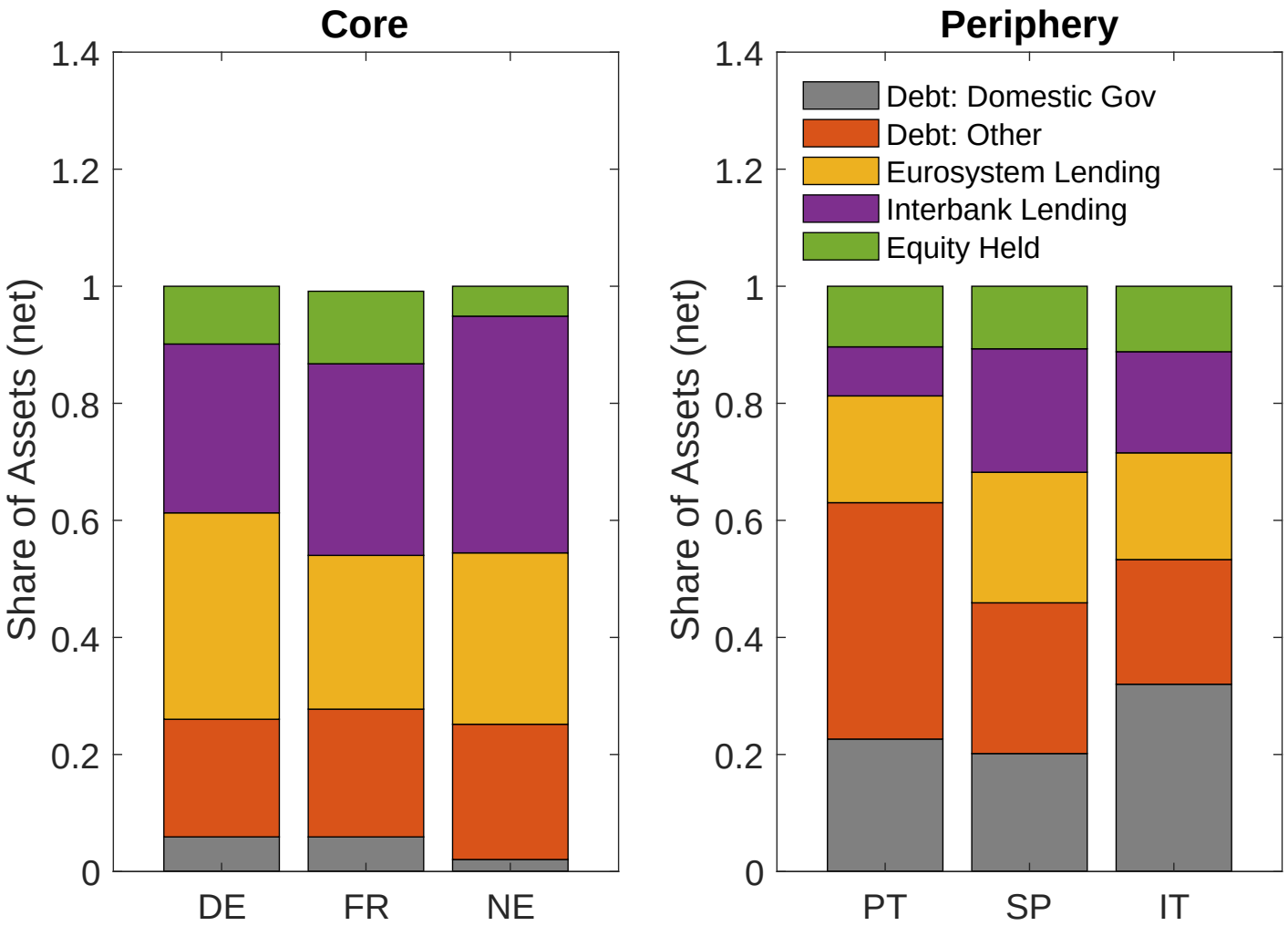


Figure 6: Breakdown of Tradable Securities: Core vs. Periphery 2020 (Source: BSI) Fact 2

Breakdown of Liabilities

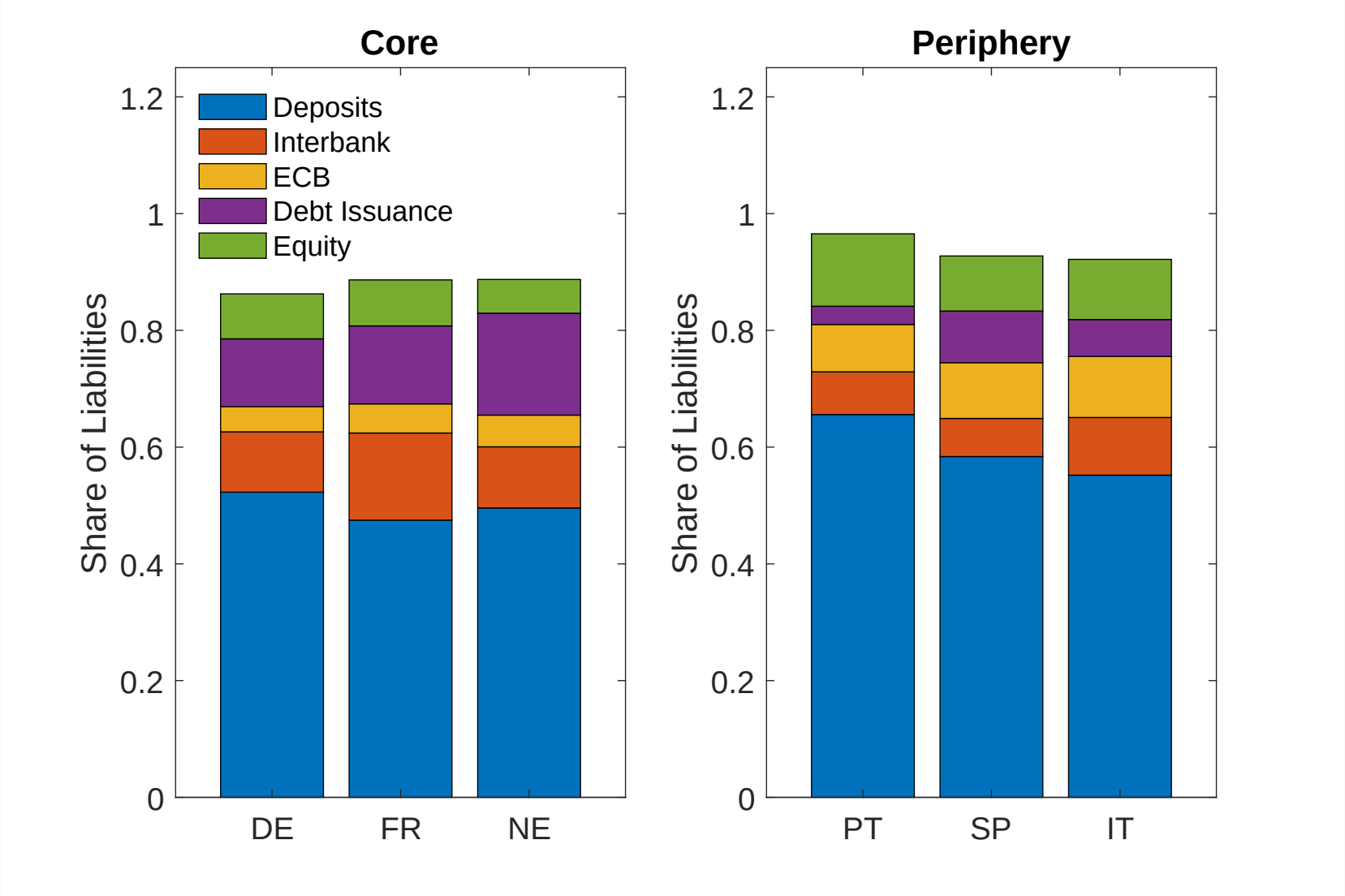


Figure 7: Breakdown of Liabilities: Core vs. Periphery 2020 (Source: BSI)

Fact 2

Breakdown of Deposits (by Counterparty)

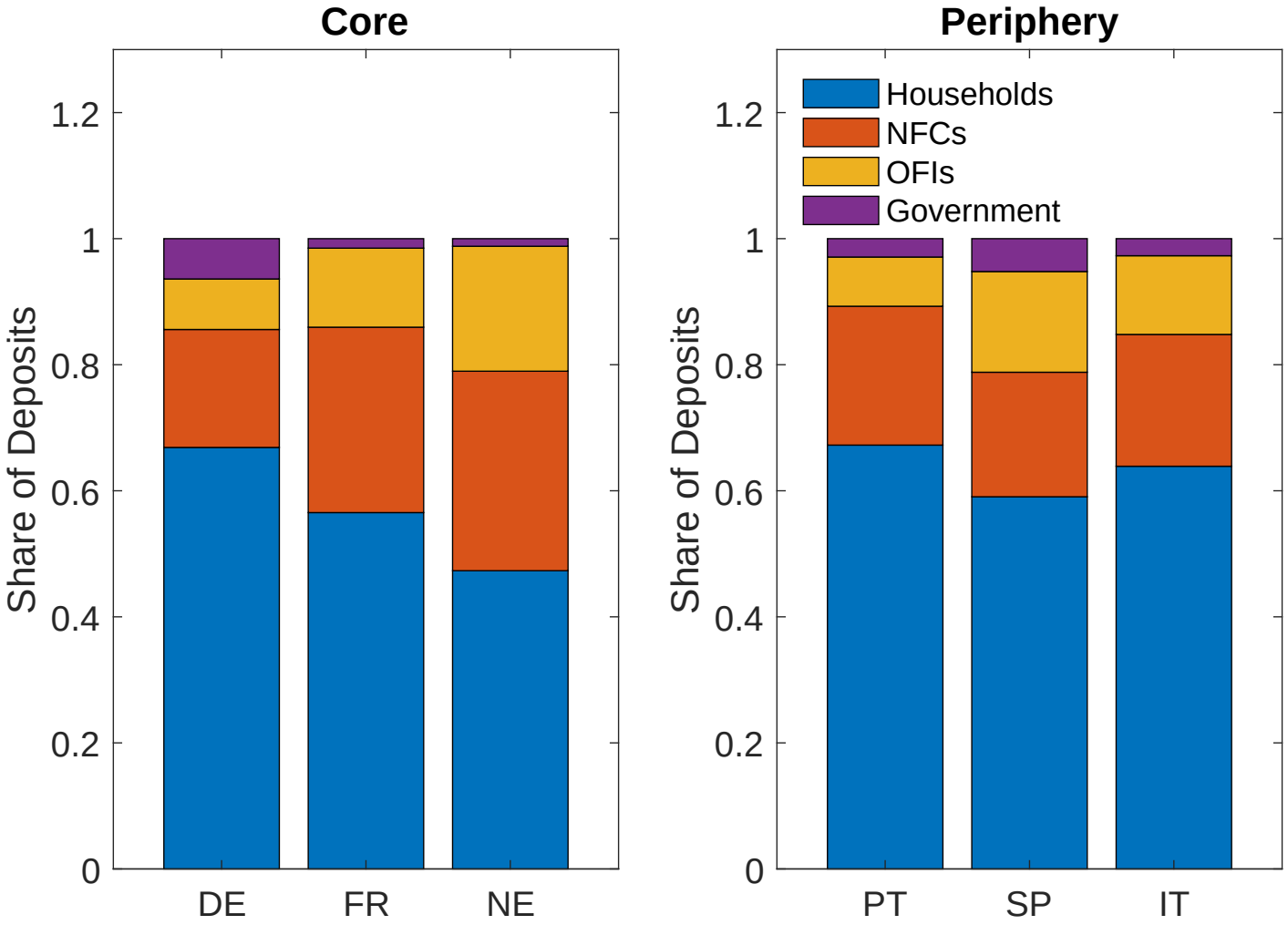


Figure 8: Breakdown of Deposits: Core vs. Periphery 2020 (Source: BSI) Fact 2

Breakdown of HH + NFC Deposits (by residency)

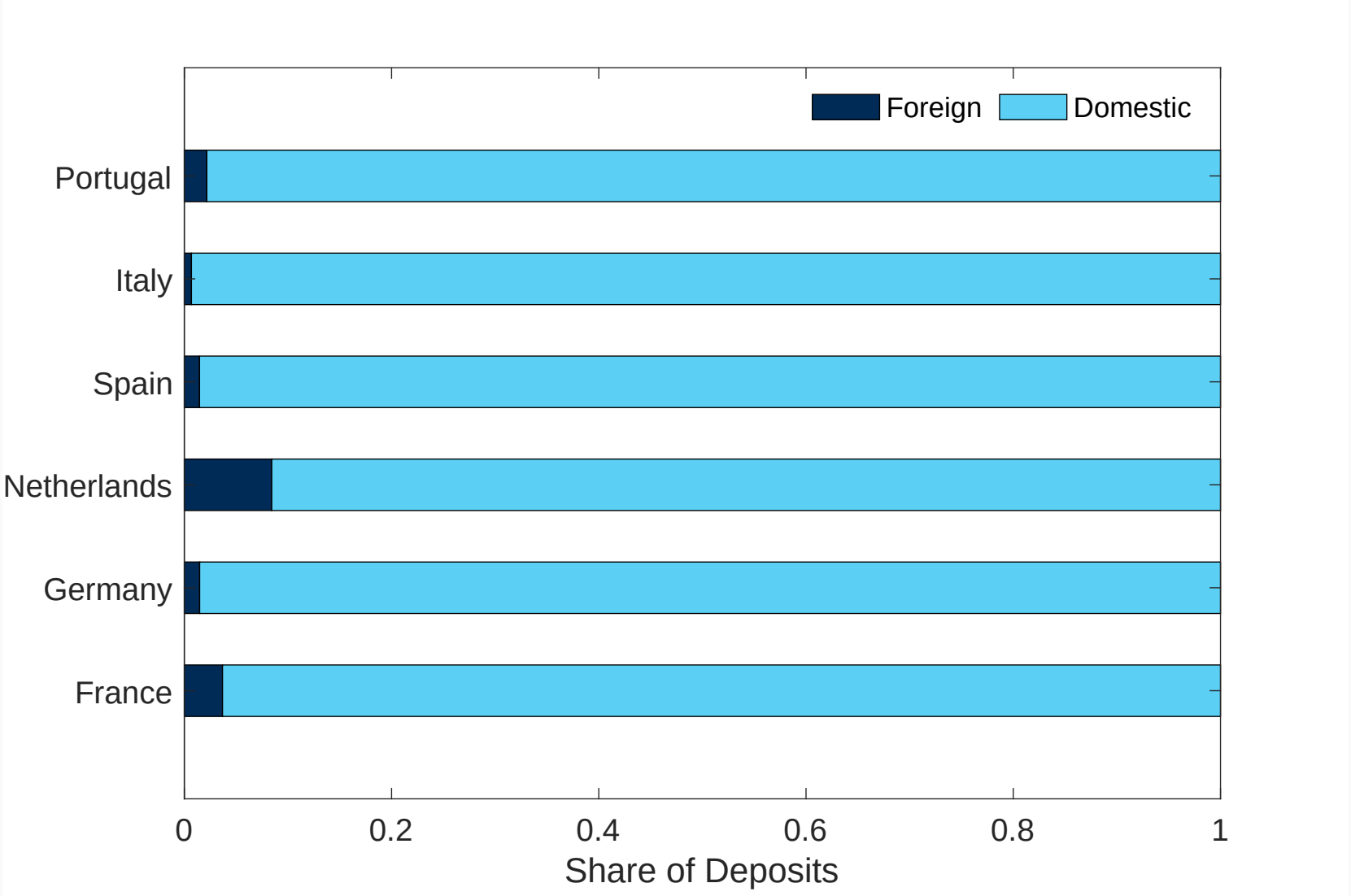


Figure 9: Breakdown of Deposits: Domestic vs. Other EA (Source: BSI) Fact 1

Loans Split by Counterparty

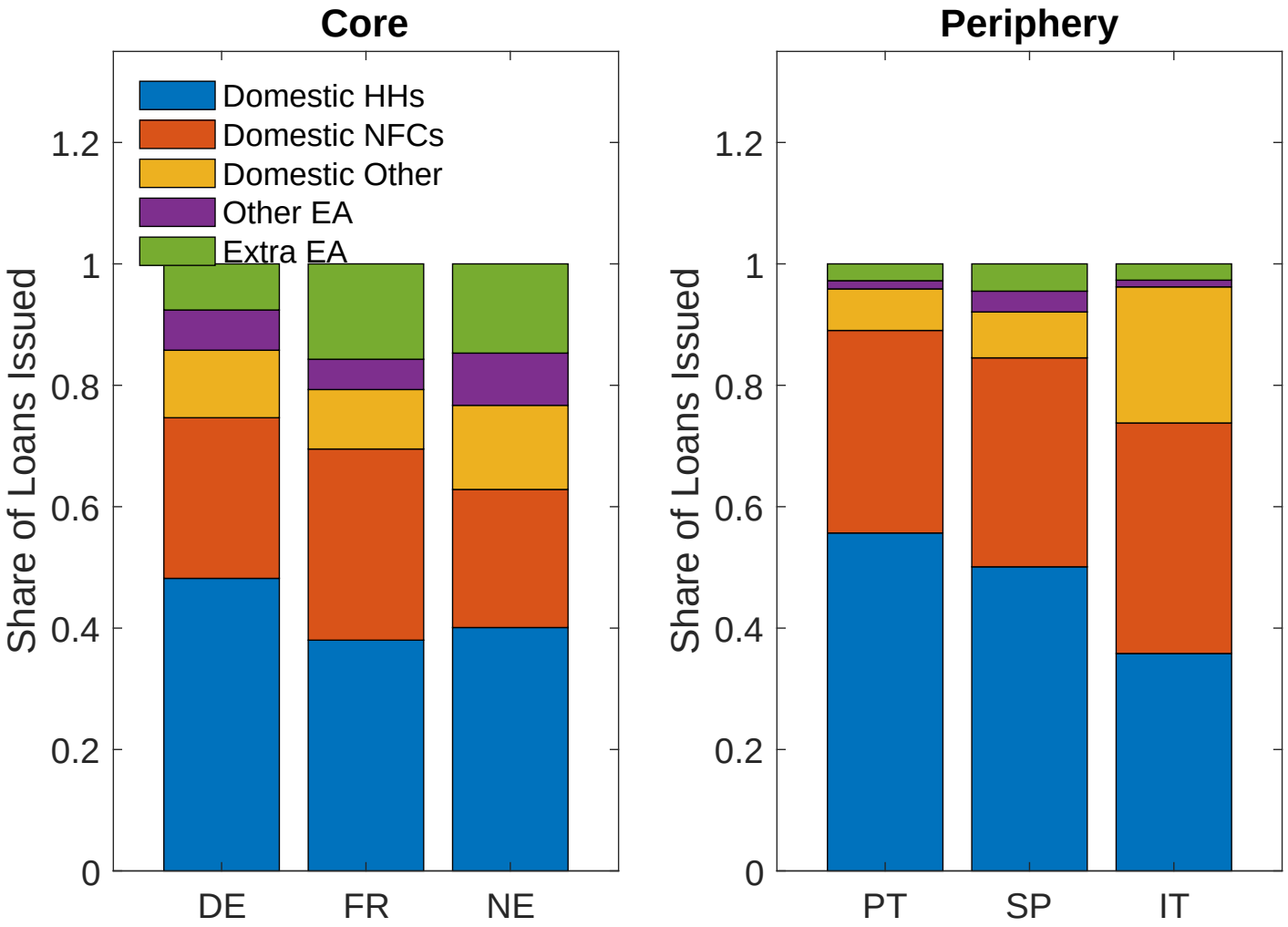


Figure 10: Loans Split by Counterparty (Source: BSI) Fact 2

Residency of Government Bonds Held

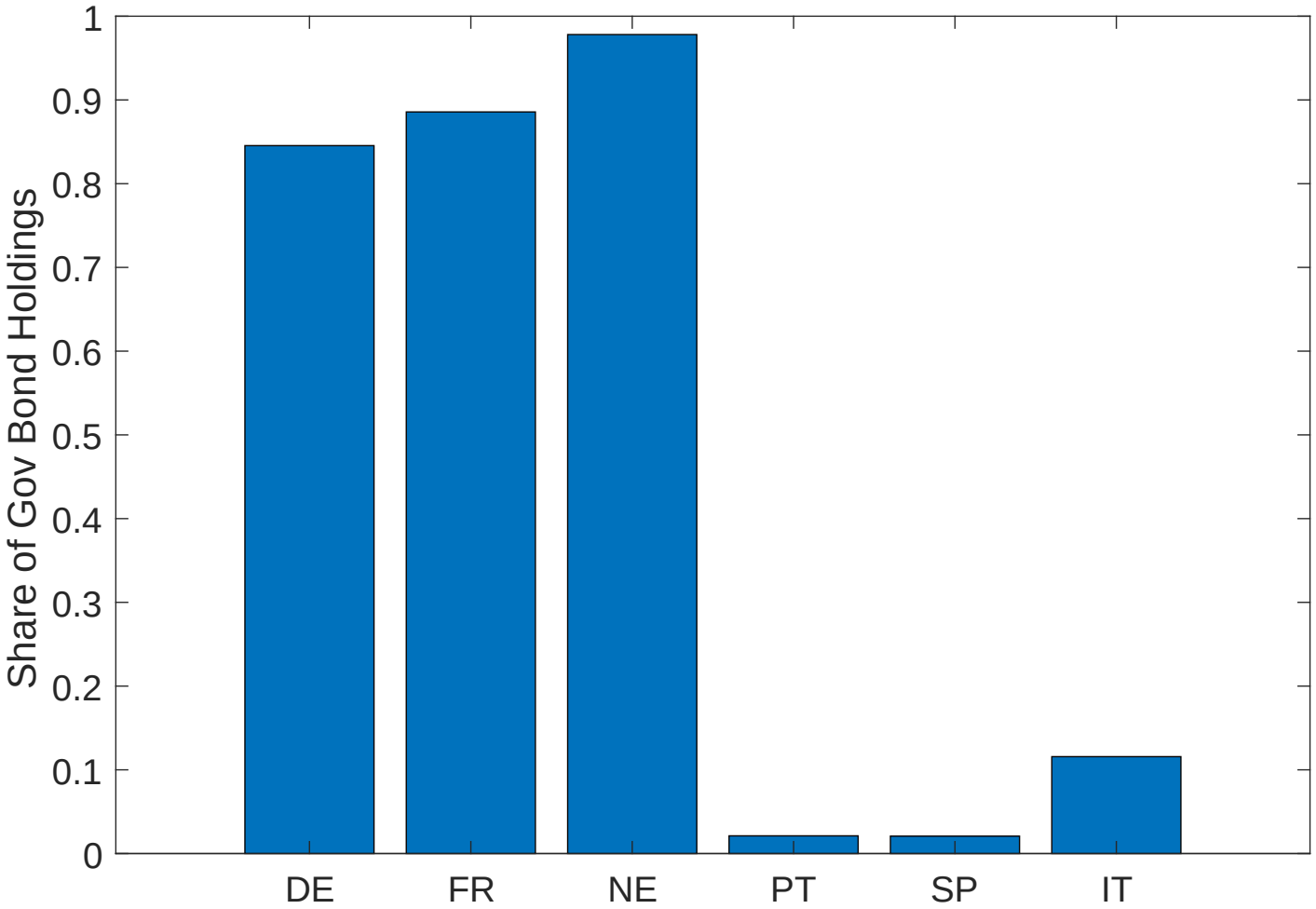


Figure 11: Core Share Government Bond Holdings (Source: EBA) Fact 2

Household Sector: Setup

Summary: Two region (I, J) variant of New Keynesian Model

- Each region produces own tradable good

Household Sector

- Representative household in each region chooses consumption (C_t), deposits (D_t), bonds (S_t) and labour supply (N_t)
- CES preferences over $(C_t, D_t/P_t)$: $U(C_t, D_t/P_t)$
  - σ - intertemporal elasticity of substitution
  - η - intratemporal elasticity ($< \sigma$ i.e. complements)

$$\max_{\{C_t, D_t, S_t, N_t\}} \sum_{t=0}^{\infty} \beta^t E_0 \left[U(C_t, D_t/P_t) - \varphi N_t^{1+\phi}/(1+\phi) \right]$$

subject to

$$P_t C_t + D_t + S_t = W_t N_t + T_t + \Pi_t + D_{t-1}(1 + i_{t-1}^D) + S_{t-1}(1 + i_{t-1}^S)$$

where $C_t = \left[a_H^{1/\gamma} C_{Ht}^{\frac{\gamma-1}{\gamma}} + a_F^{1/\gamma} C_{Ft}^{\frac{\gamma-1}{\gamma}} \right]^{\frac{\gamma}{\gamma-1}}$, $P_t = \left[a_H P_{Ht}^{1-\gamma} + a_F P_{Ft}^{1-\gamma} \right]^{\frac{1}{1-\gamma}}$

Household Sector: First Order Conditions

Euler Equation

$$\beta E_t \left[\frac{U_1(C_{t+1}, D_{t+1}/P_{t+1})}{U_1(C_t, D_t/P_t)} (1 + i_t^S) \right] = 1$$

where

$U_{12}(\ .\ ,\ .\ ) > 0.$

Deposit Spread

$$\frac{i_t^S - i_t^D}{1 + i_t^D} = U_2(C_t, D_t/P_t)$$

Labour Supply

$$\varphi N_t^{\phi} = U_1(C_t, D_t/P_t) W_t/P_t$$

Details

Firms

Each region produces domestic variety of final, intermediate goods.

Final Good Firms

Details

- Use a continuum of intermediate goods, $Y_t(f)$, to produce final good Y_t:

$$Y_t = \left(\int_0^1 Y_t(f)^{\frac{\mu-1}{\mu}} df \right)^{\frac{\mu}{\mu-1}}$$

- Taking final goods price, P_{Ht}, as given, profit maximising implies:

$$Y_t(f) = \left(\frac{P_{H,t}(f)}{P_{H,t}} \right)^{-\mu} Y_t$$

Intermediate Good Firms

- Each firm f faces linear technology $Y_t(f) = Z_t(f)N_t(f)$
- Face demand curve from final good producer
- Staggered (Calvo) price setting: with probability $(1-\theta)$, can reset price $P_{H,t}(f)$

Backus-Smith Condition

Under assumption of complete markets for securities traded internationally, then realised SDFs equate B-S

$$\underbrace{\beta \frac{U_1(C^I_{t+1}, D^I_{t+1}/P^I_{t+1})}{U_1(C^I_t, D^I_t/P^I_t)} \left(\frac{P^I_t}{P^I_{t+1}}\right)}_{\text{Region I SDF}} = \underbrace{\beta \frac{U_1(C^J_{t+1}, D^\star_{t+1}/P^J_{t+1})}{U_1(C^J_t, D^J_t/P^J_t)} \left(\frac{P^J_t}{P^J_{t+1}}\right)}_{\text{Region J SDF}}$$

Under assumption of symmetric initial conditions

$$\frac{U_1(C^I_t, D^I_t/P^I_t)}{P^I_t} = \frac{U_1(C^J_t, D^J_t/P^J_t)}{P^J_t}$$

Intuition: Consumption is allocated to region where consumption bundle is relatively cheaper and/or when deposits are relatively abundant

Bank Market Power

Setup

- In each region, continuum of banks i offering own variety (D_t^i)
- Households: CES preferences over domestic varieties: elasticity η_b

Motivation

- Documented: banks hold market power in local deposit markets - small number of banks capture majority of market share Details
  $\rightarrow$ allow for market power to permit deviation in perfectly competitive pricing of deposits

Equilibrium Bank FOC

- Price of deposits is the interest foregone vs. bonds i.e. $i_t^S - i_t^{D,i}$
- Bank i faces demand elasticity η_b

$$D_t^i = \left(\frac{i_t^S - i_t^{D,i}}{i_t^S - i_t^D} \right)^{-\eta_b} D_t$$

where i, $i_t^S - i_t^D$ reflects the aggregate price index for deposits

Deposit Market: Market Share of Top 5 Banks

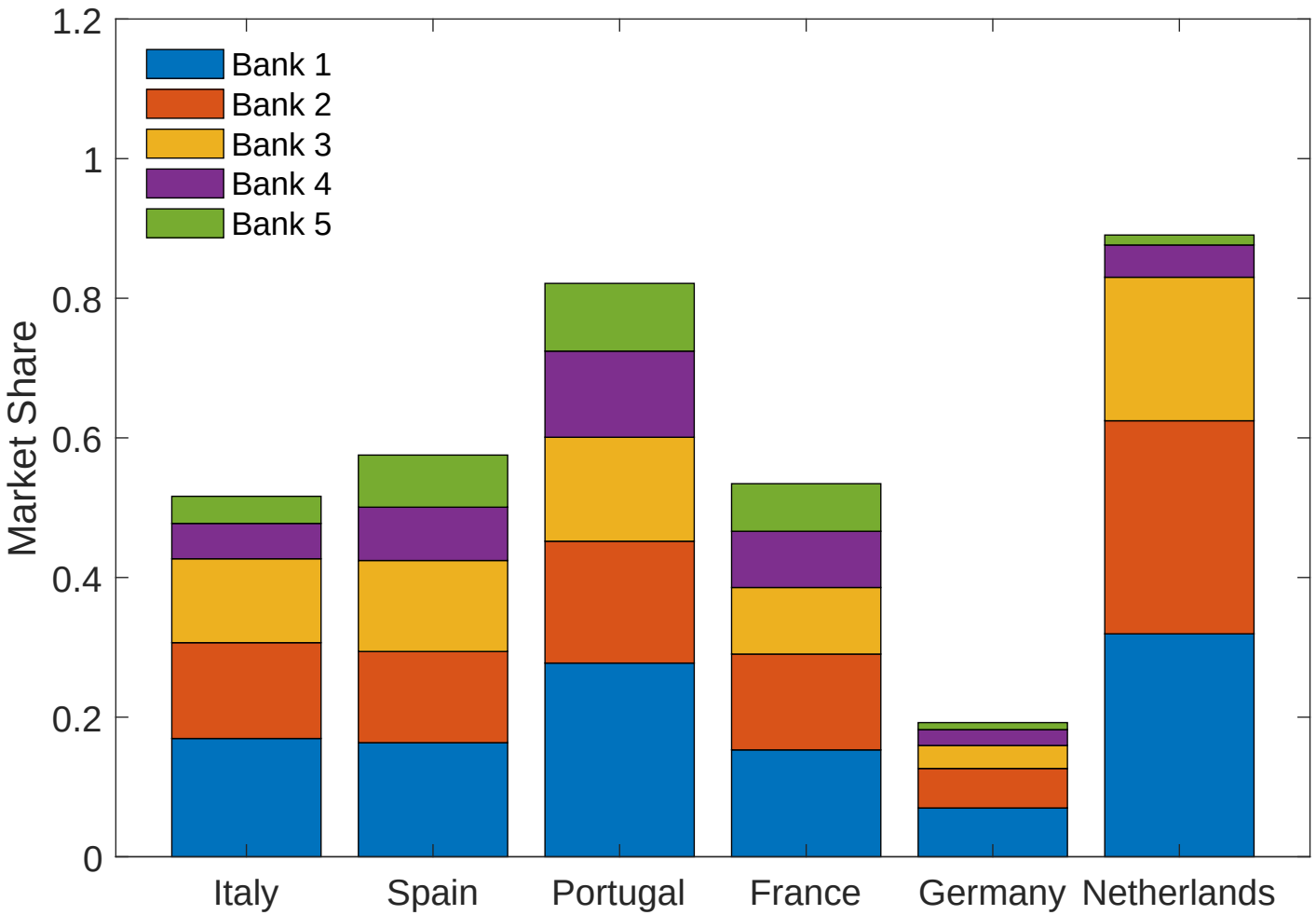


Figure 12: Deposit Markets: Market Share Top 5 Banks (Source: Orbis) Details

Change in Shares Government Bonds Outstanding

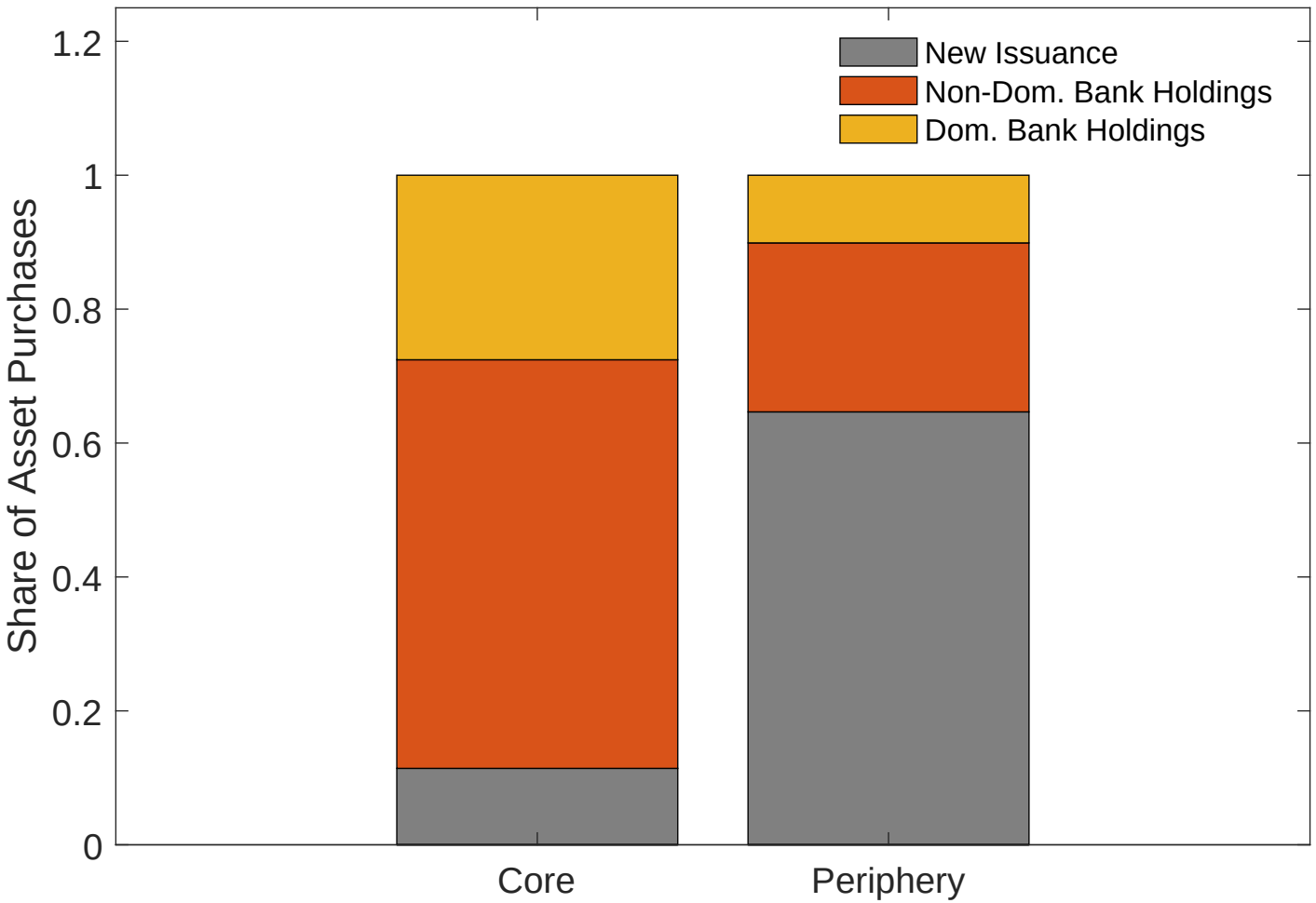


Figure 13: Allocation of ECB Asset Purchases: 2014 - 2018 (Source: IMF)

Details

Calibrated Parameters

Calibration Details

Table 1: Calibrated Parameters

Variable	Core	Periphery
Frisch Elasticity (ϕ)	0.75	0.75
Discount Factor (β)	0.99	0.99
Price Adjustment Frequency ($1-\theta$)	0.25	0.25
Velocity ($vel^{\star}$)	0.70	0.52
Deposit Rate (Annual) (r^D)	1.50%	1.45%
Leverage (ℓ)	3.4	4.6
Other Assets Collateral Value (ρ_A)	0.925	0.925
Consumption Home Bias (a_H)	0.80	0.80
Reserves Share Bank Assets ($R/(R+A)$)	0.04	0.04
Interest Elasticity of Deposits η	0.08	0.03
Reserves Spread (Annual) ($r^S - r^R$)	0.3%	-
Relative Region Size (Y^C/Y^P)	2.07	-

Bank Leverage Ratios

Balance Sheet Details

Assets	Liabilities
Central Bank Reserves	Deposits
Other Assets	Unsecured Debt
(Secured Liabilities)	Equity

Step 1: Subtract from liabilities items senior to deposits

- acts to leverage up assets backing deposits

Step 2: Add to equity all liabilities junior to deposits

- acts like a pseudo-equity buffer for deposits

$$\text{Leverage} = \frac{\text{Total Liabilities} - \text{Secured Liabilities}}{\text{Equity} + \text{Unsecured Debt}}$$

Data Source: Balance Sheet Indicator Database

- Monthly breakdown of bank balance sheets at country level in EU
- Reported at individual institution level (not banking group level)

Bank Leverage Ratios

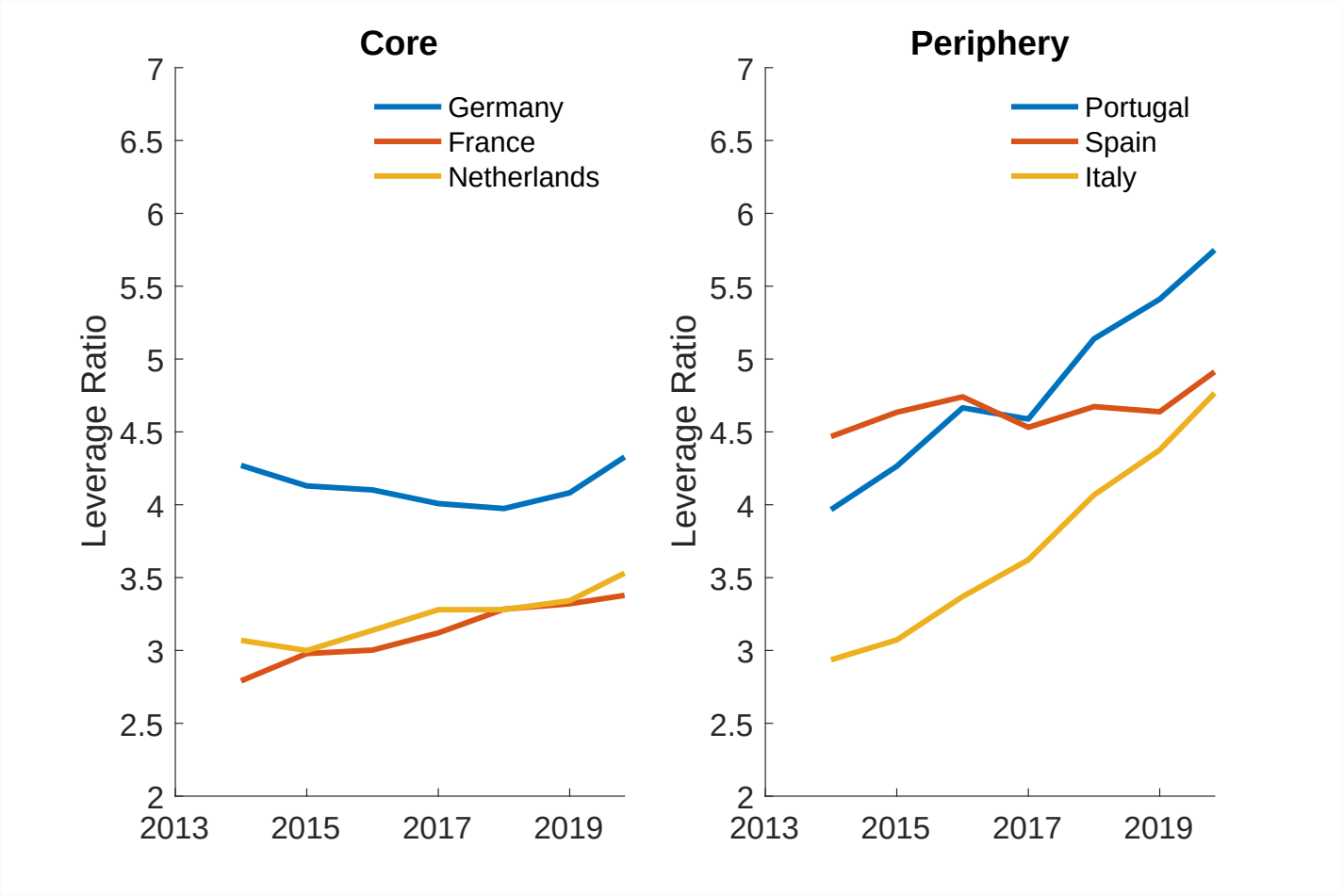


Figure 14: Leverage: Core vs. Periphery (Source: BSI)

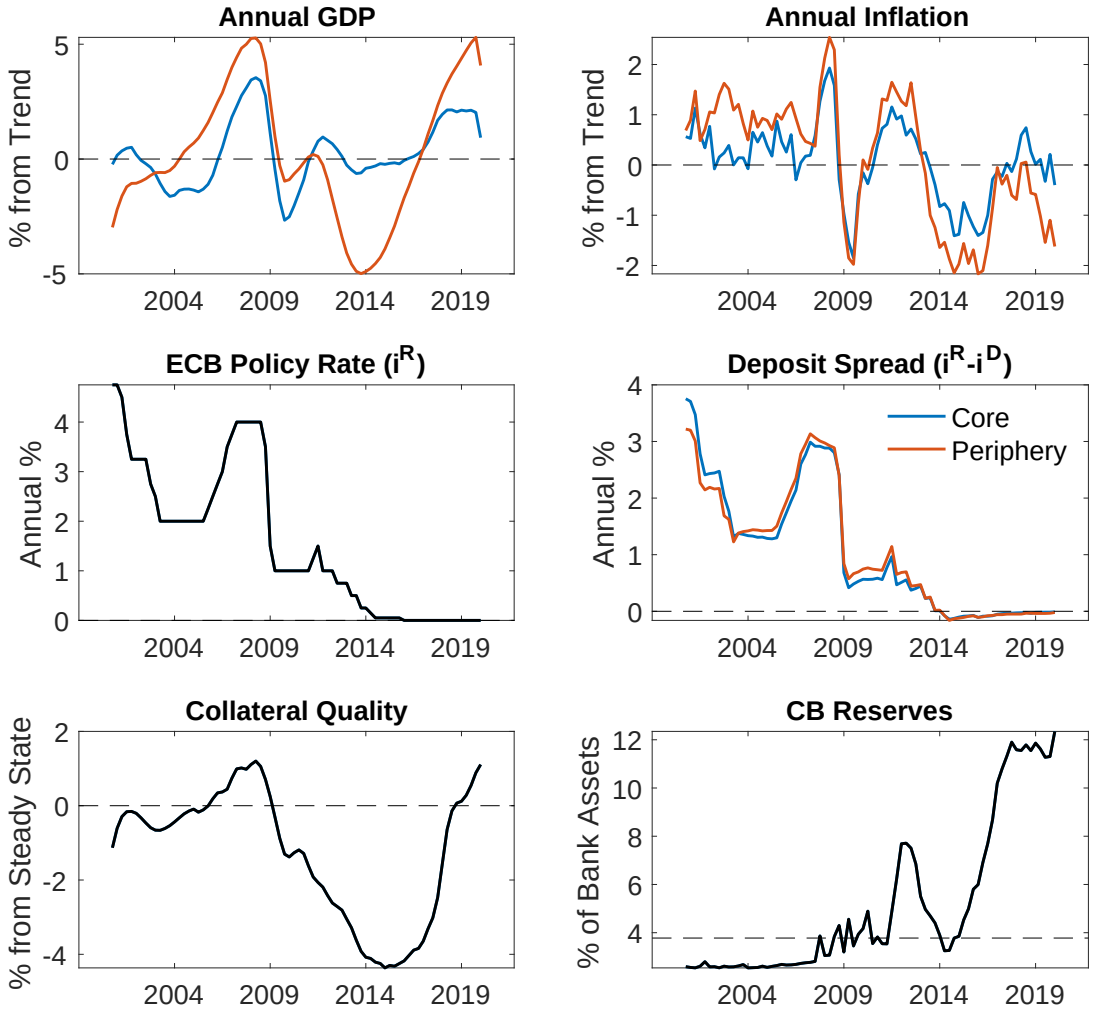
$$\text{Leverage} = \frac{\text{Total Liabilities} - \text{Secured Liabilities}}{\text{Equity} + \text{Unsecured Debt}}$$

Target Variables: Data Sources

(1) **Output**: Eurostat ESA 2010 National Accounts, Main Aggregates - Quarterly GDP at market prices, Chain-Linked volume
(2) **Inflation**: Harmonized Index of Consumer Prices (HICP), Eurostat, Overall Monthly Index, reference year 2015 (normalised to 100)
(3) **Policy Rate**: ECB MRO Rate: Statistical Data Warehouse (SDW), ECB Official Interest Rates, percent per annum
(4) **Deposit Rates** - MFI Interest Rate Statistics, overnight deposits from households/non-financial corporations, percent per annum
(5) Total Population: United Nations, World Population Prospects, 2019
(6) Overnight Deposits: BSI dataset, overnight deposits vis-a-vis non-MFIs excluding general government, denominated in Euro
(7) Currency in Circulation: BSI dataset, denominated in Euros
(8) **Central Bank Reserves**: BSI dataset, domestic loans to Eurosystem
(9) Money Supply: (6) + (7)
(10) **NPL Ratios**: IMF FSI Database Data

Data Sources

- Observation Period: 1999Q1 – 2020Q1 i.e. since inception of Euro
- Sample: Germany, France, Netherlands, Italy, Spain, Portugal (86% GDP) - Split into Regions C and P by annual GDP Details Main



Estimation of η: Data Sources

	Spain	Portugal	France	Germany	Italy	Netherlands
Sample Start	1972	1997	1978	1975	1970	1982

Table 2: η Estimation: Sample Period

Short-Term Discount Rate: Official Discount Rate (Source: National Central Banks/FRED)

Deposit Rate: Interest rate on Overnight Deposits plus Currency from ECB's SDW (post-1999)

Nominal GDP: World Bank (pre-1999); Eurostat (1999-2020)

M1 Money Supply: M1 Money supply from FRED (pre-1999), Overnight Deposits plus Currency from ECB's SDW (post-1999) Step 3

Estimation of Eta: Fitted Data

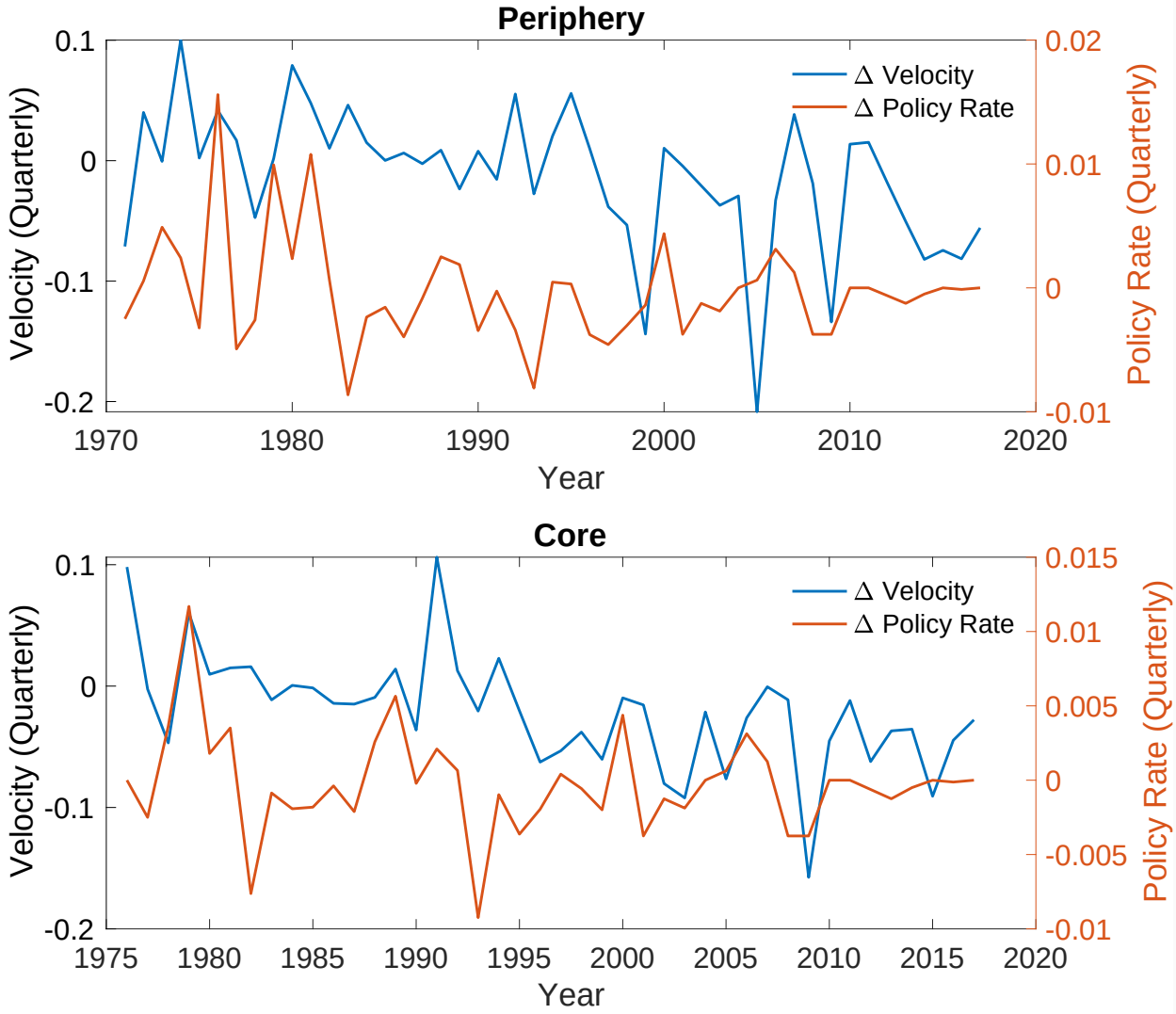


Figure 16: Δ Velocity vs Δ Policy Rate Step 3

Scarce Regime Formulation

Proposition 1: *Assuming that the scarce reserves regime setting exhibits properties*:

1. *a reserveless limit*
2. *a constant corridor i.e. the spread between the policy rate and reserve rate is fixed*

Then the system of equations is equivalent to the system for the ample reserves regime where reserves instead exhibit the following endogenous process:

$$\hat{r}_t = \hat{z}_t + \left(\frac{1}{\alpha_m}\right)\left(\frac{\epsilon}{\eta+\epsilon}\right)\left(\hat{y}_t^{UNION} - \hat{z}_t^{UNION} - \hat{\bar{\ell}}_t^{UNION}(1-\eta)\right)$$

where α_r is the share of bank collateral in the form of reserves in the ample regime, and $\epsilon \in [0, \infty)$.

Intuition: Central Bank determines policy and reserve rate $\rightarrow$ reserves supply endogenously determined (not separate iinstrument). Government

Parameters: Prior vs. Posterior Distributions

Param.	Dist.	Prior Mean	Prior StD	Post. Mode	10% / 90%C.I.
Scarce					
σ Main	N	1.00	0.25	0.81	0.66 / 0.98
ϕ_π	N	1.50	0.25	1.87	1.58 / 2.19
$\phi_{\Delta\pi}$	N	0.30	0.10	−0.08	−0.12 / −0.03
$\phi_{\Delta y}$	N	0.06	0.25	0.10	0.07 / 0.13
ρ_T	Beta	0.80	0.10	0.89	0.86 / 0.92
ρ_{z^P}	Beta	0.80	0.10	0.87	0.81 / 0.93
$\rho_{z^{\text{COMM}}}$	Beta	0.80	0.10	0.76	0.66 / 0.88
ρ_{b^P}	Beta	0.80	0.10	0.89	0.87 / 0.91
$\rho_{b^{\text{COMM}}}$	Beta	0.80	0.10	0.88	0.86 / 0.90
ρ_{ℓ^P}	Beta	0.80	0.10	0.93	0.89 / 0.96
$\rho_{\ell^{\text{COMM}}}$	Beta	0.80	0.10	0.90	0.86 / 0.94
ρ_{ρ_A}	Beta	0.80	0.10	0.98	0.97 / 0.99
Ample					
ρ_{QE}	Beta	0.50	0.20	0.58	0.40 / 0.76

Variances: Prior vs. Posterior Distributions

Param.	Dist.	Prior Mean	Prior StD	Post. Mode	10% / 90%C.I.
Scarce					
σ_v	IG	0.39	2.00	0.09	0.07 / 0.10
σ_{b^P}	IG	0.44	2.00	0.08	0.06 / 0.10
$\sigma_{b^{COMM}}$	IG	0.40	2.00	0.43	0.33 / 0.52
σ_{z^P}	IG	1.67	2.00	1.29	1.04 / 1.54
$\sigma_{z^{COMM}}$	IG	1.61	2.00	1.80	1.42 / 2.15
σ_{lev^P}	IG	7.65	15.00	4.10	3.27 / 4.99
$\sigma_{lev^{COMM}}$	IG	3.07	15.00	4.19	3.34 / 5.01
σ_{ρ_A}	IG	0.98	5.00	0.45	0.38 / 0.52
Ample					
σ_{QE}	IG	28.91	30.00	11.67	8.92 / 14.56

Table 4: Variances: Prior vs. Posterior Distributions Shocks

De-Composition of Core Macro Variables

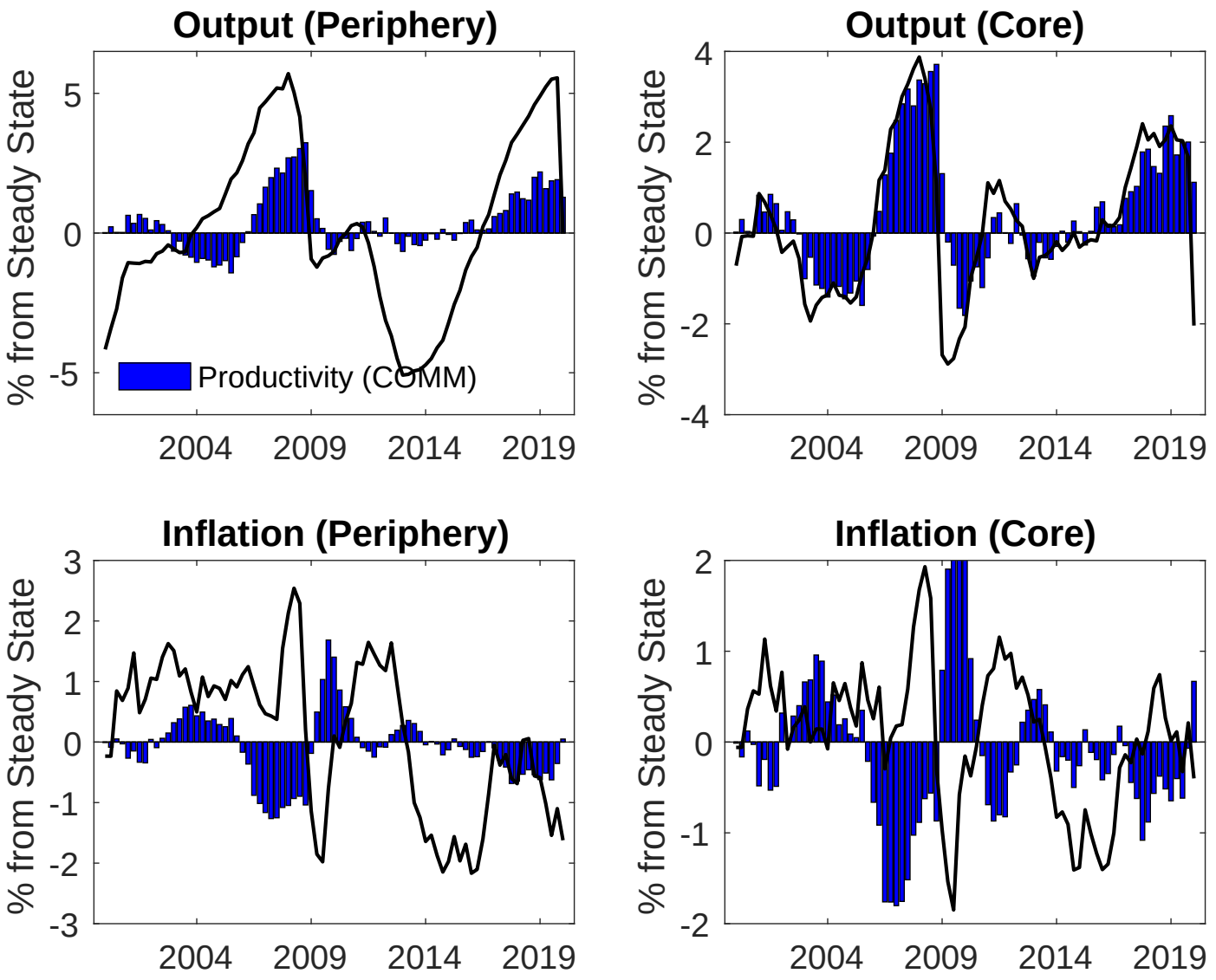


Figure 17: Contribution of Common Productivity Shocks

Main

De-Composition of Core Macro Variables

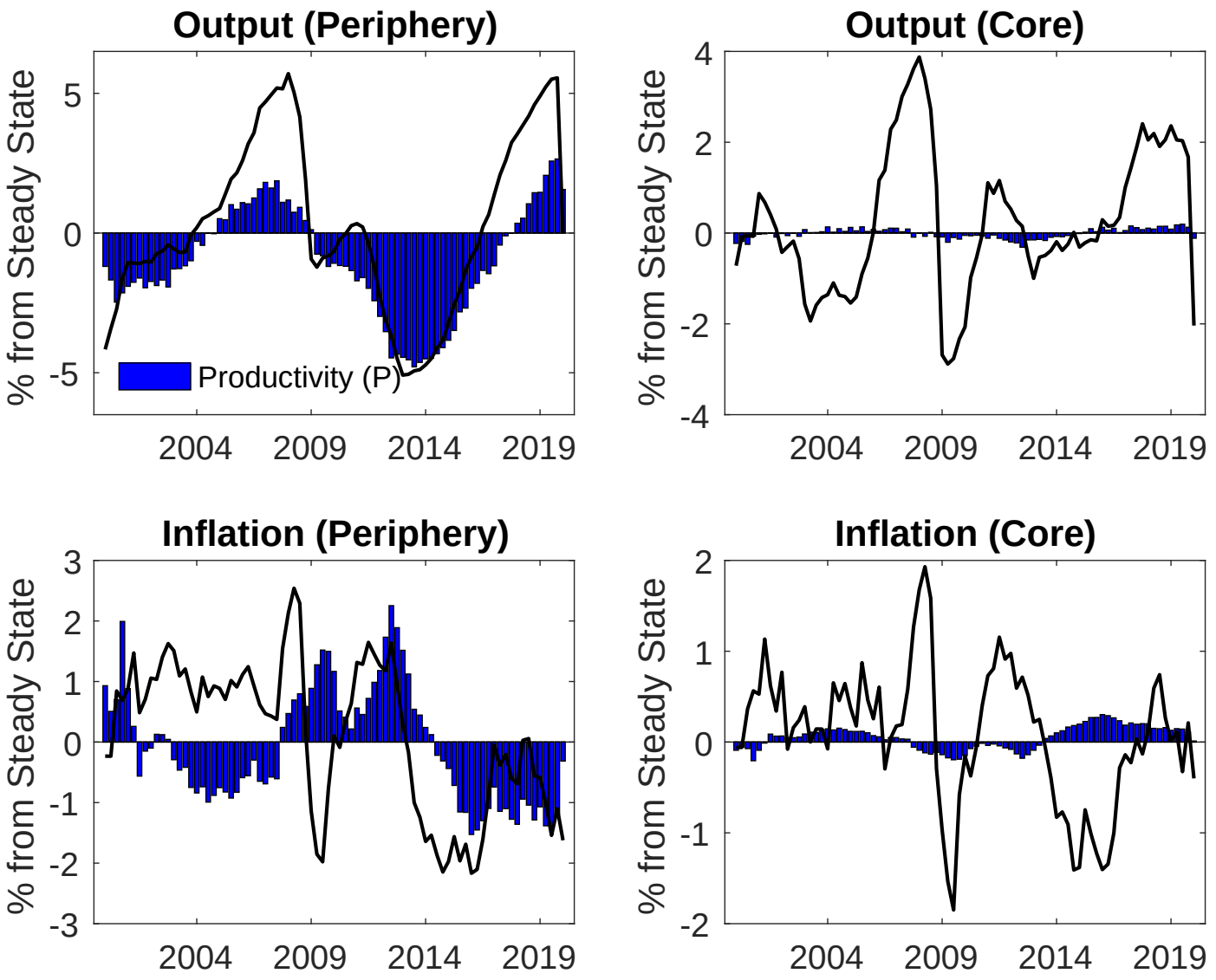


Figure 18: Contribution of Periphery Productivity Shocks

Main

De-Composition of Core Macro Variables

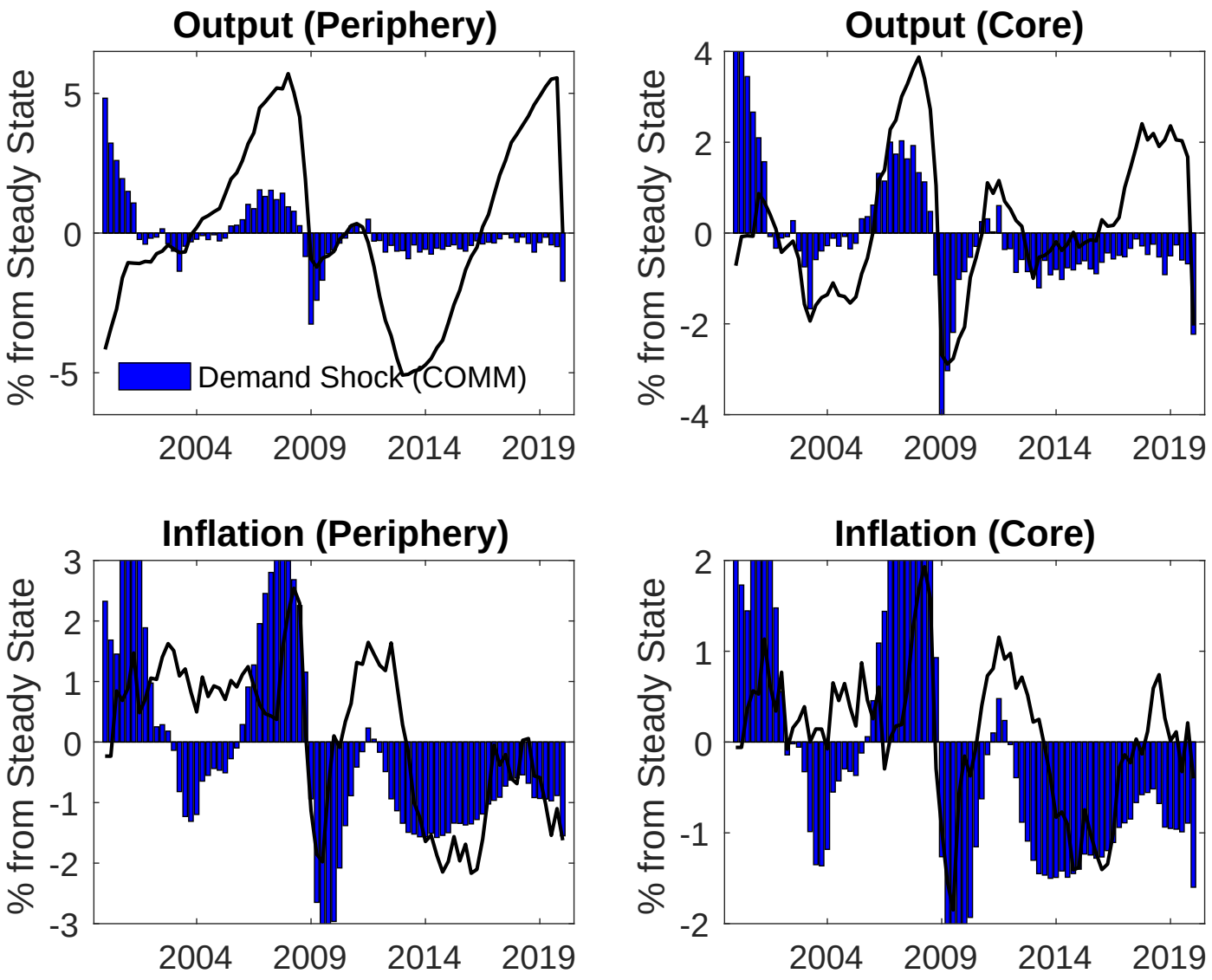


Figure 19: Contribution of Common Demand Shocks Main

De-Composition of Core Macro Variables

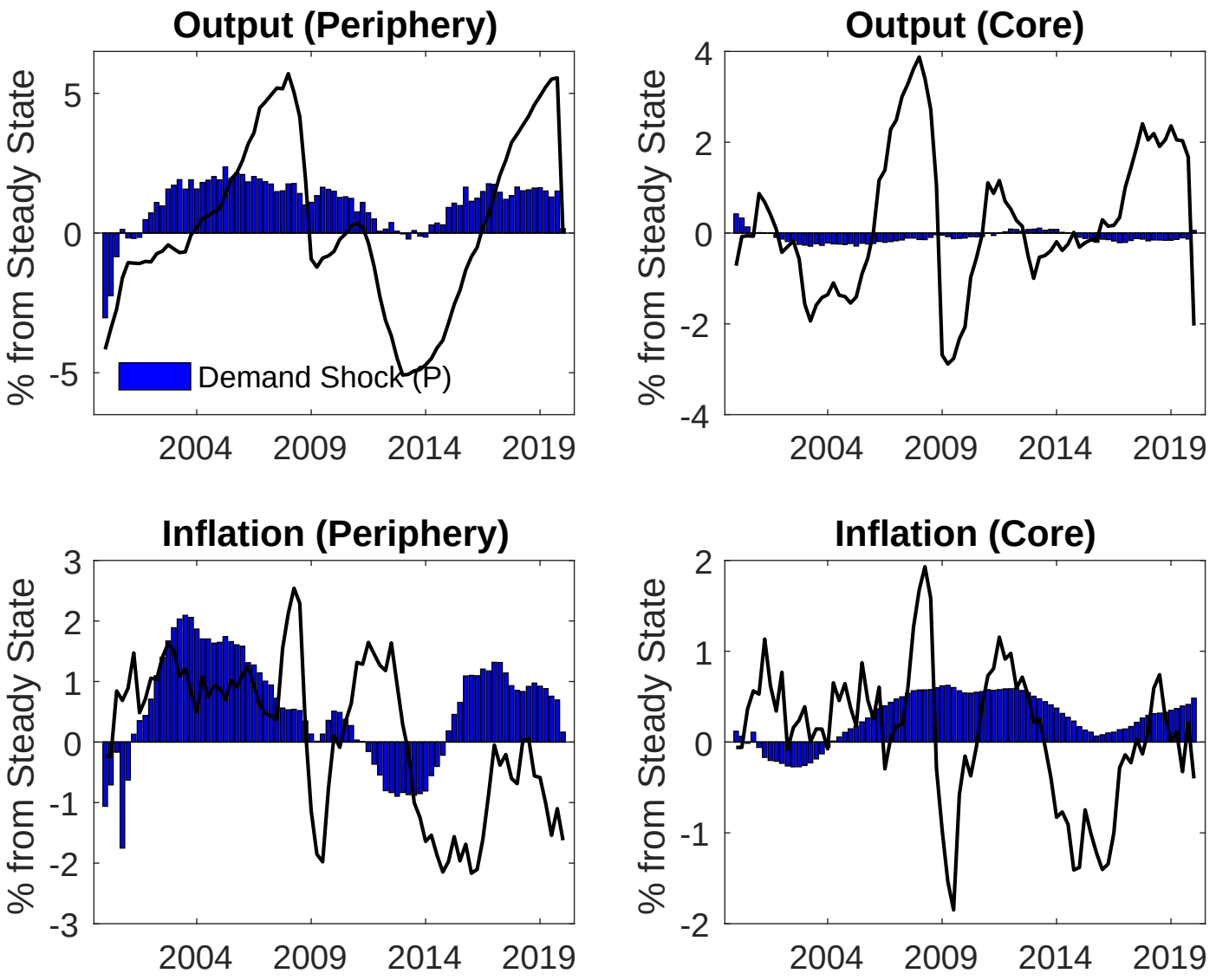


Figure 20: Contribution of Periphery Demand Shocks Main

Contribution of z^{COMM}: Role of Lower ϕ_π

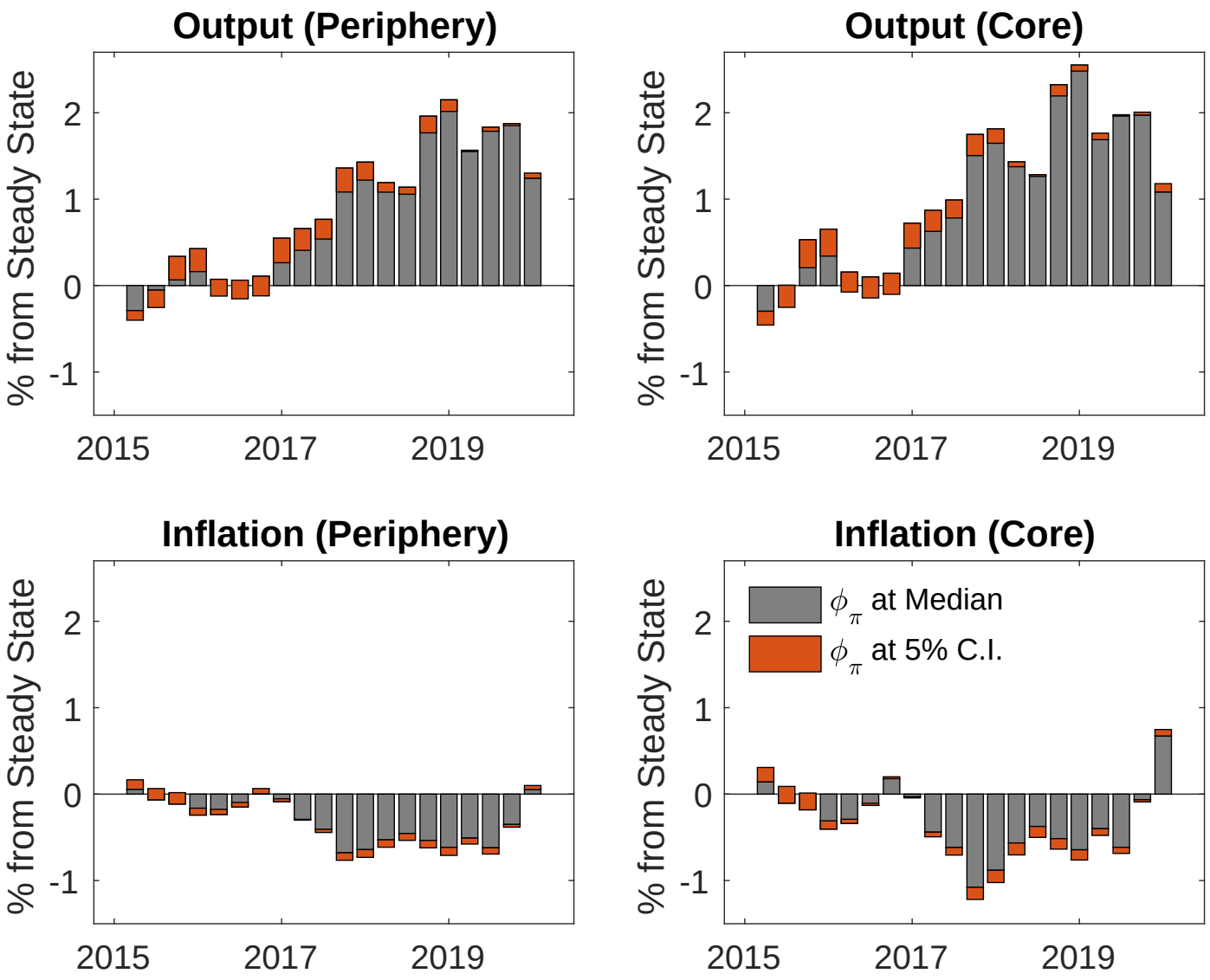


Figure 21: Role of ϕ_π for Propagation of z^{COMM} Shocks Main