The long-run effects of monetary policy

Òscar Jordà [*] Sanjay R. Singh [‡] Alan M. Taylor [§]

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[*] Federal Reserve Bank of San Francisco; University of California, Davis
[‡] University of California, Davis
[§] University of California, Davis; NBER; CEPR

Are there circumstances in which changes in aggregate demand can have an appreciable, persistent effect on aggregate supply?

— Chair Janet Yellen

question:
monetary interventions $\rightarrow$ macro outcomes 10-12 yrs after

methods:

- **long panel + data:** 125 yrs, 17 countries, output (capital, labor, TFP)
- **monetary experiments:** trilemma
- **methods:** local projections instrumental variables
- **robustness:** exclusion restriction evaluation, structural breaks, alternate identifications, control for global business cycle, sample cuts

outline & findings

panel data:

- large persistent effects with instrument + regression control for pegs
- robust to sample cuts, various robustness checks
- growth accounting: capital and TFP persistently lower, labor returns to pre-trend

US quarterly data & Romer-Romer shocks:

- evidence from long samples imply possibility of hysteresis
- persistently lower capital stock

reconciling new facts in a medium scale DSGE model:

- embed reduced form hysteresis effects $\rightarrow$ hysteresis elasticity
- hysteresis effects contingent on policy rule

some of the existing literature

identified responses to monetary shocks

- Bernanke & Mihov (1998), Romer & Romer (2004), Christiano Eichenbaum & Evans (2005), Cloyne & Hürtgen (2014), Ramey (2016), Coibion Gorodnichenko & Ulate (2017), Jordá Schularick & Taylor (2019)

interest rates and productivity

- Caballero Hoshi & Kashyap (2008), Gopinath Kalemli-Özcan Karabarbounis & Villegas-Sánchez (2017)
- Anzoategui Comin Gertler & Martinez (2019), Benigno & Fornaro (2018), Bianchi Kung Morales (2018), Garga & Singh (2016), Moran & Querlato (2018)

empirical evidence on hysteresis

- Cerra & Saxena (2008), Fernald Hall Stock & Watson (2017), Fatás & Summers (2018), Galí (2016), Yagan (2019)

data

annual 1890–2015 (excluding world wars) for 17 advanced economies

Jordà, Schularick & Taylor (2017)
www.macrohistory.net/data/
Interest rates, output, price level, investment, house prices, stock prices, consumption ...

Bergeaud, Cette & Lecat (2016)
www.longtermproductivity.com
hours worked, number of employees, capital stock (machines and buildings)...

trilemma: a quasi-natural experiment

theory of trilemma: peg + open to capital $\rightarrow$ correlated interest rates

instrument: base rate movements $\rightarrow$ home rate movements

local average treatment effect: (Jordà, Schularick and Taylor 2019)

- identification for open pegs, not for floats or bases

instrument construction

some definitions: Jordà, Schularick and Taylor (2019, JME) Details

3 subpopulations: bases, pegs, floats

$q_{i,t} \in \{0,1\}$ if peg in t and $t-1$

$k_{i,t} \in [0,1]$ Quinn, Schindler, and Toyoda (2011), 1 is open

$z_{i,t} = k_{i,t}(\Delta r_{b(i,t),t} - \Delta\widehat{r}_{b(i,t),t})$ using $x_{b(i,t),t}$ controls

- *intervention:* $\Delta r_{i,t}$ 3-mo govt. bill
- *instrument:* $z_{i,t}$: relevant and not weak

First Stage: $\Delta r_{i,t} = a_i + z_{i,t}b + x_{i,t}g + \eta_{i,t}$

	pegs ($q=1$)		**floats** ($q=0$)	
	All years	PostWW2	All years	PostWW2
b	0.52***	0.56***	0.16*	0.19**
t-statistic	[8.62]	[8.97]	[1.92]	[2.34]

implementation details

x: 2 lags, variables in log differences $\times$ 100, except interest rates and credit to GDP ratio

- log real GDP pc; log real C pc; log real I pc
- log CPI
- short-term (3m) + long-term (5y) govt. rates
- log real stock prices; log real house prices
- credit to GDP

annual sample: 17 advanced economies, yearly 1890-2015

local average treatment effect—LATE

panel local projections with **external** instruments: LP-IV

Under relevance, exogeneity and monotonicity, for pegs only, i.e., $q = 1$

$$\begin{aligned} y_{i,t+h} - y_{i,t-1} &= \alpha_{i,h} + x_{i,t}\gamma_h + \widehat{\Delta r}_{i,t}\beta_h + \nu_{i,t+h} \\ \Delta r_{i,t} &= a_i + x_{i,t}g + z_{i,t}b + \eta_{i,t} \\ h &= 0, \ldots, H-1 \end{aligned}$$

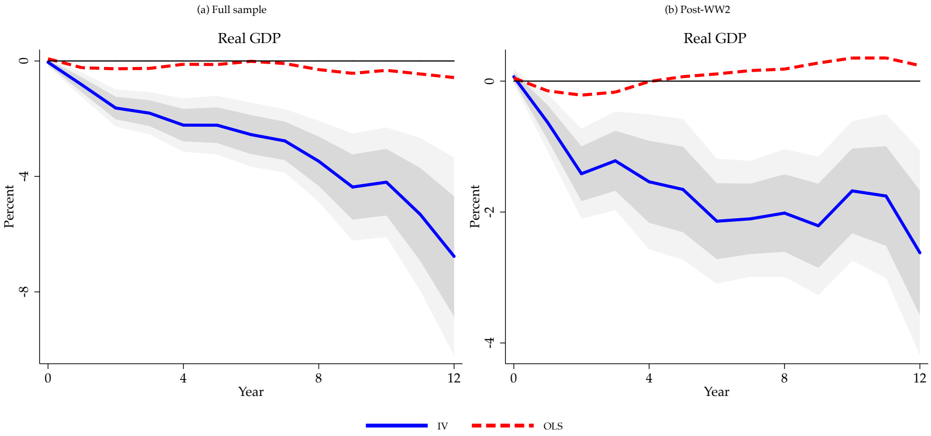
$$\mathcal{R}_{LATE} = E(y_1 - y_0 | \Delta r, x, z; q = 1) = \boldsymbol{\beta} = (\beta_0, \ldots, \beta_{H-1})'$$

why LATE?

LP-IV only valid for pegs, not bases or floats

if economies drawn from same distribution, then LATE $=$ ATE

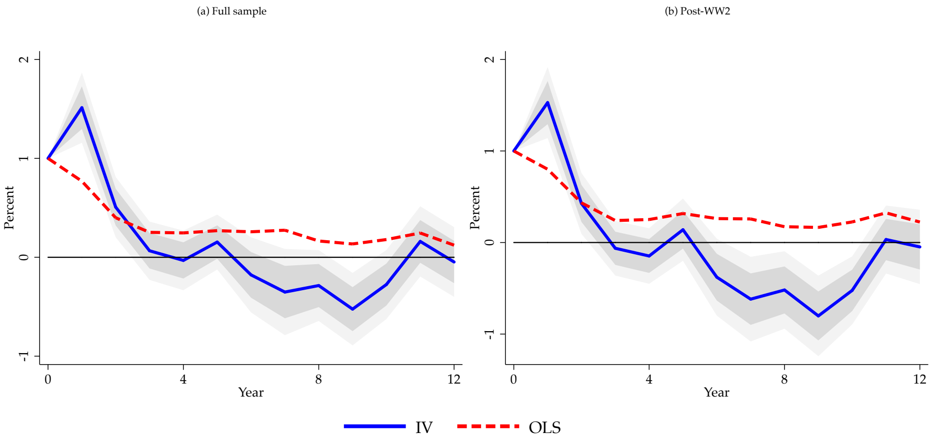
the long shadow



‡ confidence bands: 68% and 90%, cluster robust se

CPI

short term nominal interest rate



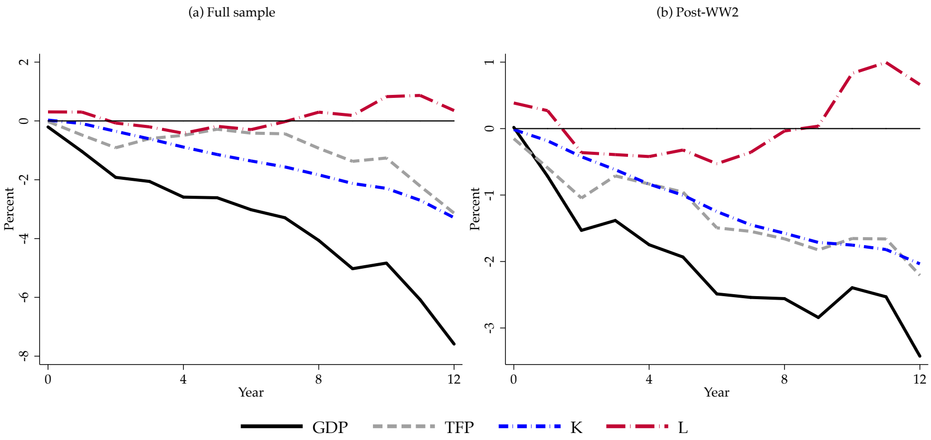
Multiplier

robustness exercises

- use GDP per capita, exclude Great Recession
- (current and future) structural breaks in TFP, GDP, GDP per capita (Bai Perron 1998)
- exclusion restriction: spillover correction through synthetic control function (Conley, Hansen & Rossi 2012)
- exclusion restriction: global gdp growth
- exclusion restriction: base country GDP growth
- exclusion restriction: current account, exchange rate with respect to float
- 5 lags of control variables, control variables in levels

GDP per capita | LP-VARS | Levels | Base Cycle | Global Cycle | Teal | Breaks in TFP | Breaks in GDP

Solow decomposition



util adjustment Confidence Bands

taking stock

panel LP-IVs

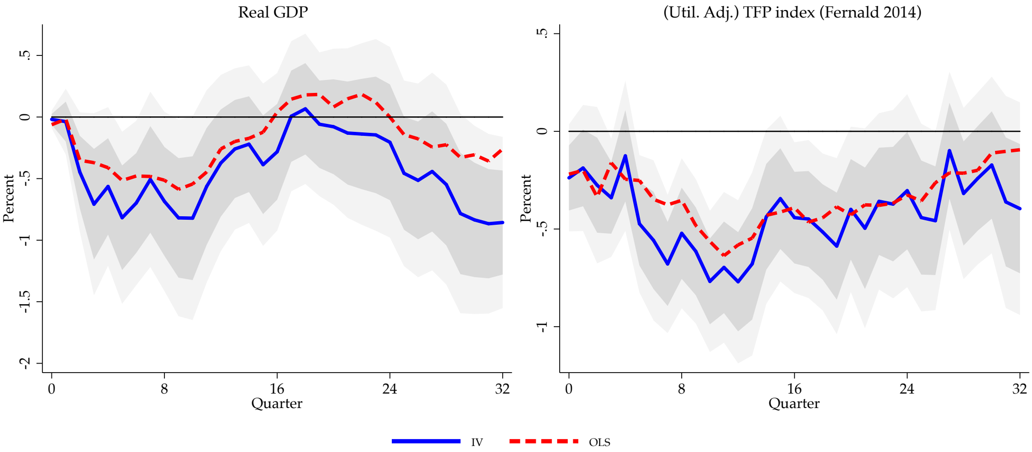
- using 125 years of data find persistent effects of monetary shocks
- persistently lower capital and TFP
- pass a variety of robustness exercises

next

- do we see similar effects for the US?

US: LP-IV + RR instruments

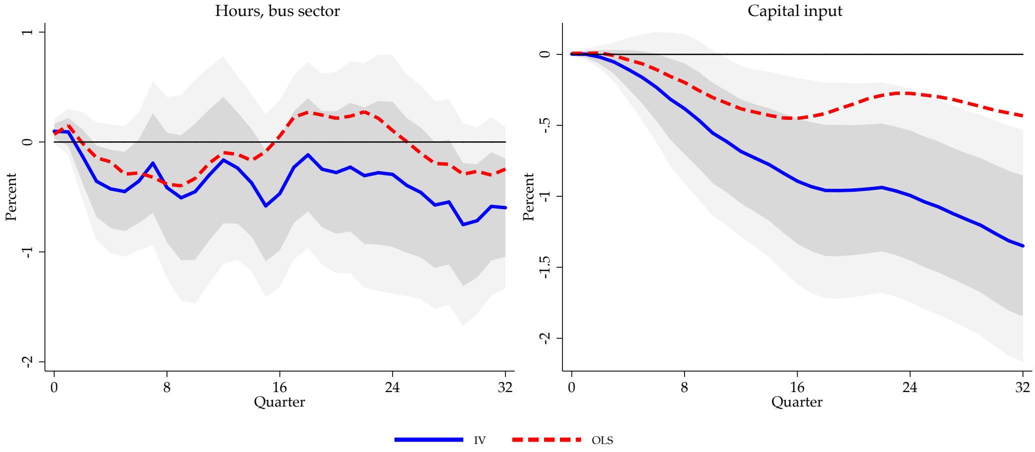
1969Q2: 2007Q4 + Romer & Romer (2004) forecast errors (Wieland & Yang 2018) + Fernald (2014) util-adjusted TFP



‡ confidence bands: 68% and 90%

Evans (1992) critique

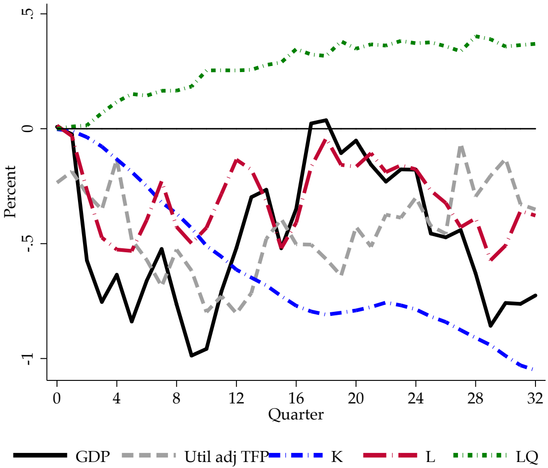
US: decomposition



‡ confidence bands: 68% and 90%

US: decomposition II

Instrument: Romer & Romer (2004) residuals



Samples CPI

taking stock

Panel LP-IVs

- use 125 years of data show persistent effects of monetary shocks
- persistently lower capital and TFP
- pass a variety of robustness exercises

LP-IVs and monetary policy shocks for US

- eight years out, lower output and capital stock
- Evans (1992) critique for quarterly utilization -adjusted TFP

How do we reconcile these new facts?

Endogenous TFP growth models (learning-by-doing, innovation, ...)

what we do

We embed hysteresis effects in a reduced form/ accounting sense

- many micro-founded models that give similar/exact equation: Anzoategui, Comin, Gertler & Martinez (2019), Benigno & Fornaro (2018), Bianchi, Kung & Morales (2019), Garga & Singh (2016)
- no micro level data to test or discriminate among mechanisms (yet)
- reduced form eqn enough to test whether macro implications exist and are large enough to be of interest
- identify a moment that quantitative models need to match
- show implications for policy rules in a set of micro-founded models that map to the reduced form eqn

medium-scale NK DSGE model

Christiano-Eichenbaum-Evans (2005), Smets-Wouters (2007)
+ hysteresis effects (Stadler 1990, Delong and Summers 2012)

what the model needs?

$$\log Z_t = \log Z_{t-1} + \mu_t + \eta \log \left(Y_{t-1} / Y_{t-1}^{f,t-1} \right)$$

microfoundations: Anzoategui et al (2019), Benigno & Fornaro (2018), Garga & Singh (2016)

the key moment to match

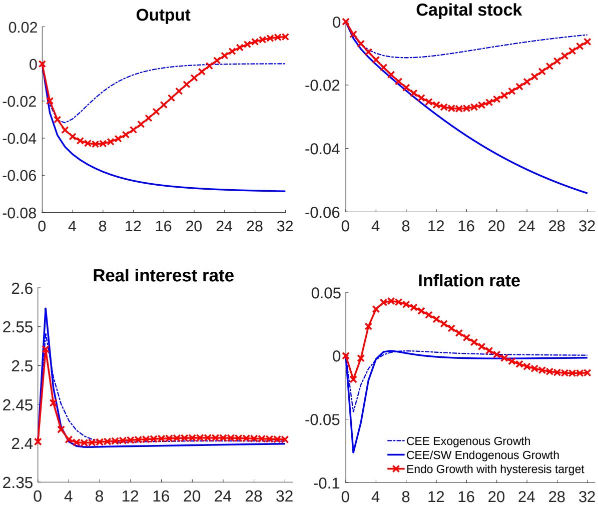
η - hysteresis elasticity $\in (0.18, 0.48)$

	pegs (trilemma)		US (RR)
Data	1890-2015	1948-2015	1969Q2 - 2015Q4
η	0.18	0.42	0.48

Delong & Summers (2012): $\eta \approx 0.24$

comparison of policy rules

$\eta = 0.18$, **Taylor Rule:** $1 + i_t = (1 + i_{t-1})^{0.8} \left[(\pi_t / \pi_{ss})^{1.5} \, y_t^{0.05} \right]^{1-0.8} (y_t / y_{t-1})^{0.2} \, \epsilon_t^{mp}$



Hysteresis target $1 + i_t = (1 + i_{t-1})^{0.8} \left[(\pi_t / \pi_{ss})^{1.5} \, y_t^{0.05} h_t^{0.2} \right]^{1-0.8} (y_t / y_{t-1})^{0.2} \, \epsilon_t^{mp}$; **where** $h_t = h_{t-1} + g_t - g_t^f$

Policy Implications

Usual prescription of inflation stabilization works

- Nominal rigidities introduce the textbook inefficiency with long-run effects Inflation
- Results hold in a set of recent endogenous growth DSGE models

Alternate tool: hysteresis targeting

- If hysteresis elasticity η high enough, reasons for policymakers to account for such effects
- Need quantitative models to understand the normative implications

Summary

- use 125 years of data to investigate persistent effects
- identification with quasi-natural experiment (trilemma) + RR instrument
- capital does not recover
- Evans (1992) critique for quarterly utilization -adjusted TFP
- model: aggressive inflation stabilization / hysteresis correction does not generate appreciable persistent effects

additional slides

home—base country links by era

Base country interest rate	Pre-WW1	Interwar	Bretton Woods	Post-BW
UK (Gold standard/BW base)	All countries		Sterling bloc: AUS*	
UK/USA/France composite (Gold standard base)		All countries		
USA (BW/Post-BW base)			All other countries	Dollar bloc: AUS, CAN, CHE, JPN, NOR
Germany (EMS/ERM/Eurozone base)				All other countries

* we treat AUS as moving to a dollar peg in 1967

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summary statistics

average peg: 21 years (note: gold + Bretton Woods)
Obstfeld and Rogoff (1995): 5yrs (developing countries)

pegs are more open than floats

average degree of capital openness: $\bar{k}$

all years		postWW2	
pegs ($q = 1$)	floats ($q = 0$)	pegs ($q = 1$)	floats ($q = 0$)
0.87	0.70	0.76	0.74
(0.21)	(0.31)	(0.24)	(0.30)

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how often do countries switch exchange rate regime?

excluding wars

	1870–2013		1870–1939		1948–2015	
	Frequency	%	Frequency	%	Frequency	%
float to peg	19	2	6	3	13	2
no change	954	96	191	93	763	97
peg to float	19	2	8	4	11	1
Total	992	100	205	100	787	100

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first-stage iv evidence

$$\Delta r_{i,t} = a_i + z_{i,t} b + x_{i,t} g + \eta_{i,t}$$

pegs ($q = 1$)	All years	PreWW2	PostWW2
b	0.52***	0.35**	0.56***
t-statistic	[8.62]	[2.05]	[8.97]
Obs	672	148	524
floats ($q = 0$)			
b	0.16*	-0.09	0.19**
t-statistic	[1.92]	[-1.66]	[2.34]
Obs	316	57	259

back

identification with external instruments

assumptions

relevance and exogeneity assumption:

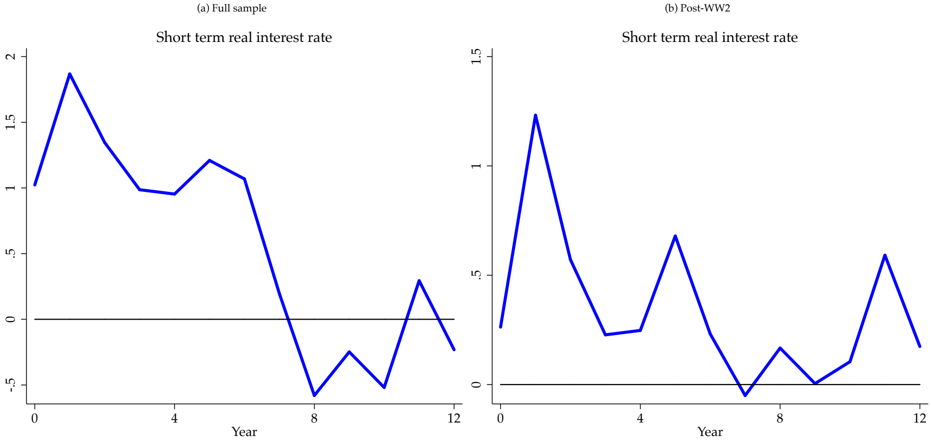
$$
\begin{array}{lll}
L(\Delta r|x,z;q=1) \neq L(\Delta|x;q=1) & & \text{relevance} \\
L(y_j|x,\Delta r,z;q=1) = L(y_j|x,\Delta r;q=1) & \text{for } j=0,1 & \text{exogeneity}
\end{array}
$$

$L(\Delta r|x,z)$ refers to linear projection of Δr on x and z

in IV identification depends on covariances only

also need **monotonicity** for $z \rightarrow \Delta r : \frac{\partial E(\Delta r|x,z)}{\partial z} \geq 0$

persistence of the shock



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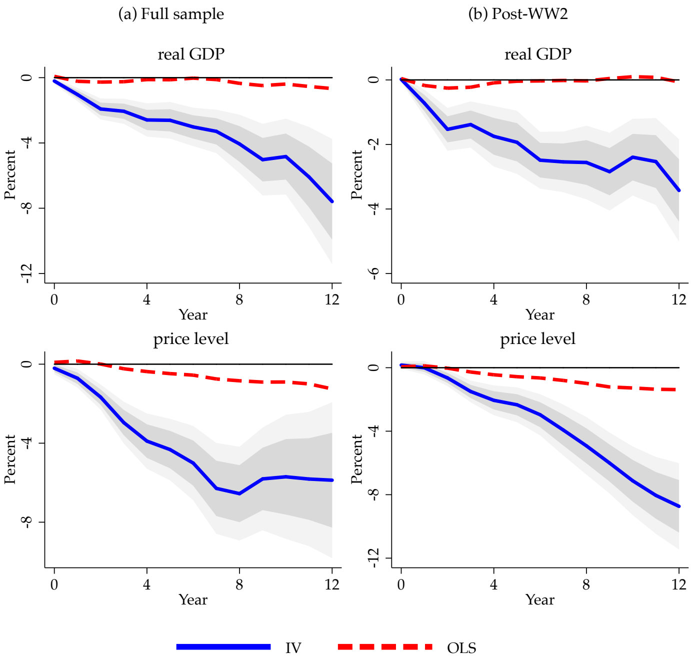
GDP and CPI



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Responses of real GDP at years 0 to 10 ($100 \times \log$ change from year 0 baseline).

	(a) Full Sample		*OLS-IV*	*(b) Post-WW2*		*OLS-IV*
Year	LP-OLS (1)	LP-IV (2)	*p-value* (3)	LP-OLS (4)	LP-IV (5)	*p-value* (6)
$h = 0$	0.08**	-0.04	0.18	0.05**	0.07	0.79
	(0.03)	(0.09)		(0.02)	(0.07)	
$h = 2$	-0.27	-1.63***	0.00	-0.21	-1.42***	0.00
	(0.16)	(0.39)		(0.13)	(0.42)	
$h = 4$	-0.11	-2.22***	0.00	-0.01	-1.54**	0.01
	(0.26)	(0.56)		(0.21)	(0.63)	
$h = 6$	-0.01	-2.55***	0.00	0.11	-2.14***	0.00
	(0.29)	(0.67)		(0.22)	(0.58)	
$h = 8$	-0.30	-3.47***	0.00	0.18	-2.02***	0.00
	(0.29)	(0.85)		(0.22)	(0.59)	
$h = 10$	-0.33	-4.20***	0.00	0.35	-1.68***	0.00
	(0.36)	(1.15)		(0.27)	(0.65)	
$h = 12$	-0.58	-6.77***	0.00	0.24	-2.62***	0.00
	(0.42)	(2.08)		(0.33)	(0.95)	
KP weak IV		68.34			69.18	
H_0: $LATE = 0$	0.00	0.00		0.00	0.00	
Observations	607	607		482	482	

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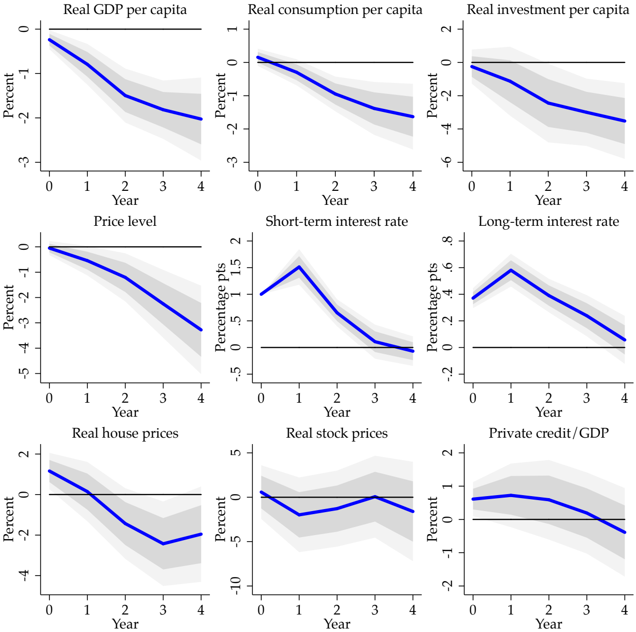
full set of IRFs



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Responses of real GDP per capita at years 0 to 10 ($100 \times \log$ change from year 0 baseline).

	(a) Full Sample		*OLS-IV*	*(b) Post-WW2*		*OLS-IV*
Year	LP-OLS (1)	LP-IV (2)	*p-value* (3)	LP-OLS (4)	LP-IV (5)	*p-value* (6)
$h = 0$	0.07***	-0.07	0.09	0.04**	0.09	0.47
	(0.03)	(0.09)		(0.02)	(0.06)	
$h = 2$	-0.28*	-1.72***	0.00	-0.25*	-1.47***	0.00
	(0.16)	(0.34)		(0.13)	(0.38)	
$h = 4$	-0.16	-2.53***	0.00	-0.08	-1.83***	0.00
	(0.26)	(0.50)		(0.21)	(0.57)	
$h = 6$	-0.06	-2.87***	0.00	0.02	-2.37***	0.00
	(0.29)	(0.66)		(0.23)	(0.55)	
$h = 8$	-0.36	-3.55***	0.00	0.10	-2.04***	0.00
	(0.29)	(0.84)		(0.22)	(0.55)	
$h = 10$	-0.40	-4.05***	0.00	0.26	-1.63***	0.00
	(0.35)	(1.08)		(0.24)	(0.62)	
KP weak IV		79.66			84.86	
H_0: $LATE = 0$	0.00	0.00		0.00	0.00	
Observations	607	607		482	482	

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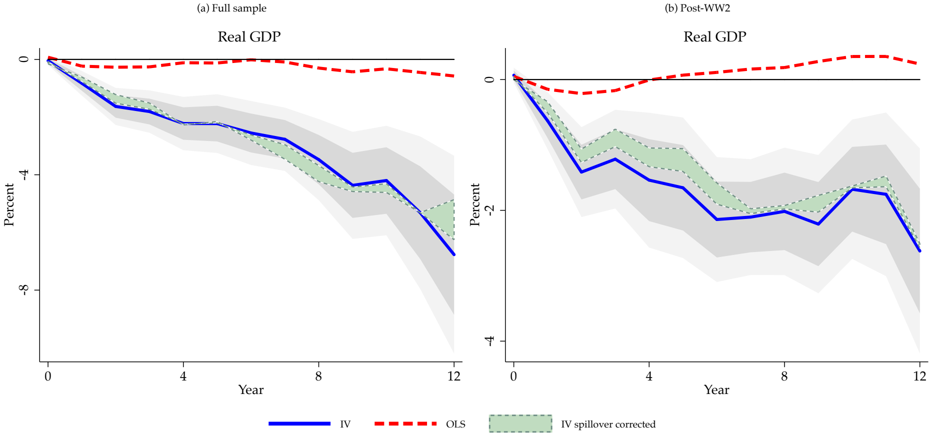
synthetic control function: spillover correction

Conley, Hansen and Rossi (2012): “plausibly exogenous”



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VAR-p vs LP : detecting long-run effects

Under invertibility, MA(∞) and AR(∞) estimate the same

$$y_t = u_t + \theta_1 u_{t-1} + \theta u_{t-2} + \ldots \iff y_t = \Phi_1 y_{t-1} + \Phi_{t-2} y_{t-2} + \ldots + u_t$$

i.e.

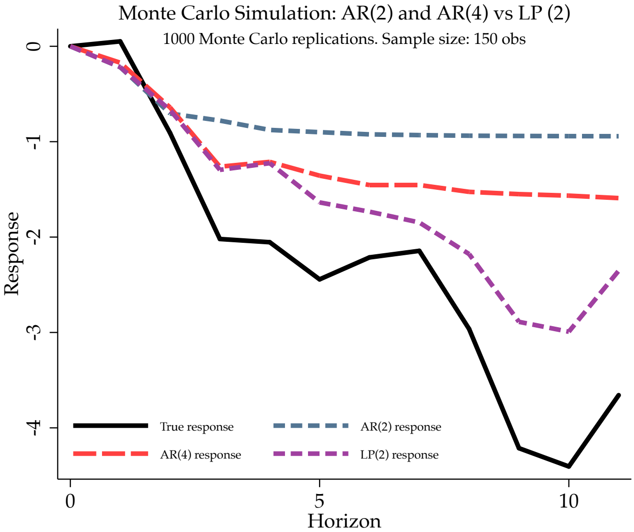
$$y_t = (1 + \theta_1 L + \ldots)(1 - \Phi_1 L - \ldots) y_t$$

In finite samples, estimate AR(∞) with AR(p) $\rightarrow$ MA terms beyond lag p based on the estimated p parameters

When # of lags p small, likely introduce bias. Back

LP-VVARs

Generate data using the estimated IRFs from a MA(12)



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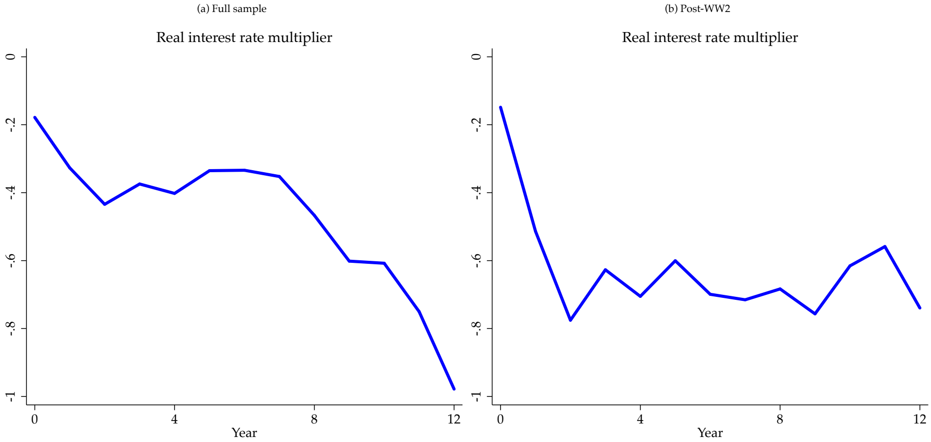
dynamic multiplier

cumulative change in GDP to the area under the real interest rate path (fiscal multiplier: Ramey and Zubairy 2018)



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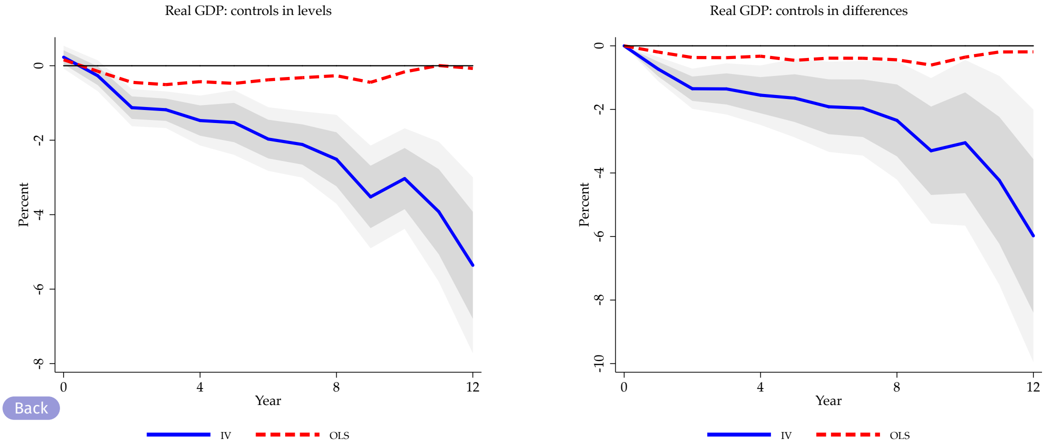
controls in levels vs differences

control for variables in levels instead of differences



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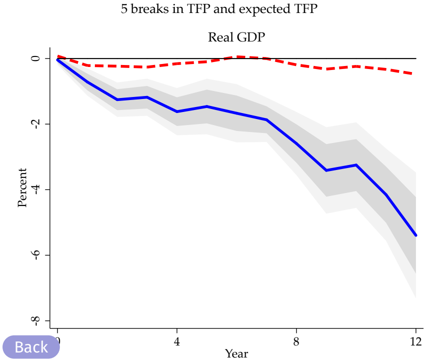
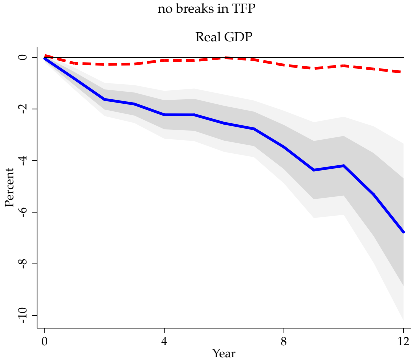
structural breaks in TFP

$$y_{i,t+h} - y_{i,t-1} = \alpha_{i,h} + \sum_{k-1} (D_{i,k,t} + D_{i,k,t+h}) + \widehat{\Delta r}_{i,t}\beta_h + \mathrm{x_{i,t}}\gamma_\mathrm{h} + \nu_{i,t+h},$$

where $D_{i,k,t+h}$ is country-specific dummy for TFP growth regime k (Bai-Perron) at horizon $h = 0, ..., H-1$ and $k \in (1, 5)$





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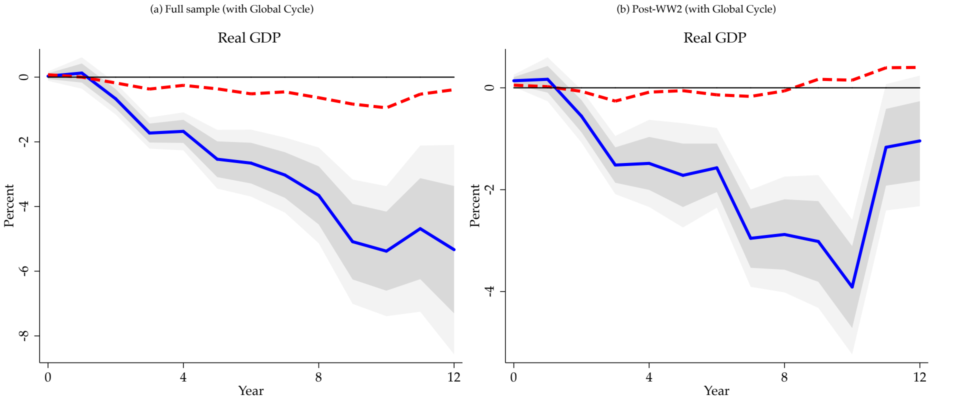
future global variables: exclusion restriction

$$y_{i,t+h} - y_{i,t-1} = \alpha_{i,h} + \widehat{\Delta r}_{i,t}\beta_h + \mathbf{x}_{i,t}\gamma_h + G_{t+h}\hat{\gamma}_h + \nu_{i,t+h}, \qquad \text{for } h = 0, \ldots, H-1$$

where G_{t+h} is global gdp growth at time $t+h$



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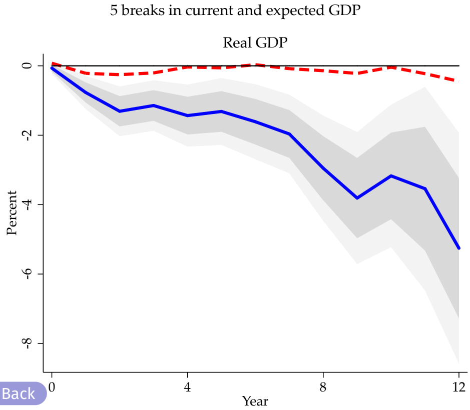
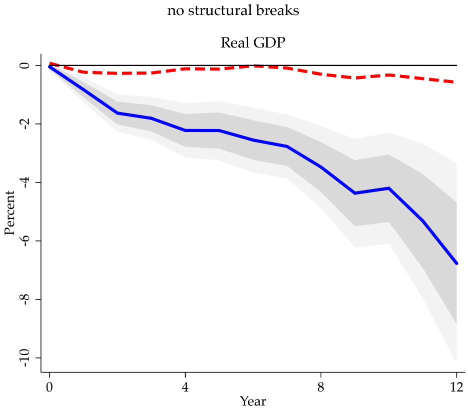
Structural Breaks in GDP

$$y_{i,t+h} = \alpha_{i,h} + \sum_{k-1} (D_{i,k,t} + D_{i,,k,t+h}) + \widehat{\Delta r}_{i,t}\beta_h + \mathrm{x}_{\mathrm{i,t}}\gamma_{\mathrm{h}} + \nu_{i,t+h},$$

where $D_{i,k,t+h}$ is country-specific dummy for GDP growth regime k at horizon $h = 0, ..., H-1$





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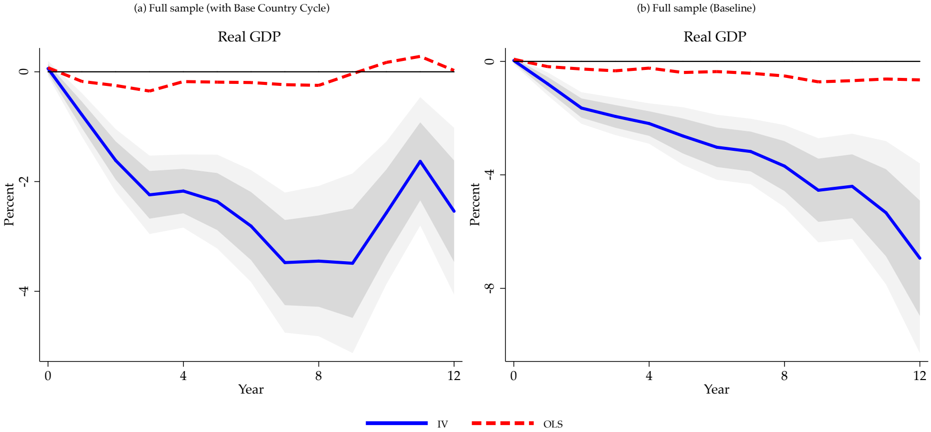
future base country variables: exclusion restriction

$$y_{i,t+h} - y_{i,t-1} = \alpha_{i,h} + \widehat{\Delta r}_{i,t}\beta_h + \mathrm{x_{i,t}}\gamma_\mathrm{h} + B_{b(i,t),t+h}\hat{\gamma}_h + \nu_{i,t+h}, \qquad \text{for } h = 0, \ldots, H-1$$

$B_{b(i,t),t+h}$ is gdp growth of base country $b(i,t)$ at time $t+h$



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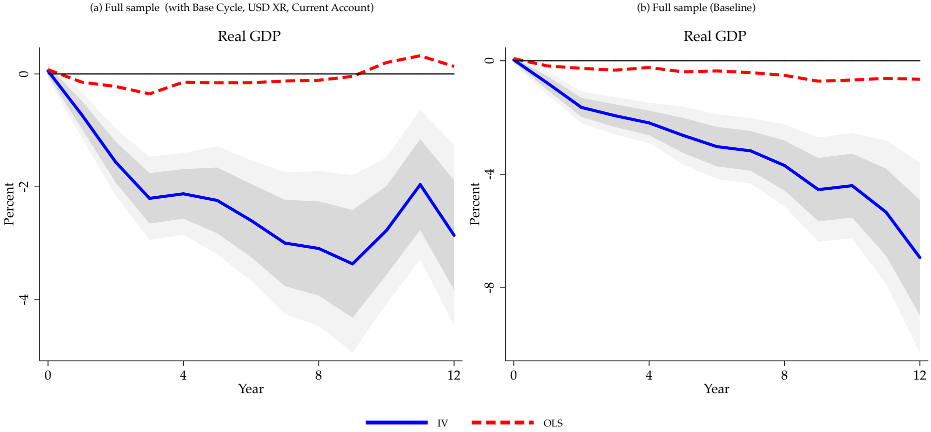
open economy variables: exclusion restriction

$$y_{i,t+h} - y_{i,t-1} = \alpha_{i,h} + \widehat{\Delta r}_{i,t}\beta_h + \mathrm{x}_{\mathrm{i,t}}\gamma_{\mathrm{h}} + \left(CA_{i,t+h}, XRUSD_{i.t+h}\right)\hat{\gamma}_h + \nu_{i,t+h}$$

$CA_{i,t+h}$: current account and $XRUSD_{i,t+h}$: exchange rate with respect to USD



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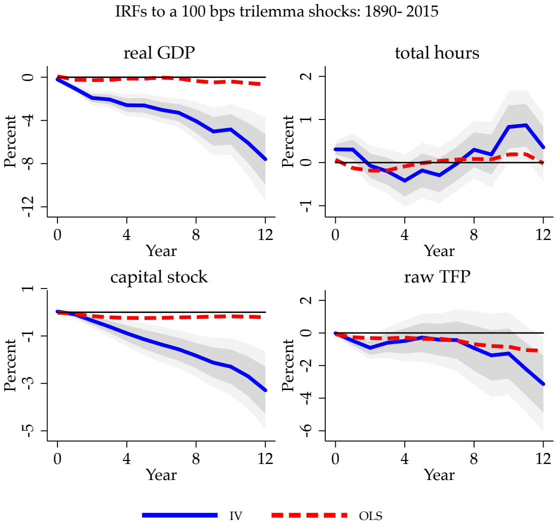
IRFs : Full Sample



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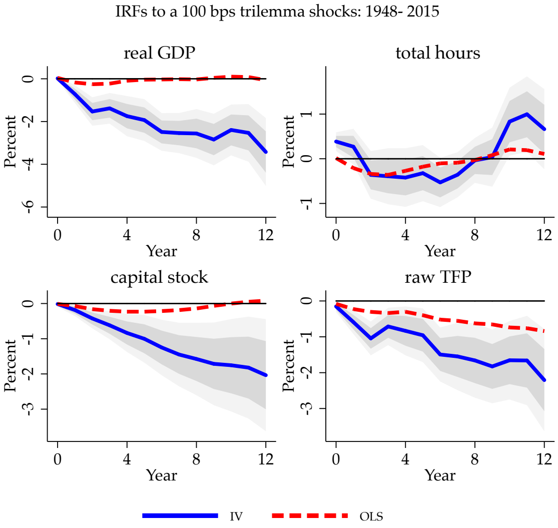
IRFs: Post WW2 Sample



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utilization adjustment

Partial equilibrium model of factor hoarding (Imbs 1999)

$$Y_t = A_t \left(K_t u_t\right)^{\alpha} \left(L_t e_t\right)^{1-\alpha}; \quad \delta_t = \delta u_t^{\phi}; \quad \phi > 1$$

Firm: $\max_{e_t, u_t, K_t} A_t \left(K_t u_t\right)^{\alpha} \left(L_t e_t\right)^{1-\alpha} - w(e_t)L_t - (r_t + \delta u_t^{\phi}))K_t$

HH: $\max_{C_t, L_t, e_t} \sum_{t=0}^{\infty} \beta^t \left[\ln C_t - \chi \frac{\left(e_t L_t\right)^{1+\nu}}{1+\nu} \right]$ s.t. budget constraint

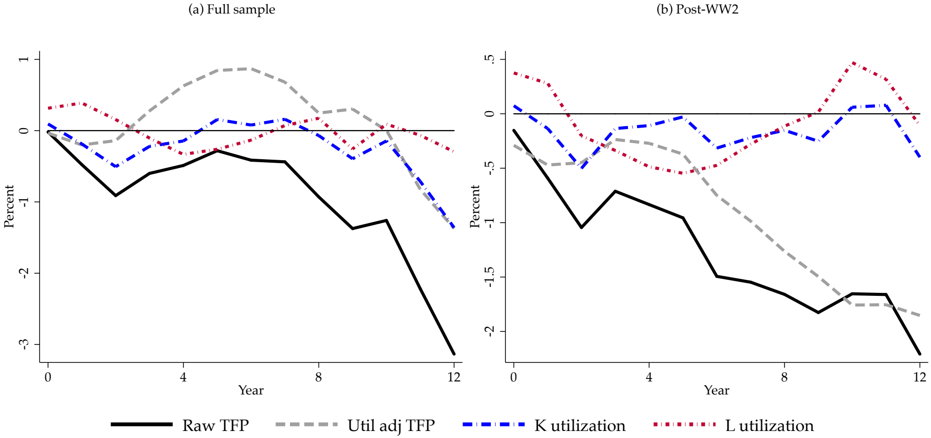
Reduces to a function of structural variables that can be measured directly (normalization: $\bar{e} = \bar{u} = 1$)

$$u_t = \left(\frac{Y_t / K_t}{Y / K} \right)^{\frac{\delta}{r+\delta}}; \quad e_t = \left(\frac{Y_t / C_t}{Y / C} \right)^{\frac{1}{1+\nu}} \frac{L}{L_t}$$

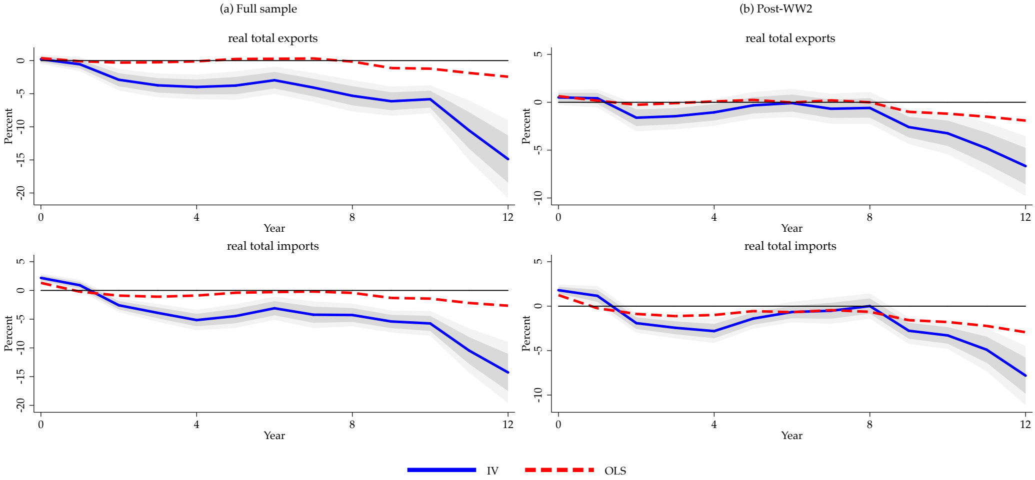
utilization adjustment

adjust for time-varying factor utilizations (Imbs 1999)

$$TFP_t \equiv \frac{Y_t}{K_t^\alpha L_t^{1-\alpha}} = A_t \times u_t^\alpha e_t^{1-\alpha}$$



Trade



(a) Full sample
(b) Post-WW2
real total exports
real total imports
Percent
Year
0
4
8
12
0
-5
-10
-15
-20
5
IV
OLS

quarterly data

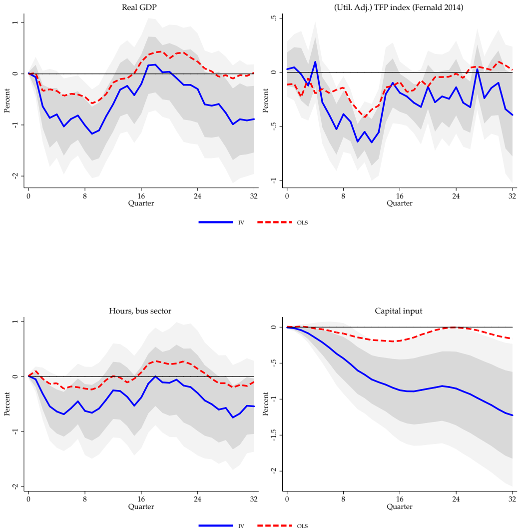
1969Q2 - 2015Q4, US

Romer & Romer (2004) extended by Wieland & Yang (2016)
Johannes Wieland's webpage
Greenbook staff forecast errors

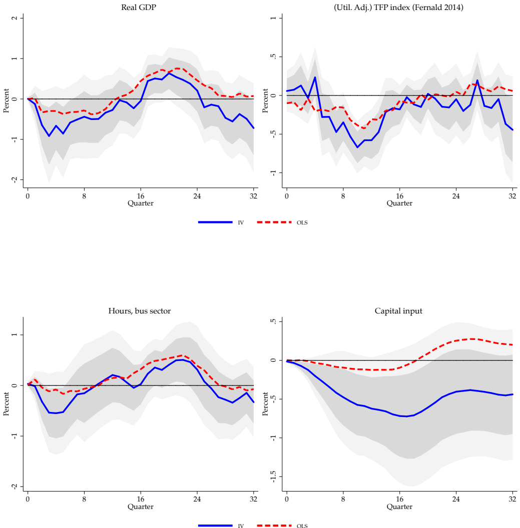
Fernald (2014)
Federal Reserve Bank of San Francisco
growth rate of output, capital, labor, labor quality, utilization adjusted TFP,...

US: LP-IV + RR instruments different subsamples

(a) Full sample: 1969Q2: 2008Q3



(b) Sample: 1973Q2: 2008Q3



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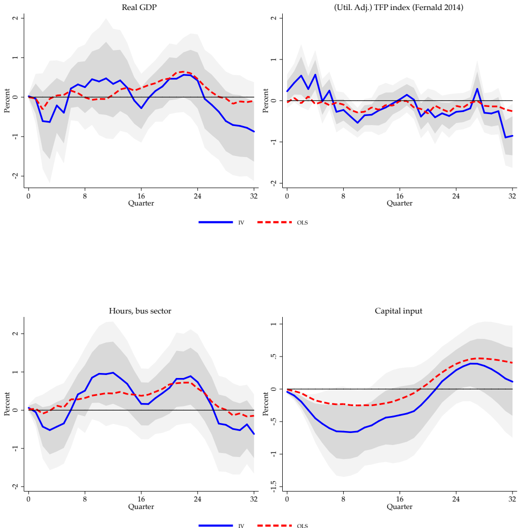
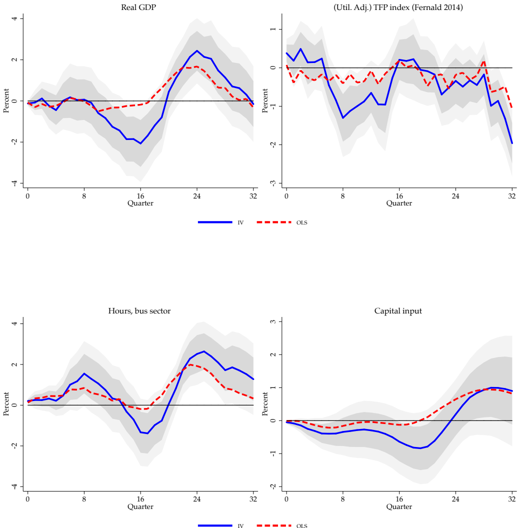
US: LP-IV + RR instruments different subsamples

(a) Sample: 1979Q3: 2008Q3



(b) Sample: 1984Q1: 2008Q3



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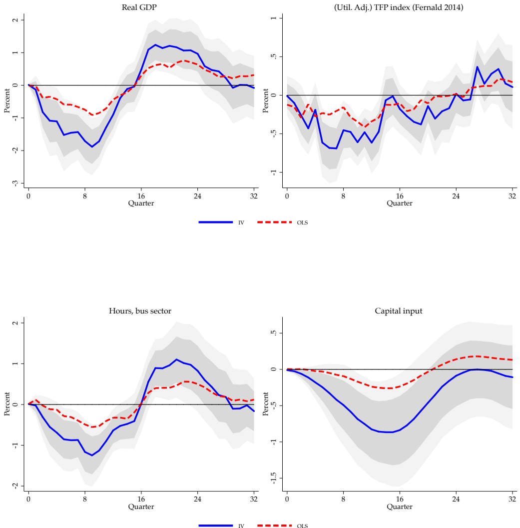
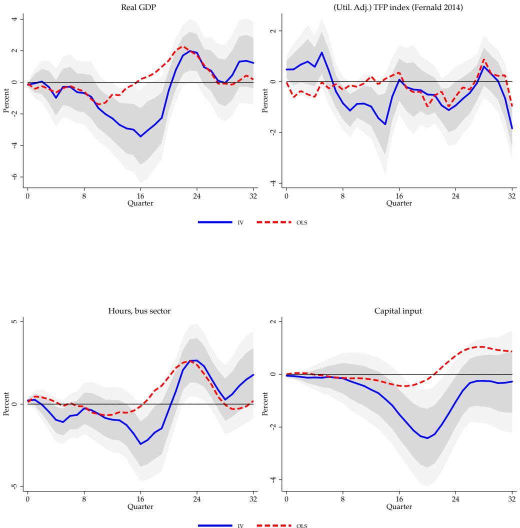
US: LP-IV + RR instruments different subsamples

(a) Sample: 1969Q2: 2002Q4



(b) Sample: 1987Q1: 2008Q3



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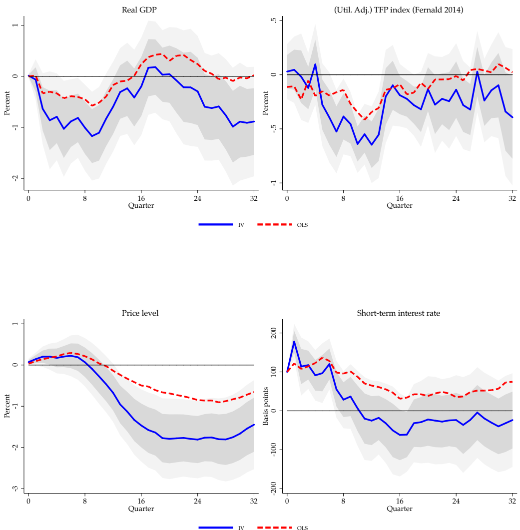
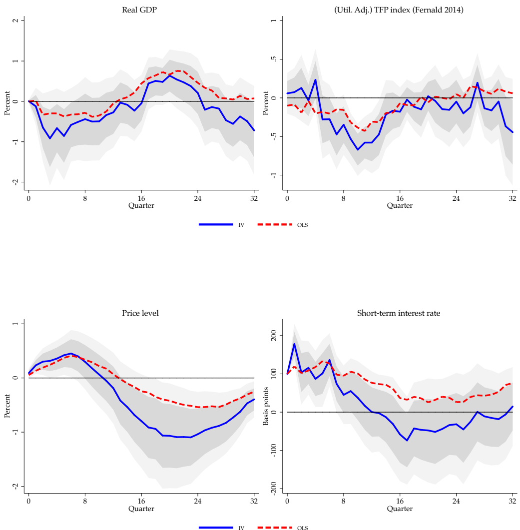
US: LP-IV + RR instruments different subsamples

(a) Full sample: 1969Q2: 2008Q3



(b) Sample: 1973Q2: 2008Q3



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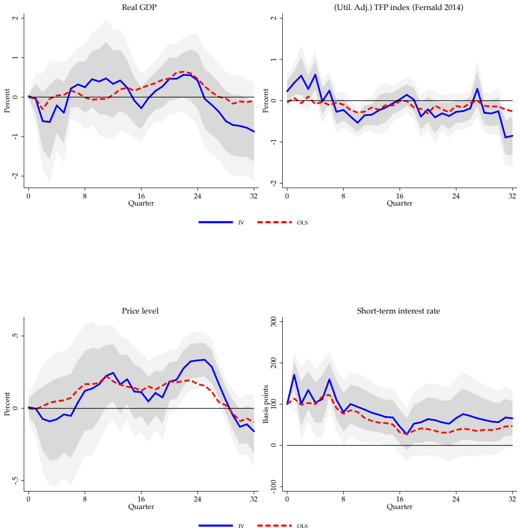
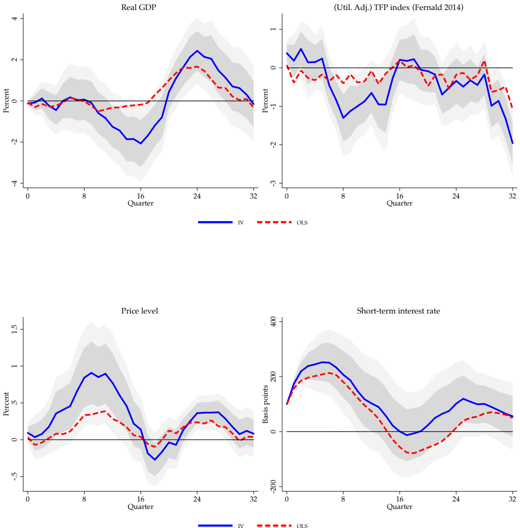
US: LP-IV + RR instruments different subsamples

(a) Sample: 1979Q3: 2008Q3



(b) Sample: 1984Q1: 2008Q3



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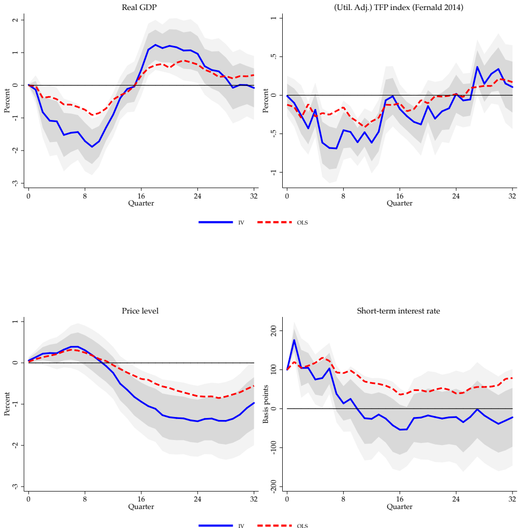
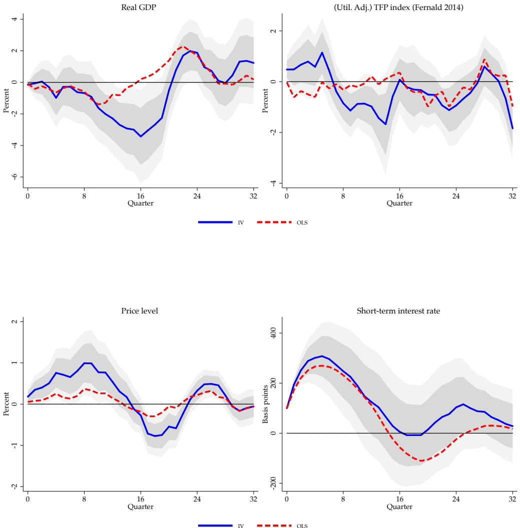
US: LP-IV + RR instruments different subsamples

(a) Sample: 1969Q2: 2002Q4



(b) Sample: 1987Q1: 2008Q3



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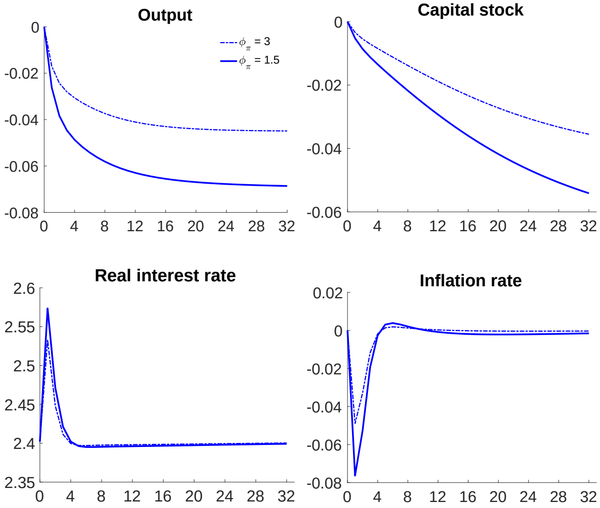
comparison of policy rules

$\eta = 0.18$, Taylor Rule: $1 + i_t = (1 + i_{t-1})^{0.8} \left[(\pi_t/\pi_{ss})^{\phi_\pi} \, y_t^{0.05} \right]^{1-0.8} (y_t/y_{t-1})^{0.2} \, \epsilon_t^{mp}$



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