The Missing Link: Labor Share and Monetary Policy

C. Cantore[1] F. Ferroni[2] M. León-Ledesma[3]

[1] Bank of England, Centre for Macroeconomics and University of Surrey

[2] Federal Reserve Bank of Chicago

[3] School of Economics and MaGHiC, University of Kent

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Motivation

- Structural models for Monetary Policy (MP) analysis that rely on nominal rigidities establish **clear transmission mechanisms** from MP shocks to real economic activity and inflation.
- One of the key mechanisms of transmission in these models operates through the **redistribution of income** between labor income, capital income and firm's profits.
- If prices are not perfectly flexible, **MP tightening** should lead to an increase in the markup and a **decrease in the income share of labor** as prices cannot react immediately to the fall in demand. This effect reduces unit labor costs leading to a downward pressure on inflation.
- For this transmission mechanism to be operative, MP shocks should affect the cyclical behavior of factor income shares in ways that are consistent with these theoretical arguments.

In this Paper

- Despite its importance, studies on the effect of MP shocks on income shares are very limited (e.g. [Christiano et al., 2010], [Ramey, 2016], [Christiano et al., 2016]).

- Our objective is to fill this gap and provide the first cross-country comprehensive study on the effects of monetary policy on the labor share.

1. We provide **new and robust evidence** on the effects of **MP shocks** on **the Labor share** for a set of **five** developed economies: The US, the Euro Area, UK, Australia and Canada.

2. We compare the empirical results with the **implied transmission mechanism** in standard **DSGE models** displaying nominal, real rigidities and labor market frictions.

    - Given our evidence, are current models used for monetary policy analysis able to match the responses of the variables of interest?

Preview of the Results

- The empirical analysis presents a **very robust set of stylized facts**: cyclically, a monetary policy tightening *increased* the **labor share** and *decreased* **real wages**, and **labor productivity**.

- These facts are **robust** across **time**, across **countries**, across different Structural Vector Autoregression (SVAR) **identification strategies** and across **sectors**.

- These stylized facts are at odds with the responses implied by the standard New Keynesian (NK) model of the business cycle where there is a one to one link between the labor share and marginal costs (mark-up).

- But this **mismatch between data and theory is not just a feature of the basic NK model but carries over in richer set ups widely used for MP analysis.**

Labor Share, the price mark-up and the Business Cycle

- MP shocks and SVAR evidence: [Christiano et al., 2005], [Olivei and Tenreyro, 2007] , [Ramey, 2016], [Basu and House, 2016].
- Labor Share and technology shocks: [Hansen and Prescott, 2005], [Choi and Ríos-Rull, 2009], and [León-Ledesma and Satchi, 2018].
- The cyclicality of mark-ups: [Bils, 1987], [Rotemberg and Woodford, 1999], [Galí et al., 2007], [Hall, 2012], [Nekarda and Ramey, 2013], [Karabarbounis, 2014] and [Bils et al., 2014].
- [Nekarda and Ramey, 2013]: Their conclusions, like ours, cast doubts on the standard transmission mechanism of NK models.
- The conditional correlation of the labor share to demand shocks is still empirically and theoretically an **open question**.

The transmission mechanism of MP in NK-DSGE models.

- Several mechanisms have been presented that can break down the labor share and the inverse of the mark-up.
  - The Cost channel of Monetary Policy: [Ravenna and Walsh, 2006], [Christiano et al., 2010].
  - Labor market search frictions: [Trigari, 2006], [Christoffel and Kuester, 2008], [Christiano et al., 2016].
  - CES production: [Cantore et al., 2014], [Cantore et al., 2015].
  - Overtime/Overhead labor: [Bils, 1987], [Nekarda and Ramey, 2013].

Cross Country Labor Share

▸ Data construction and sources

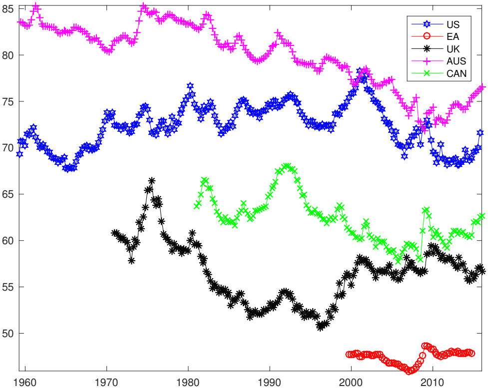


Figure: Cross Country Labor Share

▸ Descriptive Statistics

Empirical Analysis: VAR information set - Cholesky

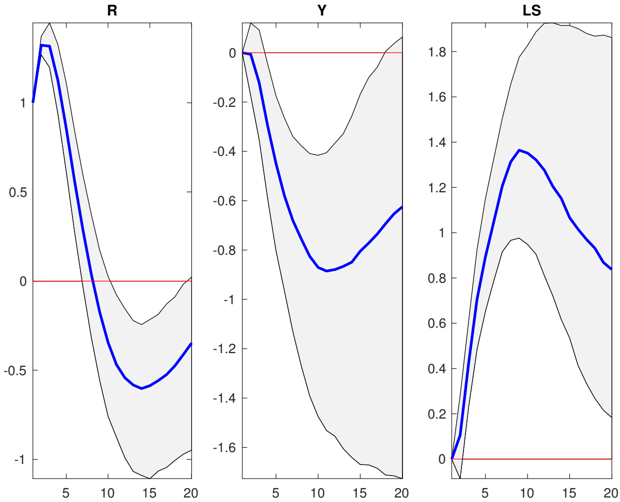
- We consider, as a baseline specification, a 7 variables VAR merging part of the information sets in [Olivei and Tenreyro, 2007] [OT] and [Christiano et al., 2005] [CEE05].
- The variables in the information set are: the log of Real GDP, the log of GDP deflator, the log of an index for price of commodities, log of CPI, log Labor Share, short term interest rates and M2 growth. ▸ Details
- The advantages of using the labor share instead of it's components is that the *composition bias* in the response of real wages and productivity cancels out when one takes their ratio (see [Basu and House, 2016]).
-

Country	Sample	
US	1984:Q1	2007:Q4
EA	1999:Q4	2011:Q3
AUS	1985:Q1	2009:Q4
CAN	1985:Q1	2011:Q1
UK	1986:Q1	2008:Q1

VAR Identification Scheme: Cholesky

normalized 1% increase in the short term interest rate - US

▸ Full VAR



▸ Other Countries

VAR Robustness: Information Set and Sample

- Using different labor share proxies constructed for the US, Australia and Canada. ▸ Details
- The exact same info sets as in [Olivei and Tenreyro, 2007] and [Christiano et al., 2005].
- Only for the US: the original sample as [CEE05] 1965:Q1-1995Q3 and 1965:Q1-2007:Q4. ▸ Details
- ▸ Larger VAR
- ▸ Summary

VAR Robustness: Alternative Identification Schemes

- **Sign restrictions**, as in [Uhlig, 2005].
- **External/instrumental variable approach** as proposed by [Stock and Watson, 2012] and by [Mertens and Ravn, 2013].
- Details

Sectoral Evidence

- Is this evidence robust also across sectors?
- Is the increase in the labor share due to changes in the composition of output from sectors with low to sectors with high labor shares rather than a change of the labor share within sectors?
- We exploit the cross-section and time-series variation of labor shares at the disaggregated sector level.
- Using NBER-CES and Klems data we show that the increase in the LS happens also within sectors.
- Details

Labor share components IRFs

- What drives the Labor share responses?
- A countercyclical response of the labor share to a monetary policy shock can occur either because real wages are more countercyclical than labor productivity or, vice versa, because labor productivity is more procyclical than real wages. $s_t^h = w_t - lp_t$
- The two scenarios have very different implications for the transmission mechanism of MP and will prove to be crucial in evaluating the performance of business cycle models.

Labor share components IRFs

- We control for different deflators of wages and output ([Pessoa and Van Reenen, 2013]). ▸ Details
- We check the responses of real wages and labor productivity in the same VAR specifications.
- We find consistently that $s_t^h \uparrow$ because $lp \downarrow > w \downarrow$. ▸ Details
- We also control for the *composition bias* discussed before. This makes the response of the *representative agent* real wage (and productivity) more negative than what we find using aggregate data.
- This is in line with the results of: [Christiano et al., 2005] using macro data and [Basu and House, 2016] using micro-data. ▸ Details
- ▸ Details - composition bias adjusted data

Theory

- Are current models of economic fluctuations able to match the response of the labor share, real wages and productivity? And, if so, at which cost?
- We check from the simplest version of the NK model, as in [Galí, 2008], to medium scale DSGE models with a broad set of nominal and real frictions ([Christiano et al., 2005], [Christiano et al., 2016]) like the ones currently used for monetary policy analysis.
- Given the size of most of these models we do this using a **three step approach**:

1. **Prior Sensitivity Analysis** (PSA): we asses the likelihood of each of the models to generate the sign of LS IRFs consistent with the data, conditional on the model and on a very loose prior specification.

2. **Monte Carlo Filtering** (MCF): to identify the parameters that are able to generate those patterns.

3. **Bayesian IRF Matching** ([Christiano et al., 2010]): estimate the models (including the parameters identified in step 2) by minimizing the distance between the VAR and DSGE IRFs to a MP shock for a selected number of variables.

Theory: Labor Share in DSGE models

- It is well known that in standard NK models the labor share is equivalent to the inverse of the price markup. [Galí et al., 2007], [Nekarda and Ramey, 2013]

$$s_t^h = \frac{\pi_t - \beta \mathbb{E}_t \pi_{t+1}}{\lambda}$$

- Several mechanisms have been presented that can break down the labor share and the inverse of the mark-up:
  - The Cost channel of Monetary Policy: [Ravenna and Walsh, 2006], [Christiano et al., 2010].
  - Labor market search frictions: [Trigari, 2006], [Christoffel and Kuester, 2008], [Christiano et al., 2016].
  - CES production: [Cantore et al., 2014], [Cantore et al., 2015].
  - Overtime/Overhead labor/Fix costs: [Bils, 1987], [Nekarda and Ramey, 2013].

Details

Pool of DSGE Models we compare against the SVAR

NK Medium scale DSGE model with sticky prices and wages + other real rigidities. [Christiano et al., 2005] , [Smets and Wouters, 2007]

NK_CES Medium scale DSGE model + CES production. [Cantore et al., 2014], [Cantore et al., 2015]

NK_WKN Medium scale DSGE model + Working capital + firm networks. [Phaneuf et al., 2015].

NK_SM Medium scale DSGE model with sticky prices and search frictions with Alternating bargaining (no sticky wages). [Christiano et al., 2016]

- Each model has the same Taylor rule $r_t = \rho^r r_{t-1} + (1-\rho^r)[\rho^\pi \pi_t + \rho^y y_t] + \varepsilon_t^r$ and the agents information set is consistent with the Cholesky recursive identification of the SVAR.
- We also checked other models like: NK without capital [Galí, 2008], [Galí, 2010]. Sticky Information [Mankiw and Reis, 2007]. Right to manage [Christoffel and Kuester, 2008].

Prior Sensitivity Analysis

1 How likely is the structural model to generate the sign pattern of the conditional moments (IRF) we observe in the data?

- As explained by [Canova, 1995], [Lancaster, 2004] and [Geweke, 2005], prior predictive analysis is a powerful tool to shed light on complicated objects that depend on both the joint prior distribution of parameters and the model specification.
- By generating a random sample from the prior distributions, one can compute the reduced form solution and the model-implied statistics of interest, e.g. impulse responses.
- Many replicas of the latter generates an empirical distribution of the model- and prior-implied statistics of interest. ([Leeper et al., 2015] and [Féve and Sahuc, 2014])

Priors

<table>
<tr><th>Description</th><th>NK</th><th>NK_CES</th><th>NK_WKN</th><th>NK_SM</th></tr>
<tr><td>Inverse of Frish Elasticity of Labor Supply</td><td>$U[1, 10]$</td><td>-</td><td>$U[1, 10]$</td><td>$U[1, 10]$</td></tr>
<tr><td>Investment adjustment costs</td><td colspan="4">$U[1, 10]$</td></tr>
<tr><td>Habits in Consumption</td><td colspan="4">$U[0, 1]$</td></tr>
<tr><td>Variable Capital Utilization</td><td colspan="4">$U[0, 1]$</td></tr>
<tr><td>Calvo price stickiness</td><td colspan="4">$U[0, 1]$</td></tr>
<tr><td>Calvo wage stickiness</td><td>$U[0, 1]$</td><td>$U[0, 1]$</td><td>$U[0, 1]$</td><td>-</td></tr>
<tr><td>price markup</td><td colspan="4">$U[1, 1.2]$</td></tr>
<tr><td>wage markup</td><td>$U[1, 1.2]$</td><td>$U[1, 1.2]$</td><td>$U[1, 1.2]$</td><td>-</td></tr>
<tr><td>Interest rate smoothing</td><td colspan="4">$U[0, 1]$</td></tr>
<tr><td>Taylor rule response to inflation</td><td colspan="4">$U[1.01, 5]$</td></tr>
<tr><td>Taylor rule response to output</td><td colspan="4">$U[0, 1]$</td></tr>
<tr><td>Price Indexation</td><td>$U[0, 1]$</td><td>$U[0, 1]$</td><td>-</td><td>-</td></tr>
<tr><td>Wage Indexation</td><td>$U[0, 1]$</td><td>$U[0, 1]$</td><td>-</td><td>-</td></tr>
<tr><td>K/L elasticity of substitution</td><td>-</td><td>$U[0.01, 5]$</td><td>-</td><td>-</td></tr>
<tr><td>working capital fraction (labor)</td><td>-</td><td>-</td><td>$U[0, 1]$</td><td>$U[0, 1]$</td></tr>
<tr><td>Intermediate inputs share in production</td><td>-</td><td>-</td><td>$U[0, 1]$</td><td>-</td></tr>
<tr><td>working capital fraction (capital)</td><td>-</td><td>-</td><td>$U[0, 1]$</td><td>-</td></tr>
<tr><td>working capital fraction (intermediate inputs)</td><td>-</td><td>-</td><td>$U[0, 0.7]$</td><td>-</td></tr>
<tr><td>technology diffusion</td><td>-</td><td>-</td><td>-</td><td>$U[0, 1]$</td></tr>
<tr><td>prob. of barg. session determination</td><td>-</td><td>-</td><td>-</td><td>$U[0, 1]$</td></tr>
<tr><td>replacement ratio</td><td>-</td><td>-</td><td>-</td><td>$U[0, 1]$</td></tr>
<tr><td>hiring fixed cost relative to output %</td><td>-</td><td>-</td><td>-</td><td>$U[0, 2]$</td></tr>
<tr><td>search cost relative to output %</td><td>-</td><td>-</td><td>-</td><td>$U[0, 2]$</td></tr>
<tr><td>matching function share of unemployment</td><td>-</td><td>-</td><td>-</td><td>$U[0, 1]$</td></tr>
<tr><td>job survival rate</td><td>-</td><td>-</td><td>-</td><td>$U[0, 1]$</td></tr>
<tr><td>vacancy filling rate</td><td>-</td><td>-</td><td>-</td><td>$U[0, 1]$</td></tr>
</table>

Uniform Distribution bounds for PSA and MCF.

Details

Prior Sensitivity Analysis

We check the % of the parameter space that generates a (+) IRF of labor share and a (-) IRF of wages and labor productivity from quarters 2 to 5 and 5 to 8.

	Restrictions			
	2:5 quarters		5:8 quarters	
Model	ls (+)	ls (+); lp (-); w (-)	ls (+)	ls (+); lp (-); w (-)
NK	30.9%		59.7%	
NK_CES	11.2%		55.1%	
NK_WKN	26.5%		54.4%	
NK_SM	6.2%		46.0%	

Prior Sensitivity Analysis

We check the % of the parameter space that generates a (+) IRF of labor share and a (-) IRF of wages and labor productivity from quarters 2 to 5 and 5 to 8.

	Restrictions			
	2:5 quarters		5:8 quarters	
Model	ls (+)	ls (+); lp (-); w (-)	ls (+)	ls (+); lp (-); w (-)
NK	30.9%	1.7%	59.7%	13.9%
NK_CES	11.2%	0.7%	55.1%	4.6%
NK_WKN	26.5%	9.2%	54.4%	13.3%
NK_SM	6.2%	2.8%	46.0%	13.5%

Monte carlo filtering methods

2 Which are the parameters that mostly drive these patterns in each model?

- This question is more subtle because it requires an inverse mapping. Montecarlo filtering (MCF) techniques offer a statistical framework to tackle this question.
- MCF are computational tools that allow researchers to recover, in a nonlinear model, the critical inputs that generate a particular model output.
- In MCF all parameters move simultaneously.
- Smirnoff test offers implicitly a statistical ranking of parameters from the most to the least influential ones.

MCF: Parameters driving prior restrictions in each model.

Description	NK	NK_CES	NK_WKN	NK_SM
Relative Risk Aversion				
Inverse of Frish Elasticity of Labor Supply				
Investment adjustment costs	✓ (red, underlined)	✓ (red)	✓ (red)	✓ (red)
Habits in Consumption		✓ (red)	✓	
Variable Capital Utilization				
Calvo price stickiness	✓ (red, underlined)	✓ (red, underlined)	✓ (red, underlined)	
Calvo wage stickiness	✓	✓ (red, underlined)	✓ (red, underlined)	
price markup	✓ (red, underlined)		✓ (red, underlined)	✓ (red, underlined)
wage markup				
Interest rate smoothing	✓ (red)	✓ (red)	✓ (red, underlined)	
Taylor rule response to inflation				
Taylor rule response to output				
Price Indexation				
Wage Indexation				
K/L elasticity of substitution		✓		
working capital fraction (labor)			✓	✓ (red, underlined)
Intermediate inputs share in production			✓ (red, underlined)	
working capital fraction (capital)				
working capital fraction (intermediate inputs)				
technology diffusion				
prob. of barg. session determination				
replacement ratio				✓ (red, underlined)
hiring fixed cost relative to output %				
search cost relative to output %				
matching function share of unemployment				✓ (red, underlined)
job survival rate				✓ (underlined)
vacancy filling rate				

Parameters responsible for matching prior restrictions over quarters 2:5 (black checkmark), 5:8 (red checkmark) and 2:8 (red underlined checkmark).

CDF

Bayesian IRF Matching

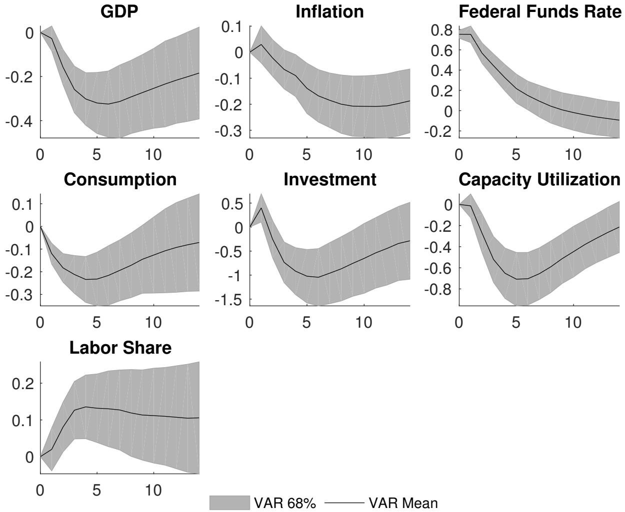
- We partition each model parameters into two groups. The first is composed of **calibrated** ones.
- The second group of parameters, for each model, is estimated by minimizing a measure of the distance between the models and empirical impulse response functions.
- ▸ details
- Follow [Christiano et al., 2005], [Christiano et al., 2010] and [Christiano et al., 2016] we use a Limited information Bayesian approach. ▸ details

IRF Matching: 11 Variables SVAR - US 59Q2:08Q4

- Combine our baseline Cholesky specification with the three different price indices with the specification of [Altig et al., 2011].
-

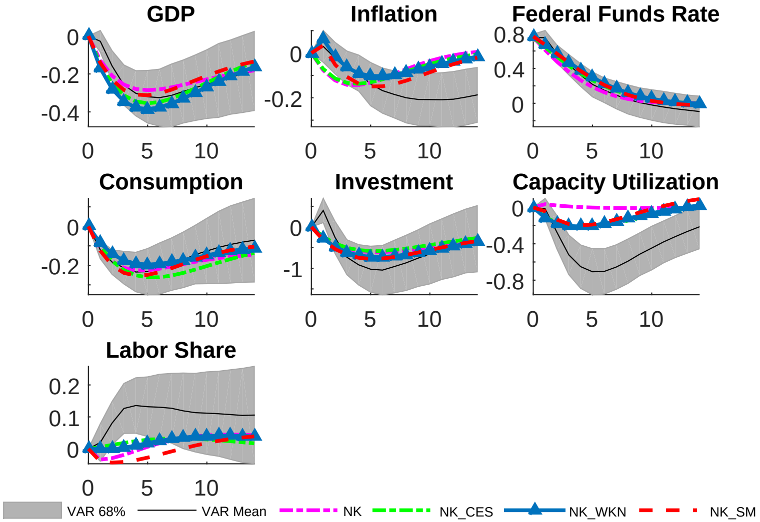
$$\underbrace{Y_t}_{11x1} = \begin{bmatrix} \Delta ln(relative\ price\ of\ investment_t) \\ \Delta ln(GDP_t) \\ \Delta ln(GDP\ deflator_t) \\ \Delta ln(price\ of\ commodities_t) \\ \Delta ln(CPI_t) \\ Capacity\ Utilization_t \\ \Delta ln(Consumption_t) \\ \Delta ln(Investment_t) \\ ln(Labor\ Share_t) \\ Federal\ Funds\ Rate_t \\ \Delta M2_t \end{bmatrix}. \quad (1)$$

IRF Matching: 11 Variables SVAR - US 59Q2:08Q4



IRF Matching: 11 Variables SVAR - US 59Q2:08Q4

▸ posterior modes



▸ More

Conclusions

- We shed some light on the effect of monetary policy on factor shares and their components: key transmission mechanism of MP in NK models.
- We present **a robust set of stylized facts**: cyclically, a monetary policy tightening (easing) increased (decreased) the labor share and decreased (increased) real wages and labor productivity.
- We show that this is at odds with the theoretical transmission mechanism of monetary policy in structural models widely used for policy analysis.
- Models that can do a reasonable job at reproducing the dynamic responses of real variables cannot simultaneously match the dynamics of the labor share.

Conclusions

- Our results emphasise the need to develop model extensions able to replicate the cyclical behaviour of the labor share and its components.
- So far, neither models with price or/and wage rigidities and other relevant real frictions are able to match the dynamics observed in the data, **casting doubts on the traditional theoretical transmission mechanism attributed to MP**.
- This suggest that serious models of joint profit and wage determination, or models with firm and worker heterogeneity where markups and wages display pro-cyclical patterns appear as promising potential avenues for research.

Appendix

Data Construction and Sources: Labor Share

▸ return

- Measuring the share of labor in total income is complicated by problems associated with how to impute certain categories of income to labor and capital owners.
- The existence of self-employment income, the treatment of the government sector, the role of indirect taxes and subsidies, household income accruing from owner occupied housing, and the treatment of capital depreciation, are common problems highlighted in the literature.
- These have been discussed at length in [Gollin, 2002]), [Gomme and Rupert, 2004] and more recently in [Muck et al., 2015].
- We use 7 different proxies of Labor share for the US.

Data Construction and Sources: US Labor Share - 7 measures

▸ return

- LS1 An index of the Labor Share in the Non-Farm Business Sector taken from BLS.
- LS2 Labor share in the domestic corporate non-financial business sector as discussed by GR07. (*No issues with proprietors income and rental income, two ambiguous components of factor income.*)
- LS3 Deals with imputing ambiguous income (AI) and corresponds to the second alternative measure of the labor share proposed in GR07. The measure excludes the household and government sectors.
- LS4 Same as the above LS3 but not corrected for inventory valuation adjustment and an adjustment for capital consumption.
- LS5 Deals with AI as in [Ríos-Rull and Santaeulália-Llopis, 2010] in the calculation of the capital share.
- LS6 Taken from [Fernald, 2014]. In computing the capital share assumes non-corporate sector has the same factor shares as the corporate non-financial sector.
- LS7 An index of the Labor Share in the Non-Financial Corporation Sector taken from BLS.

▸ Details

Data Construction and Sources: Labor Share

return

- We constructed measures of the labor share on a quarterly basis for some other countries for which data were available for a sufficiently long period of time.

- Those countries are Australia (1959:Q3-2016:Q1), Canada (1980:Q2-2016:Q1), the Euro Area (1980:Q1-2014:Q4) and the UK (1955:Q1-2016:Q1).

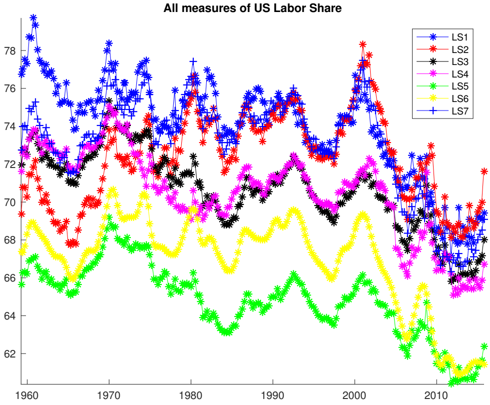
- For some of these countries, however, data availability limits the extent to which we can obtain corrected labor share measures and, in many cases, we work with rough estimates of labor shares.

- We use one each for the Euro Area and the UK, 2 for Canada and 5 for Australia. Details

- Data on Wages and Labor Productivity

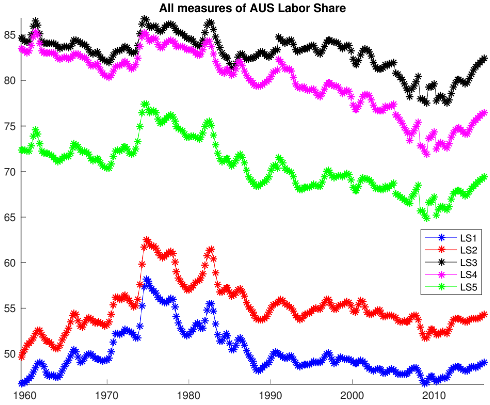
US Proxies

▸ return



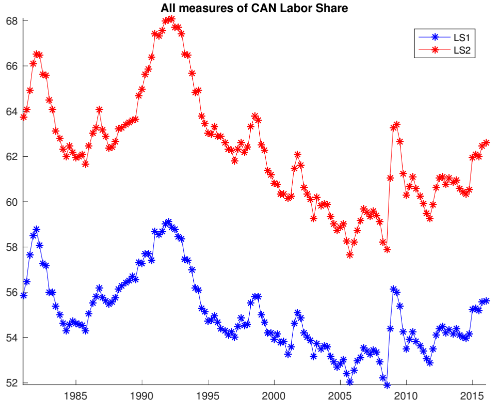
AUS Proxies

return



CAN Proxies

▸ return



Data Construction and Sources: Wages and Labor Productivity

return

- For real wages, we used nominal compensation of employees deflated by the CPI over hours worked from the Valery Ramey database and [Ohanian and Raffo, 2012].
- Labor productivity is calculated as real GDP over hours worked from the same databases.

Data Construction and Sources

return

1 ***Labor share 1***: Labor share in the non-farm business sector. This is taken directly from BLS. The series considers only the non-farm business sector. It calculates the labor share as compensation of employees of the non-farm business sector plus imputed self-employment income over gross value added of the non-farm business sector. Self-employment imputed income is calculated as follows: an implicit wage is calculated as compensation over hours worked and then the imputed labor income is the implicit wage times the number of hours worked by the self-employed.

Data Construction and Sources

return

2 ***Labor share 2***: Labor share in the domestic corporate non-financial business sector. This follows [Gomme and Rupert, 2004] first alternative measure of the labor share. The use of data for the non-financial corporate sector only has the advantage of not having to apportion proprietors income and rental income, two ambiguous components of factor income. It also considers the wedge introduced between the labor share and one minus the capital share by indirect taxes (net of subsidies), and only makes use of unambiguous components of capital income. This approach also takes into account the definition of aggregate output in constructing the labor share. In all the above measures we used GDP, however sectoral studies often use gross value added (GVA) (see [Bentolila and Saint-Paul, 2003], [Young, 2010] and [Young, 2013]). [Valentinyi and Herrendorf, 2008] and [Muck et al., 2015] show that factor shares in value added differ systematically from factor income shares in GDP. By considering gross value added net interest and miscellaneous payments (NI_t^{gva}, NIPA Table 1.14), gross value added corporate profits (CP_t^{gva}, NIPA Table 1.14), net value added (NVA_t, NIPA Table 1.14) and gross value added taxes on production and imports less subsidies (Tax_t^{gva}, NIPA Table 1.14) the labor share is thus calculated as:

$$\textbf{Labor Share 2}: LS_t = 1 - \frac{CP_t^{gva} + NI_t^{gva} - Tax_t^{gva}}{NVA_t}.$$

Data Construction and Sources

▸ return

3 ***Labor share 3***: This approach deals with imputing ambiguous income for the macroeconomy and corresponds to the second alternative measure of the labor share proposed in [Gomme and Rupert, 2004]. The measure excludes the household and government sectors. They define unambiguous labor income (Y^{UL}) as compensation of employees, and unambiguous capital income (Y^{UK}) as corporate profits, rental income, net interest income, and depreciation (same series as above from NIPA Tables 1.1.12 and 1.7.5). The remaining (ambiguous) components are then proprietors' income plus indirect taxes net of subsidies (NIPA Table 1.1.12). These are apportioned to capital and labor in the same proportion as the unambiguous components. The resulting labor share measure is:

$$\textbf{Labor Share 3}: LS_t = \frac{CE_t}{CE_t + RI_t + CP_t + NI_t + \delta_t} = \frac{Y^{UL}}{Y^{UK} + Y^{UL}}.$$

▸ return

4 ***Labor share 4***: This is the same as the above *Labor Share 3* but not corrected for inventory valuation adjustment and an adjustment for capital consumption. Using rental income of persons (without CCAdj) (RI_t^a, NIPA Table 1.1.12) and corporate profits before tax (without IVA and CCAdj) (CP_t^a, NIPA Table 1.1.12):

$$\textbf{Labor Share 4}: LS_t = \frac{CE_t}{CE_t + RI_t^a + CP_t^a + NI_t + \delta_t} = \frac{Y^{UL}}{Y^{UK} + Y^{UL}}.$$

Data Construction and Sources

return

5 ***Labor share 5***: Follows [Ríos-Rull and Santaeulália-Llopis, 2010] and is similar to *PI-2-GDP*. The labor share of income is defined as one minus capital income divided by output. As above, to deal with mixed income, they assume that the proportion of ambiguous capital income to ambiguous income is the same as the proportion of unambiguous capital income to unambiguous income. But the calculation somewhat differ in the computation of Unambiguous income and in the use of Gross National Product (GNP_t, NIPA Table 1.7.5) instead of GDP.

$$CS_t^U = \frac{UCI_t + \delta_t}{UI_t} = \frac{RI_t + NI_t + GE_t + CP_t + \delta_t}{RI_t + NI_t + GE_t + CP_t + \delta_t + CE_t}$$

$$ACI_t = CS_t^U AI_t$$

Labor Share 5: $LS_t = 1 - CS_t = 1 - \dfrac{UCI_t + \delta_t + ACI_t}{GNP_t}$

Data Construction and Sources

▸ return

6 ***Labor share 6***: Is taken from [Fernald, 2014] and it's utilization adjusted quarterly series. In computing the capital share he assumes that the non-corporate sector has the same factor shares as the corporate non-financial sector. But it's not exactly the same implementation as in *Labor Share 2*.One difference, for example, is in the treatment of some taxes on production and imports that represents payments for capital, namely property taxes and motor vehicle taxes.

7 ***Labor share 7***: Labor share in the non-finanical corporation sector. This is taken directly from BLS (FRED series id PRS88003173 provided as an index number). The series considers only the non-finanical corporations sector.

Data Construction and Sources: Australia 1959:Q3-2016:Q1 Source: Australian Bureau of Statistics

▸ return

1. Total wages and salaries (including social security contributions) over GDP (AUS_LS1).

2. Total wages and salaries (including social security contributions) over total factor income (AUS_LS2).

3. One minus gross operating surplus of private non-financial corporations as a percentage of total factor income (AUS_LS3).

4. One minus gross operating surplus of private non-financial corporations plus all financial corporations as a percentage of total factor income (AUS_LS4).

5. (total income - surplus of all corporations - gross operating surplus of government - mixed income imputed to capital)/total income (AUS_LS5).

Data Construction and Sources: Canada
1980:Q2-2016:Q1 Source: Statistics Canada

return

1. Compensation of employees over total factor income (GDP corrected by taxes and subsidies) (CAN_LS1).

2. We imputed mixed income in the same proportion as unambiguous labor and capital income, and added it to the previous measure of labor income (CAN_LS2) .

Data Construction and Sources: UK, and EA

▸ return

UK Compensation of employees over gross value added at factor costs (UK_LS). (1955:Q1-2013:Q3 from the Office for National Statistics).

EA Compensation of employees over GDP at factor costs (EA_LS). (1999:Q1-2013:Q4 period from the Area Wide Model database).

Descriptive Statistics

▸ return

Country	Sample	LS	W	LP
US	1955Q1-2015Q3	[-0.29 , 0.04]	[0.13 , 0.47]	[0.14 , 0.50]
EA	1999Q1-2014Q4	[-0.91 , -0.37]	[-0.34 , 0.46]	[0.84 , 0.95]
UK	1971Q1-2016Q1	[-0.41 , 0.11]	[-0.26 , 0.19]	[0.19 0.64]
AUS	1959Q3-2013Q4	[-0.23 , 0.12]	[[-0.35 , -0.01]	[0.13 , 0.43]
CAN	1981Q2-2013Q4	[-0.56 , -0.07]	[-0.49 , -0.04]	[0.16 , 0.47]

Table: Correlation with HP filtered Output. GMM 95 % Confidence Intervals. Wages and Labor productivity are HP filtered

Descriptive Statistics

return

Country	Sample	LS	W	LP
US	1955Q1-2015Q3	[0.28 , 0.60]	[-0.51 , -0.12]	[-0.55 , -0.19]
EA	1999Q1-2014Q4	[-0.76 , -0.28]	[-0.92 , -0.58]	[-0.85 , -0.18]
UK	1971Q1-2016Q1	[-0.52 , 0.08]	[-0.90 , -0.79]	[-0.94 , -0.82]
AUS	1959Q3-2013Q4	[0.49 , 0.70]	[-0.67 , -0.36]	[-0.68 , -0.38]
CAN	1981Q2-2013Q4	[0.45 , 0.72]	[-0.91 , -0.82]	[-0.92 , -0.85]

Table: Correlation with the policy rate. GMM 95 % Confidence Intervals. Wages and Labor productivity are HP filtered.

Descriptive Stats US Proxies

return

	Mean	Median	Std_Dev
LS1	0.74	0.75	0.03
LS2	0.72	0.72	0.02
LS3	0.71	0.71	0.02
LS4	0.71	0.71	0.02
LS5	0.65	0.65	0.02
LS6	0.67	0.68	0.02
LS7	0.73	0.74	0.03
W	0.00	-0.01	0.15
LP	0.00	0.00	0.28

Descriptive Stats US Proxies

return

	LS1	LS2	LS3	LS4	LS5	LS6	LS7	W	LP
LS1	1.00	0.41	0.89	0.87	0.87	0.91	0.87	-0.78	-0.82
LS2	0.41	1.00	0.33	0.30	0.34	0.64	0.75	0.11	0.10
LS3	0.89	0.33	1.00	0.93	0.99	0.88	0.82	-0.68	-0.79
LS4	0.87	0.30	0.93	1.00	0.93	0.85	0.79	-0.72	-0.78
LS5	0.87	0.34	0.99	0.93	1.00	0.88	0.83	-0.63	-0.76
LS6	0.91	0.64	0.88	0.85	0.88	1.00	0.97	-0.59	-0.65
LS7	0.87	0.75	0.82	0.79	0.83	0.97	1.00	-0.50	-0.56
W	-0.78	0.11	-0.68	-0.72	-0.63	-0.59	-0.50	1.00	0.96
LP	-0.82	0.10	-0.79	-0.78	-0.76	-0.65	-0.56	0.96	1.00

Table: Correlations

Descriptive Stats US Proxies

▸ return

	Bootstrapped		GMM	
	ub	lb	ub	lb
LS1	-0.166	0.067	-0.234	0.125
LS2	-0.221	-0.013	-0.289	0.043
LS3	-0.176	0.051	-0.249	0.122
LS4	-0.219	-0.008	-0.284	0.054
LS5	-0.135	0.099	-0.214	0.173
LS6	-0.130	0.081	-0.192	0.146
LS7	-0.128	0.090	-0.190	0.151
W	0.176	0.407	0.129	0.469
LP	0.178	0.435	0.140	0.497

Table: 95% Confidence Intervals for correlation with Output (HP Filtered). Wages and Labor productivity are also HP filtered.

Descriptive Stats US Proxies

return

	Bootstrapped		GMM	
	ub	lb	ub	lb
LS1	0.423	0.614	0.365	0.680
LS2	0.341	0.543	0.283	0.596
LS3	0.220	0.448	0.152	0.530
LS4	0.105	0.353	0.022	0.444
LS5	0.222	0.450	0.152	0.534
LS6	0.493	0.653	0.448	0.703
LS7	0.527	0.680	0.477	0.724
W	-0.445	-0.201	-0.510	-0.125
LP	-0.486	-0.267	-0.546	-0.195

Table: 95% Confidence Intervals for correlation with Fed Funds Rates (Raw)

Descriptive Stats AUS Proxies

return

	Mean	Median	Std_Dev
LS1	0.50	0.49	0.03
LS2	0.56	0.55	0.03
LS3	0.83	0.83	0.02
LS4	0.79	0.80	0.03
LS5	0.70	0.70	0.03
W	0.00	-0.04	0.35
LP	0.00	-0.02	0.40

Descriptive Stats AUS Proxies

▸ return

	LS1	LS2	LS3	LS4	LS5	W	LP
LS1	1.00	0.97	0.78	0.86	0.97	-0.75	-0.80
LS2	0.97	1.00	0.82	0.85	0.95	-0.64	-0.71
LS3	0.78	0.82	1.00	0.93	0.85	-0.72	-0.75
LS4	0.86	0.85	0.93	1.00	0.93	-0.88	-0.90
LS5	0.97	0.95	0.85	0.93	1.00	-0.80	-0.85
W	-0.75	-0.64	-0.72	-0.88	-0.80	1.00	1.00
LP	-0.80	-0.71	-0.75	-0.90	-0.85	1.00	1.00

Table: Correlations

Descriptive Stats AUS Proxies

▸ return

	Bootstrapped		GMM	
	ub	lb	ub	lb
LS1	-0.263	0.029	-0.301	0.076
LS2	-0.296	0.009	-0.345	0.063
LS3	-0.235	0.015	-0.284	0.052
LS4	-0.182	0.076	-0.233	0.118
LS5	-0.210	0.068	-0.253	0.118
W	-0.302	-0.023	-0.342	-0.009
LP	0.171	0.400	0.132	0.433

Table: 95% Confidence Intervals for correlation with Output (HP Filtered). Wages and Labor Productivity are also HP Filtered.

Descriptive Stats AUS Proxies

return

	Bootstrapped		GMM	
	ub	lb	ub	lb
LS1	0.352	0.563	0.287	0.629
LS2	0.380	0.597	0.317	0.665
LS3	0.332	0.511	0.270	0.570
LS4	0.533	0.661	0.492	0.702
LS5	0.413	0.603	0.358	0.662
W	-0.610	-0.424	-0.675	-0.363
LP	-0.615	-0.436	-0.677	-0.376

Table: 95% Confidence Intervals for correlation with Short term interest rates (Raw)

Descriptive Stats CAN Proxies

return

	Mean	Median	Std_Dev
LS1	0.55	0.55	0.02
LS2	0.62	0.62	0.03
W	0.00	-0.03	0.19
LP	0.00	-0.01	0.22

	LS1	LS2	W	LP
LS1	1.00	0.97	-0.61	-0.69
LS2	0.97	1.00	-0.65	-0.71
W	-0.61	-0.65	1.00	0.99
LP	-0.69	-0.71	0.99	1.00

Table: Correlations

Descriptive Stats CAN Proxies

return

	Bootstrapped		GMM	
	ub	lb	ub	lb
LS1	-0.408	-0.066	-0.521	0.031
LS2	-0.453	-0.141	-0.558	-0.070
W	-0.425	-0.092	-0.492	-0.038
LP	0.183	0.431	0.157	0.474

Table: 95% Confidence Intervals for correlation with Output (HP Filtered). Wages and Labor Productivity are also HP Filtered.

	Bootstrapped		GMM	
	ub	lb	ub	lb
LS1	0.523	0.709	0.477	0.767
LS2	0.502	0.672	0.453	0.723
W	-0.891	-0.838	-0.906	-0.822
LP	-0.911	-0.865	-0.923	-0.851

Table: 95% Confidence Intervals for correlation with Short term interest rates (Raw)

Descriptive Stats EA

▸ return

	Mean	Median	Std_Dev
LS	0.47	0.48	0.01
W	0.00	-0.01	0.03
LP	0.00	0.00	0.03

	LS	W	LP
LS	1.00	0.41	-0.13
W	0.41	1.00	0.85
LP	-0.13	0.85	1.00

Table: Correlations

Descriptive Stats EA

▸ return

	Bootstrapped		GMM	
LS	-0.773	-0.412	-0.907	-0.375
W	-0.233	0.351	-0.339	0.460
LP	0.842	0.934	0.839	0.950

Table: 95% Confidence Intervals for correlation with Output (HP Filtered). Wages and Labor Productivity are also HP filtered.

	Bootstrapped		GMM	
	ub	lb	ub	lb
LS	-0.663	-0.367	-0.759	-0.283
W	-0.847	-0.618	-0.918	-0.573
LP	-0.705	-0.302	-0.848	-0.179

Table: 95% Confidence Intervals for correlation with Short term interest rates (Raw)

Descriptive Stats UK

▸ return

	Mean	Median	Std_Dev
LS	0.56	0.56	0.03
W	0.00	-0.05	0.25
LP	0.00	0.02	0.21

	LS	W	LP
LS	1.00	0.34	0.15
W	0.30	1.00	0.98
LP	0.15	0.98	1.00

Table: Correlations

Descriptive Stats UK

▸ return

	Bootstrapped		GMM	
LS	-0.303	0.018	-0.415	0.115
W	-0.195	0.135	-0.260	0.196
LP	0.243	0.559	0.195	0.638

Table: 95% Confidence Intervals for correlation with Output (HP Filtered). Wages and Labor Productivity are also HP filtered.

	Bootstrapped		GMM	
	ub	lb	ub	lb
LS	-0.411	-0.046	-0.519	0.077
W	-0.881	-0.814	-0.903	-0.795
LP	-0.913	-0.838	-0.936	-0.823

Table: 95% Confidence Intervals for correlation with Short term interest rates (Raw)

VAR Data details: US

▸ return

- CPI: CPI of all good for all urban consumers for US.
- Real GDP all Economy.
- GDP Deflator.
- Price of commodity index: CBR SPOT commodity index.
- M2 from IMF.
- Federal Funds Rates
- Real wages: we used nominal compensation of employees deflated by the CPI over hours worked from the Valery Ramey database.
- Labor productivity is calculated as real GDP over hours worked from the same databases.

VAR Data details: EA

return

- Price of commodity index: CBR SPOT commodity index.
- We consider the OECD and New AWM database.
- HICP excluding energy
- Short-term interest rate
- real GDP
- the GDP deflator
- M2 from IMF.
- For Real wages: compensation of employees from OECD QNA deflated by CPI and total hours from AWM.
- For Labor productivity we use Real GDP over total hours.
- All variables are in logs but short term interest rate.

VAR Data details: AUS, CAN and UK

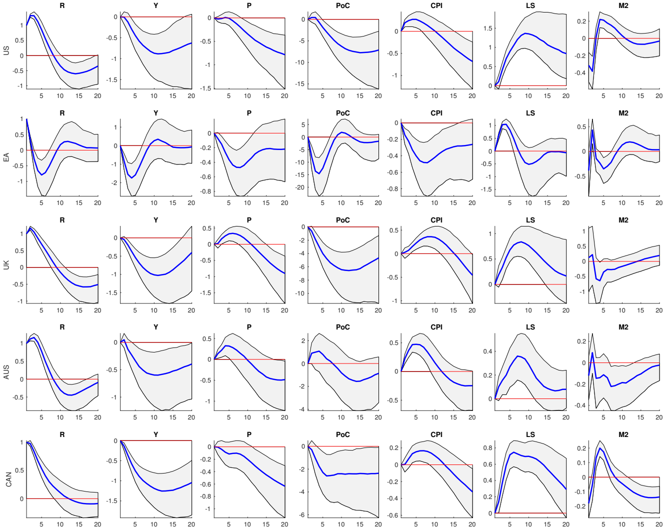
▸ return

- For core CPI we used OECD consumer prices of all goods.
- Price of commodity index: CBR SPOT commodity index.
- For real consumption expenditure we used real private final consumption expenditure from the OECD.
- For real investment we used real gross fixed capital formation from the OECD.
- Short term interest rates
- M2 from datastream
- For Real wages: compensation of employees from OECD QNA deflated by CPI and total hours from [Ohanian and Raffo, 2012].
- For Labor productivity we use Real GDP over total hours.

VAR Identification Scheme: Cholesky

normalized 1% increase in the short term interest rate

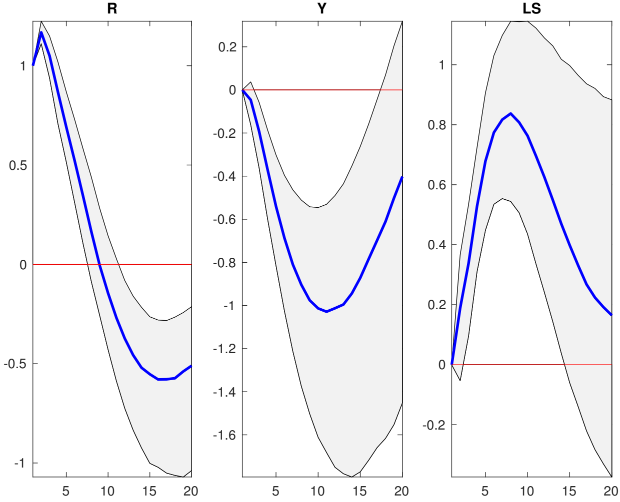
return



VAR Identification Scheme: Cholesky

normalized 1% increase in the short term interest rate - UK

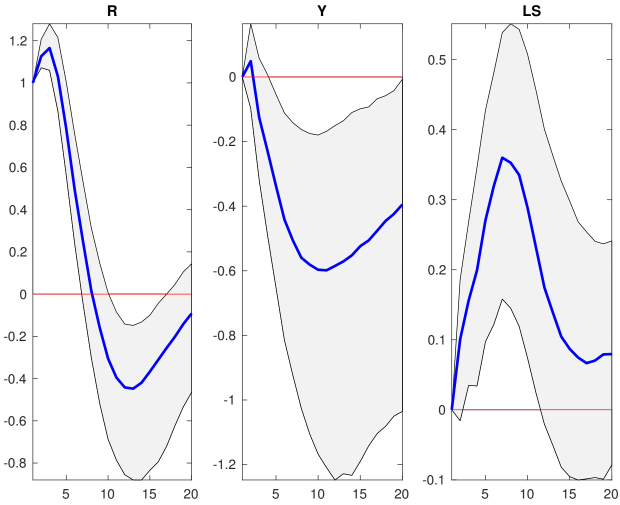
return



VAR Identification Scheme: Cholesky

normalized 1% increase in the short term interest rate - AUS

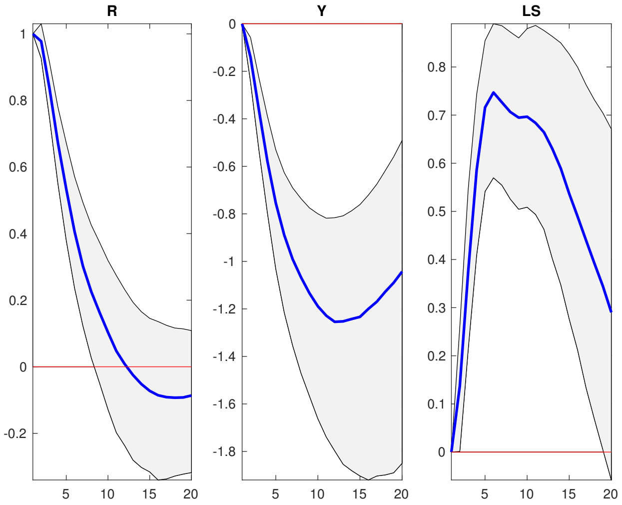
return



VAR Identification Scheme: Cholesky

normalized 1% increase in the short term interest rate - CAN

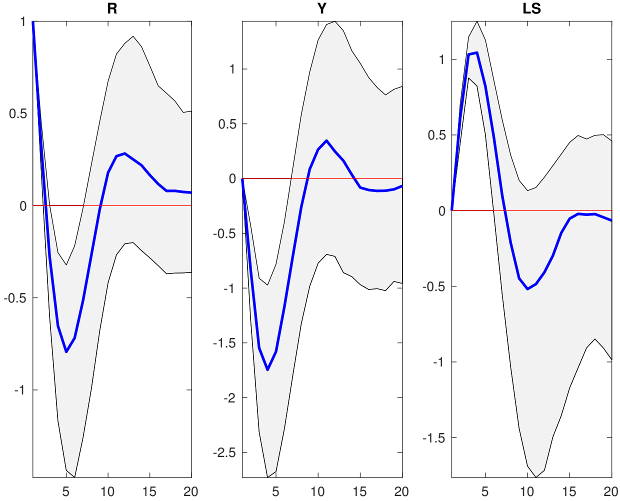
return



VAR Identification Scheme: Cholesky

normalized 1% increase in the short term interest rate - EA

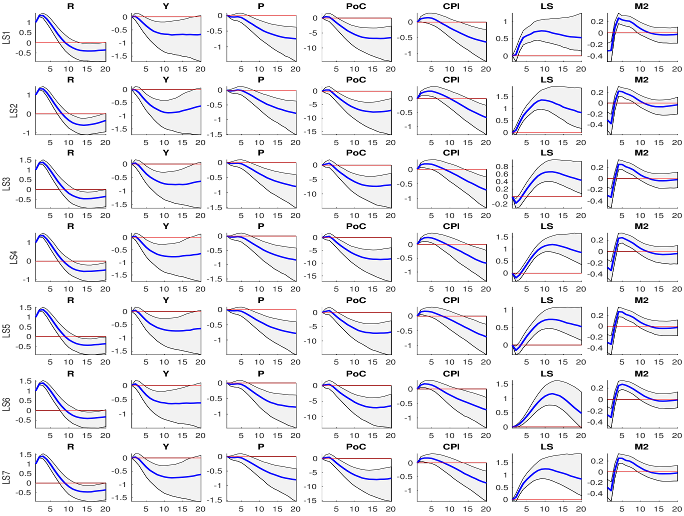
return



VAR Robustness - Cholesky US different proxies

normalized 1% increase in the short term interest rate. 1984Q1-2007Q4

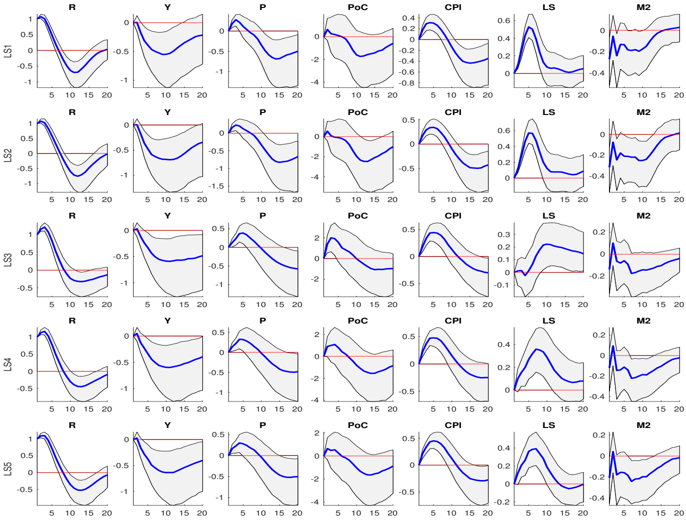
return



VAR Robustness - Cholesky AUS different proxies

normalized 1% increase in the short term interest rate.

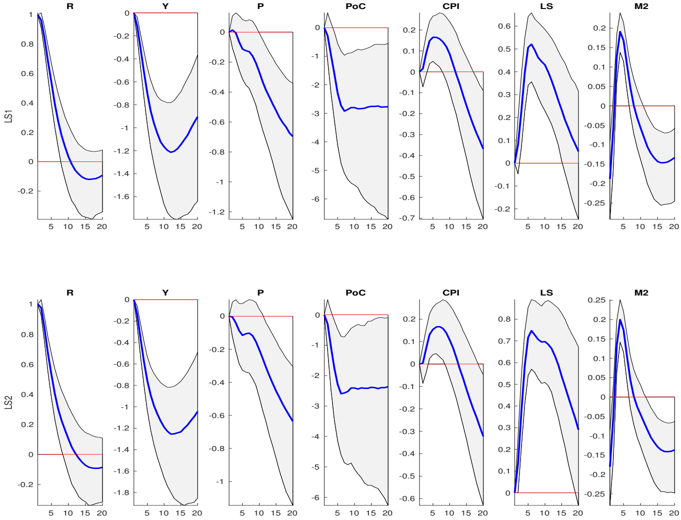
return



VAR Robustness - Cholesky CAN different proxies

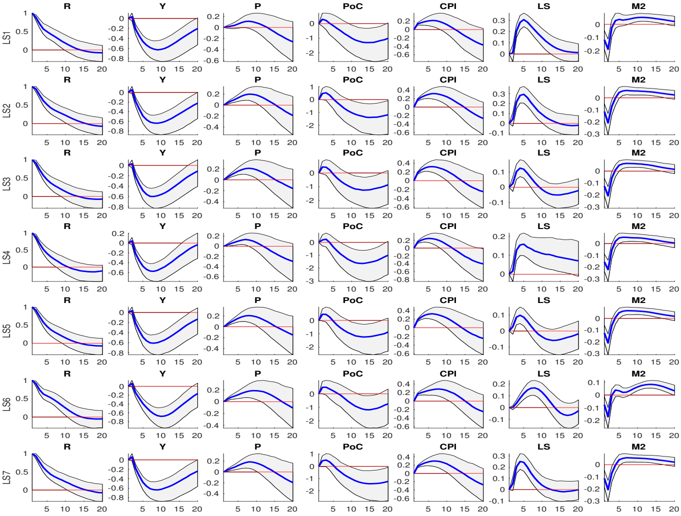
normalized 1% increase in the short term interest rate.

return



VAR Robustness - Cholesky US Sample 1965Q3-1995Q3

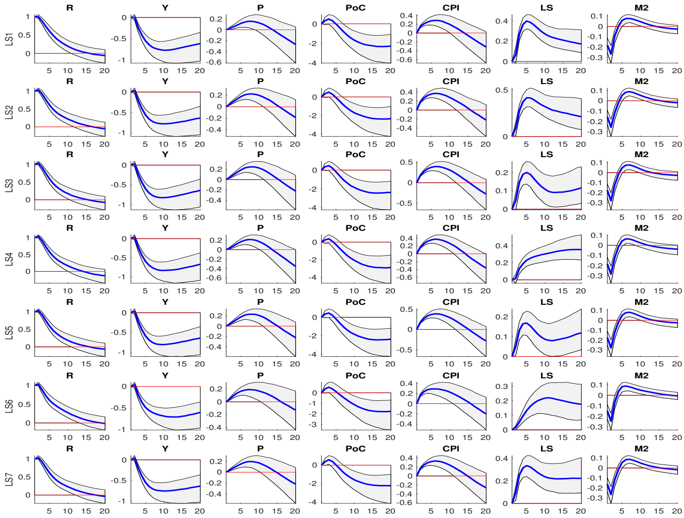
normalized 1% increase in the short term interest rate.



VAR Robustness - Cholesky US Sample 1965Q3-2007Q4

normalized 1% increase in the short term interest rate.

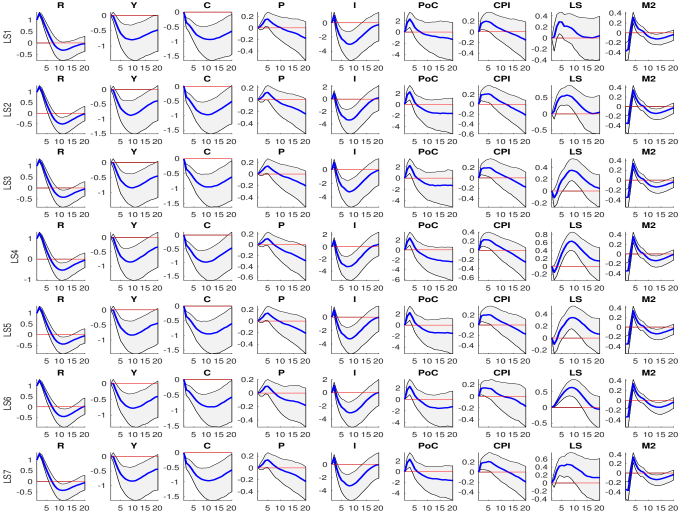
return



VAR Robustness - Cholesky US - 9 variable VAR

normalized 1% increase in the short term interest rate.

return



VAR Robustness - Cholesky summary

▸ return

Country	Info set	Sample	LS + reponse
US	Baseline CEE05 OT	84-07	ALL Proxies ALL Proxies ALL Proxies
	Baseline CEE05 OT	65-95	ALL Proxies ALL Proxies ALL Proxies
	Baseline CEE05 OT	65-07	ALL Proxies All except LS6 ALL Proxies
EA	Baseline CEE05 OT	99-11	Yes Yes Yes
UK	Baseline CEE05 OT	86-08	Yes No Yes
AUS	Baseline CEE05 OT	85-09	ALL Proxies ALL Proxies except LS3 ALL Proxies
CAN	Baseline CEE05 OT	85-11	ALL Proxies ALL Proxies ALL Proxies

Table: VAR Cholesky robustness

VAR Robustness: Alternative Identification Schemes

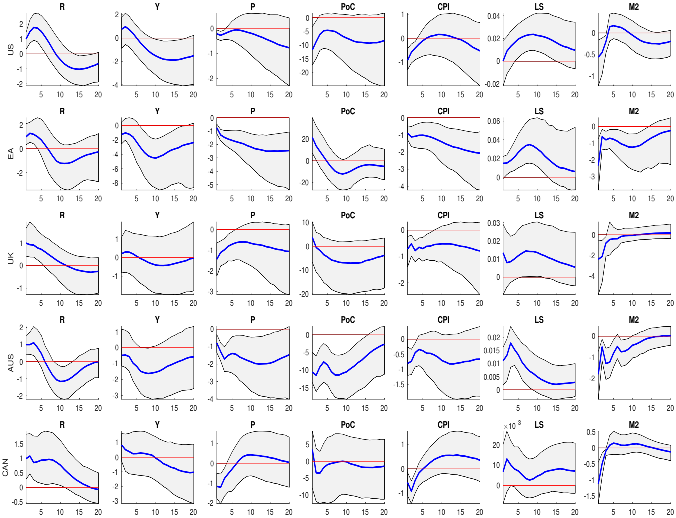
return

- **Sign restrictions**, see [Uhlig, 2005]. We postulate that a monetary policy shock
  - increases the short term nominal interest rate at $t = 0, 1, 2$
  - decreases prices, i.e. the GDP deflator and CPI at $t = 0, 1, 2$
  - induces a contraction in M2 at $t = 0, 1, 2$

VAR Results: Robustness - Sign Restrictions

normalized 1% increase in the short term interest rate.

return



VAR Robustness: Alternative Identification Schemes

▸ return

- Using the **external/instrumental variable approach** as proposed by [Stock and Watson, 2012] and by [Mertens and Ravn, 2013].
  - The monetary policy shock in the structural VAR is identified as the predicted value in the population regression of the instrument on the reduced form VAR residuals.
  - For this result to hold, the instrument needs to be valid; that is it needs to be relevant (correlated with the unobserved monetary policy shock of the VAR) and exogenous (uncorrelated with the other shocks).
  - We use 5 different proxy or instruments for monetary policy surprises for the US.

VAR Results: Robustness - External Instrument

▸ return

R&R [Romer and Romer, 2004] narrative measure of monetary policy.

GSS The ’target’ factor of [Gürkaynak et al., 2005], which measures surprise changes in the target federal funds rate (quarterly sums of daily data, 1990Q1-2004Q4).

SW Estimated monetary policy innovations in the [Smets and Wouters, 2007] model and spans the period 1959q1-2004q4.

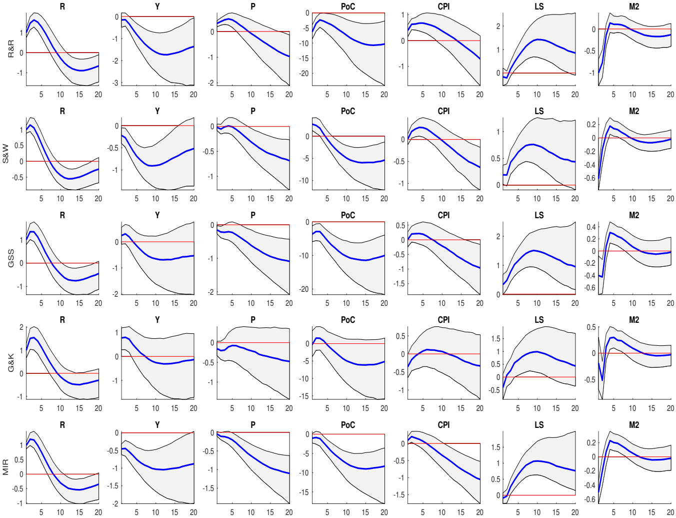
G&K [Gertler and Karadi, 2015] measure of monetary policy surprise and spans the period 1991q1 - 2012q4. It is constructed as the surprise of the current federal funds rate within a 30 minutes window of the FOMC announcement.

MIR The component in market-based monetary surprises that is orthogonal to the central bank’s forecasts about the current and future economic outlook. [Miranda-Agrippino, 2016], [Miranda-Agrippino and Ricco, 2017]

VAR Results: Robustness - External Instrument

normalized 1% increase in the short term interest rate.

return



Sectoral Evidence: Panel model

▸ return

- We can estimate the impact of the shock on sectoral labor shares by running the following panel model:

$$S^h_{i,t} = \alpha_i + \alpha_t + \rho S^h_{i,t-1} + \theta MP_t + \epsilon_{i,t}, \tag{2}$$

- where α_i and α_t are sector and time-specific fixed effects, and $\epsilon_{i,t}$ is an error term.

- θ then captures the contemporaneous effect of the MP shock on the labor share controlling for past values of the labor share as well as sector and time fixed effects.

- To capture the effect of the MP shock on the labor share after the shock, we estimate:

$$S^h_{i,t+h} = \alpha_i + \alpha_{t+h} + \rho S^h_{i,t+h-1} + \theta_h MP_t + \epsilon_{i,t+h}. \tag{3}$$

  with $h = 1, 2, 3, 4$.
- Coefficient θ_h then captures the effect of the MP shock at time t on the labor share $t + h$ periods ahead.

Sectoral Evidence: Data

- Two databases:
  - NBER-CES productivity database: highly disaggregated split of the US manufacturing sector (464 sectors - 1985-2007).
  - Klems database: less disaggregated split by sectors but covers not only manufacturing but all sectors in the economy including services (30 sectors - 1987-2007).
- The labor share at the sector level is defined as compensation of employees over value added.
- The measure of MP_t is obtained by aggregating quarterly shocks from the Cholesky SVAR using aggregate data.
- Standard errors are estimated following Driscoll and Kraay (1998). Data

return

Sectoral Evidence: NBER - Cholesky VAR MP

return

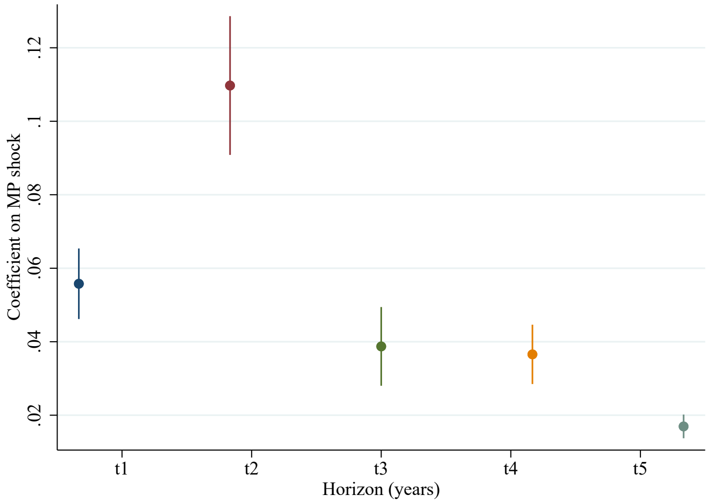


Figure: Coefficient on monetary policy shock variable (Cholesky VAR) using the NBER manufacturing database (464 manufacturing sectors). Period is 1985-2007. The plot shows the coefficient on the year of impact (t_1) and four years after.

Sectoral Evidence: NBER - Romer and Romer VAR MP

return

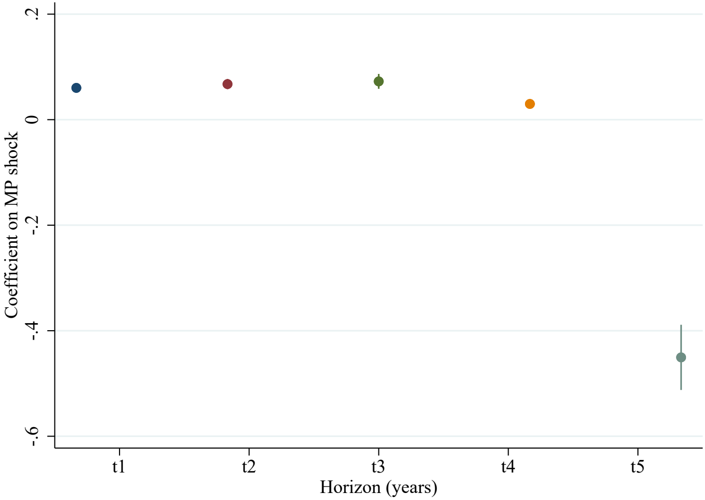


Figure: Coefficient on monetary policy shock variable (Romer and Romer) using the NBER manufacturing database (464 manufacturing sectors). Period is 1985-2007. The plot shows the coefficient on the year of impact (t_1) and four years after.

Sectoral Evidence: Klems - Cholesky VAR MP

return

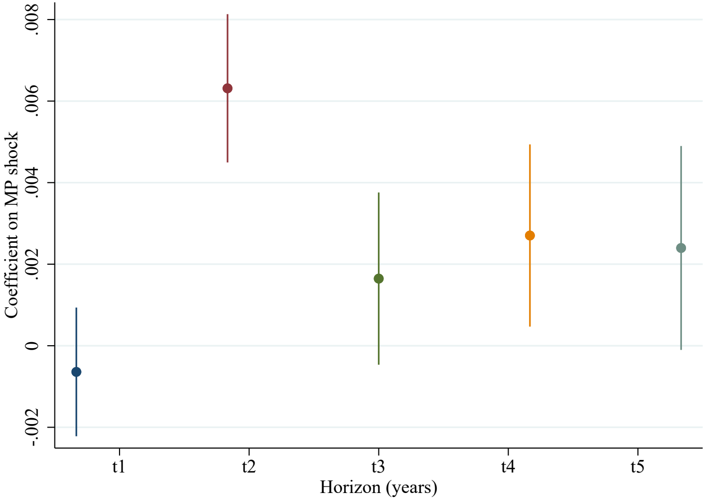


Figure: Coefficient on monetary policy shock variable (Cholesky VAR) using the Klems database (30 sectors). Period is 1987-2007. The plot shows the coefficient on the year of impact (t_1) and four years after.

Sectoral Evidence

return

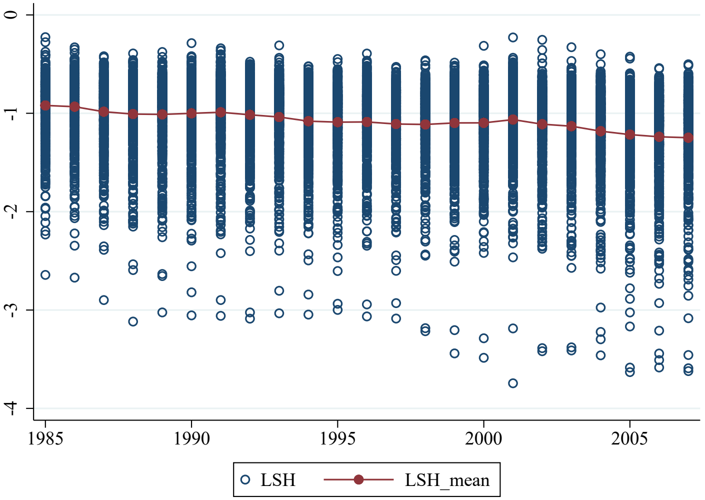


Figure: Average and dispersion of (log) labor shares in the NBER productivity database, 1985-2007.

Labor share components and the deflators

▸ return

- In the data, real wages are usually deflated using a different price index (typically CPI) from the one of income or GDP (see [Pessoa and Van Reenen, 2013]).

- Labor share is defined as the ratio between real hourly compensation (W^r) and labor productivity (LP) which is the ratio between real GDP deflated using the GDP deflator and a measure of hours:

$$LS = \frac{W^r}{LP} = \underbrace{\frac{W^n}{P^{CPI}}}_{Real\ \ Hourly\ \ Wage} \quad \underbrace{\frac{HP}{Y^n}}_{Labor\ \ Productivity} \quad \underbrace{\frac{P^{CPI}}{P}}_{Deflator\ \ Ratios} \tag{4}$$

- In most the theory models, instead, W^r and LP have, by construction, the same deflators and we need take this into account when comparing empirical and theoretical IRFs.

Labor share components IRFs

▸ return

- For the US now we use data for the non-financial corporate sector only in the VAR.

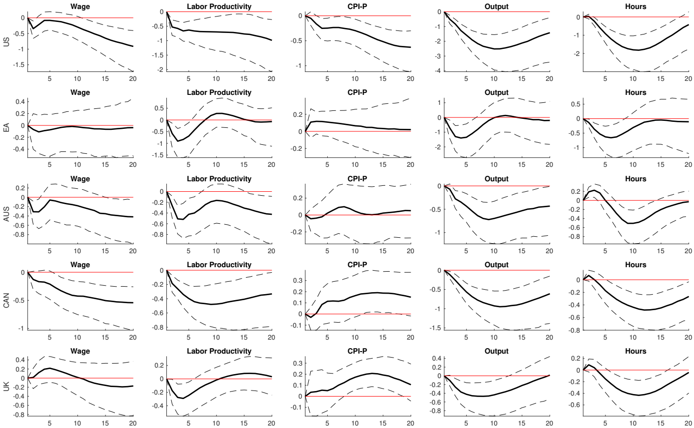
- We use the same Choleski identification assumption as before and we run a VAR under two different information sets.

  1 A 8 variable set that augments the baseline 7 variable VAR by substituting the labor share with (the log of) real wages and labor productivity.

  2 We substitute labor productivity with hours worked.

Labor share components IRFs

return



Composition bias

▸ return

- We argued that one of the advantages of using the labor share is that the *composition bias* in the response of real wages and productivity is alleviated when one takes their ratio as argued by [Basu and House, 2016].
- It can be shown that if anything the *composition bias* would work in favour of our evidence thus making the response of the *representative agent* real wage (and productivity) more negative than what we find using aggregate data.
- ▸ Details - composition bias adjusted data

Composition bias

▸ return

- We simplify the argument in [Basu and House, 2016], abstracting from entry and exit of new workers and matching quality.
- Calling x_t our measure of *aggregate* labor productivity or real hourly wages (w_t^r, LP_t).
- Assume we can classify workers in a discreet grid of N levels of "human capital" or skills from lowest to highest, $j = 1, \ldots, N$.
- Then, aggregate productivity or wages are simply the weighted sum by level of human capital: $x_t = \sum_j x_{j,t}\alpha_{j,t}$ where $\alpha_{j,t}$ is the weight of hours worked by workers of human capital level j in total hours worked ($\alpha_{j,t} = \frac{H_{j,t}}{\sum_j H_{j,t}}$).
- We can decompose that measure in two terms:

$$x_t = \sum_j x_{j,t}\alpha_{j,t} = \overline{x}_t + \sum_j \left(x_{j,t} - \overline{x}_t\right)\left(\alpha_{j,t} - \overline{\alpha}_t\right) = \underbrace{\mu_t}_{\text{un-weighted average}} + \underbrace{\theta_t}_{\text{covariance}},$$

  where $\overline{x}_t$ and $\overline{\alpha}_t$ are the averages of wages/productivity and the shares of workers of different levels of human capital respectively.

Composition bias

▸ return

- μ_t is the wage/productivity of the "representative" worker.
- θ_t tells us about the structure of the labor force: whether shares are increasing or decreasing in productivity (the skill-composition). Changes in this term would precisely be related to the composition bias.
- Our interest is in the cyclical evolution of μ_t conditional on a MP tightening, since this is the direct correspondence between data and models in a large class of representative agent DSGEs.
- Call $f(., t)_{MP}$ the impulse response function (IRF) over $t = 1, \ldots, T$ of any variable to a MP tightening.
- $f(x_t, t)_{MP} = f(\mu_t, t)_{MP} + f(\theta_t, t)_{MP} \; \forall t$.
- Suppose, for simplicity, $f(x_t, t)_{MP} = 0 \; \forall t$.
- This implies that: $f(\mu_t, t)_{MP} = -f(\theta_t, t)_{MP}$.

Composition bias

▸ return

- Suppose we know that, in an expansion, the share of low skilled workers increases and it falls in a recession as discussed in [Basu and House, 2016].
- Thus, the change in this covariance is negative during an expansion. [Basu and House, 2016] also show that, conditional on a MP shock, the composition bias changes: the covariance increases (falls) with a MP tightening (loosening).
- It immediately follows then that, if the aggregate response is zero, then the “representative worker” response must be negative with a MP tightening.
- Our findings above show that the response of aggregate labor productivity is negative and aggregate real wages respond *at least* non-positively (and negatively in most cases).
- From the above argument, the response of the representative agent wage/productivity would then be negative. That is, it will be more negative than the one obtained using aggregate data.

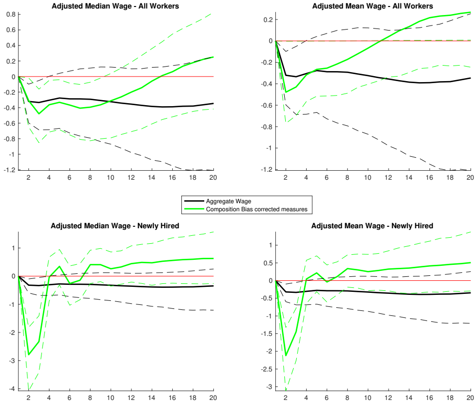
Labor share components IRFs

▸ return

- Here we present results using the same baseline cholesky specification substituting the labor share in turn with data on aggregate wages in the US and composition bias corrected measures of wage as constructed by [Haefke et al., 2013].
- The sample is 1984-2006 as their datasets stops in 2006.

Labor share components IRFs

▸ return



Theory: Simple NK model

▸ return

- $s_t^h = w_t + h_t - y_t$

- Assuming monopolistic competition in production, Calvo price stickiness and competitive labor market: $w_t = \underbrace{\theta_t}_{real\ marginal\ costs} + \underbrace{y_t - h_t}_{labor\ productivity}$

- $\rightarrow s_t^h = \theta_t = \frac{\pi_t - \beta \mathbb{E}_t \pi_{t+1}}{\lambda}$

- A temporary decline in inflation (tighter MP) will see marginal costs (*labor share*) decline and mark-up increase.

- This result is independent of: factor adjustment costs, nominal wage rigidities, financial frictions.

- The result above is true in an economy with or without capital accumulation provided that the production function is either Cobb-Douglas or linear in labor.

- Furthermore if we assume for simplicity $y_t = h_t \Rightarrow w_t = s_t^h = \theta_t$.

Theory: The cost channel of Monetary policy

▸ return

- The cost-push channel, of, e.g. [Ravenna and Walsh, 2006], introduces a direct effect of the interest rate on the marginal cost $w_t = \theta_t + y_t - h_t - rn_t$
- This implies $s_t^h = \theta_t - rn_t$This implies $s_t^h = \theta_t \Uparrow - rn_t \Downarrow$
- Nominal interest rate rn_t moves counter-cyclically, therefore it reinforces the pro-cyclicality of the labour share.
- This channel is able to reproduce a pro-cyclical movement of the price mark-up following a monetary policy shock but it is not able to reproduce the counter-cyclicality of the labor share because $\Delta rn > \Delta\theta$ if monetary policy satisfies the taylor principle.

Theory: CES production function

▸ return

- [Galí et al., 2007] and [Nekarda and Ramey, 2013] show that the CES production function provides a simple way of introducing a wedge between the labor share and the marginal costs:

- $s_t^h = \theta_t + \frac{1-\sigma}{\sigma}(y_t - h_t), s_t^h = \theta_t \Downarrow + \underbrace{\frac{1-\sigma}{\sigma}(y_t - h_t)}_{if\ \sigma > 1} \Uparrow$

- where σ is the elasticity of substitution between capital and labor.

- For any reasonable parameterization, the reaction of θ_t to an MP shock always dominates, and the CES assumption does not change significantly the reaction of the labor share, which is always strongly correlated with θ_t.

Theory: Fixed/Overhead Costs

return

- $Y_t = H_t - F$ in levels
- $y_t = h_t(1 + \frac{F}{Y})$ in log-linear deviations
- $w_t = \theta_t$ but now $s_t^h = w_t - h_t + y_t = \theta_t - h_t + h_t(1 + \frac{F}{Y})$
- $\Rightarrow s_t^h = \theta_t - h_t \frac{F}{Y} s_t^h = \theta_t \Downarrow -h_t \frac{F}{Y} \Uparrow$
- Given that hours (output) responds procyclically to a MP shock then the higher $\frac{F}{Y}$ the higher the wedge between labor share and marginal costs.
- Numerical results show that this might work only on impact and for implausibly high values of $\frac{F}{Y}$.

Theory: Search and Matching (SM) no capital

▸ return

- Wages as determined by nash bargaining, $w_t \neq \theta_t + lp_t$. [Galí, 2010]
- Hence $s_t^h \neq \theta_t$. The dynamics of the LS will differ since now wages and marginal product of labor behave differently.
- Considering only the extensive margin for now and again a linear production function $y_t = n_t$
- The labor share is now given by:

$$s_t^h = w_t \neq \theta_t$$

- Hence to generate an increase in the labor share the only possibility is to have a counter-factual response of wages to a monetary policy shock.
- Without wage rigidities, it would be difficult for wages to display a positive response given that the bargaining power of workers is bounded by one. The combination of both nominal wage and labor market rigidities, instead, proves to be enough to generate a positive response of real wages.

Priors: NK

return

Table: Parameter Values

Parameter	Value/Uniform Prior Bounds	Description
β	0.990	Discount Factor
δ	0.025	Capital depreciation
$\bar{H}$	0.330	Steady State Hours
$\bar{S}^h$	0.670	Steady State Labor Share
ζ	$\frac{\lambda_p}{\lambda_p - 1}$	elasticity of substitution between differentiated goods
$\frac{F}{Y}$	$\frac{1}{\zeta - 1}$	Fix costs over output
μ	$\frac{\lambda_p}{\lambda_p - 1}$	Elasticity of substitution between labour types
$\bar{MC}$	$1 - \frac{1}{\zeta}$	Steady State Marginal Costs
α	$1 - \bar{S}^h$	capital share
ϕ	[1,10.00]	Inverse of Frish Elasticity of Labor Supply
ϕ^X	[0.1,10]	Investment adjustment costs
ξ_p	[0,1]	Calvo price stickyness
ξ_w	[0,1]	Calvo wage stickyness
λ_p	[1.1,2]	price mark-up
λ_w	[1.1,2]	wage mark-up
ρ^r	[0,1]	Interest rate smoothing
θ^π	[1.01,5.00]	Taylor rule coeff of inflation
θ^y	[0.0,1]	Taylor rule coeff of output
γ^p	[0,1]	Price Indexation
γ^w	[0,1]	Wage Indexation
b	[0,1]	Habits in Consumption
ψ	[0,1]	Variable capital utilization

Table: Uniform prior distributions details - **NK model**

Priors: NK_CES

return

Table: Parameter Values

Parameter	Value/Uniform Prior Bounds	Description
β	0.990	Discount Factor
δ	0.025	Capital depreciation
$\bar{H}$	0.330	Steady State Hours
$\bar{S}^h$	0.670	Steady State Labor Share
ζ	$\frac{\lambda_p}{\lambda_p - 1}$	elasticity of substitution between differentiated goods
μ	$\frac{\lambda_p}{\lambda_p - 1}$	Elasticity of substitution between labour types
$\bar{MC}$	$1 - \frac{1}{\zeta}$	Steady State Marginal Costs
$\frac{F}{Y}$	$\frac{1}{\zeta - 1}$	Fix costs over output
α	$1 - \bar{S}^h$	capital share
σ_c	[1,10.00]	Intertemporal elasticity of substitution
ϕ^X	[0.1,10]	Investment adjustment costs
σ	[0.01,5]	Elasticity of Substitution between Capital and Labor
ξ_p	[0,1]	Calvo price stickyness
ξ_w	[0,1]	Calvo wage stickyness
λ_p	[1.1,2]	price mark-up
λ_w	[1.1,2]	wage mark-up
ρ^r	[0,1]	Interest rate smoothing
θ^π	[1.01,5.00]	Taylor rule coeff of inflation
θ^y	[0,1]	Taylor rule coeff of output
γ^p	[0,1]	Price Indexation
γ^w	[0,1]	Wage Indexation
b	[0,1]	Habits in Consumption
ψ	[0,1]	Variable capital utilization

Table: Uniform prior distributions details - **NK_CES model**

Priors: NK_WK

return

Table: Parameter Values

Parameter	Value/Uniform Prior Bounds	Description
β	0.990	Discount Factor
δ	0.025	Capital depreciation
$\bar{H}$	0.330	Steady State Hours
$\bar{S}^h$	0.670	Steady State Labor Share
ζ	$\frac{\lambda_p}{\lambda_p - 1}$	elasticity of substitution between differentiated goods
$\frac{F}{Y}$	$\frac{1}{\zeta - 1}$	Fix costs over output
μ	$\frac{\lambda_p}{\lambda_p - 1}$	Elasticity of substitution between labour types
$\bar{MC}$	$1 - \frac{1}{\zeta}$	Steady State Marginal Costs
α	$1 - \bar{S}^h$	capital share
ϕ	[1,10.00]	Inverse of Frish Elasticity of Labor Supply
ϕ^X	[0.1,10]	Investment adjustment costs
ξ_p	[0,1]	Calvo price stickyness
ξ_w	[0,1]	Calvo wage stickyness
λ_p	[1.1,2]	price mark-up
λ_w	[1.1,2]	wage mark-up
ρ^r	[0,1]	Interest rate smoothing
θ^π	[1.01,5.00]	Taylor rule coeff of inflation
θ^y	[0.0,1]	Taylor rule coeff of output
γ^p	[0,1]	Price Indexation
γ^w	[0,1]	Wage Indexation
b	[0,1]	Habits in Consumption
ψ	[0,1]	Variable capital utilization
ν	[0,1]	working capital fraction

Table: Uniform prior distributions details - **NK_WK model**

Priors: NK_SM

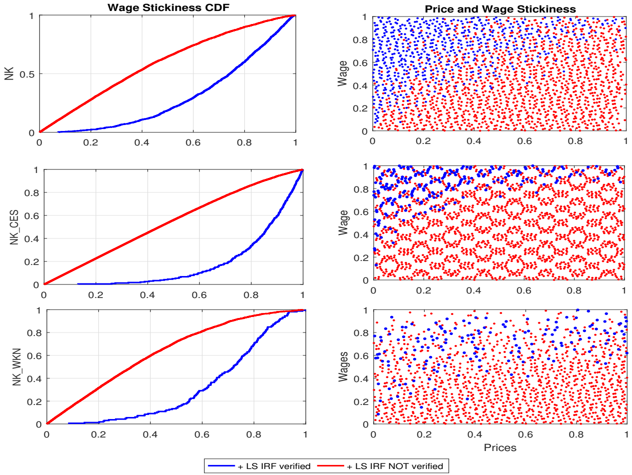
Parameter	Value/Uniform Prior Bounds	Description
β	0.990	Discount Factor
δ^k	0.025	Capital depreciation
$\bar{H}$	0.910	Steady State Employment
$\bar{S}^h$	0.670	Steady State Labor Share
$\bar{\pi}$	2.25	inflation target
ζ	$\frac{\lambda_p}{\lambda_p - 1}$	elasticity of substitution between differentiated goods
$\frac{F}{Y}$	$\frac{1}{\zeta - 1}$	Fix costs over output
σ_c	[1,10.00]	Intertemporal elasticity of substitution
b	[0,1]	Habits in Consumption
ϕ^X	[0.1,10]	Investment adjustment costs
ξ	[0,1]	Calvo price stickyness
λ_p	[1.1,2]	price mark-up
ν	[0,1]	working capital fraction
ψ	[0,1]	Variable capital utilization
θ	[0,1]	technology diffusion
ρ^r	[0,1]	Interest rate smoothing
θ^π	[1.01,5.00]	Taylor rule coeff of inflation
θ^y	[0.0,1]	Taylor rule coeff of output
δ	[0,1]	prob. of bargaining session determination
$\bar{W}^u$	[0,1]	Replacement Ratio
η^h	[0,2]	hiring fix cost relative to output %
η^s	[0,2]	search cost relative to output %
σ	[0,1]	matching function share of unemployment
ρ	[0,1]	job survival rate
Q	[0,1]	vacancy filling rate

Table: Uniform prior distributions details - **NK_SM model**

return

MCF CDF

return



The wage stickiness Cumulative Density Function (CDF) on the left panels; in blue (red) the CDF that does (not) generate a positive response of the labor share. On the right panels, the combination of random draws from price and wage stickiness that do (not) verify the labor share IRF in blue (red). From top to bottom, the $\mathbb{NK}$ model, the $\mathbb{NK\_CES}$ model, and the $\mathbb{NK\_WKN}$ model.

Bayesian IRF Matching

- Let γ be the vector of parameter to estimate and $\Psi(\gamma)$ denote the mapping from γ to the model IRFs.
- Let $\hat{\Psi}$ denote the corresponding empirical IRFs from the SVAR.
- $\hat{\Psi} \overset{a}{\sim} N(\Psi(\gamma^0), V(\gamma^0, \zeta^0, T))$.
- $\hat{\Psi}$ are treated as 'data' and we choose γ to make $\Psi(\gamma)$ as close as possible to $\hat{\Psi}$.
- Approximate likelihood function

$$f(\hat{\Psi}|\gamma) = \left(\frac{1}{2\pi}\right)^{\frac{N}{2}} V^{-\frac{1}{2}} exp\left[-\frac{1}{2}\left(\hat{\Psi} - \Psi(\gamma)\right)' V^{-1}\left(\hat{\Psi} - \Psi(\gamma)\right)\right]. \quad (5)$$

- V is a diagonal matrix with the sample variances of the $\hat{\Psi}$'s along the diagonal.
- So, given this choice of V, γ is effectively chosen so that $\Psi(\gamma)$ lies as much as possible inside the $\hat{\Psi}$'s confidence intervals.

return

Calibration

▸ return

Description	NK	NK_CES	NK_WK	NK_SM
Discount Factor	0.99	0.99	0.99	0.99
Capital depreciation	0.025	0.025	0.025	0.025
Steady State Hours	0.330	0.330	0.330	-
Unemployment rate	-	-	-	5.5%
Steady State Labor Share	0.670	0.670	0.670	0.670
Inverse of Frish Elasticity of Labor Supply	1	-	1	1
Fix cost in production	calibrated to ensure 0 profits in steady state			
Relative Risk Aversion	1	1	1	1
wage mark-up	1.2	1.2	1.2	-
Elasticity of substitution between intermediate goods	$\frac{\lambda_p}{\lambda_p - 1}$	$\frac{\lambda_p}{\lambda_p - 1}$	$\frac{\lambda_p}{\lambda_p - 1}$	$\frac{\lambda_p}{\lambda_p - 1}$

For NK_SM model all the parameters not shown here are calibrated as in [Christiano et al., 2016]

Priors

▸ return

Description	NK	NK_CES	NK_WK	NK_SM
Investment adjustment costs	$\Gamma(8, 2)$			
Habits in Consumption	$B(0.5, 0.15)$			
Variable Capital Utilization	$\Gamma(0.5, 0.3)$			
Calvo price stickyness	$B(0.66, 0.1)$			
Calvo wage stickyness	$B(0.66, 0.1)$	$B(0.66, 0.1)$	$B(0.66, 0.1)$	-
price mark-up (λ_p)	$\Gamma(1.2, 0.05)$			
Interest rate smoothing	$B(0.7, 0.15)$			
Taylor rule response to inflation	$\Gamma(1.7, 0.15)$			
Taylor rule response to output	$\Gamma(0.1, 0.05)$			
Price Indexation	$B(0.5, 0.15)$	$B(0.5, 0.15)$	$B(0.5, 0.15)$	-
Wage Indexation	$B(0.5, 0.15)$	$B(0.5, 0.15)$	$B(0.5, 0.15)$	-
K/L elasticity of substitution	-	$N(1, 0.3)$	-	-
working capital fraction	-	-	$B(0.8, 0.1)$	$B(0.8, 0.1)$
technology diffusion	-	-	-	$B(0.5, 0.2)$
prob. of barg. session determination	-	-	-	$\Gamma(0.5, 0.4)$
replacement ratio	-	-	-	$B(0.4, 0.1)$
hiring fix cost relative to output %	-	-	-	$\Gamma(1, 0.3)$
search cost relative to output %	-	-	-	$\Gamma(0.1, 0.07)$
matching function share of unemployment	-	-	-	$B(0.5, 0.1)$
job survival rate	-	-	-	$B(0.8, 0.1)$
MP shock	$\Gamma(0.74, 0.05)$			

Distributions: Γ *Gamma*, *B Beta*, *N Normal*.

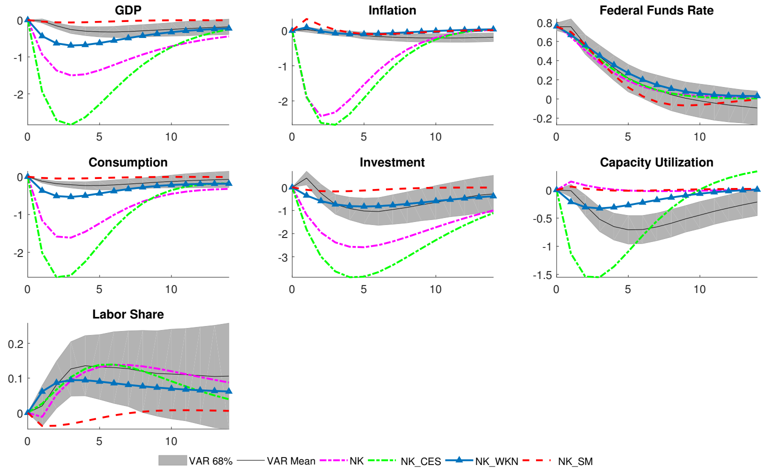
Posterior Mode - US 11 VAR IRF Matching

▸ return

Description	NK	NK_CES	NK_WKN	NK_SM
Investment adjustment costs	9.22 (5.78-12.84)	12.3 (6.56-18.9)	10.1 (6.55-13.8)	9.93 (6.39-13.6)
Habits in Consumption	0.78 (0.70-0.86)	0.88 (0.83-0.93)	0.81 (0.75- 0.87)	0.81 (0.74-0.87)
Variable Capital Utilization	0.63 (0.13-1.25)	0.93 (0.15-1.81)	0.73 (0.10-1.49)	0.18 (0.02-0.40)
Calvo price stickiness	0.79 (0.70-0.88)	0.78 (0.66-0.89)	0.66 (0.55-0.77)	0.60 (0.50-0.71)
Calvo wage stickiness	0.89 (0.85-0.94)	0.93 (0.90-0.96)	0.77 (0.66-0.86)	-
price markup	1.27 (1.18-1.37)	1.20 (1.10-1.30)	1.25 (1.17-1.34)	1.28 (0.19-1.37)
Interest rate smoothing	0.83 (0.80-0.87)	0.87 (0.84-0.91)	0.86 (0.83-0.89)	0.87 (0.83-0.90)
Taylor rule response to inflation	1.73 (1.45-2.02)	1.70 (1.41-2.00)	1.76 (1.49-2.03)	1.74 (1.47-2.03)
Taylor rule response to output	0.10 (0.01-0.19)	0.07 (0.01-0.14)	0.03 (0.01-0.05)	0.04 (0.01-0.07)
Price Indexation	0.63 (0.35-0.90)	0.59 (0.28-0.87)	-	-
Wage Indexation	0.47 (0.19-0.75)	0.51 (0.22-0.80)	-	-
K/L elasticity of substitution	-	0.67 (0.03-1.23)	-	-
working capital fraction (labor)	-	-	0.71 (0.40-1.00)	0.82 (0.66-0.97)
Intermediate inps share in prod.	-	-	0.58 (0.44-0.70)	-
working capital fraction (capital)	-	-	0.81 (0.53-1.00)	-
working capital fraction (intermediates)	-	-	0.82 (0.56-1.00)	-
technology diffusion	-	-	-	0.50 (0.12-0.87)
prob. of barg. session determination	-	-	-	0.50 (0.002-1.27)
replacement ratio	-	-	-	0.60 (0.39-0.80)
hiring fixed cost relative to output %	-	-	-	1.07 (0.52-1.67)
search cost relative to output %	-	-	-	0.05 (0.001-0.14)
matching function share of unemp.	-	-	-	0.46 (0.27-0.65)
job survival rate	-	-	-	0.33 (0.19-0.48)
MP shock stdev	0.77 (0.71-0.83)	0.76 (0.70-0.81)	0.75 (0.69-0.81)	0.75 (0.70-0.81)

Posterior mean of the parameters. 95% HDP interval in parenthesis.

IRF Matching - Matching only Federal Funds Rates and the Labor share



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