Demystifying DSGE Models

5. Extensions to NK: Banking, Housing

Outline

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V. Extensions to the NK DSGE - The Financial and Housing Sectors
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Demystifying DSGE Models

5a. Financial Sector in the NK DSGE Model

Financial Frictions

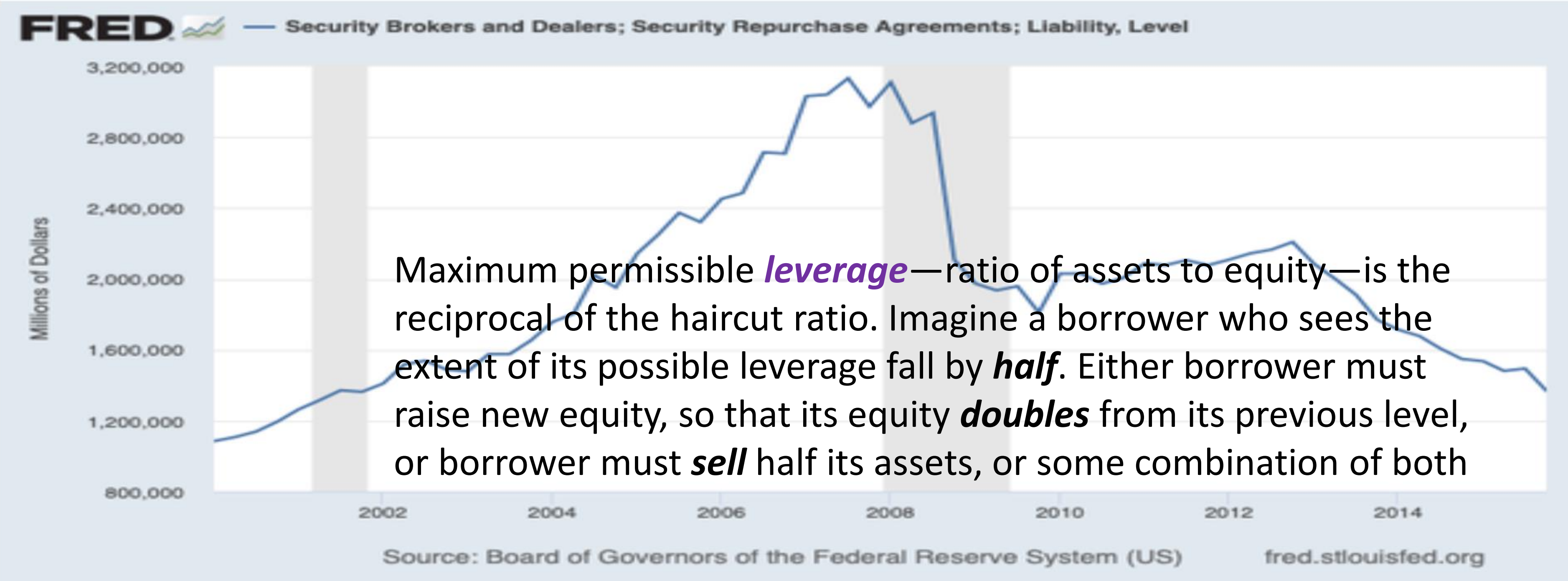
- SW model ***by far*** most important NK DSGE ever
- Cited, analysed, built-upon by countless papers
- Constructed using best available academic ***theory***
- By central bankers seeking best ***empirical fit***
- ➔seven structural shocks
- ➔(almost) no calibration, instead ***estimation***
- Using (new) ***Bayesian FIML*** techniques
- Published in 2007
- Unfortunately, next year was 2008!
- And SW model had no financial sector …

Bernanke Gertler Gilchrist 1999

- From an economic point of view, banking is ***any*** form of ***financial intermediation*** that offers people seemingly ***liquid*** assets while using their wealth to make ***illiquid*** investments
- In many countries (eg, US, Switzerland) retail bank deposits are (substantially) covered by deposit insurance
- Hence risk of "bank runs" relatively small
- Obvious recent exceptions being Silicon Valley Bank (US) and Crédit Suisse

- And since 2000 there has been a sharp rise in the importance of "***shadow banking***" ie, bank-like activities that don't involve standard bank deposits
  - For example, many corporations park their cash not in low-yield ***deposits*** but in higher-yield "***repo***" — ***overnight*** loans using things like mortgage-backed securities as collateral – but with no safety net
- Thus, shadow banking highly vulnerable to ***runs***
- Moreover, the (especially sub-prime) ***mortgage*** market has also been a source of financial crises
- First case was Northern Rock (UK) in September 2007
- Followed by Bear Stearns in March 2008 and Lehman Brothers in September 2008, precipitating a global financial crisis

• Fortunately Bernanke was Chairman of the Fed …



Maximum permissible ***leverage***—ratio of assets to equity—is the reciprocal of the haircut ratio. Imagine a borrower who sees the extent of its possible leverage fall by ***half***. Either borrower must raise new equity, so that its equity ***doubles*** from its previous level, or borrower must ***sell*** half its assets, or some combination of both

The run on shadow banking. FRED

A borrower holding AAA-rated residential mortgage-backed securities would have seen a ***ten-fold*** increase in haircuts, meaning that its ***leverage*** must fall ten-fold, eg from 50 (the case for Northern Rock) to just 5 !

Haircuts for Repos during March 2008

Security	*Typical haircuts*	*March 2008 haircuts*
Treasuries	$< 0.5\%$	$0.25\% \sim 3\%$
Corporate bonds	5%	10%
AAA asset-backed securities	3%	15%
AAA residential mortgage-backed securities	2%	20%
AAA jumbo prime mortgages	5%	30%

- At beginning of course, I noted that one version of ***US Fed model*** was essentially ***SW2007 + BGG*** (a model allowing ***financial frictions***)
- ***BGG*** show that ***credit-market*** frictions may significantly ***amplify*** both ***real*** and ***nominal*** shocks to an economy ["***accelerator***" effect]
- ***BGG*** $\therefore$ help resolve "puzzle" of how ***large real effects*** can be caused by relatively ***small shocks***
  - eg, modest changes in real interest rates [induced by monetary policy]
  - or, small average changes in firm costs [induced by even a relatively large movement in oil prices]

- Introducing credit-market frictions also helps explain important ***cyclical phenomena*** such as changes in ***credit*** extension and ***spreads*** between ***safe*** and ***risky*** interest rates
- Recent empirical work on ***consumption***, for example, has emphasized importance of ***limits on borrowing*** [eg, our TANK/LAMP model]
- ∃ also considerable evidence that cash flow, ***leverage***, and other ***balance-sheet*** factors also have a major influence on ***investment*** spending

- Overall, ***BGG*** model attempts to explain how ***deteriorating credit-market conditions***, eg
  - sharp increases in insolvencies and bankruptcies ☑
  - rising real debt burdens ☑
  - collapsing asset prices ☑
  - bank failures ☑
- are not simply passive ***reflections*** of a declining real economy, but are in themselves a ***major factor*** depressing economic activity

- ***BGG*** framework exhibits a "***financial accelerator***":
- Endogenous developments in ***credit markets*** work to ***propagate*** and ***amplify*** shocks to macro economy
- ***Key mechanism***: ***inverse*** link between
  - "external finance ***premium***" (≡ ***difference*** between cost of funds raised ***externally*** and opportunity cost of funds ***internal*** to firm) and
  - ***net worth*** of potential borrowers (≡ borrowers' ***liquid assets*** plus ***collateral*** value of illiquid assets less outstanding ***obligations***)

- Why does external finance ***premium*** depend ***inversely*** on borrowers' ***net worth?***
  - ***Smaller*** is borrower’s wealth contribution to project financing, ***greater*** is potential ***divergence of interests*** between ***borrower*** and ***suppliers*** of external funds ➔ increased ***agency costs***
  - Lenders must be ***compensated*** for these higher agency costs by a ***larger premium***
  - ➔ ***inverse dependence***
- Also, external finance ***premium magnifies*** effect of adverse ***shocks***, as it raises cost of borrowing and further worsens balance sheet conditions

- ***After*** observing project outcome, entrepreneur ***decides*** whether to ***repay*** her debt or to ***default***
- If she ***defaults***, lender audits loan and ***recovers*** whatever is left from project less monitoring costs
- ➔ marginal external financing cost *f* = gross real ***opportunity costs*** (ie, riskless interest rate) plus gross ***premium for external funds***:

$$E_t f_{t+1} = (r_t - E_t \pi_{t+1}) + \text{prem}_t$$

- ***Premium*** in turn depends on ***leverage ratio*** (ie, value of capital relative to net worth)

$$\text{prem}_t = \omega(q_t + k_t - n_t)$$

(log-linearised) ***leverage ratio*** ≡ qK/N where q = price of capital

elasticity of external finance premium with respect to leverage ratio

- Entrepreneur's ***net worth*** n_t depends on (i) past net worth and (ii) return on capital relative to expected return:

$$n_t = \boxed{\text{lev}} f_t - (\text{lev} - 1)(\text{prem}_{t-1} + r_{t-1} - \pi_t) + v n_{t-1}$$

- where
  - *lev* = SS value of ***leverage ratio***
  - *v* is ***probability*** that entrepreneur will ***survive*** until next period
- First term reflects leveraged realised ***return*** on entrepreneur's ***net worth***
- Second term represents required ***payment*** to holders of entrepreneur's ***debt***

- There is also a (slight) modification in equation for ***price of capital*** (q)
- This now becomes

$$q_t = -f_t + \frac{r^k}{r^k + (1-\delta)} r^k_{t+1} + \frac{(1-\delta)}{r^k + (1-\delta)} q_{t+1}$$

- where $\boldsymbol{f_t}$ is ***external financing cost***
- Rest of model is ***identical*** to SW2007

- When these equations are added, model ***IRF responses vary*** considerably
- Below are some ***examples***, based on parameters estimated over the original SW data period (1965Q1 – 2004Q4)
- Note that models are ***otherwise identical***; ***only*** addition of financial frictions distinguishes them
- Look at
  - MonPol shock (as always ...)
  - Risk premium shock (which should be highly impacted by new financial frictions)
  - Idiosyncratic investment shock (ditto)

• MonPol shock

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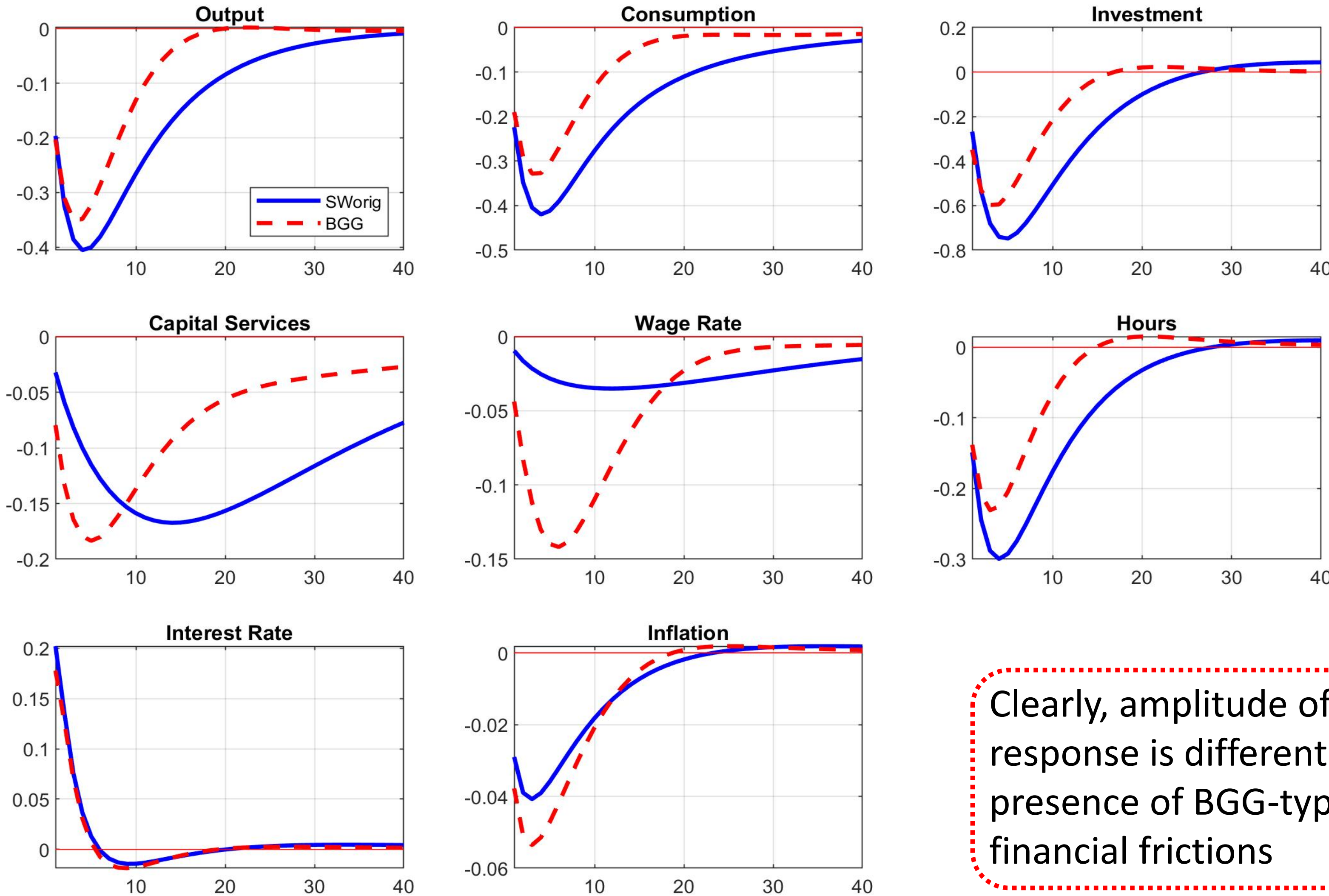

Clearly, amplitude of response is different in presence of BGG-type financial frictions

- Risk Premium Shock

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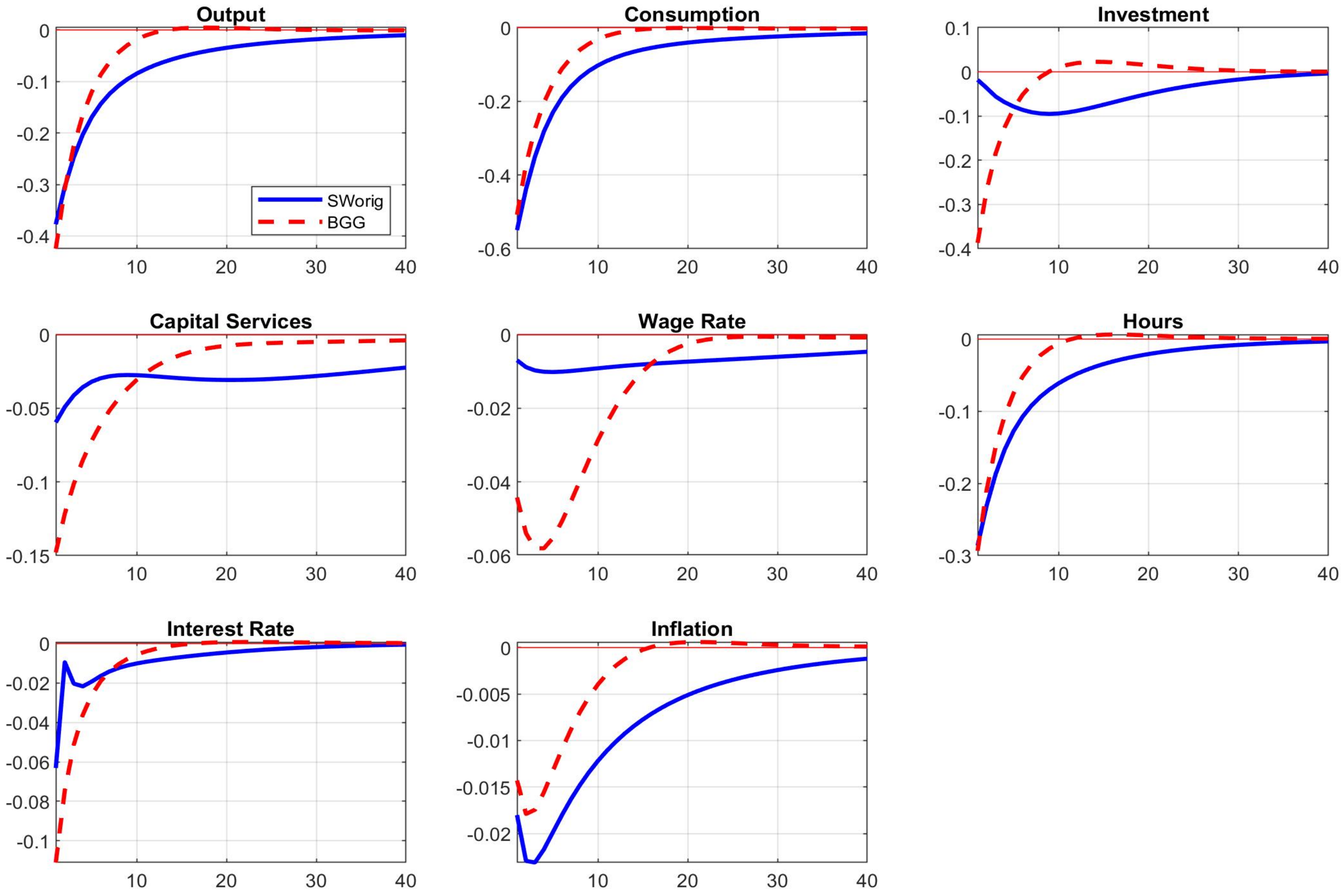

- Idiosyncratic Investment Shock

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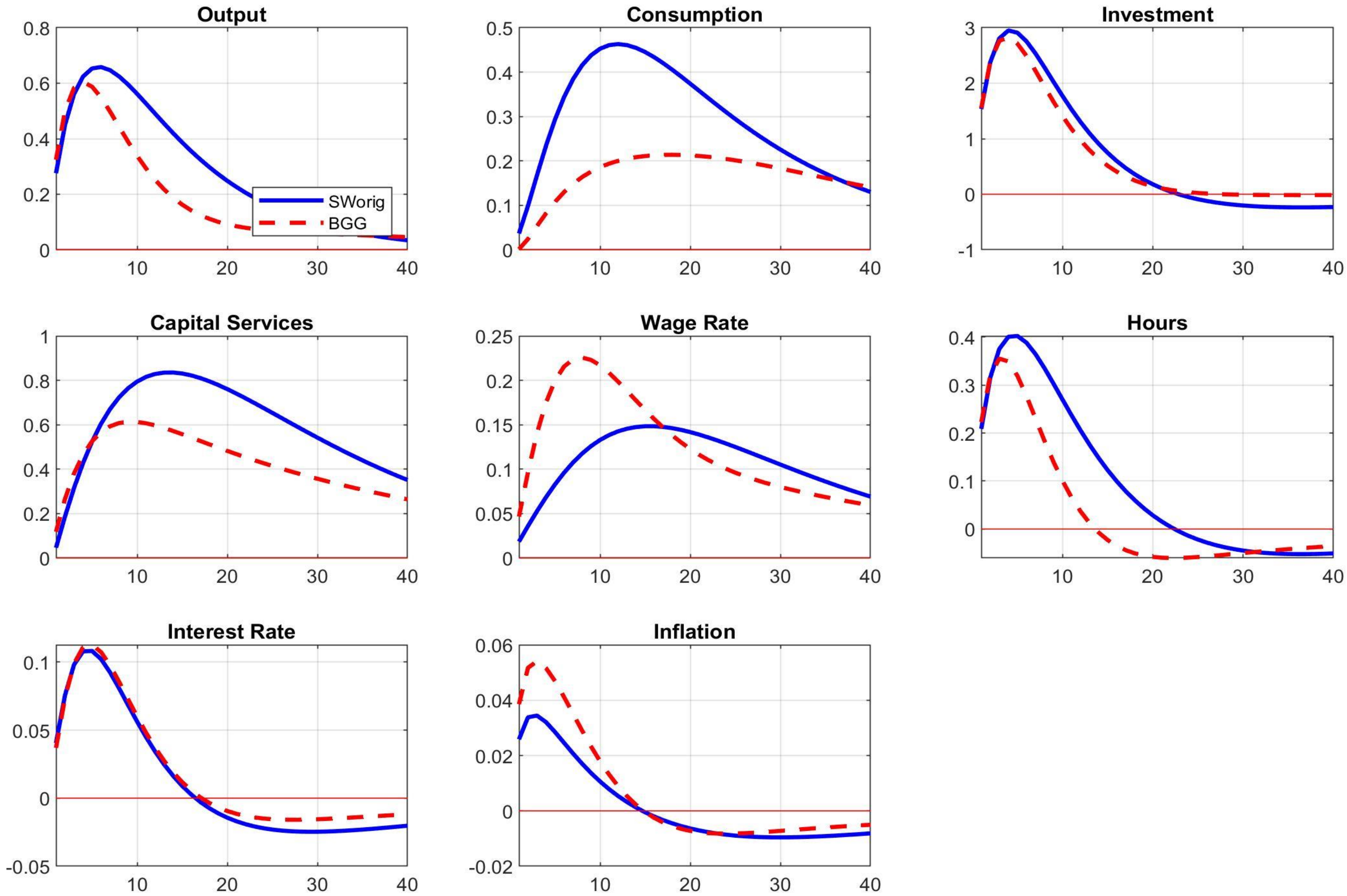

Gertler Kiyotaki Prestipino 2020

- ***Gertler Kiyotaki and Prestipino (2020)*** note that banks have a heavy reliance on ***short term debt***
- ➔ ***highly exposed*** to risk of adverse returns to their balance sheet
- ***Why?*** Possibly because of bank CEO ***expectations*** that government will ***intervene*** to ***stabilise*** financial markets in a ***crisis*** (just as SNB/Conseil Fédéral did in spring 2023 with Credit Suisse)
- ***GKP*** ∴ set up model ∍ ***anticipated credit policy*** will induce banks to adopt ***riskier*** balance sheet
- which will in turn require ***larger-scale*** credit market intervention during a crisis

- ***GKP*** model is essentially similar to SW model already studied ***except that*** they do ***not*** explicitly allow for price and wage ***rigidities***
- They nevertheless argue that their use of ***GHH*** preferences "provides a simple way for the model to produce reasonably sized fluctuations in hours in the absence of either nominal price rigidities or labor market friction":

$$E_t \sum_{\tau=t}^{\infty} \beta^{\tau-t} \frac{1}{1-\gamma} \left(C_\tau - hC_{\tau-1} - \frac{\chi}{1+\varphi} L_\tau^{1+\varphi} \right)^{1-\gamma}$$

Recall, ***SW*** use ***KPR*** preferences.
GHH and KPR are special cases of ***Jaimovich-Rebelo*** preferences.

- ***Producers*** are ***separated*** conceptually into those producing ***intermediate and final*** goods and those producing ***capital*** goods
- ***Intermediate and final*** goods producers rely exclusively on ***banks*** to obtain ***funds***, then use these funds to buy new ***capital*** goods from capital goods producers
- They then combine this capital with labour to produce output using ***Cobb-Douglas*** technology
- ***Capital*** goods producers make new capital using only final goods as input, subject to adjustment costs, as in SW

- *[Standard]* ***Cobb-Douglas*** production function

$$Y_t = A_t K_t^{\alpha} L_t^{1-\alpha}, \quad 0 < \alpha < 1$$

- but *[NEW]* with a ***capital quality shock*** serving as an exogenous trigger of ***asset price*** dynamics

$$K_{t+1} = \psi_{t+1} S_t$$

where K_{t+1} is capital ***actually used*** for production after realisation of multiplicative shock ψ_{t+1} to capital ***quality***

$$S_t = (1-\delta)K_t + I_t$$

- Shock ψ_t captures both ***economic obsolescence*** (as opposed to physical ***depreciation***) and ***"black swan shocks"*** which instigate ***financial crises***

- *[Standard]* ∃ convex ***adjustment costs*** in rate of change of investment, so that

$$Y_t = C_t + \left[1 + f\left(\frac{I_t}{I_{t-1}}\right)\right] I_t + G_t$$

- *[NEW]* As in GK2010, each ***household*** is a family with a share ***1-f*** of "***workers***" and ***f*** "***bankers***"
- Each ***banker*** manages a financial intermediary ("FI" or "bank") and transfers ***dividends*** back to her household, subject to its flow of funds constraint
- *[NEW]* Households ***do not*** acquire ***capital*** nor do they provide funds ***directly*** to nonfinancial firms; instead, they supply funds to ***banks***

- ***[NEW]*** Banks offer households ***2 types*** of liabilities:
  - (non-contingent) riskless short term debt (***deposits***)
  - ***equity*** (i.e. ***contingent*** debt) **unless there is a *bank run* – eg SVB or Crédit Suisse !!**
- Equity issued by banks and held by households is ***"outside" equity***
- This contrasts with ***"inside" equity***, i.e. ***accumulated retained earnings*** of a banker who manages an FI
- Both ***bank deposits*** and ***government debt*** are ***one period*** real riskless bonds (∴ ***perfect substitutes***) and pay ***same gross real return*** R_t from t-1 to t

unless government defaults on debt – eg, US !!

- *[NEW]* Household's ***flow of funds constraint*** is $\therefore$

$$C_t + D_{ht} + q_t \bar{e}_t = W_t L_t + \Pi_t - T_t + R_t D_{ht-1} + [Z_t + (1-\delta) q_t] \psi_t \bar{e}_{t-1}$$

D_h = household deposits at bank

- where last term on RHS is payoff at t for a share of ***outside equity*** $\bar{e}_t$ (priced at q_t) acquired at t-1

Z = rental rate on capital = $\alpha A(L/K)^{1-\alpha}$

- and Π_t is net distributions from ownership of ***both*** banks ***and*** capital producing firms
- Further assume that with i.i.d. ***probability 1-σ***, a banker ***exits*** banking next period and becomes a worker [***1-σ*** is very small !]

This guarantees that banks never accumulate enough internal funds to avoid the need for external finance

- Upon exiting, banker ***transfers*** her accumulated retained earnings to her household as ***dividends***
- ***Surviving*** bankers ***reinvest*** all their ***net worth*** in bank

Note that ***expected survival time*** of bank = 1/(1-σ) and may be quite ***long*** (as σ is close to 1)

- To keep ***relative proportion*** of each group ***fixed*** over time, each period ***(1-σ)f workers*** randomly become ***bankers*** = number of bankers that become workers
- And because bankers cannot operate without any financial resources, each new banker receives a ***"start up" transfer*** from her household = small constant fraction of aggregate assets of bankers
- Goods producers ***borrow from banks*** to finance their rentals of ***factors of production*** (capital and labour)
- They do so by issuing new ***contingent debt*** (ie, ***equity*** shares) at price $\boldsymbol{Q_t}$ (which by perfect competition = price of new capital goods)

- To provide funds to goods producers in each period, banks ***raise funds*** both ***internally*** from ***retained earnings*** and ***externally*** from households (in form of ***deposits***)
- Total value of ***bank loans*** is equal to ***number*** s_t times ***price*** Q_t of contingent securities issued by borrowing firms (firm "debt" = bank "asset")
- Thus ***bank's flow of funds constraint*** is

$$Q_t s_t = n_t + q_t e_t + d_t$$

- where n_t is ***bank net worth***, $q_t e_t$ is ***outside equity*** and d_t is ***deposits***

Note that in general, Q_t (price of firm ***debt***) need not equal q_t (price of outside ***equity***); when bank is financially constrained, $q_t > Q_t$

- ***Bank net worth*** n_t = gross payoff from assets funded at t-1, ***net of*** returns to ***outside equity holders*** and ***depositors*** $\boxed{R_{kt} = \frac{[Z_t + (1-\delta)Q_t]\psi_t}{Q_{t-1}}}$ $\boxed{R_{et} = \frac{[Z_t + (1-\delta)q_t]\psi_t}{q_{t-1}}}$

$$n_t = \boxed{R_{kt}} Q_{t-1} s_{t-1} - \boxed{R_{et}} q_{t-1} e_{t-1} - R_t d_{t-1}$$

- ***Outside equity*** permits bank to ***hedge*** against fluctuations in return on its assets
- It is this ***hedging value*** that makes it ***attractive*** to a bank to issue outside equity
- After a bank obtains funds, banker managing it may ***"transfer"*** a fraction of assets to her family
- Fraction of funds bank may ***divert*** to its family depends on ***composition*** of its ***liabilities*** because …

- At margin, it is more difficult to ***divert*** (e.g., by exaggerated "bonus" payments to oneself) assets funded by ***short-term deposits*** than by ***outside equity*** ***…***
- because ***short-term deposits*** require bank to continuously meet a non-contingent payment (otherwise, there could be a ***bank run*** à la ***SVB*** or ***CS***)
- ***Dividend*** payments, by contrast, are normally tied to ***performance*** of bank's assets, which is difficult for outsiders to monitor
- By giving banks less ***discretion*** over payouts, short-term ***deposits*** offer more ***discipline*** over bank managers than does outside ***equity***

Exception: SVB, First Republic, etc

- In ***GKP*** model, bank may ***divert*** (ie, siphon off for its managers) a ***fraction Θ(x_t)*** of assets where x_t is ***fraction*** of bank assets funded by ***outside equity*** and

$$\Theta\left(x_t\right) = \theta\left(1 + \varepsilon x_t + \frac{\kappa}{2}x_t^2\right)$$

- Because its ***creditors recognise*** bank's incentive to divert funds, they ***restrict*** amount they lend to it
- ➔bank faces an ***external financing constraint***
- Given bank's ***asset and liability configuration*** (i.e., s_t, x_t, n_t) its ***net worth*** is then

recall, s = # of loans (asset)
x = outside equity (liability)

$$n_t = \left[R_{kt} - x_{t-1}R_{et} - \left(1 - x_{t-1}\right)R_t\right]Q_{t-1}s_{t-1} + R_t n_{t-1}$$

paid to equity holders

paid to depositors

- ***Key feature*** of banking sector is ***leverage ratio ϕ*** which determines total private assets (= ***loans***) that a bank can intermediate: $\boldsymbol{Q_t s_t = \phi_t n_t}$
- From bank's optimization problem, ϕ is given by

$$\phi_t = \frac{\nu_t}{\Theta\left(x_t\right) - \left(\mu_{st} + x_t \mu_{et}\right)}$$

$\Lambda_{t,t+1}$ is stochastic discount factor; $E_t(\Lambda_{t,t+1}\Omega_{t+1})$ is "augmented stochastic discount factor" by which bank values its expected returns

- where

shadow value of a unit of net worth

marginal cost of deposits

$$\boxed{\nu_t} = E_t\left(\Lambda_{t,t+1}\boxed{\Omega_{t+1}}\right) R_{t+1}$$

$$\boxed{\mu_{st}} = E_t\left[\Lambda_{t,t+1}\Omega_{t+1}\left(R_{kt+1} - R_{t+1}\right)\right]$$

net profit of bank assets

excess cost of deposits wrt outside equity

$$\boxed{\mu_{et}} = E_t\left[\Lambda_{t,t+1}\Omega_{t+1}\left(R_{t+1} - R_{et+1}\right)\right]$$

- ***Aggregating*** over ***all*** banks in economy ➔ relation between ***aggregate demand*** for securities by banks S_t and ***aggregate net worth*** in banking sector N_t: $\boldsymbol{Q_t S_t = \phi N_t}$
- ***Evolution*** of N_t $\therefore$ plays an ***important*** role in ***dynamics*** of economy:
- When banks are financially constrained, ***demand for capital*** ($Q_t S_t$) is ***restricted*** by amount of financial intermediaries' ***net worth*** (N_t)
- ***Shocks*** to economy are $\therefore$ ***amplified*** through fluctuations in banking sector's ***equity capital***
- But bankers ***do not internalize*** this effect that their net worth has on economy ➔ ***inefficiency***

- ➔ examine carefully banking sector net worth $\boldsymbol{N_t}$ since relation $\boldsymbol{Q_t S_t = \phi N_t}$ is ***key***
- ***Total*** net worth in banking sector $\boldsymbol{N_t}$ clearly equals sum of net worth of ***existing*** bankers and of newly ***entering*** bankers ($N_t = N_{et} + N_{nt}$)
- Aggregate net worth of ***existing*** bankers N_{et} equals ***earnings*** on ***assets*** held in previous period ***net*** of cost of ***outside equity*** and ***deposits***, multiplied by fraction that ***survive*** until current period (σ)
- Aggregate net worth of newly ***entering*** bankers N_{nt} depends on (assumed small) ***fraction*** (ξ) of total assets of exiting bankers ***transferred*** to them by households

- ➔ equation for evolution of N_t

capital quality shock

recall, Q_t (price of firm ***debt***) need not equal ***q_t*** (price of outside ***equity***)

$$N_t = (\sigma + \xi)[Z_t + (1-\delta)\boxed{Q_t}]\boxed{\psi_t} S_{t-1} - \sigma[Z_t + (1-\delta)\boxed{q_t}]\boxed{\psi_t}\bar{e}_{t-1} - \sigma R_t D_{t-1}$$

- Observe that a ***deterioration of capital quality*** (a decline in ψ_t) directly ***reduces rate of return*** on assets and net worth
- Further, since $S = \phi N/Q$, higher bank ***leverage*** (ϕ) ***increases*** percentage ***impact*** of return fluctuations on net worth
- Use of ***outside equity*** ($\bar{e}$), however, ***reduces impact*** of return fluctuations on net worth

- Putting all this into our NK DSGE model is a challenging task
- Fortunately for us, Stefania Villa, a collaborator of Raf Wouters, has translated (an earlier version of) the GKP model into format of ***SW2007*** model we know so well
- This involves addition of 11 equations relating to
  - ***FI net worth***
  - ***leverage ratio***
  - ***external finance premium***

- Let us now compare results from ***original SW2007***, ***BGG*** version and ***GKP*** version, estimated on same data as original
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- # MonPol shock

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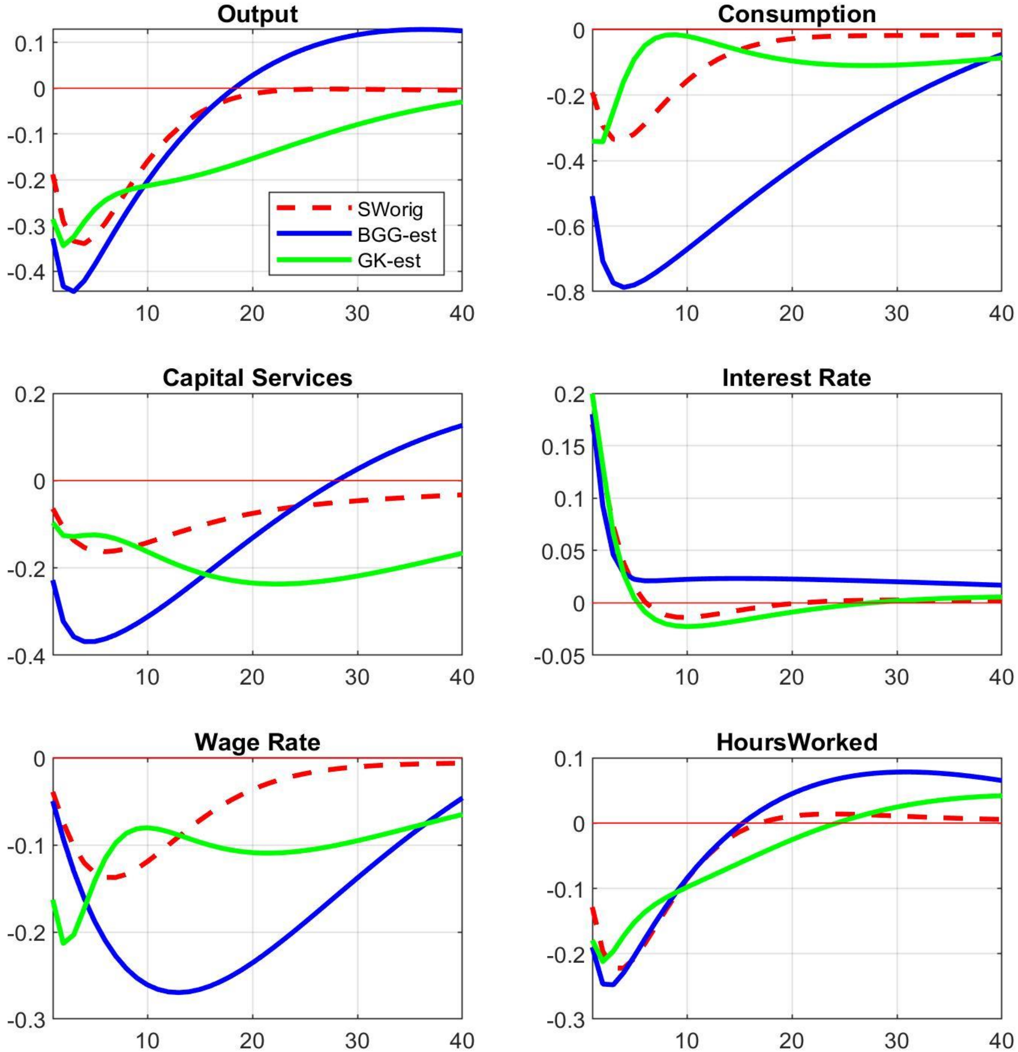

Why are the BGG results so different?

	SW	BGG	GK
crpi	2.0046	**1.6169**	2.1419
crr	0.8139	0.7699	0.8982
cry	0.0991	**0.1453**	0.0617
crdy	0.2278	0.2167	0.4399
crhoms	0.1286	**0.3023**	0.0376

- TFP shock

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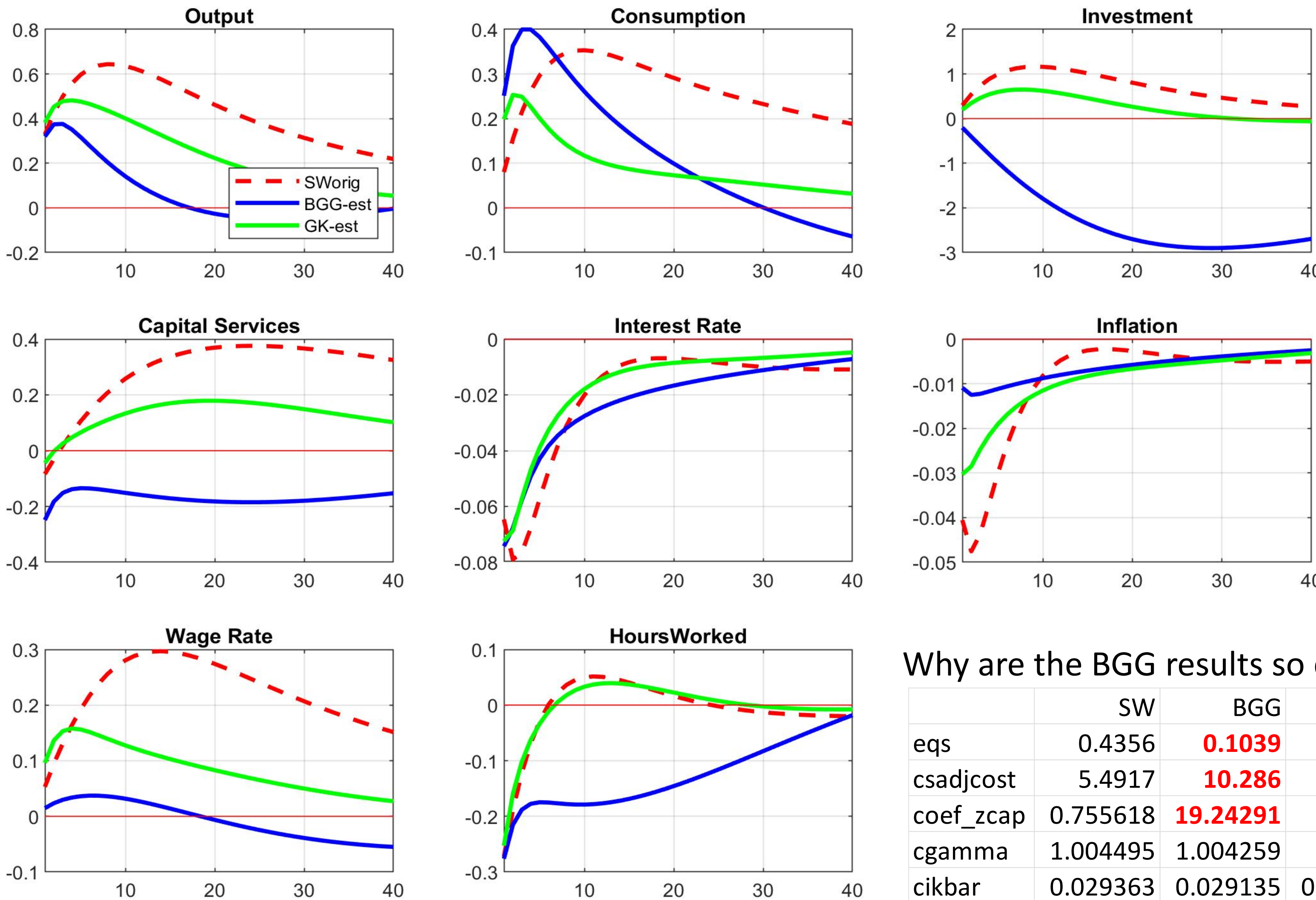

Why are the BGG results so different?

	SW	BGG	GK
eqs	0.4356	**0.1039**	0.4549
csadjcost	5.4917	**10.286**	8.9606
coef_zcap	0.755618	**19.24291**	0.39237
cgamma	1.004495	1.004259	1.00362
cikbar	0.029363	0.029135	0.028517
coef_inve	0.180467	**0.096397**	0.110796

• Investment shock

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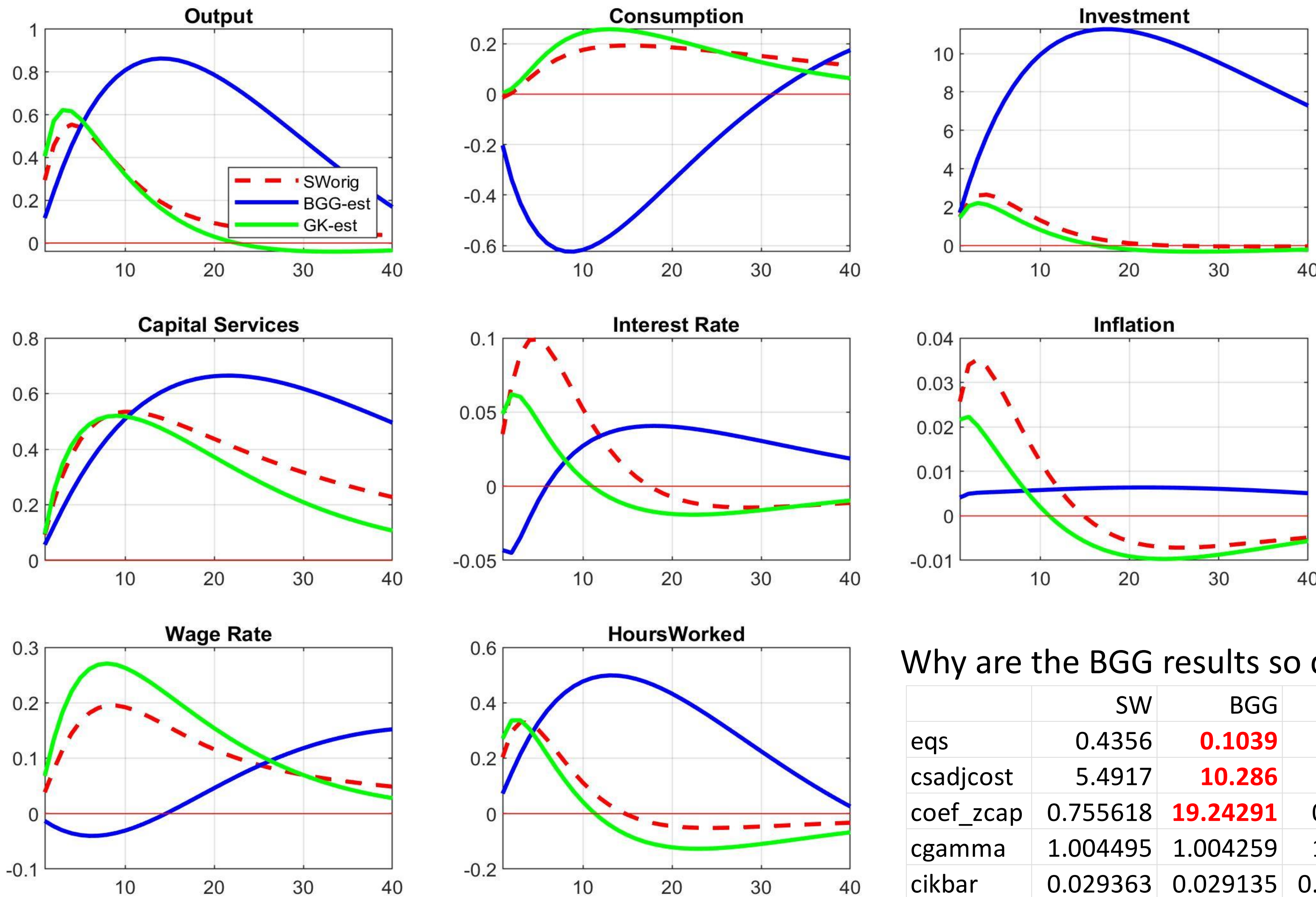

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coef_inve	0.180467	**0.096397**	0.110796

- # Capital Quality shock

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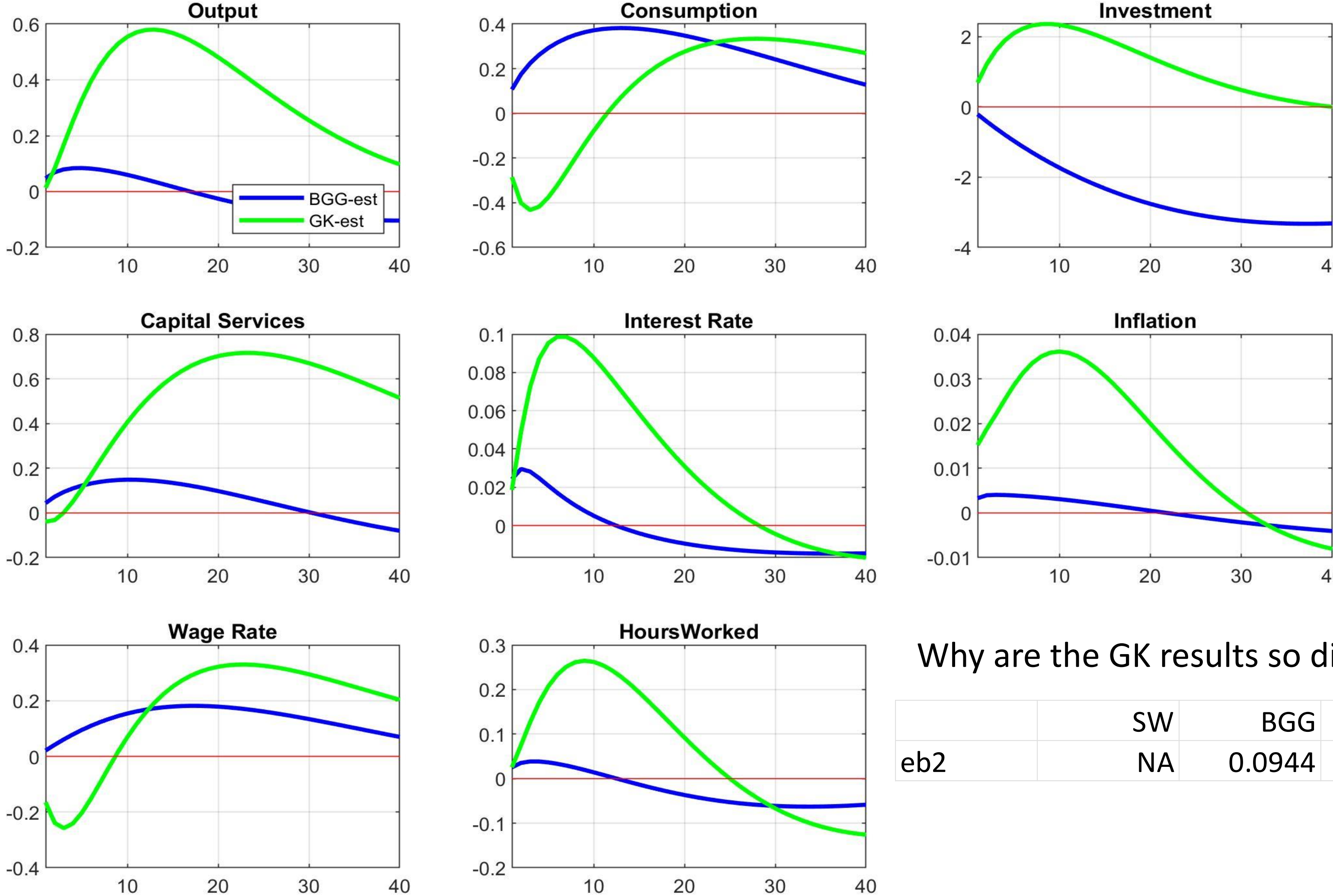


Why are the GK results so different?

	SW	BGG	GK
eb2	NA	0.0944	**0.4198**

Demystifying DSGE Models

5b. Housing Sector in NK DSGE Model

Guerrieri and Iacoviello 2017

- Financial crisis starting in 2008 demonstrated that as housing prices ***rise***, household borrowing rises, fuelling a ***debt–driven*** consumption ***boom***
- And as housing prices ***decline***, households are forced to borrow less, and ***deleveraging*** pushes ***economic contraction*** into overdrive
- ***Guerrieri and Iacoviello (2017)*** therefore developed a model to take into account role of ***housing wealth*** as ***collateral*** for ***borrowing***
- Their model also allows for ***asymmetric effects*** of housing booms and busts depending on whether housing collateral ***constraints*** are ***binding*** or not

- Guerrieri and Iacoviello (2017) start from standard NK DSGE model à la ***SW2007***
- Model features (***as usual***)
  - nominal wage and price ***rigidities (Calvo)***
  - ***habit*** formation in consumption
  - investment ***adjustment costs***
  - monetary authority using a ***Taylor Rule***
- To these are added a ***housing sector***
- ***Housing*** has a ***dual*** role:
  - it is a ***durable good*** (which enters utility function ***separately*** from consumption and labour)
  - it serves as ***collateral*** for “impatient” households

- ➔ split households into ***two types***:
- ***Patient*** (lenders) and ***Impatient*** (borrowers)
- ***Patient*** households work, consume and accumulate housing
- They own economy's productive ***capital*** and supply ***funds*** to firms ***and*** to impatient households
- ***Impatient households*** also work, consume and accumulate housing
- ***But*** because of their high impatience [aka, profligacy], they accumulate ***only*** enough net worth to finance ***down-payment*** on their home, spending the rest

- Impatient households ∴ face a ***housing collateral constraint***
- → fluctuations in ***housing*** values affect ***borrowing*** and ***spending*** capacity of such constrained households
- ***Supply*** of housing is supposed ***fixed*** in short term (but its ***price*** is allowed to vary ***endogenously***)
- And ***reallocation*** of housing occurs across "***patient***" and "***impatient***" households in response to an array of shocks
- ***Economic size*** of each group of households is measured by its ***wage share***, which is assumed to be ***constant*** in short term

- ***Within*** each group, a representative household maximises:

NEW !!

$$E_0 \sum_{t=0}^{\infty} \beta^t z_t \left(\Gamma_c \log \left(c_t - \varepsilon_c c_{t-1} \right) + \boxed{j_t \Gamma_h \log \left(h_t - \varepsilon_h h_{t-1} \right)} - \frac{1}{1+\eta} n_t^{1+\eta} \right);$$

$$E_0 \sum_{t=0}^{\infty} \left(\beta'\right)^t z_t \left(\Gamma_c' \log \left(c_t' - \varepsilon_c c_{t-1}' \right) + j_t \Gamma_h' \log \left(h_t' - \varepsilon_h h_{t-1}' \right) - \frac{1}{1+\eta} n_t'^{1+\eta} \right).$$

- where prime (‘) ➔ ***impatient*** households
- c_t = consumption, **h_t** = housing, and n_t = labour hours
- **j_t** captures ***shocks*** to ***housing preferences***: an ***increase*** in **j_t** shifts preferences ***away*** from consumption and leisure and ***towards*** housing ➔ increase in housing ***demand*** and, therefore, housing ***prices***

$$E_0 \sum_{t=0}^{\infty} \beta^t z_t \left(\boxed{\Gamma_c} \log\left(c_t - \varepsilon_c c_{t-1}\right) + j_t \boxed{\Gamma_h} \log\left(h_t - \varepsilon_h h_{t-1}\right) - \frac{1}{1+\eta} n_t^{1+\eta} \right)$$

- z_t is ***shock*** to ***intertemporal*** preferences: a rise in z_t increases households' willingness to spend today, acting as a ***consumption demand*** shock
- Both j_t and z_t follow usual AR(1) processes
- ε_c and ε_h measure ***habits*** in consumption and housing services respectively
- Γ_c and Γ_h are merely ***scaling factors*** to ensure that marginal utilities of consumption and housing are independent of habits (in steady state)

- ***Patient*** households maximize utility subject to a budget constraint that in ***real*** terms reads:

$$c_t + q_t h_t + b_t + i_t = \frac{w_t n_t}{x_{w,t}} + q_t h_{t-1} + \frac{R_{t-1} b_{t-1}}{\pi_t} + r_{k,t} k_{t-1} + div_t$$

markup (due to monopolistic competition in labour market) between ***wage*** paid ***by*** wholesale firm and wage paid ***to*** households

- ***Patient*** agents choose ***consumption*** c_t, ***investment*** i_t, ***capital*** k_t (which depreciates at rate δ_k), ***housing*** h_t (priced, in units of consumption, at q_t), ***hours*** n_t and ***loans*** to ***impatient*** households b_t to ***maximise utility*** subject to budget constraint and law of motion of capital

a_t is an ***investment shock*** affecting technology transforming investment goods into capital goods

$$k_t = a_t \left(i_t - \phi \frac{(i_t - i_{t-1})^2}{\bar{i}} \right) + (1 - \delta_k) k_{t-1}$$

investment ***adjustment costs***

- ***Impatient*** households (‘) do ***not*** accumulate capital ***nor*** own final good firms but ***do*** own housing
- Their budget constraint is given by:

$$c'_t + q_t h'_t + \frac{R_{t-1} b_{t-1}}{\pi_t} = \frac{w'_t n'_t}{x'_{w,t}} + q_t h'_{t-1} + b_t + div'_t$$

- ***Impatient*** households face a ***borrowing constraint*** that limits amount they can borrow (b_t) to a fraction ***m*** of house value [***collateral value***]
- Borrowing constraints adjust ***only sluggishly*** to reflect ***market value*** of housing stock because they are fully ***reset only*** for those agents who ***refinance*** their mortgage

$$b_t \le \gamma \frac{b_{t-1}}{\pi_t} + (1-\gamma) m q_t h'_t$$

$\gamma \cong 0.75$

- ***As usual***, ***differentiate*** between
  - ***intermediate*** good (wholesale) firms producing wholesale goods under ***competitive flexible price*** conditions
  - ***final*** good firms operating under ***monopolistic competition*** subject to implicit costs to adjusting nominal prices
- ***Wholesale firms*** hire capital and labour supplied by ***both*** types of households to produce wholesale goods y_t and maximise net revenue

real rental rate of capital

$$\frac{y_t}{x_{p,t}} - w_t n_t - w'_t n'_t - r_{k,t} k_{t-1}$$

price **markup** of **final** over **wholesale** goods ≅ 1.2

- ***Production technology*** is ***usual*** ***Cobb-Douglas***, but now with labour from ***both*** ***patient*** (n) and ***impatient*** (n') households:

$$y_t = n_t^{(1-\sigma)(1-\alpha)} n_t'^{\sigma(1-\alpha)} k_{t-1}^{\alpha}$$

- where **σ** measures labour income share that accrues to ***impatient*** households
- When **σ** approaches zero, so does economic weight of ***impatient*** households, and model collapses to standard NK model

- ***Final good*** firms (owned by ***patient*** households)
  - buy ***wholesale*** goods y_t from wholesale firms in a competitive market
  - ***differentiate*** these goods at no cost
  - ***sell*** them at a ***markup*** $x_{p,t}$ over marginal cost
- CES (***Dixit-Stiglitz***) aggregates of these goods are converted back into homogeneous consumption and investment goods by households
- ***As usual*** (***Calvo***) each period, a fraction $1 - \theta_\pi$ of final good firms set prices ***optimally***, while a fraction θ_π cannot do so, and ***index*** prices to steady state inflation π

- This leads to ***usual*** forward-looking ***price Phillips curve***:

$$\log(\pi_t/\overline{\pi}) = \beta E_t \log(\pi_{t+1}/\overline{\pi}) - \varepsilon_\pi \log(x_{p,t}/\bar{x}_p) + \mathrm{u}_{p,t}$$

- where ε_π measures ***sensitivity*** of inflation to changes in ***price markup*** relative to its steady-state value $\bar{x}_p$
- $u_{p,t}$ denotes an i.i.d. price markup shock

- ***Wage setting*** is modelled as in ***SW2007***:
- ***Households*** supply homogeneous labour services to ***unions***
- which ***differentiate*** labour services
- ***set wages*** subject to a ***Calvo*** scheme
- ***offer*** labour services to ***labour "packers"***
- who **reassemble** these services into homogeneous labour ***composites*** n_c and n'_c
- ***Wholesale firms*** then hire labour from these "packers" [ie, unions]

- Pricing rules set by unions imply, after linearisation, usual ***wage Phillips curves*** (now differentiated by ***impatient/patient*** origin):

$$\log\left(\omega_t/\overline{\pi}\right) = \beta E_t \log\left(\omega_{t+1}\overline{\pi}\right) - \varepsilon_w \log\left(x_{w,t}/\overline{x}_w\right) + \mathrm{u}_{w,t},$$

$$\log\left(\omega'_t/\overline{\pi}\right) = \beta' E_t \log\left(\omega'_{t+1}/\overline{\pi}\right) - \varepsilon'_w \log\left(x'_{w,t}/\overline{x}'_w\right) + \mathrm{u}_{w,t}$$

- where ε_w measures ***sensitivity*** of inflation to changes in ***wage markup*** relative to its steady-state value $\overline{w}_p$
- $u_{w,t}$ denotes an i.i.d. wage markup shock

- Finally, and again ***as usual***, ***monetary policy*** follows a ***Taylor Rule*** that allows for ***interest rate smoothing*** and responds to year-on-year ***inflation*** and ***GDP deviations*** from their steady-state values

- To get a sense of model, below are its parameters
- First, those ***calibrated*** [NB: ***quarterly***]:

Table 1
Calibrated and estimated parameter values.

	Calibrated parameters		Value
m	Maximum LTV	➔ min down-payment = 10%	0.9
η	Labor disutility		1
β	Discount factor, patient agents		0.995
$\overline{\pi}$	Steady-state gross inflation rate		1.005
α	Capital share in production		0.3
δ_k	Capital depreciation rate		0.025
$\overline{j}$	Housing weight in utility	➔ SS ratio of housing wealth to annual output = 1.5	0.04
$\overline{x}_p$	Steady-state price markup		1.2
$\overline{x}_w$	Steady-state wage markup		1.2

- Next, those estimated:

	Estimated parameters	Prior [mean, std]	Posterior			
			Mode	5%	Median	95%
β'	Discount factor, impatient	beta [0.984, 0.006][a]	0.9922	0.9780	0.9884	0.9929
ε_c	Habit in consumption	beta [0.7, 0.1]	0.6842	0.6351	0.7214	0.8074
ε_h	Habit in housing	beta [0.7, 0.1]	0.8799	0.6633	0.8087	0.9498
ϕ	Investment adjustment cost	gamma [5, 2]	4.1209	3.0756	5.0509	9.6887
σ	Wage share, impatient	beta [0.333, 0.20]	0.5013	0.2915	0.4421	0.5838
r_π	Inflation resp. Taylor rule	normal, 1.5, 0.25]	1.5379	1.5379	1.8129	2.1102
r_R	Inertia Taylor rule	beta [0.75, 0.1]	0.5509	0.4779	0.5681	0.6606
r_Y	Output response Taylor rule	beta [0.125, 0.025]	0.0944	0.0577	0.0915	0.1231
θ_π	Calvo parameter, prices	beta [0.5, 0.075]	0.8913	0.8913	0.9149	0.9343
θ_w	Calvo parameter, wages	beta [0.5, 0.075]	0.9163	0.8941	0.9159	0.9364
γ	Inertia borrowing constraint	beta [0.75, 0.1]	0.6945	0.4466	0.6443	0.8196
ρ_J	AR(1) housing shock	beta [0.75, 0.1]	0.9835	0.9595	0.9797	0.9906
ρ_K	AR(1) investment shock	beta [0.75, 0.1]	0.7859	0.7249	0.7831	0.8369
ρ_R	AR(1) monetary shock	beta [0.5, 0.1]	0.6232	0.4931	0.6142	0.7123
ρ_Z	AR(1) intertemporal shock	beta [0.75, 0.1]	0.7556	0.6136	0.7250	0.8146
σ_J	Std. housing demand shock	invgamma [0.01, 1]	0.0513	0.0513	0.0863	0.1490
σ_K	Std. investment shock	invgamma [0.01, 1]	0.0360	0.0286	0.0423	0.0718
σ_P	Std. price markup shock	invgamma [0.01, 1]	0.0030	0.0027	0.0031	0.0036
σ_R	Std. interest rate shock	invgamma [0.01, 1]	0.0012	0.0012	0.0013	0.0015
σ_W	Std. wage markup shock	invgamma [0.01, 1]	0.0100	0.0089	0.0101	0.0116
σ_Z	Std. intertemporal shock	invgamma [0.01, 1]	0.0163	0.0144	0.0186	0.0263

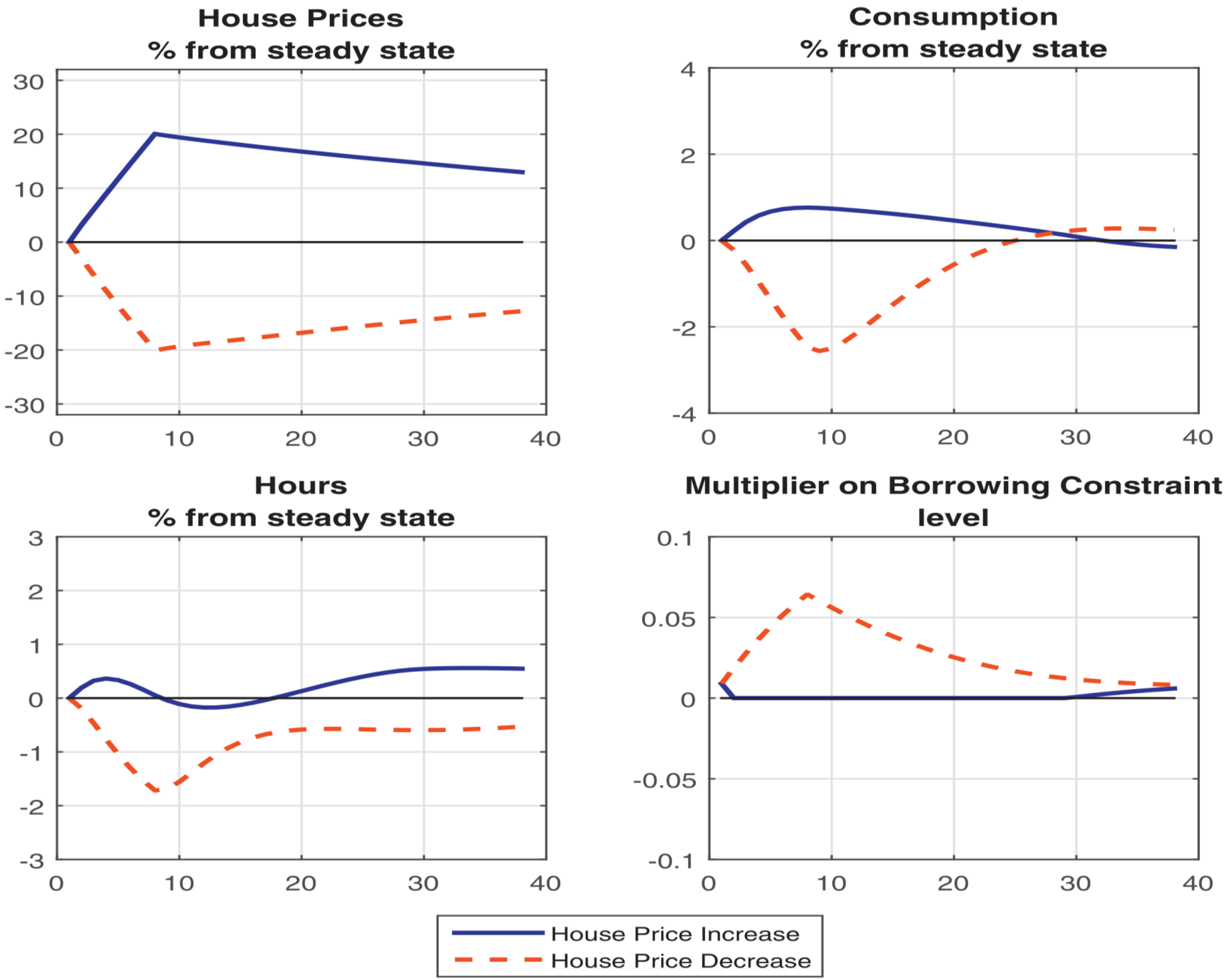
- Consider effects of shocks to housing preferences, governed by process j_t

$$E_0 \sum_{t=0}^{\infty} \beta^t z_t \left(\boxed{\Gamma_c} \log \left(c_t - \varepsilon_c c_{t-1}\right) + j_t \boxed{\Gamma_h} \log \left(h_t - \varepsilon_h h_{t-1}\right) - \frac{1}{1+\eta} n_t^{1+\eta} \right)$$

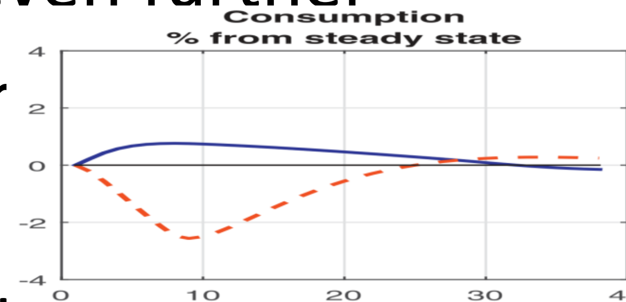
Recall, z_t is ***shock*** to ***intertemporal*** preferences

Recall, ε_h measures ***habits*** in housing services

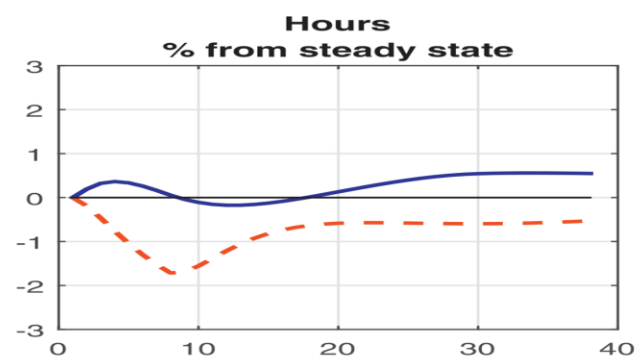
- Example: Let two series of shocks to j_t occur between periods 1 and 8:
  - One ***lowers*** house prices by 20%
  - Other ***raises*** house prices by 20%
- From period 9 onwards, there are no more shocks and the shock j_t follows its usual autoregressive process
- All parameters are set to their estimated posterior modes


House Prices
% from steady state
30
20
10
0
-10
-20
-30
0
10
20
30
40
Consumption
% from steady state
4
2
0
-2
-4
0
10
20
30
40
Hours
% from steady state
3
2
1
0
-1
-2
-3
0
10
20
30
40
Multiplier on Borrowing Constraint
level
0.1
0.05
0
-0.05
-0.1
0
10
20
30
40
House Price Increase
House Price Decrease

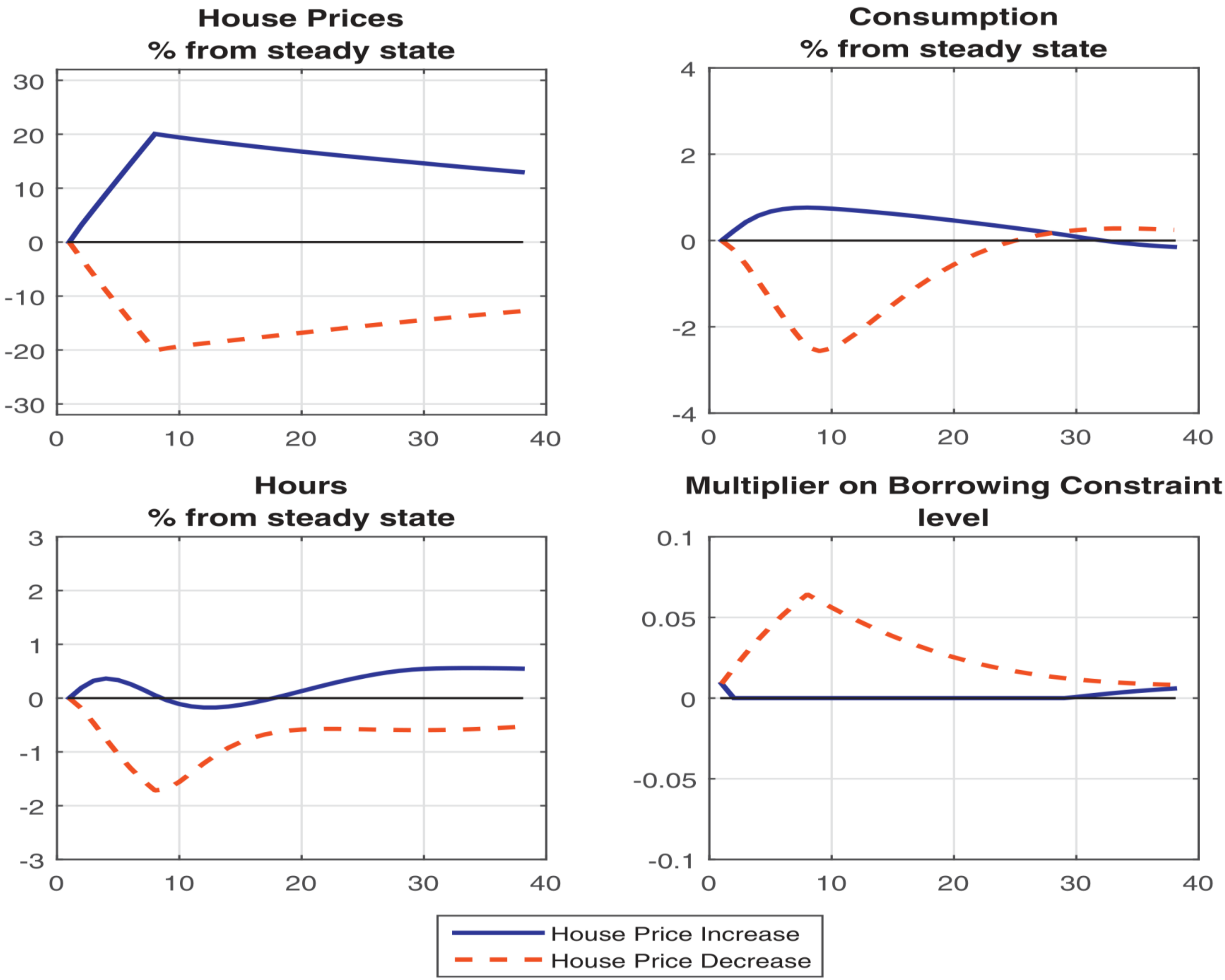
- ***Dashed lines*** denote effects of a ***decline*** in house prices
- This decline reduces ***collateral capacity*** of constrained households, who ***borrow less*** and are forced to curtail their ***non-housing consumption*** even further



- At its trough, consumption is near 3% below its steady state
- nominal and real rigidities ➔ decline in aggregate consumption translates into lower demand for ***labour*** from firms



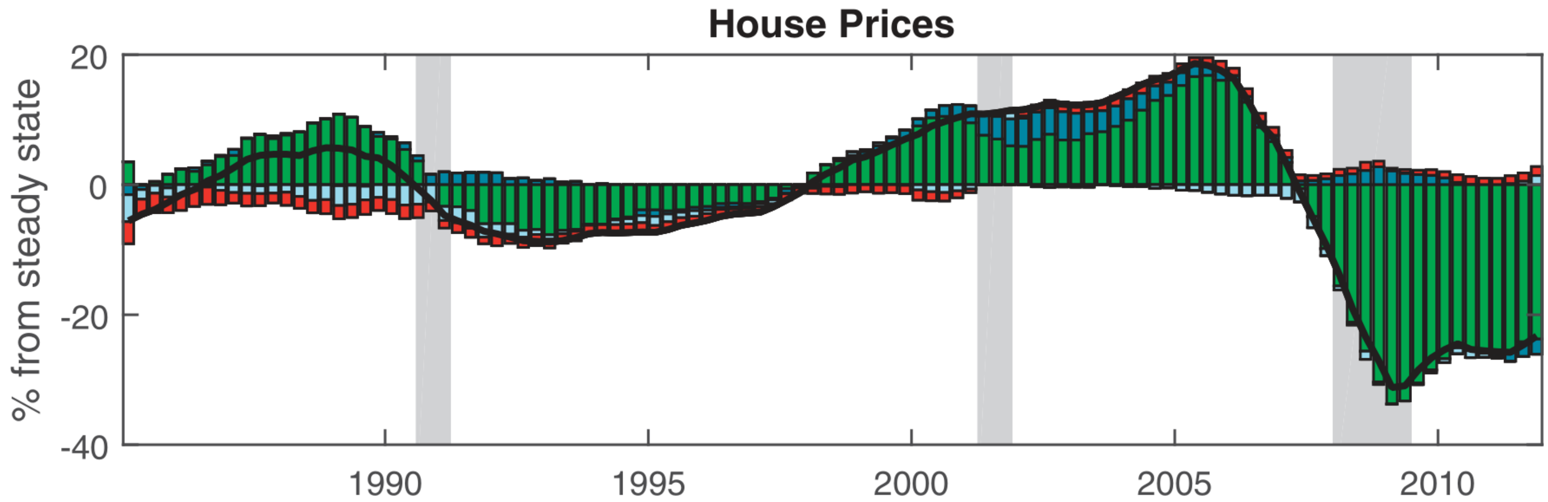
- ➔ ***hours worked*** fall about 2% below baseline


House Prices
% from steady state
Consumption
% from steady state
Hours
% from steady state
Multiplier on Borrowing Constraint
level
House Price Increase
House Price Decrease

- *Solid lines* plot responses to a shock of same magnitude and profile but with opposite sign➔ house prices increase 20%
- Note that a protracted ***increase*** in house prices can make borrowing constraint ***slack***
- ***Lagrange multiplier*** for borrowing constraint bottoms out at zero and ***remains at zero*** for some time, before rising as house prices revert to baseline
- When constraint is ***slack***, borrowing constraint channel remains operative ***only in expectation***
- ➔ ***impatient*** households discount that channel more heavily the longer constraint is expected to remain slack

- ➔ response of ***consumption*** to house price ***increases*** is not as dramatic as reaction to equally-sized house price ***declines*** ➔ ***asymmetry***
- At its peak, consumption rises about 1% above its baseline, a magnitude only ***one third*** as large as for house price decline
- In turn, increase in ***hours*** is also muted, peaking at about 0.5% above baseline

- What was rôle of of house price declines in collapse of consumption during Great Recession?
- Figures on next slides decompose house prices and consumption in terms of underlying shocks
  - By construction, marginal contributions of each shock sum to observed series

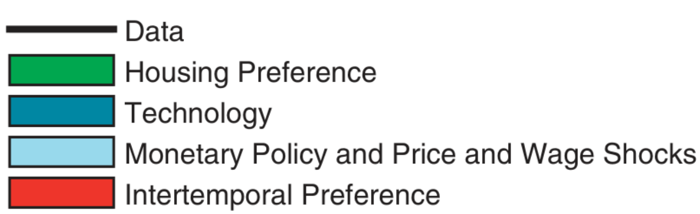


Decomposition for ***house prices*** shows that ***housing demand shocks*** (**green**) explain lion's share of movements in house prices

➔ housing boom preceding Great Recession rooted in forces largely uncorrelated with economic conditions

Other shocks also influence house prices

eg, ***investment technology shocks*** (**blue**) played a sizable rôle in housing price boom

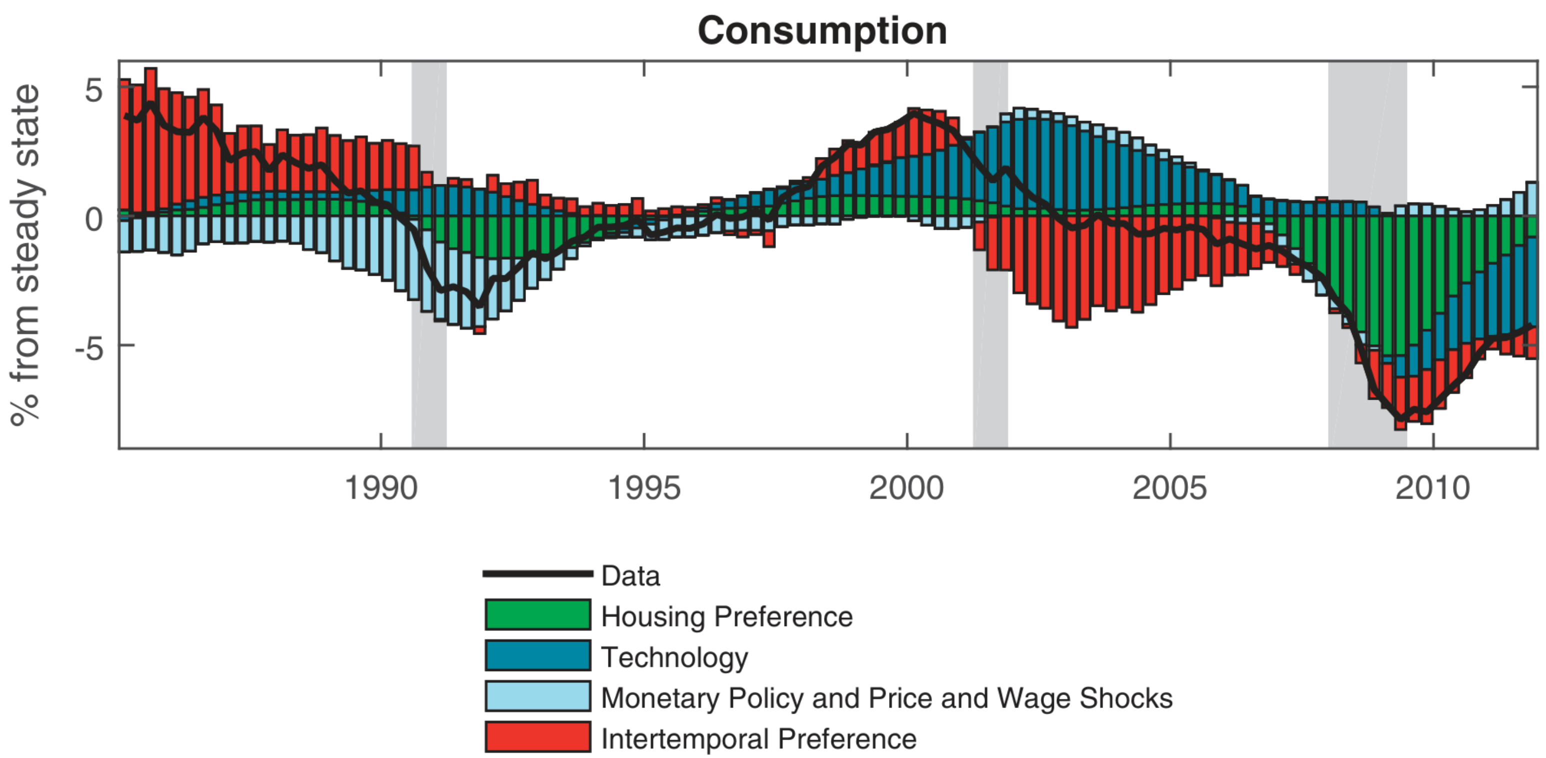


Regarding ***consumption***, about 70% of consumption decline 2007 - 2009 can be traced to ***housing demand shocks*** (green) that impact consumption through collateral channel

But these shocks accounted for only a modest part of rise in consumption prior to Great Recession

Why? Because ***housing demand shocks*** (green) have no implications for consumption in absence of collateral constraints

And housing price boom 1998 – 2005 (see previous slide) ➔ slack collateral constraint



- Why did house price collapse starting at end of 2005 not, at first, have a substantial effect on consumption?
- Answer: preceding house price boom relaxed borrowers’ collateral constraints ➔ initial reductions in house prices could be counteracted by ***increasing borrowing*** rather than ***curbing consumption***
- Only as house prices kept falling after 2008 did borrowers’ collateral constraints tighten ➔ large reduction in consumption

Comparing Models

- ***Kass and Raftery (1995)*** provide a simple and elegant way to compare (pairwise) competing models
- Use "***Log data density [Laplace approximation]***" as computed by **Dynare** for each model
- ***Construct*** KR = 2*log(BF_{ij}) where log(BF_{ij}) = ***difference*** between Log data densities for models i and j
- Values of KR:
  - > 10 ➔ ***very strong evidence*** in favour of model i
  - between 6 and 10 ➔ ***strong evidence***
  - between 2 and 6 ➔ ***positive evidence***
  - between 0 and 2 ➔ "***not worth more than a bare mention***"

- ***Example 1:***
- Log data density [Laplace approximation] for SW model with ***no cointegration*** and ***including Financial frictions*** [FF] = -1296.003325
- Log data density [Laplace approximation] for SW model with ***imposed cointegration*** and ***including Financial frictions*** [CIwFF] = -1309.394501
- KR = 2*log(BF_{ij}) = 2*(-1296.003325 - -1309.394501) = 26.78 > 10 ➔ ***very strong evidence*** for FF model which does ***not*** impose cointegration
- Not very surprising!!

- ***Example 2:***
- Log data density [Laplace approximation] for SW model with ***no cointegration*** and no Financial frictions [***noFF***] = -923.823015
- Log data density [Laplace approximation] for SW model with ***imposed cointegration*** and no Financial frictions [CI***noFF***] = -930.268207
- KR = 2*log(BF_{ij}) = 2*(-923.823015 - -930.268207) = 12.89 > 10 ➔ ***very strong evidence*** for noFF model which does ***not*** impose cointegration
- Not very surprising!!

- ***Example 3:***
- Log data density [Laplace approximation] for SW model with ***imposed cointegration*** and ***including*** Financial frictions [CIwFF_4KR] = -954.122681
- Log data density [Laplace approximation] for SW model with ***imposed cointegration*** and ***no*** Financial frictions [CInoFF] = -930.268207
- KR = 2*log(BF_{ij}) = 2*(-930.268207 - -954.122681) = 47.71 >> 10 ➔ ***very strong evidence*** for CInoFF
- Very surprising!!
- ➔ delNGS version of FF is not very good!

Appendix: Other Models

Gortz Tsoukalas Zanetti 2021

- ***Gortz, Tsoukalas and Zanetti (2021)*** developed a model which includes ***eight*** different types of economic agents:
  - ***[Standard] Households consume***, ***save*** in interest-bearing deposits and ***supply labour*** on a monopolistically competitive labour market
  - ***[Standard] (Lazy) employment agencies*** aggregate different types of labour into a homogeneous aggregate for intermediate goods production
  - ***[NEW] Intermediate goods firms*** use labour and capital services as inputs to produce ***investment*** and ***consumption*** goods in ***two distinct sectors***

- *[Standard]* Intermediate goods firms rent ***labour services*** from employment agencies and rent ***capital services*** on a perfectly competitive market from capital services producers
- *[Standard]* ***Final goods producers*** aggregate ***intermediate*** producers' output in each sector
- *[Standard]* ***Physical capital producers*** in each sector use a fraction of investment goods and existing capital to produce ***new capital goods***
- *[NEW]* ***Financial intermediaries*** accept ***deposits*** from households and ***finance capital acquisitions*** of capital services producers
- *[Standard]* ***Central bank*** controls nominal ***interest rate***

- *[Standard]* ∃ Calvo-type ***price and wage rigidities***
- ***Labour*** is ***mobile*** across sectors
- ***NEW:***
- But ***capital*** is ***immobile*** across sectors ➔ ***two*** sets of investment and capital utilisation decisions
- ∃ two ***financial shocks*** for each sector:
  - shock to ***value of assets*** in banks' portfolios (valuation shock) [eg, Credit Suisse after Archegos]
  - shock to banks' ***equity capital*** [eg, regulation change]
- Further, ***CB*** may react to ***credit spreads***

- ➔ ***Except for*** inclusion of financial intermediaries (whose workers are called "***bankers***") rest of model is ***essentially identical to SW2007***
- but now with ***two goods sectors*** (consumption goods and investment goods)
- separately indexed, but ***symmetric***
- For example, each ***household*** maximises

GTZ assume $\sigma_c = 0$!

$$E_0 \sum_{t=0}^{\infty} \beta^t b_t \left[\ln(C_t - hC_{t-1}) - \varphi \frac{\left(\boxed{L_{C,t}(j)} + \boxed{L_{I,t}(j)}\right)^{1+\nu}}{1+\nu} \right]$$

- where $L_{C,t}$ and $L_{I,t}$ are labour supplied to ***consumption*** and ***investment*** sector respectively

- Similarly, solving optimisation problem of ***capital producers*** → ***standard SW2007*** capital accumulation equation

marginal efficiency of investment (MEI) shock

$$\bar{K}_{x,t} = (1-\delta_x)\,\bar{K}_{x,t-1} + \mu_t \left(1 - S\left(\frac{I_{x,t}}{I_{x,t-1}}\right)\right) I_{x,t}$$

- So only really "new" bit is equations needed to implement ***financial intermediaries (FI)***
- ***FI*** use ***deposits*** from households plus their ***own equity*** to finance acquisitions of physical capital by capital services producers

- Because model is two-sector, it assumes ∃ specialised ***FI*** for financing ***each*** sector
- ***Essential*** mechanics of ***FI*** described by ***three key equations*** [there are ***many*** more ...]:
  - ***balance sheet*** identity
  - ***demand for assets*** that links ***equity*** with value of assets (physical capital)
  - evolution of ***equity***

- ***(1) Balance sheet*** (in ***nominal*** terms) of a ***bank branch*** (= ***FI***) which lends in sector x = C,I is

$$Q_{x,t}\, P_{C,t}\, S_{x,t} = N_{x,t}\, P_{C,t} + B_{x,t}$$

- $S_{x,t}$ = quantity of ***financial claims*** on capital services producers held by bank branch
- $P_{C,t}$ = consumption sector ***price*** level
- $Q_{x,t}$ = ***(real) price*** per unit of claim [$P_{C,t}$ ➔ nominal]
- $N_{x,t}$ = ***(real) equity*** at end of period t [ditto]
- $B_{x,t}$ = ***(nominal)*** value of household ***deposits***

- ***FI maximise their expected terminal wealth*** = discounted sum of future equity
- **But ∃ "*moral hazard*"** problem: bankers could ***abscond*** with clients' money [or "lose" it: ***CS***]
- This introduces an ***endogenous leverage constraint***, limiting bank's ability to acquire assets
- Constraint is formalised in equation that determines ***(2) demand for assets in sector x***:

$$Q_{x,t}\, S_{x,t} = \boxed{\varrho_{x,t}} N_{x,t}$$

- ➔ (real) value of assets that FI can acquire is limited to ***equity*** $N_{x,t}$ scaled by ***leverage ratio*** $\varrho_{x,t}$

- ***leverage ratio*** $\varrho_{x,t}$ is ratio of FI's intermediated assets to equity
- $\varrho_{x,t}$ is limited to value at which FI's maximised ***expected terminal wealth*** equals its gains from "diverting" a fraction λ_B from clients' funds
- In "***macroprudential***" models, this leverage ratio can be used as a ***policy instrument*** to ensure financial ***solvency***

- Sector specific ***assets*** $Q_{x,t}$ $S_{x,t}$ ***held by*** financial intermediary ***pay to FI a (stochastic) return*** $R^B_{x,t+1}$ in next period
- At (t+1), ***FI pay*** non-contingent ***gross return*** R_t to ***households*** for their ***deposits*** made at time t
- ➔ intermediary branch ***(3) equity*** evolves over time as

Nominal value of assets

$$N_{x,t+1}P_{C,t+1} = R^B_{x,t+1}\pi_{C,t+1}P_{C,t}Q_{x,t}S_{x,t} - R_t B_{x,t}$$

Gross inflation

Nominal value of equity next period

- To finance their physical capital acquisitions ($\bar{K}_{x,t}$ priced at $Q_{x,t}$) ***capital services producers*** issue
- ***one-period corporate bonds [held by FI]***
- whose (real) value $Q_{x,t} S_{x,t}$
- = (real) value of physical capital acquired $Q_{x,t} \bar{K}_{x,t}$
- And as in SW2007, ***physical*** capital is transformed into capital ***services*** via ***capital utilisation*** function

$$K_{x,t} = u_{x,t} \xi^{K}_{x,t} \bar{K}_{x,t-1} \qquad x = C, I$$

- where $\xi^{K}_{x,t}$ is a ***capital quality shock*** [eg, Nikola EV]

- As noted, ***FI pay*** (at t+1) a ***gross return*** R_t to households for their ***deposits*** made (at time t)
- But they ***earn*** $R^B_{x,t+1}\,\pi_{C,t+1}$ from sector specific assets held during that period
- ➔ "***Risk premium***" on assets earned by banks is

$$R^S_{x,t} = R^B_{x,t+1}\,\pi_{C,t+1} - R_t\,,\quad x = C,I$$

- which is equal to ***corporate bond yield spread***
- ***If*** capital markets were ***perfect***, arbitrage would reduce risk premium to ***zero***
- but credit constraints in ***imperfect*** capital markets ➔ $R^S_{x,t} > 0$

- ***Evolution of equity*** described by law of motion:

risk premium

$$N_{x,t+1} = \left(\theta_B [\boxed{(R^B_{x,t+1}\pi_{C,t} - R_t)} \varrho_{x,t} + R_t] \frac{N_{x,t}}{\pi_{C,t+1}} + \varpi \boxed{Q_{x,t+1} S_{x,t+1}} \right)$$

real value of corporate bonds held by FI

- $R^B_{x,t+1}$ = ***real*** rate of return on FI capital
- R_t = (gross) ***nominal*** interest rate paid on deposits
- $\pi_{C,t}$ = (gross) rate of consumer price ***inflation***
- θ_B = ***survival rate*** of bankers (into next period) eg, 0.96
- ϖ = fraction of assets passed on to ***new*** bankers
- $\varrho_{x,t}$ = leverage ratio

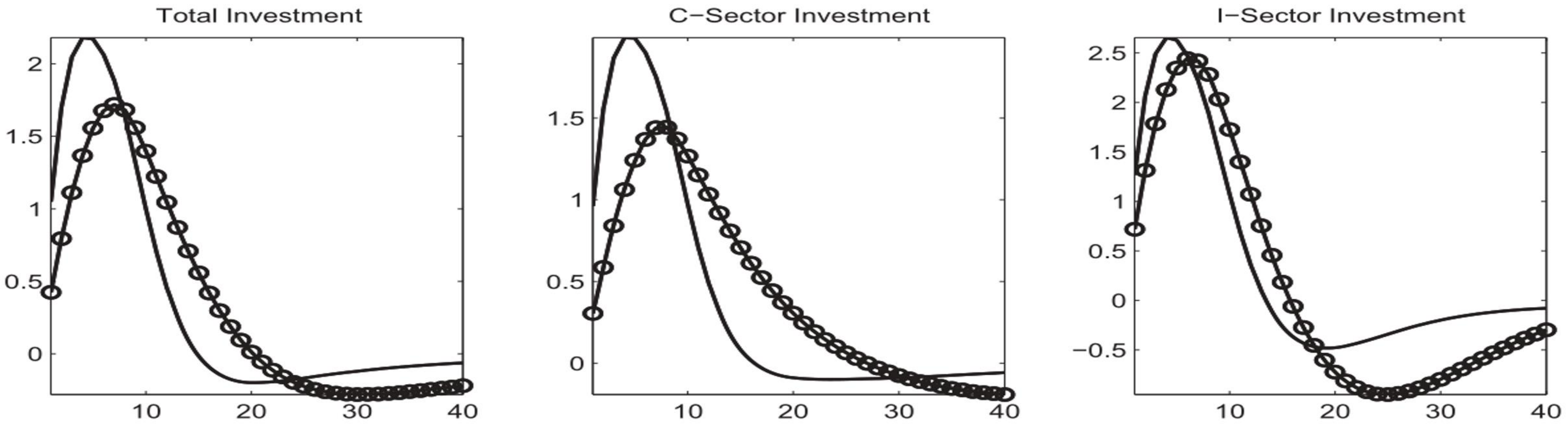
Each period, some bankers retire or quit or die or are sent to prison and some new bankers enter

- ***Performance*** of banks ***differ by sector*** because ***demand*** for capital differs across sectors
- ➔ ***sector-specific (real) prices*** of capital ($Q_{x,t}$) and nominal ***rental rates*** for capital ($R^{K}_{x,t}$)
- ∃ substantial number of equations setting out details of accounting for banks
- But ***ultimately three bank parameters*** are critical:
  - risk of ***bankruptcy*** (= 1 - ***survival*** rate θ_B)
  - fraction of wealth with which bankers can ***abscond*** (λ_B)
  - ***leverage ratio*** ($\varrho_{x,t}$)

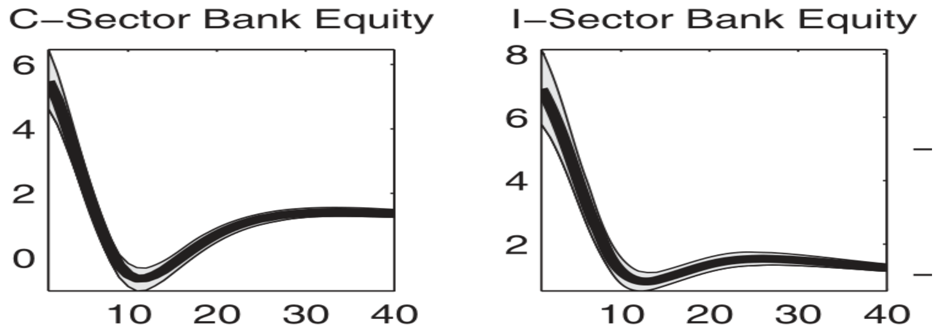
- A ***technical point***: in **Dynare** model used,
- a separate **Dynare** programme is included dealing with computation of ***steady-state***,
- necessary as underlying model is highly non-linear
- done by adding **@#include "GTZ2021_SS.mod"** before Shock section
- In slides below, SW2007 and GTZ2021 are both ***estimated over GTZ2021's period*** (1990Q2-2011Q1)
- J:\MyCourseDSGEs2024\Tests\SW2007vsGT2021_Walsh.m

- TFP shock ➔↑ output, consumption, investment and also hours worked, as usual
- but more ***with FI*** than without
- ***Two-sector*** structure of model propagates TFP shock to ***investment*** sector

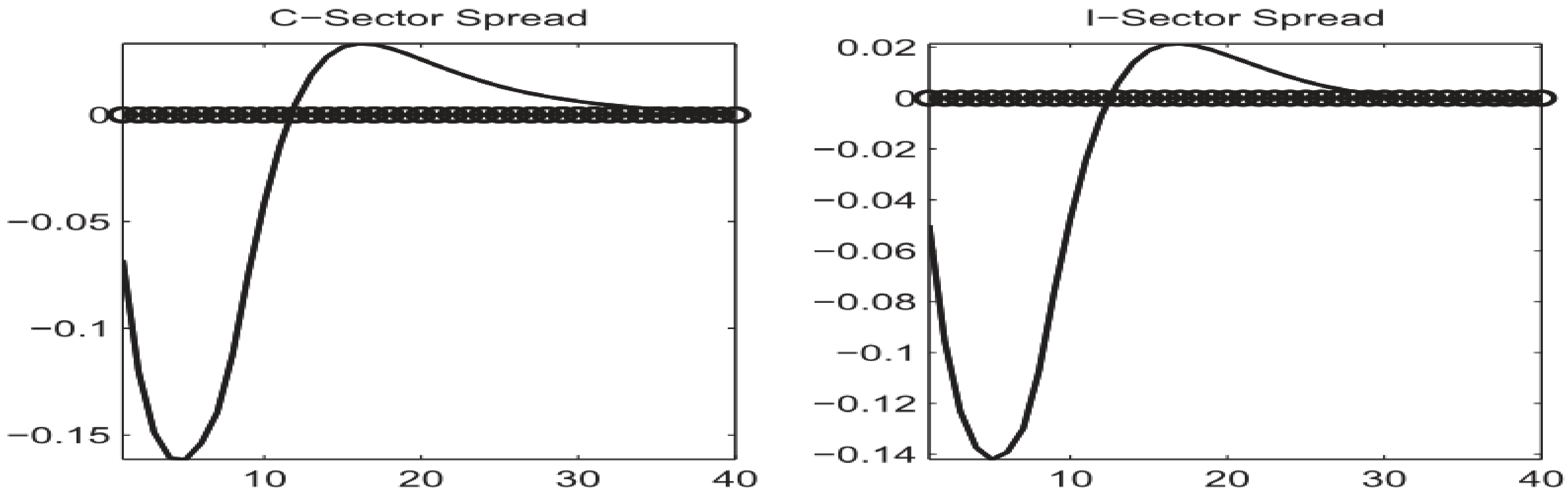
solid line = ***with*** FI; line with circle = ***without*** FI: ∃ clear amplification with FI



- Anticipation that future ***productivity*** of capital will be permanently higher in ***consumption*** sector creates ***demand for capital goods*** produced by ***investment*** sector
- This strong demand causes ***capital prices*** (and ***FI equity***) to rise
- ***Thereafter***, as more capital gets installed, capital prices, return to capital, and bank equity ***decline***



- ***Since*** sectoral ***bond spread*** in model corresponds to expected ***excess return*** to capital
- ***and*** expected return to capital (between time t and t + 1) ***declines*** because capital prices are expected to fall as more capital is installed
- ➔ ***bond spreads decline*** before eventually recovering as shock wears off



Gertler and Kiyotaki 2010

- Other models, also building on SW2007, go further in this direction
- ***Gertler and Kiyotaki (2010)***: Households comprise both ***workers*** and ***bankers*** (in fixed proportions)
- ∃ a (small) finite ***probability*** each period that a banker will go ***bankrupt***
- Banking sector composed of a retail and a wholesale market
- ***Retail*** market allows banks to raise ***deposits*** from ***households***
- ***Wholesale*** market is an ***interbank*** market where banks provide funding ***to each other***

- ***Intermediate goods*** firms finance their capital acquisitions each period by obtaining funds from banks
- But intermediate goods firms now assumed to ***differ*** in their opportunities to issue debt
- In each period, a given fraction of firms can ***issue*** new debt [financed by banks]
- while remaining fraction merely ***rolls over*** its existing debt
- Opportunity to issue new debt arrives ***randomly*** to firms [via ***Calvo financial fairy***]

- ***Relationship-based*** financial system that predominates in Europe ➔ firms and banks ***jointly*** establish ***expected liquidity needs***
- To finance these expected liquidity needs, banks use
  - ***deposits*** collected from households
  - accumulated ***retained earnings*** [net worth]
- After Calvo fairy defines realisation of investment opportunities, banks are in either ***short*** or ***surplus*** supply of ***liquidity***, depending on which firms enter their business relationships
- ➔ need for ***interbank market*** to allow banks to ***manage*** their short-term liquidity needs

Kannan, Rabanal, Scott

- Financial crisis starting in 2008 demonstrated that as housing prices ***rise***, household borrowing rises, fuelling a ***debt–driven*** consumption ***boom***
- And as housing prices ***decline***, households are forced to borrow ***less*** → ***deleveraging*** worsens ***economic contraction***
- ***Kannan, Rabanal and Scott*** of IMF therefore developed a model to take into account role of ***housing*** as a store of ***wealth***
- Their model is ***very similar to GTZ2021*** (see details in next section of these appendices)

- KRS do a very ***interesting experiment*** with variations on ***Taylor Rule***
- ***Monetary*** policy already has ***real*** effects because of presence of sticky prices
- But significant deviations of ***credit growth*** from its average levels are empirically associated with ***subsequent*** house price ***busts***
- ➔ allow CB to ***further*** influence market ***lending rates*** by imposing ***additional*** capital requirements (***provisioning***) when ***credit growth*** is above its steady-state value

- This can be ***implemented*** as follows:
- ***Baseline policy régime*** is a Taylor Rule with a weight of 1.3 on CPI inflation and 0.5 on output gap (0.125 in quarterly terms)
- ***Second régime*** adds a term in ***growth rate of nominal credit***
- ***Third régime*** further adds a "***macroprudential***" ***instrument*** which mimics effects of ***regulations*** that require banks to ***set aside*** more capital as asset prices ***rise***
- Here this is specified as a reaction to lagged nominal credit changes

- In **Dynare** version of model, ***second régime*** is implemented via a Taylor Rule specification:
- r = gammaR*r(-1)
- + (1 - gammaR)*(gammapi*deltapC(-1)
- + gammay*(y(-1) - ystar(-1))
- + gammab*(bB(-1) - bB(-2) + deltapC(-1))
-);

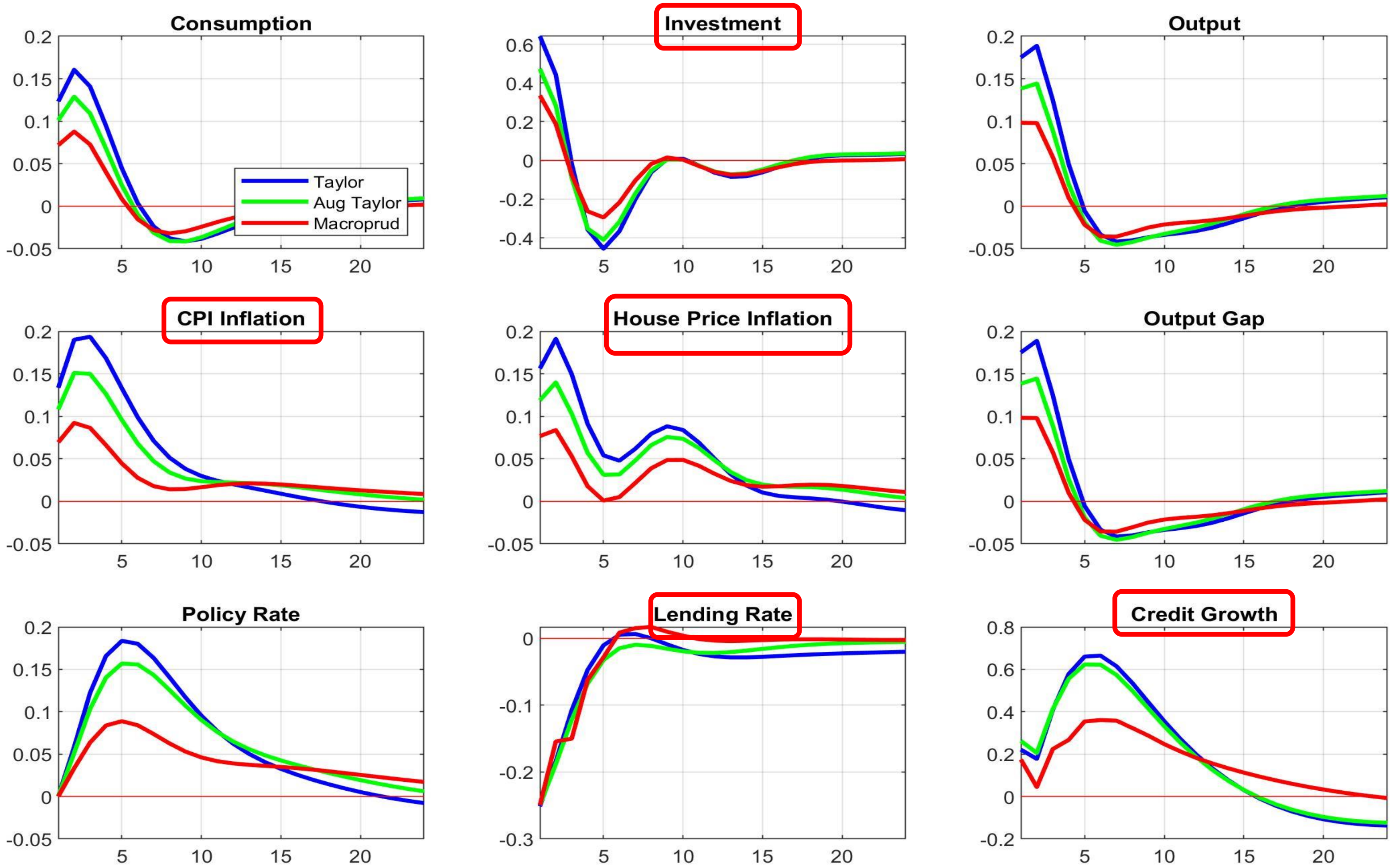
In "normal" Taylor Rule (régime one), $\gamma_B = 0$

- where
  - deltapC = CPI ***inflation***
  - **ystar** = ***potential*** GDP [here defined ***without*** use of "shadow" flex-price economy]
  - **bB** = (log) value of ***credit*** [➔ bB(-1) - bB(-2) + deltapC(-1) = ***nominal credit growth***]

- In addition to Taylor Rule of second régime, ***third régime adds*** macroprudential variable as ***last term*** in equation for effective ***interest rate*** for borrowers
- rL = r
- + kappa*(bB – dB - q)
- – **v**
- + $\boxed{\text{tau}}$*(bB(-1) - bB(-2) + deltapC(-1));
- where
  - **rL** = interest rate for borrowers
  - **bB** = (log) value of ***credit***
  - **dB** = consumption of durables (***housing***) by borrowers
  - **q** = (log) relative price of durables vs nondurables
  - **v** = financial ***shock***

Without macroprudential regulation, $\tau = 0$ so last term ***drops out*** in regimes one and two

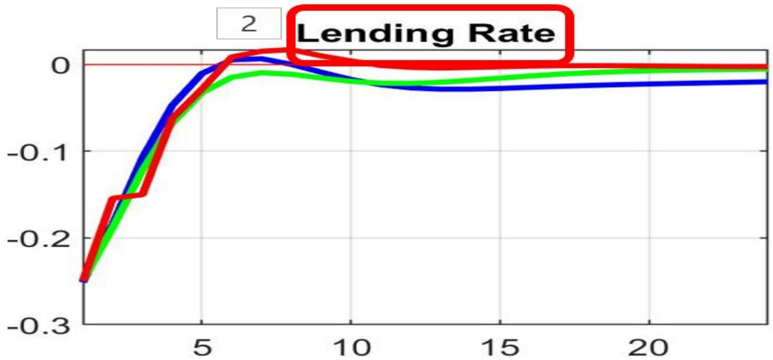
- IRFs below show ***comparative effects*** of these three ***régimes***. First, ***Financial shock (v)***



- A ***financial shock*** causes an ***immediate increase*** in ***residential investment*** and ***house prices***
- Shock feeds on itself because banks are assumed to ***lower lending rates*** when collateral rises :

  rL=r + kappa*(bB-dB-q)- v + tau*(bB(-1)-bB(-2)+deltapC(-1)) ↓ when q ↑

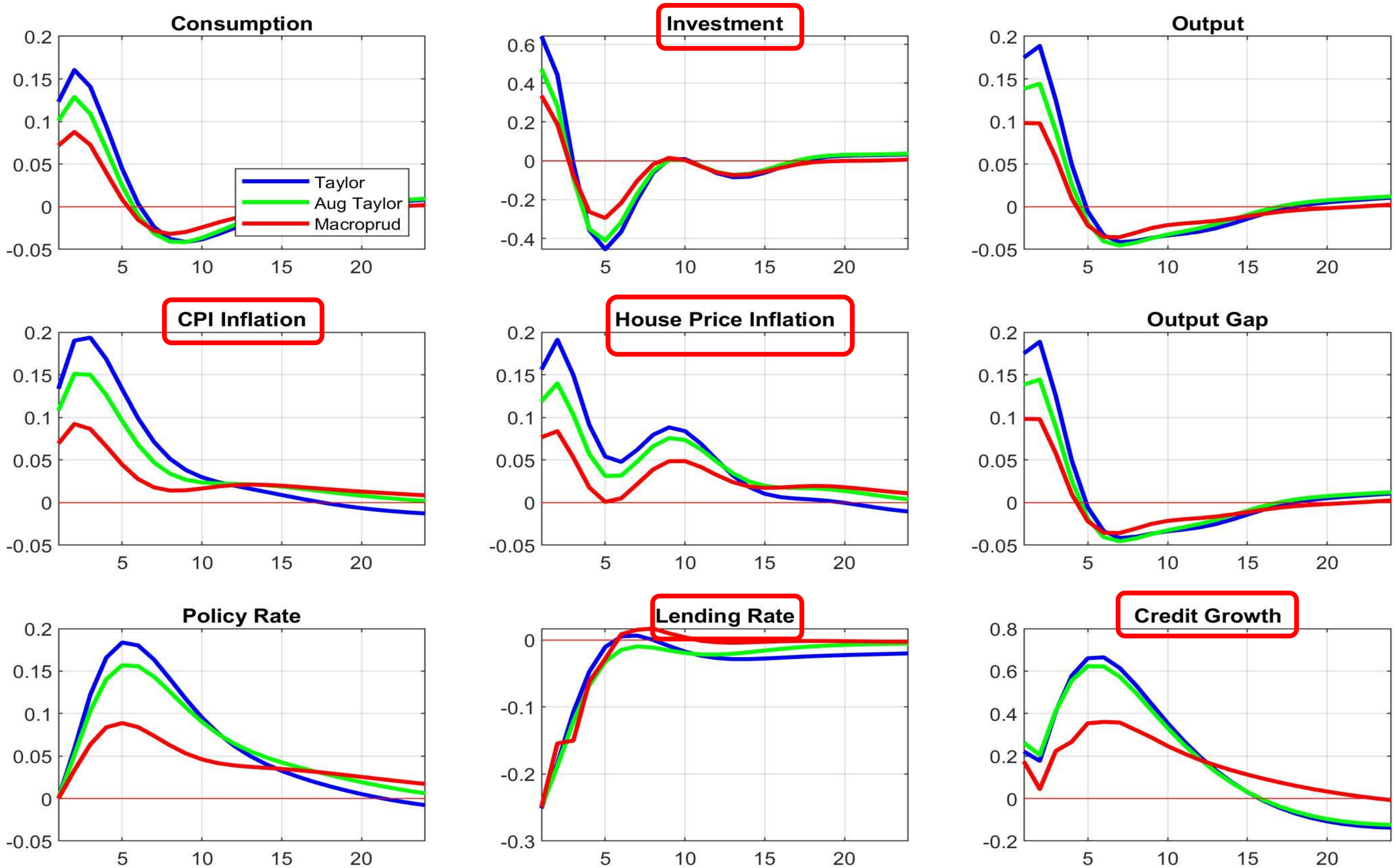
  - increased housing demand raises ***house prices***
  - ***collateral*** values increase
  - ***lending rates*** are lowered
  - households increase ***loans***



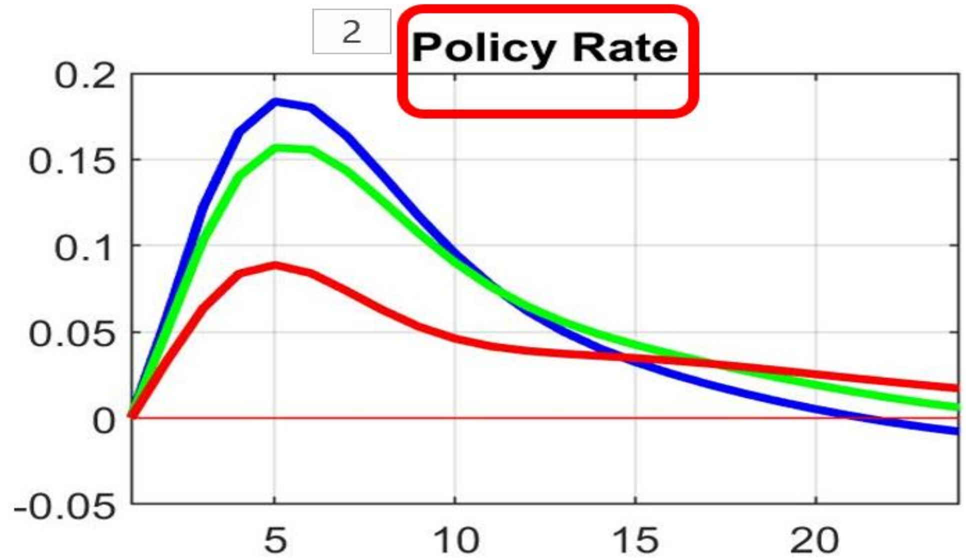
- ➔ ***credit accelerator*** mechanism at work
- Lower rates also lead to higher demand for ***nondurable*** consumption goods by borrowers, pushing up ***CPI inflation***

- But ∃ ***house price bust*** in aftermath of this shock:
  - as financial conditions normalise, ***residential investment*** must ***undershoot*** for a period to bring housing stock back to equilibrium
- This process ***spills over*** to rest of economy ➔ temporary ***recession*** and raising ***volatility*** in all markets
- ***Reaction*** of ***CB*** following ***first régime*** (simple Taylor Rule) **[blue]** is straightforward:
  - to extent that output gap and CPI inflation are positive following increase in housing demand, ***policy rates*** are ***raised***
- ➔ eventually, output and
- inflation ***stabilise***

- Repeat, ***Financial shock (v)***

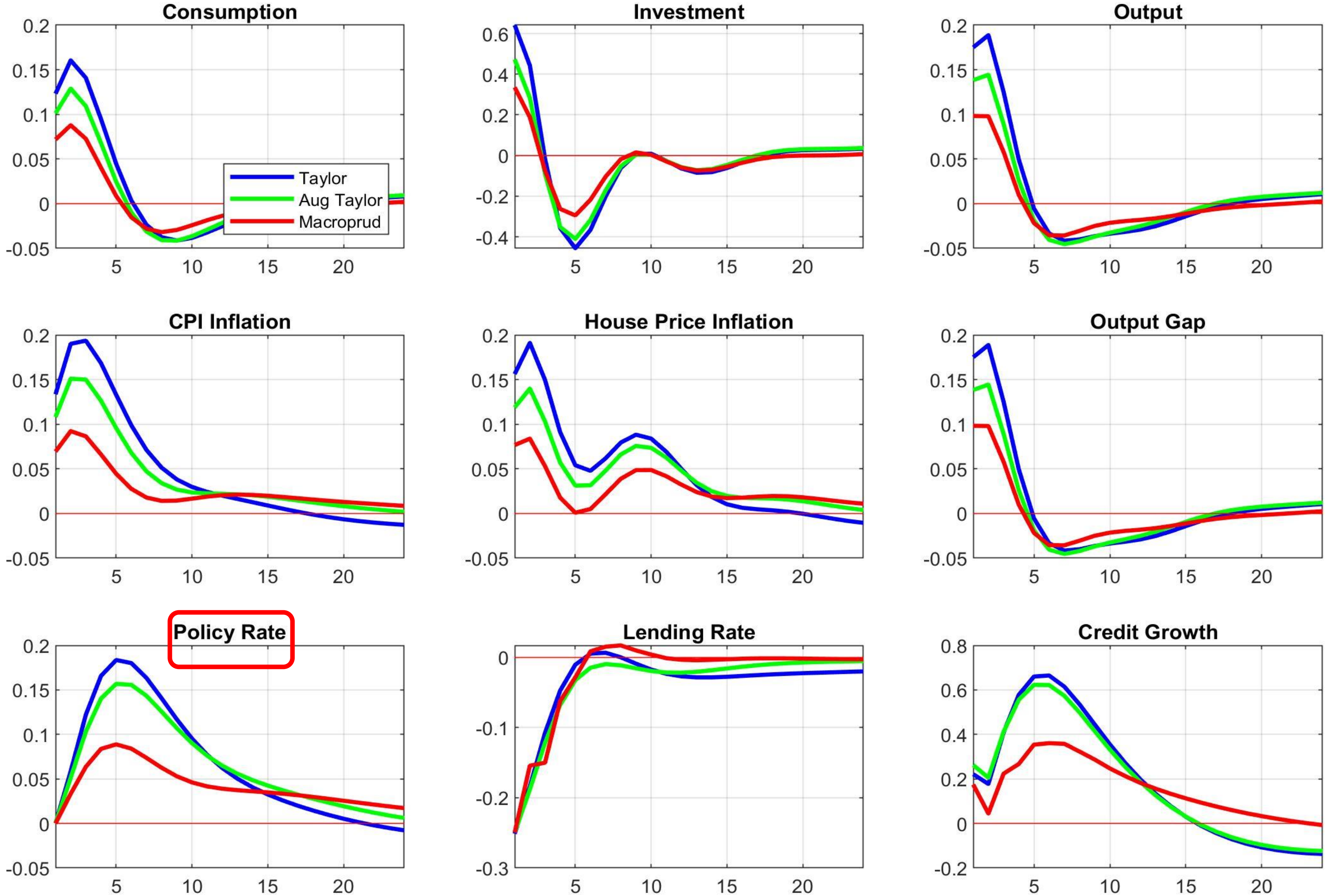


- If CB follows ***second regime*** [green] CB reacts directly to ***credit growth***, in addition to ***output gap*** and ***inflation*** ➔ greater stability: lower ***volatility*** of
  - consumption
  - residential investmen
  - output gap
  - House price
  - CPI inflation
  - interest rates



- ***Why*** (slightly) less volatile ***interest rates*** even though policy rule is more aggressive?
- Because model has fully ***forward-looking*** private agents ➔ very strong ***expectations effects***

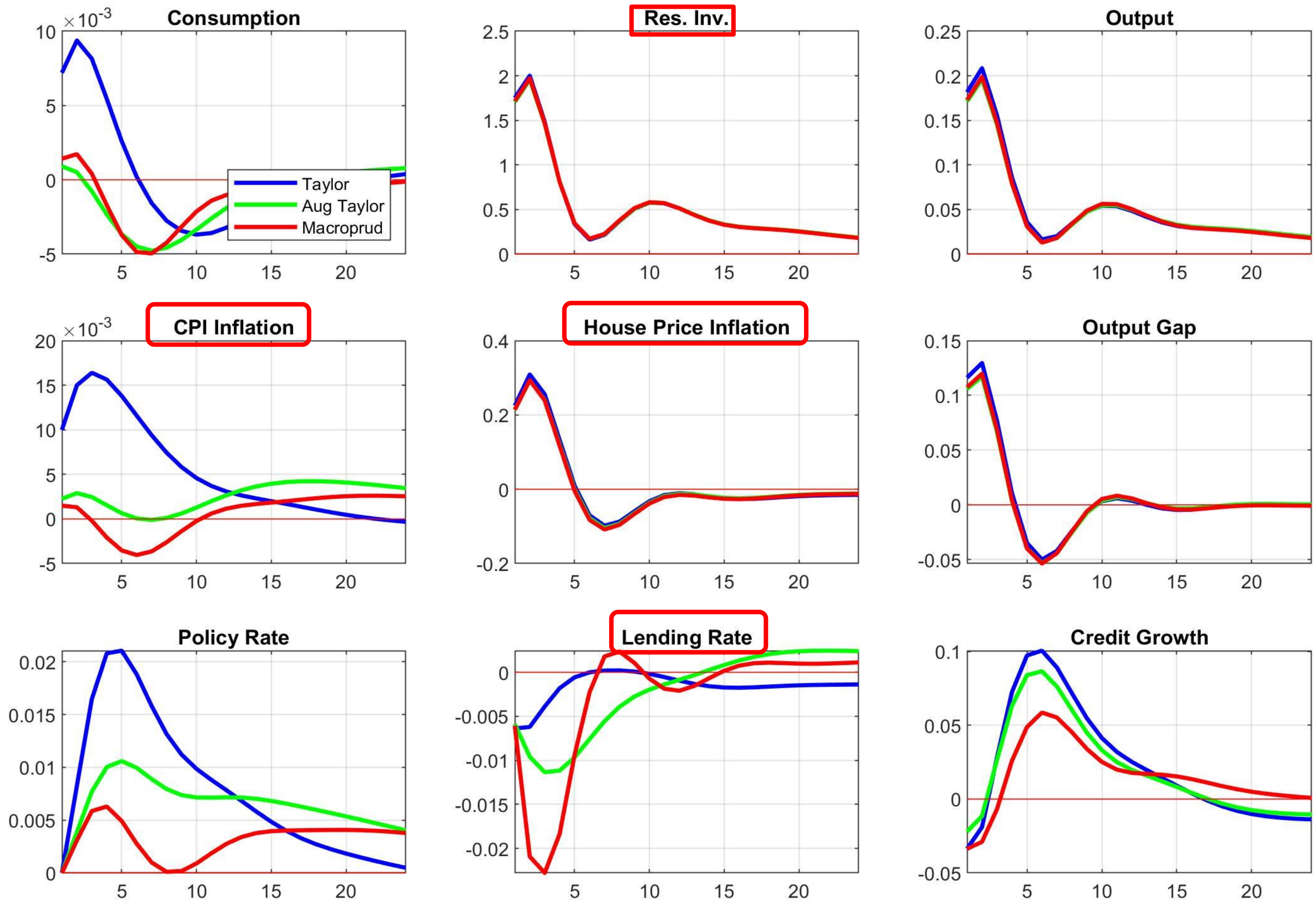
• ***Financial shock*** [repeat]



- Macroeconomic ***stabilisation*** is ***even better served*** under ***third régime*** **[red]** under which CB complements augmented Taylor Rule with use of macroprudential instrument

- ➔ ***further reduction*** of ***volatility***
- of CPI ***inflation*** and ***output gap***
- Moroever, because there is now a ***second policy instrument***, monetary policy does not have to react so strongly to financial shocks ➔ ***further reduction*** of ***volatility*** of ***policy rate***
- Thus, monetary policy can also work through ***threat*** of a stronger reaction, rather than by ***actually delivering*** that stronger reaction

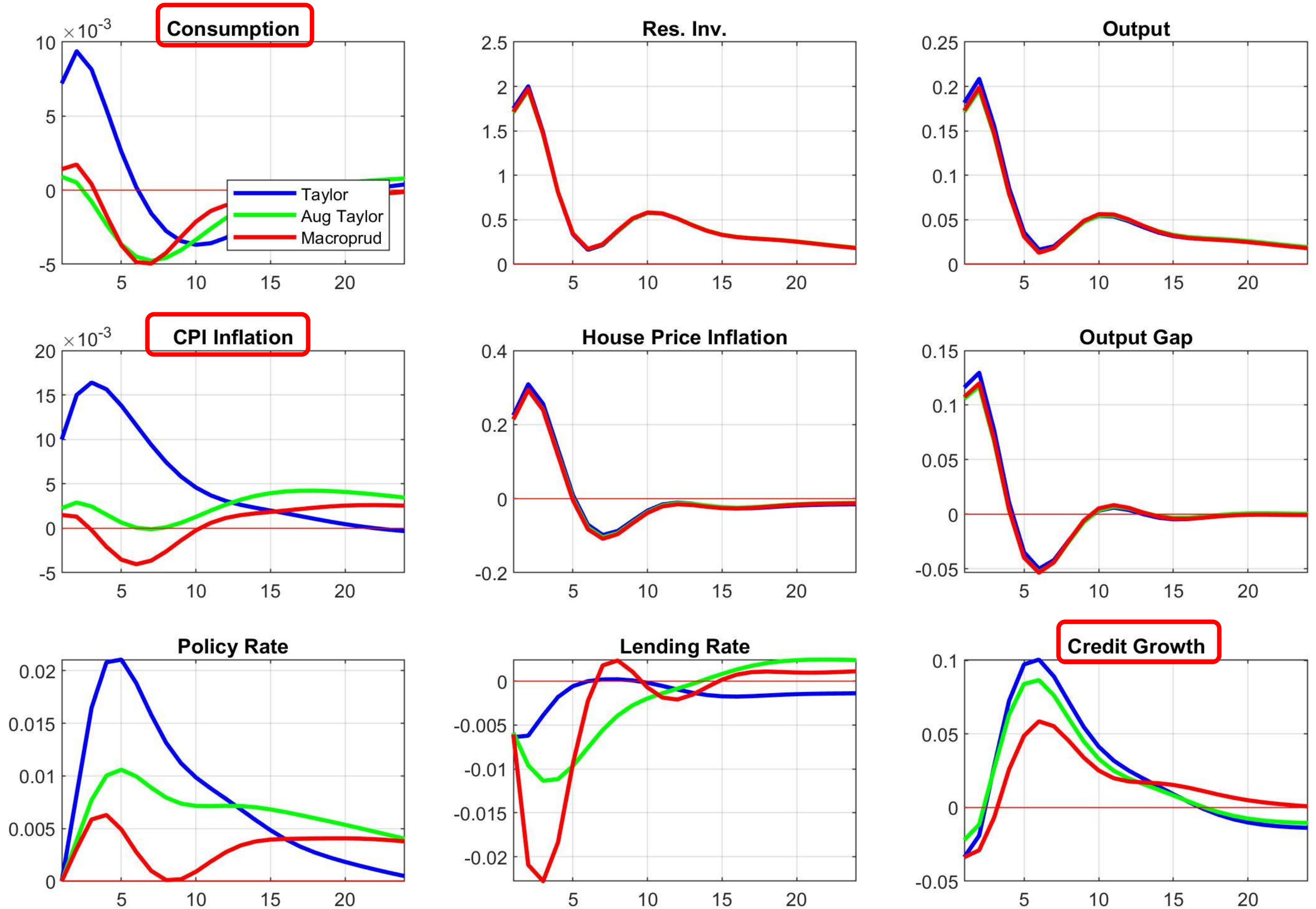
• ***Housing demand*** shock



- What about a ***Housing demand*** shock?
- under ***first régime*** **[blue]** ↑demand for housing (by both savers and borrowers) ➔ ↑ ***residential investment*** and ***house prices***
- Accelerator effects ➔ ↓ ***lending rates*** ➔ ↑ ***private consumption*** also when housing demand increases
- ➔ ***positive comovement*** between private consumption and residential investment
- This feature ***typically holds*** in real-world data, on account of ***wealth effects*** from ***higher house prices*** and ***better access to credit*** for those agents who want to ***borrow***

- These ***spillover effects*** ➔ ↑ ***CPI inflation*** ➔ central bank ***tightens*** monetary policy in ***first regime***
- Extending monetary policy to include additional indicators works mostly through attenuating impact of ***spillover effects*** of housing to nondurable consumption, rather than cooling off housing market ***directly***
- ➔ under ***second regime*** [green] CB reacts to credit growth ➔ ***volatility of credit*** is (slightly) reduced, and accelerator effect is dampened ➔ ***nondurable consumption*** ↓ slightly instead of ↑

- ***Housing demand*** shock



- ***nondurable consumption*** ↓ ➔ ***CPI inflation*** ↓
- Effects on ***output gap*** are ***modest***, because augmented Taylor régime cannot do much to reduce volatility of ***residential investment***, which is ***main driver*** of response of output gap
- Similar to case of ***financial shocks***, most important ***channel of monetary policy*** is to affect ***expectations***, and ultimately, CB raises ***interest rates*** by ***less than*** in case of ***first régime***
- Under ***second régime*** where monetary policy reacts to credit, ***volatility*** is ***reduced*** [and ***welfare improved*** – see later]

- In ***third régime*** (augmented Taylor plus macroprudential) ***volatility*** of aggregate variables is ***very similar*** to that obtained ***without macroprudential measures***
- → need to compare on some other measure
- Define ***objective function of CB*** as "***minimise volatility*** of both CPI inflation and output gap"
- → in **Dynare** model, add
  - Utility = 0.5*ygap^2 + 0.5*deltap;
  - Objective = Utility + beta*Objective(+1);
- "Objective" is to be ***minimised***

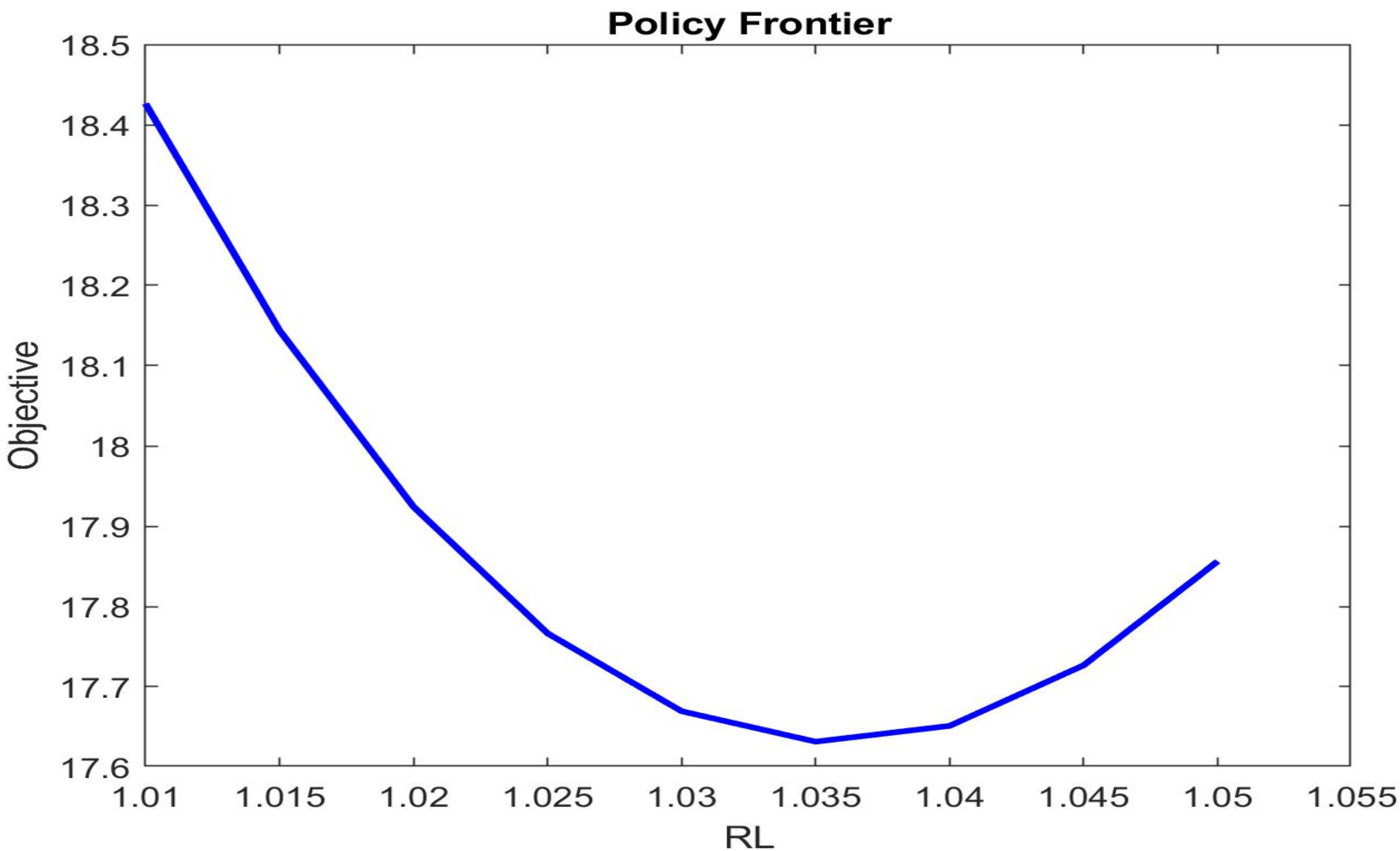
- Comparing results across 3 ***regimes***:

Régime	Objective	Std. Deviation
First	17.9093	1.2908
Second	17.0064	0.8845
Third	15.0410	0.7241

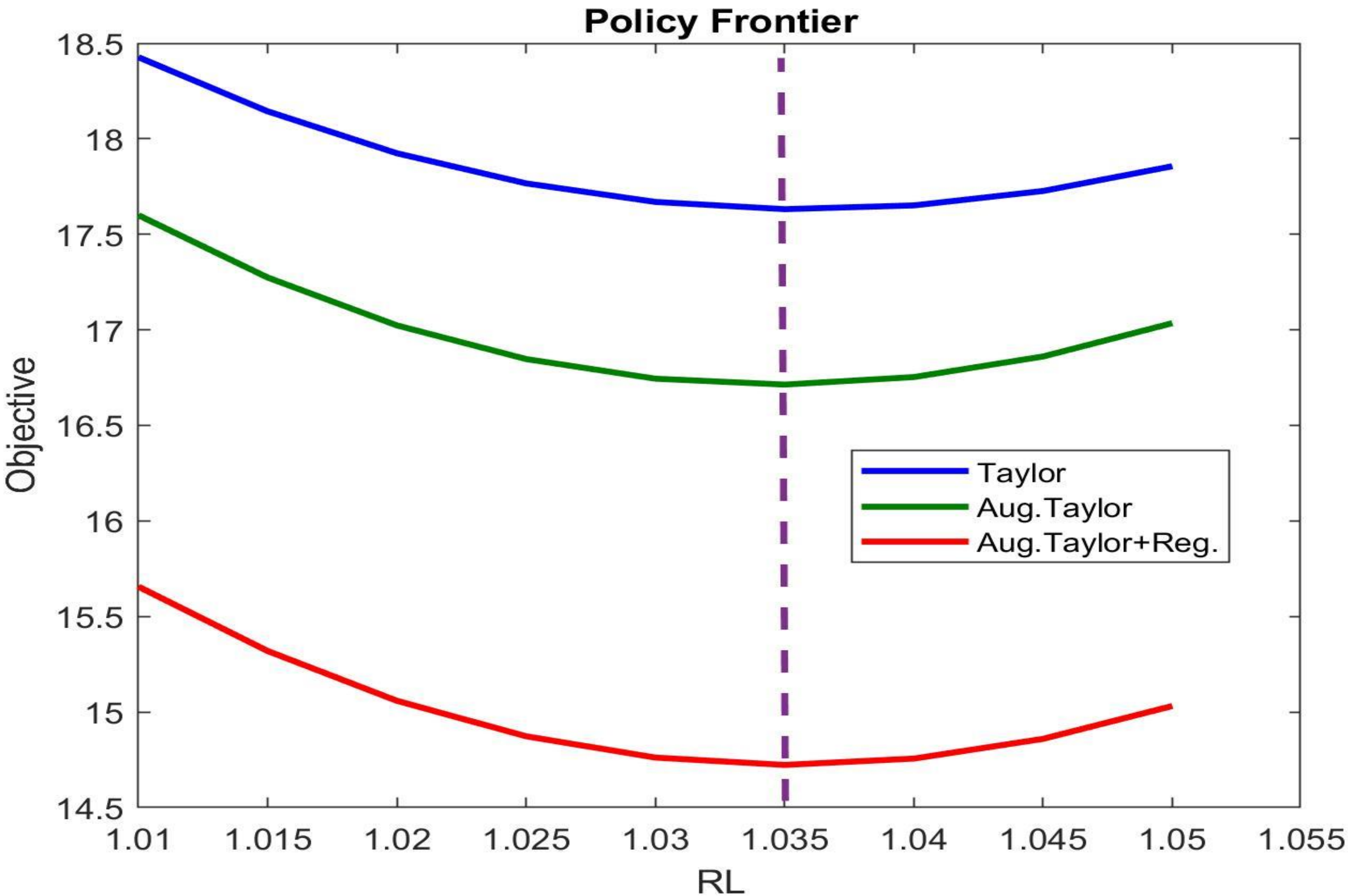
J:\MyCourseDSGEs2024\Tests\KRS2_macro5b3.mod + macro6b + macro7b

- Clearly, ***third régime*** does ***best*** in minimising value of both ***Objective*** and its ***variation*** [stabilisation]
- NB: here, variation of Objective is calculated by taking 1000 replications of model

- It is also interesting to construct a "***Policy Frontier***" showing how Objective varies with a key parameter, such as base ***lending rate***



- Comparison across our three ***régimes***:



KRS - Detail

- Model features (***as usual***)
  - nominal wage and price ***rigidities (Calvo)***
  - ***habit*** formation in consumption
  - investment ***adjustment costs***
  - ***monopolistic competition*** in intermediate goods
  - monetary authority using a ***Taylor Rule***
- To these are added ***housing sector***
- ***Housing*** has a ***dual*** role:
  - it is a ***durable good*** (which enters utility function ***separately*** from consumption and labour)
  - it serves as ***collateral*** for "impatient" households
- ➔ ***two goods sectors*** (durables and non-durables)

- For simplicity, there is ***no capital*** used in production of durable and nondurable goods
- ➔∃ ***no non-residential*** investment [could easily add]
- ***Residential investment*** adjusts slowly owing to ***adjustment costs***
- Assumed ***costly*** for workers to ***shift*** from production of ***consumption*** goods to building ***houses*** and ↔
- ***Housing wealth*** quantitatively ***more important*** for households than wealth held in ***equities***
- House purchases typically require ***debt financing***
- ➔ distinction between ***borrowers*** and ***lenders***

- → split ***households*** into ***two types***:
- ***patient*** (lenders) and ***impatient*** (borrowers)
- ***Patient*** households work, consume and accumulate housing
- They own economy's productive ***capital*** and supply ***funds*** to firms ***and*** to impatient households
- ***Impatient households*** also work, consume and accumulate housing
- ***But*** because of their high impatience [a polite way to put it!], they accumulate ***only*** enough net worth to finance ***down-payment*** on their home, spending remainder

- In this model (as preponderantly in reality), savers ***cannot*** lend to borrowers ***directly***
- ➔ need for financial intermediaries (***banks***) which:
  - take ***deposits*** from savers (***patient*** households)
  - ***lend*** them to borrowers (***impatient*** households)
  - ***charging*** a ***spread***
- ***Spread*** here depends on ***loan-to-value ratio***
- which in turn depends on market valuations of borrowers' ***collateral***
- ➔ spread depends on ***net worth*** of borrowers

- Fraction λ of households are ***savers*** and remaining fraction 1 - λ are ***borrowers***
- Since borrowers are more ***impatient*** than savers, they have a ***smaller discount factor***
- Each ***saver*** j ∈ [0; λ] maximises her ***utility function***:

$$E_0 \left\{ \sum_{t=0}^{\infty} \beta^t \left[\gamma \log(C_t^j - \varepsilon C_{t-1}) + (1-\gamma)\xi_t^D \log(D_t^j) - \frac{(L_t^j)^{1+\varphi}}{1+\varphi} \right] \right\}$$

- where for each ***saving*** household j:
  - C^j_t = consumption of ***nondurable*** goods
  - D^j_t = consumption of ***durable*** goods [***housing***]
  - L^j_t = total hours worked by household
  - ξ^D_t = ***housing preference shock***

- Model further assumes that there is ***imperfect substitutability*** of labour supply ***across sectors***:

$$L_t^j = \left[\alpha^{-\iota_L}\left(L_t^{C,j}\right)^{1+\iota_L} + (1-\alpha)^{-\iota_L}\left(L_t^{D,j}\right)^{1+\iota_L}\right]^{\frac{1}{1+\iota_L}}$$

- where
  - $\iota_L > 0$
  - α = economic size of nondurable sector
  - $L^{x,j}_t$ = total hours worked by household j in sector x [C or D]
- As noted earlier, this imperfect substitutability ➔ ***reallocating*** labour ***across sectors*** following a shock is ***costly***

- ***Budget constraint*** of ***savers***, in nominal terms:

$$P_t^C C_t^j + P_t^D I_t^j + B_t^j \leq R_{t-1} B_{t-1}^j + W_t^C L_t^{C,j} + W_t^D L_t^{D,j} + \Pi_t^j$$

- where
  - W^C_t = wage in ***nondurable*** sector
  - W^D_t = wage in ***durable*** sector [***housing***]
  - **B^j_t** = ***debt instruments*** or deposits that borrowers place in financial intermediaries
  - at gross ***interest rate*** of R_t
  - Π^j_t = ***nominal profits*** from intermediate goods producing firms and financial intermediaries which are ultimately ***owned by savers***

- Given ***investment adjustment costs*** (as in SW), law of motion of capital stock (here just ***housing***) is

$$D_t^j = (1-\delta)D_{t-1}^j + \left[1 - S\left(\frac{I_t^j}{I_{t-1}^j}\right)\right] I_t^j$$

- where S is ***usual convex function*** as in ***SW2007***
- which generates hump-shaped responses of ***residential investment*** to shocks

- Each ***borrower*** j ∈ (λ;1] maximises his ***utility function***:

$$E_0 \left\{ \sum_{t=0}^{\infty} \beta^{B,t} \left[\gamma \log \left(C_t^{B,j} - \varepsilon C_{t-1}^{B} \right) + (1-\gamma) \xi_t^D \log \left(D_t^{B,j} \right) - \frac{\left(L_t^{B,j} \right)^{1+\varphi}}{1+\varphi} \right] \right\}$$

- where for each ***borrowing*** household j:
  - $C^{B,j}_t$ = consumption of ***nondurable*** goods
  - $D^{B,j}_t$ = consumption of ***durable*** goods [***housing***]
  - $L^{B,j}_t$ = total hours worked by household
  - ξ^{D}_t = ***housing preference shock***
  - $\beta^{B,t} < \beta$ = discount factor of borrowers

- ***Budget constraint*** of ***borrowers***, in nominal terms:

$$P_t^C C_t^{B,j} + P_t^D I_t^{B,j} + R_{t-1}^L B_{t-1}^{B,j} \leq B_t^{B,j} + W_t^C L_t^{C,B,j} + W_t^D L_t^{D,B,j}$$

- where borrowers may obtain ***loans*** B^B_t from banks at a ***lending rate*** of $\mathbf{R^L_t}$
- **Spread** between lending and borrowing rate:

leverage ≡ ratio of debt B^B_t to value of housing stock

$$\frac{R_t^L}{R_t} = \upsilon_t F\left(\boxed{\frac{B_t^B}{P_t^D D_t^B}}\right)\tau_t$$

- where
  - $\mathbf{v_t}$ = AR(1) ***financial shock*** [= reduction in margin banks charge over funding costs, caused by (i) increase in competition and quest for market share or (ii) reduction in perceived lending risk]
  - F = ***increasing*** function of borrowers' ***leverage***

- ***F increasing*** means that ***greater leverage*** of borrower ➔ ***higher interest rate*** charged on loan
- Final term τ_t represents a ***macroprudential instrument*** that allows ***central bank*** to affect market rates by imposing ***additional capital requirements or loan provisions*** whenever credit growth is above its steady-state value
- ***Spread equation*** ➔ when ***house*** prices ***increase***, ***borrowers*** can
  - take on ***more debt***
  - **refinance** at a ***lower rate***
  - or a ***combination*** of both

$$\frac{R_t^L}{R_t} = \upsilon_t F\left(\frac{B_t^B}{P_t^D D_t^B}\right)\tau_t$$

- ***Producers***:
- *As usual* ***final goods*** producers operate under ***perfect competition***
- purchasing intermediate goods from their producers and ***aggregating*** them into a final good according to ***usual Dixit-Stiglitz function***
- which for ***durable goods sector*** is

$$Y_t^D \equiv \left[\int_0^1 Y_t^D(i)^{\frac{\sigma_D - 1}{\sigma_D}} di\right]^{\frac{\sigma_D}{\sigma_D - 1}}$$

- and ***similarly*** for non-durable goods sector (change D above into C)

- Again *as usual*, ***intermediate goods*** producers operate under ***monopolistic competition*** and face ***Calvo-type rigidities***
- ***Calvo fairy*** allows a faction $(1 - \theta_k)$ in each sector k to reset optimally their prices ("***reset price***")
- Remainder ("***legacy price***") are subject to a ***Calvo Rule***, with φ_k defining degree to which they index their price to last period's ***sectorial inflation*** rate
- Since only labour is used, production functions are:

TFP shock

$$\begin{aligned} Y_t^C(i) &= A_t^C L_t^C(i), \text{ for all } i \in [0,1], \\ Y_t^D(i) &= L_t^D(i), \text{ for all } i \in [0,1]. \end{aligned}$$

- ***Cost minimisation*** → sectoral real marginal cost of production is (***as usual***)

$$MC_t^C = \frac{W_t^C / P_t^C}{A_t^C}, \text{ and } MC_t^D = W_t^D / P_t^D$$

- Labour costs may ***differ across sectors*** because of ***imperfect labour substitutability***
- which can lead to ***different*** real (product) ***wages***
- Also, real ***unit labour costs*** can differ across sectors because of ***sector-specific technology shocks*** in ***nondurable*** sector [A^C_t]

- Given Calvo pricing, evolution of price level in ***durables*** sector [***housing***] is (***as usual***)

$$P_t^D = \left\{\theta_D \left[P_{t-1}^D \left(\Pi_{t-1}^D\right)^{\varphi_D}\right]^{1-\sigma_D} + (1-\theta_D)\left(\hat{P}_t^D\right)^{1-\sigma_D}\right\}^{\frac{1}{1-\sigma_D}}$$

Calvo Rule: Indexation

Optimal "Reset" price

- Firms in ***nondurables*** sector face a similar maximisation problem
- ➔ optimal price and evolution of price level have similar expressions, *mutatis mutandis*

- ***Market clearing***:
- Total production in ***nondurable sector*** is equal to total consumption ➔

$$Y_t^C = \lambda C_t + (1-\lambda)\, C_t^B$$

- Total ***durable*** production equals aggregate ***residential investment***

$$Y_t^D = \lambda I_t + (1-\lambda)\, I_t^B$$

- ***Aggregate real GDP*** is then given by

$$Y_t = \alpha Y_t^C + (1-\alpha) Y_t^D$$

- And market clearing in ***deposit/lending market*** ➔

$$\lambda B_t + (1-\lambda) B_t^B = 0$$

- Next slide shows Calibrated Parameters for this model

Table 1: Calibrated Parameters

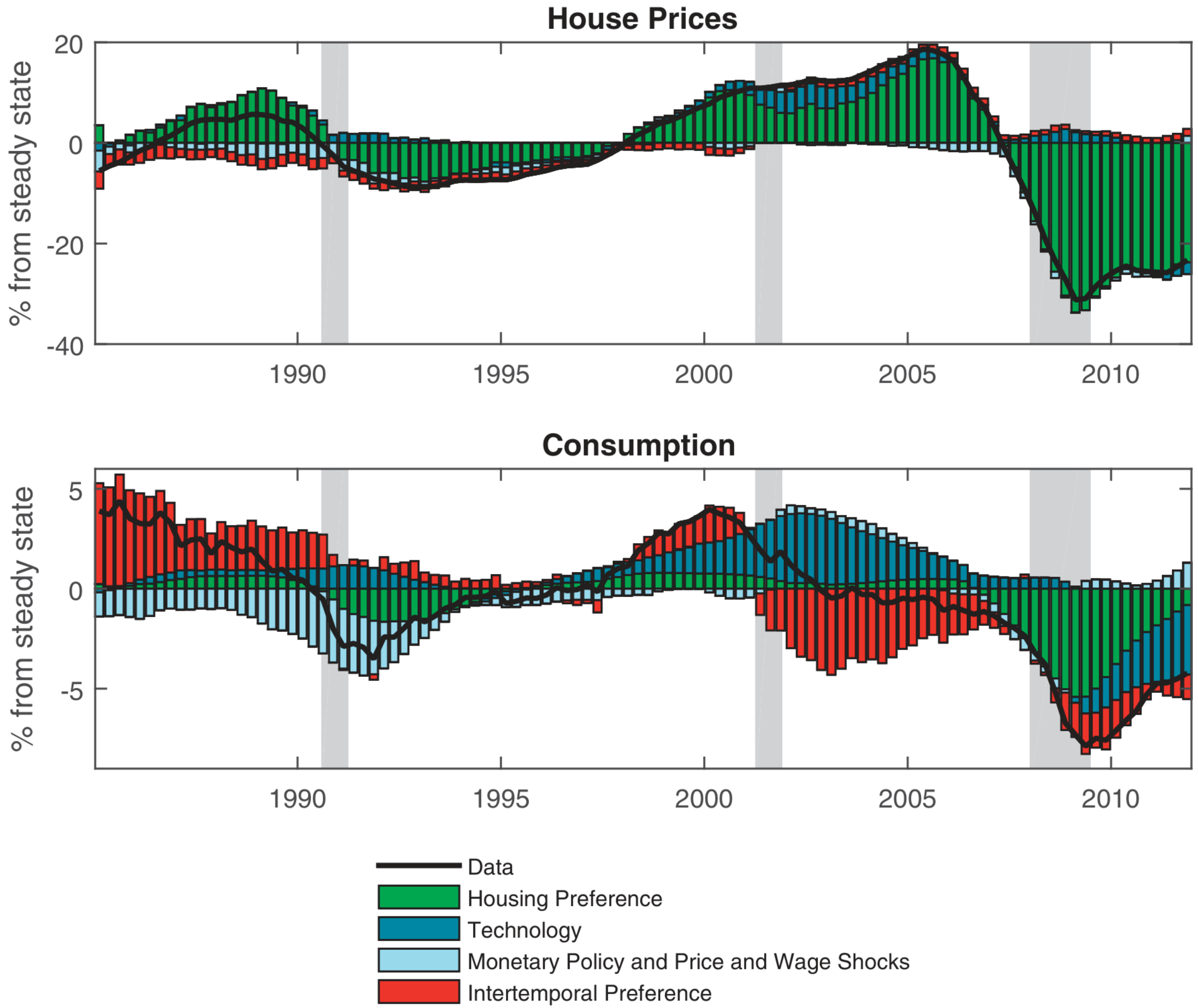
Parameter	Description	Value
β	Discount factor savers	0.99
β^B	Discount factor borrowers	0.98
δ	Depreciation rate	0.025
λ	Share of savers	0.5
χ	Down payment rate (1 minus LTV)	0.2
$\sigma/(\sigma-1)$	Average markup	1.1
ι_L	Labor disutility of switching sectors	1
φ	Inverse Frisch elasticity of labor supply	1
ε	Habit formation	0.8
η	Adjustment cost residential investment	0.5
κ	Elasticity of spread with respect to net worth	0.05
α	Share of nondurables in GDP	0.9
θ_c	Calvo lottery nondurable	0.75
θ_d	Calvo lottery durable	0.75
ϕ_c	Backward looking behavior nondurable	1
ϕ_d	Backward looking behavior durable	1
γ_π	Taylor rule coefficient on inflation	1.3
γ_y	Taylor rule coefficient on output gap	0.125
γ_r	Taylor rule coefficient on lagged interest rates	0.7
γ_b	Augmented Taylor rule coefficient on credit growth	0.3
τ	Augmented Taylor rule plus macroprudential coefficient on credit growth	0.3
ρ_a	AR(1) coefficient on TFP shocks	0.98
ρ_v	AR(1) coefficient on financial shock	0.95
ρ_d	AR(1) coefficient on housing demand shock	0.95
σ_a	Standard deviation TFP shock (in %)	1.5
σ_v	Standard deviation financial shock (in %)	0.125
σ_d	Standard deviation housing demand shock (in %)	2.5

Table 2: Second Moments in the Data and in the Model

	Std. Dev.		Variance Decomposition		
	Data	Model	TFP	HD	Financial
Consumption Growth	0.57	0.56	98.0	0.1	1.9
Residential Investment Growth	3.40	3.27	58.4	39.5	2.0
CPI Inflation	0.50	0.50	83.0	0.5	16.5
Nominal House Price Inflation	1.05	1.06	73.8	23.1	3.1
Deposit Rate	0.63	0.59	84.5	0.7	14.8
Spread	0.29	0.32	9.4	9.3	81.3
Credit Growth	1.05	1.07	30.3	12.0	57.7
Output Gap	-	0.38	52.2	30.1	17.7

- As is usual in RBC-based literature, ***TFP*** shock dominates in response of (non-durable) consumption, inflation and interest rates
- But ***Housing (HD)*** shocks are very important for residential investment and house price inflation
- And ***Financial*** shocks for rate spread and credit growth

- IRFs for Housing Demand shock (detail later)


House Prices
% from steady state
20
0
-20
-40
1990
1995
2000
2005
2010
Consumption
% from steady state
5
0
-5
1990
1995
2000
2005
2010
Data
Housing Preference
Technology
Monetary Policy and Price and Wage Shocks
Intertemporal Preference

Demystifying DSGE Models

More on DelNGS (2015)

- Additional equations of ***DelNegro et al*** model are:

```
% Additions to SW ===> SWBGG
% real value of existing capital stock [modified from SW2007]
        pk = (1/((1-ctou)/ceffe))*((f(-1) + b2(-1))- (crk/ceffe)*rk(-1) + pk(-1)) ;
% real net worth of entrepreneurs
        (1/(cv*ceffe))*nw =clev*f-elast*(clev-1)*(pk(-1)+k(-1))-(clev-1)*(r(-1)-pinf)+(elast*(clev-1)+1)*nw(-1);
 % expected next-period external finance cost
        ef=(r-pinf(+1)) + elast*(pk+k(+1)-nw(+1));
% definition
        ef=f(+1);
% risk premium
        prem =ef-(r-pinf(+1)) ;
% leverage ratio
        lev=pk+k(+1)-nw(+1);
```

```
% variables
 f      ${f}$      (long_name='External financing cost')
 nw     ${nw}$     (long_name='Net worth of entrepreneurs')
 prem   ${prem}$   (long_name='External finance premium')
 lev    ${lev}$    (long_name='Leverage ratio')
```

```
% DelNGD2015 use a Taylor Rule with a time-varying inflation target pistar
        r =  crpi*(1-crr)*(pinf-pist)+cry*(1-crr)*(y-yf)+crdy*(y-yf-y(-1)+yf(-1))+crr*r(-1)+ms  ;
        pist = rho_pist*pist(-1)+psi_pist; %   time-varying inflation target
```

```
% parameters
  elast    ${\omega}$     (long_name='Elasticity ext fin wrt leverage')
  cv       ${\nu}$        (long_name='Entrepreneurial survival probabilty')
  clev     ${\beta_{lev}}$   (long_name='Steady-state leverage ratio')
  ceffe    ${\beta_{rk}}$    (long_name='Steady-state return to capital')
```

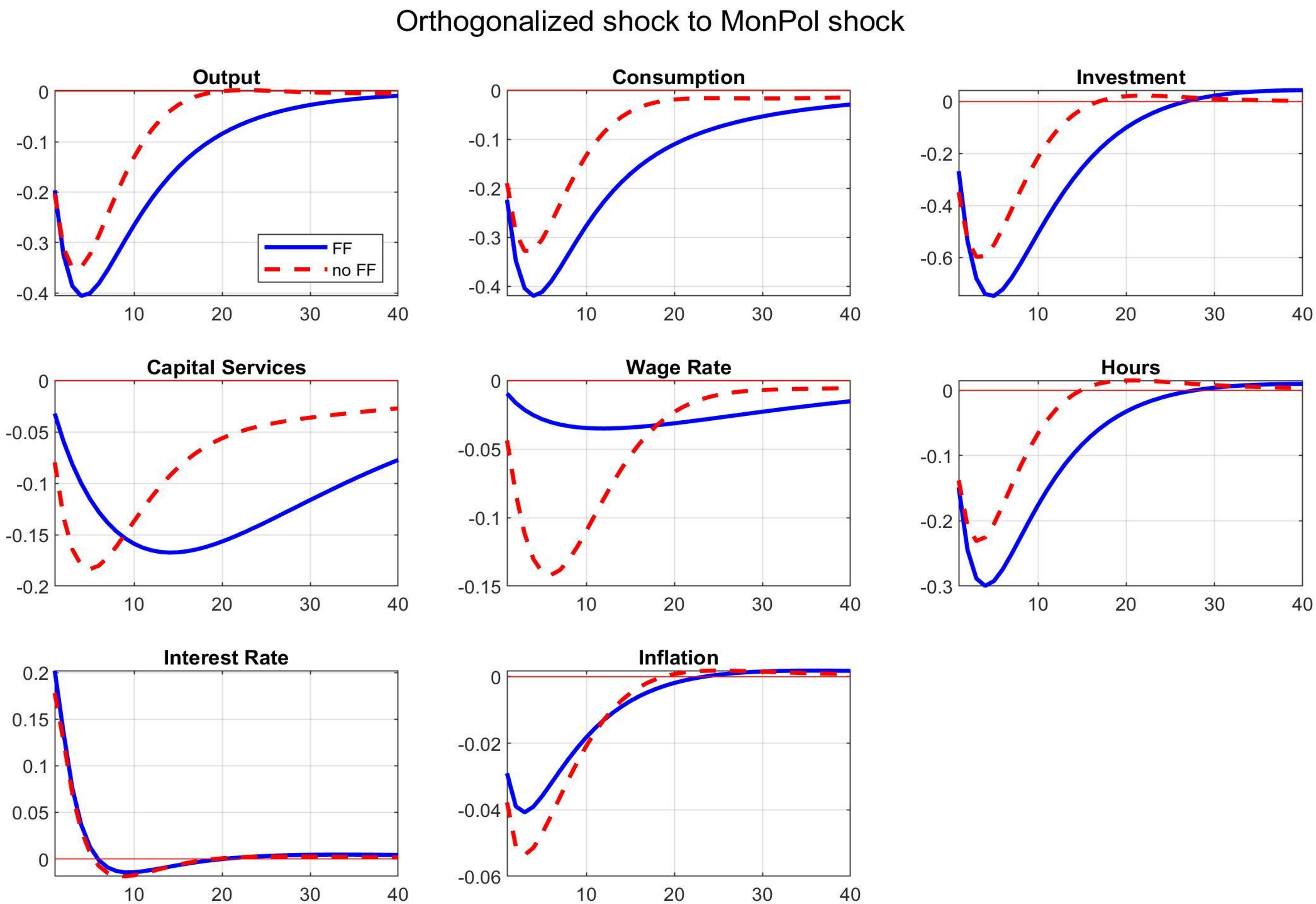
- DelNGS (2015) ***calibrate*** these new financial parameters
- Merola (2015) – who uses essentially same SW2007+ model – ***estimates*** them using SW data augmented by ***two financial variables***:
  - interest rate ***spread*** between corporate BAA yield and corporate AAA yield [for risk premium]
  - growth rate of ***S&P-500*** stock index [for Δ net worth]
- ➔ two ***new*** measurement equations: measurement error
  - sobs = prem + me_Prem + constePrem;
  - dlSP500 = nw - nw(-1) + me_N + consteN;

- When these equations are added, model ***IRF responses vary*** considerably
- Below are some ***examples***, based on parameters estimated over the original SW data period (1965Q1 – 2004Q4)
- Note that models are ***otherwise identical***; ***only*** addition of financial frictions distinguishes them
- Look at
  - MonPol shock (as always ...)
  - Risk premium shock (which should be highly impacted by new financial frictions)
  - Idiosyncratic investment shock (ditto)

- Below are slides comparing the Cuddy notation version of SWFF (Merola) vs SW including CI, using Cuddy data
  J:\MyCourseDSGEs2024\Tests\SW2007_CIwFF_jc2.mod
  J:\MyCourseDSGEs2024\Tests\SW2007_CInoFF_jc2.mod
- J:\MyCourseDSGEs2024\Tests\SWvsMerolaNewNotation_Walsh2a.m
- Note that above version of SWFF uses the original SW data period (1965Q1 – 2004Q4)
- Merola uses the period 1967Q1 - 2012Q4 and results for this period (without CI) are in
- J:\MyCourseDSGEs2024\Tests\SW2007_CFF_jc3.mod
  J:\MyCourseDSGEs2024\Tests\SW2007_noFF_jc3.mod
- J:\MyCourseDSGEs2024\Tests\SWvsMerolaNewNotation_Walsh2b.m

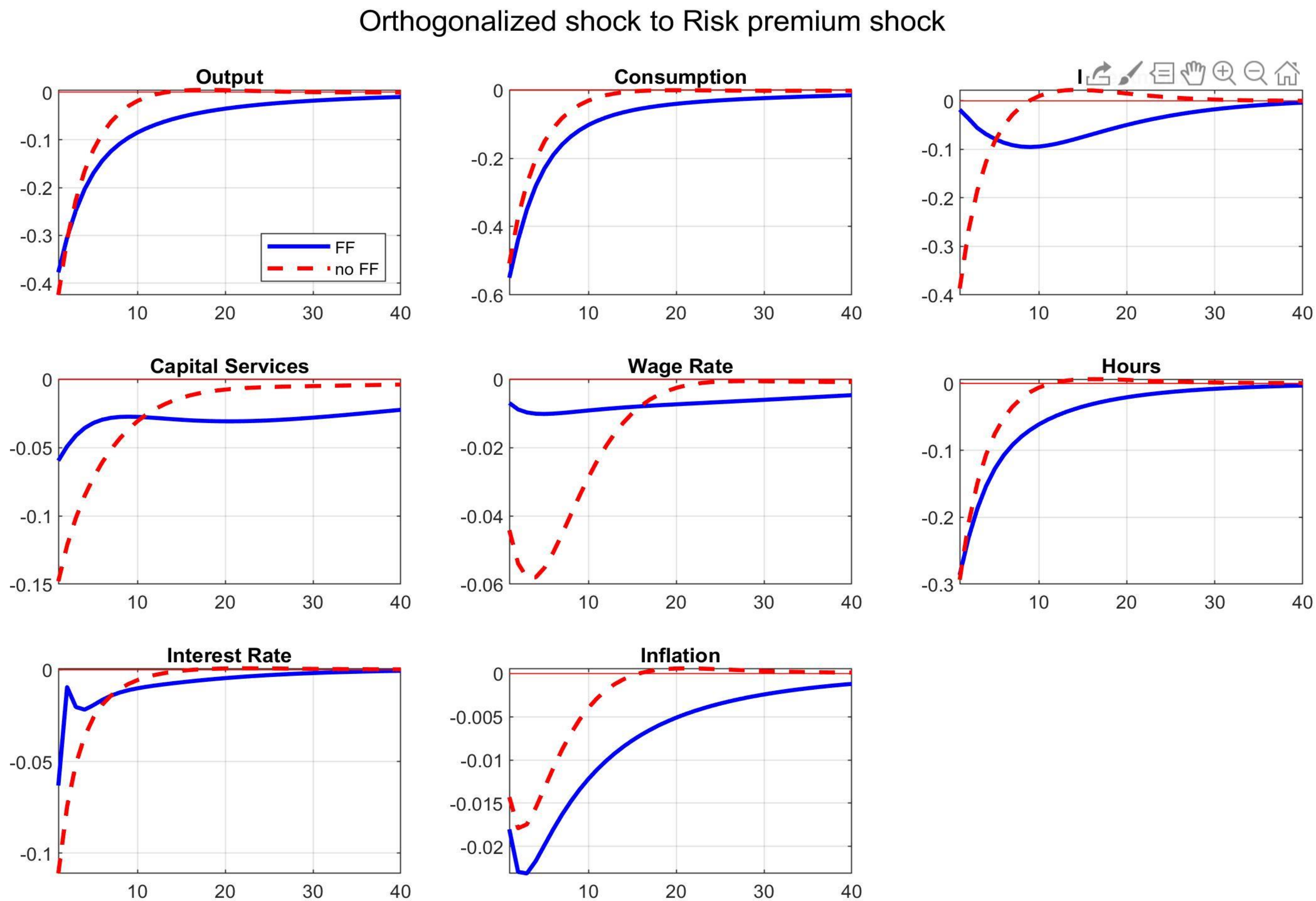
- MonPol shock

J:\MyCourseDSGEs2024\Tests\SWvsSWFFvM2_MonPol.jpg



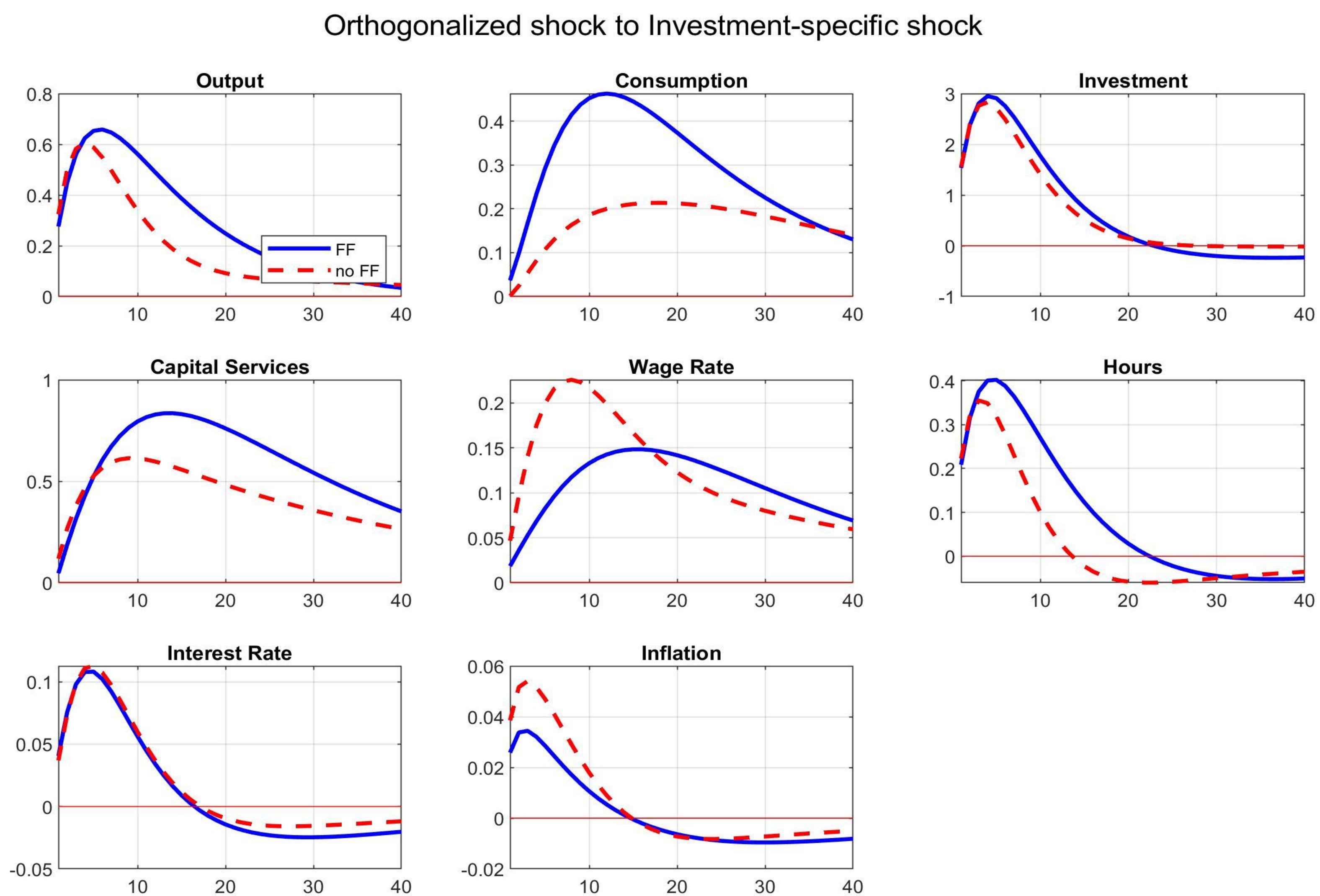
- Risk Premium Shock

J:\MyCourseDSGEs2024\Tests\ SWvsSWFFvM2_RiskPrem.jpg
J:\MyCourseDSGEs2024\Tests\SWvsMerolaNewNotation_Walsh2a.m



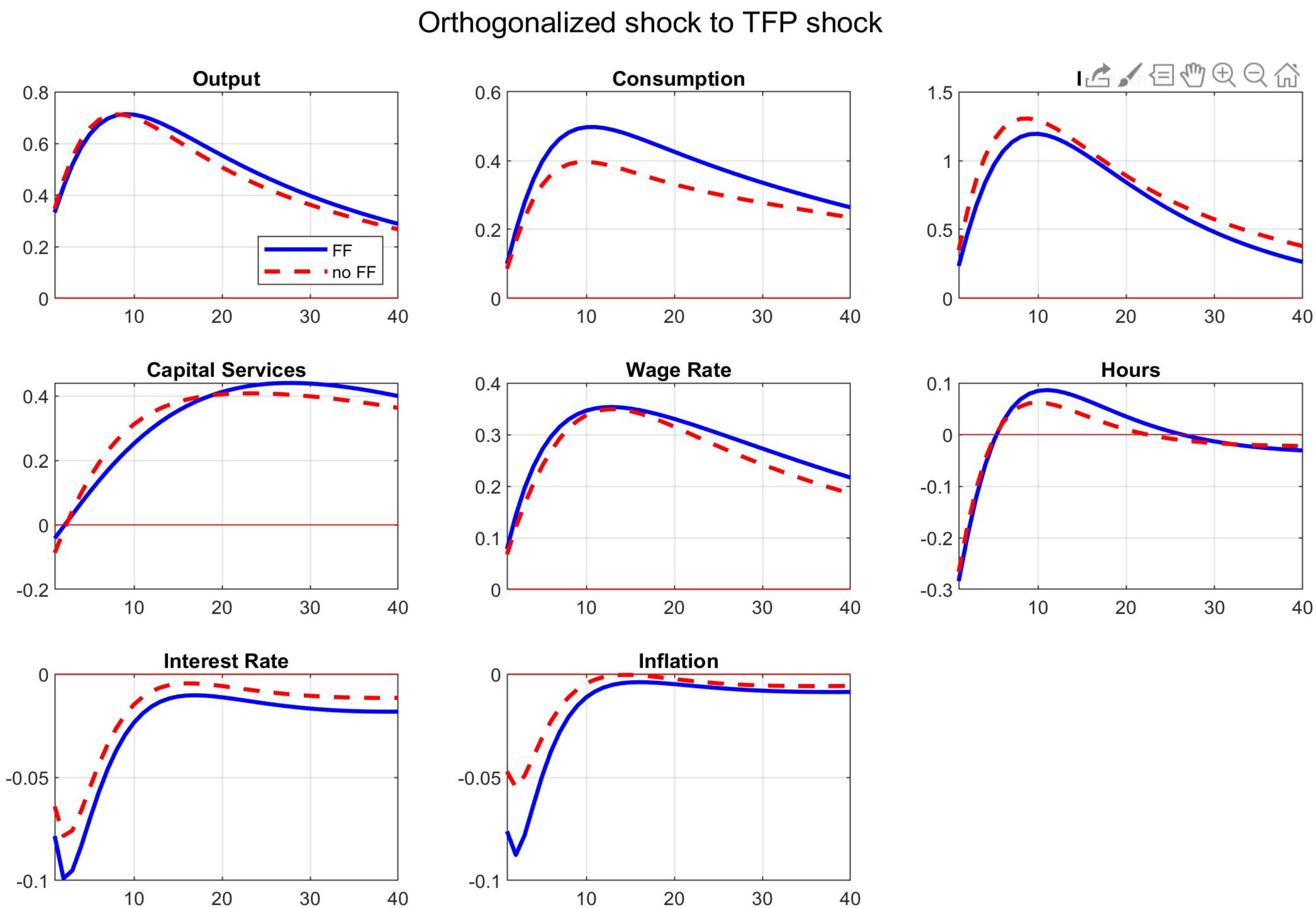
• Idiosyncratic Investment Shock

J:\MyCourseDSGEs2024\Tests\ SWvsSWFFvM2_Inv.jpg



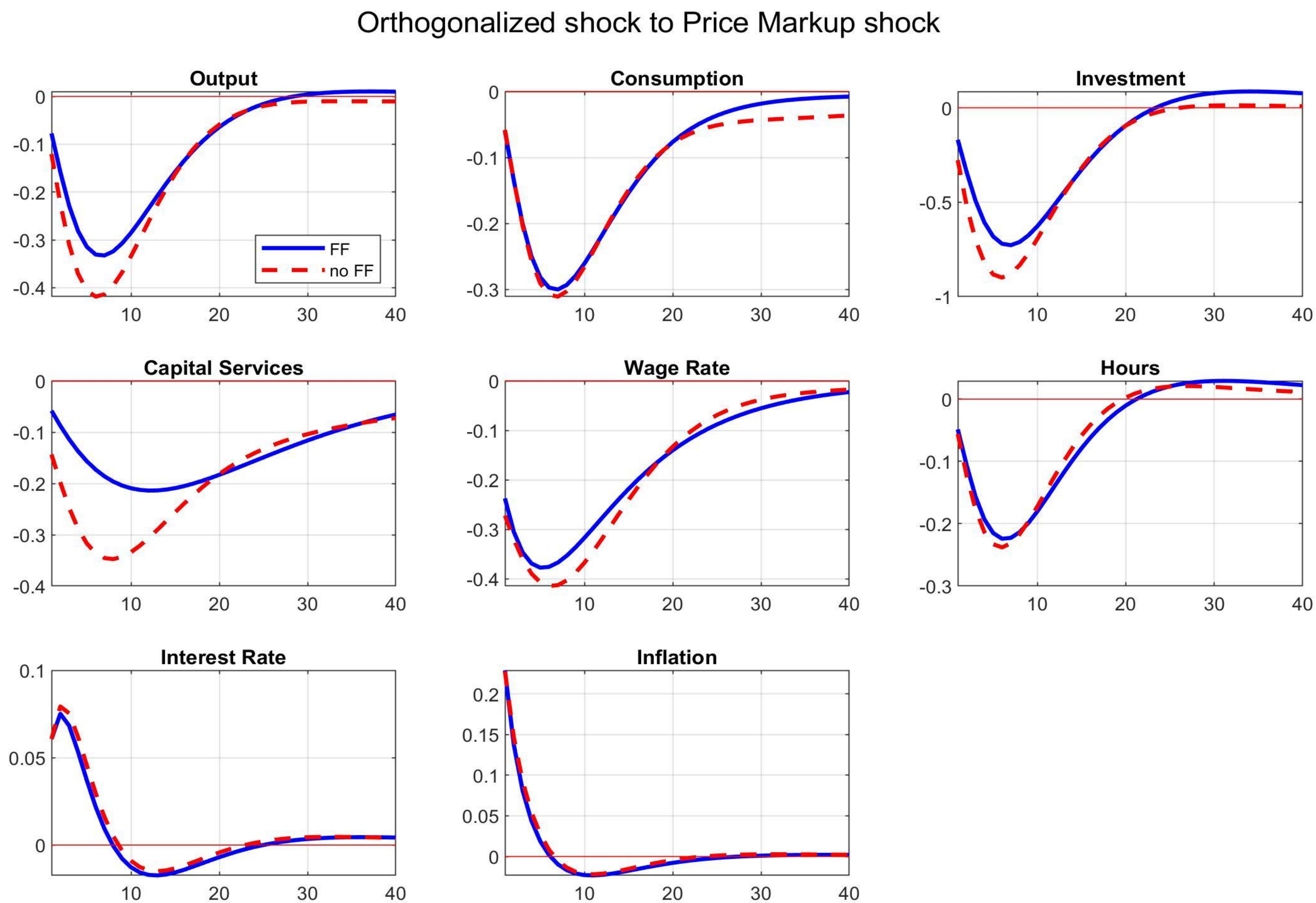
- TFP Shock

J:\MyCourseDSGEs2024\Tests\ SWvsSWFFvM2_TFP.jpg



• Price Markup Shock

J:\MyCourseDSGEs2024\Tests\ SWvsSWFFvM2_PriceMarkup.jpg



• Wage Markup Shock

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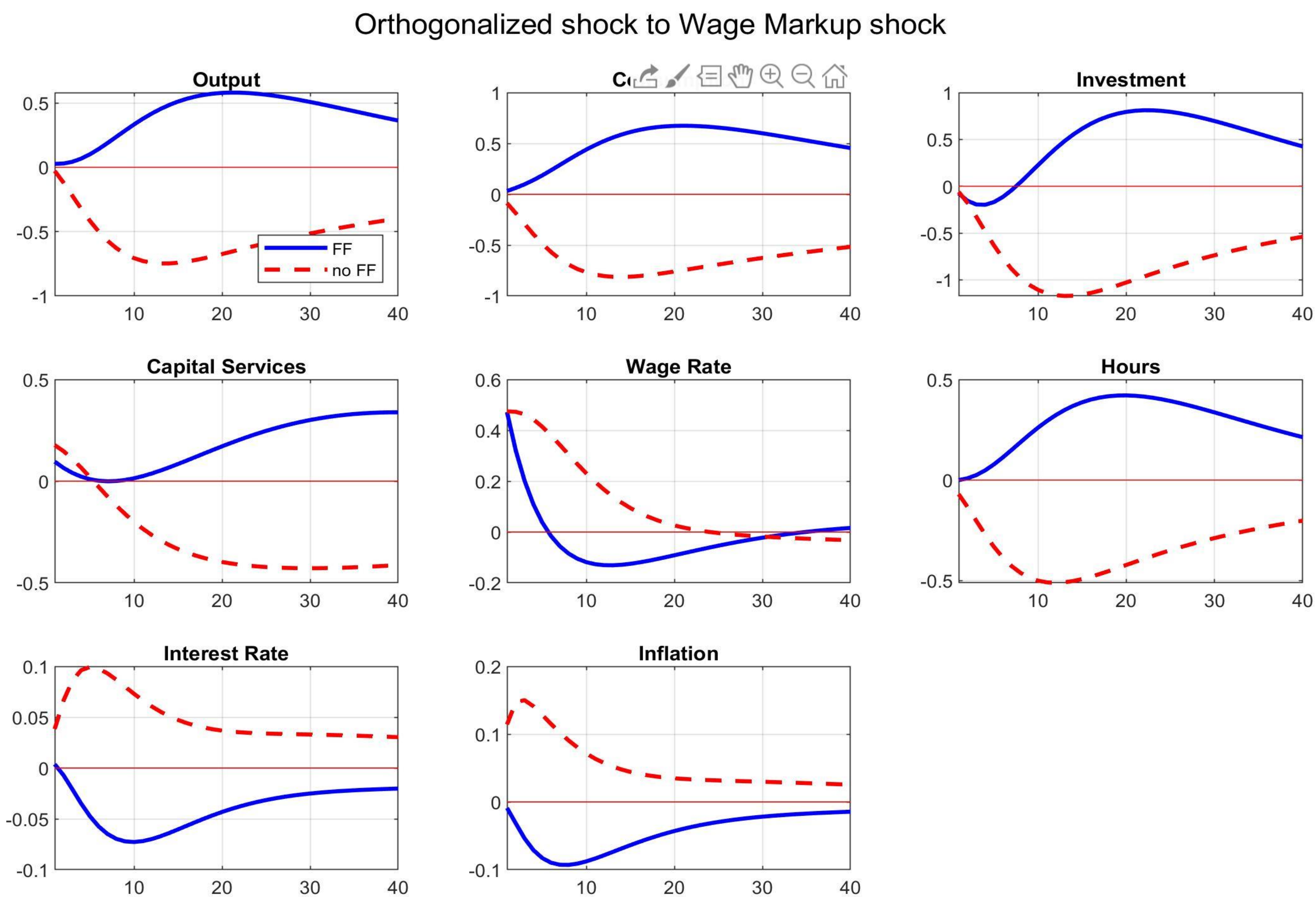

• Government Spending shock

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