Cyclical Skill-Biased Technological Change

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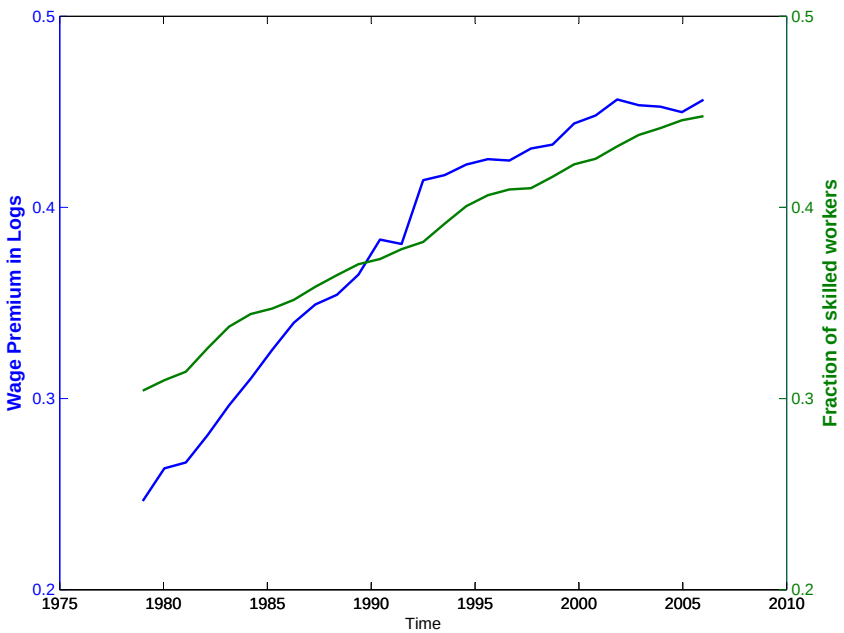
Skill-Biased Technological Change

Skill bias is an important feature of technological change
(Katz and Murphy '92; Acemoglu '02; Autor et al. '98, '05, '08)



- Substantial increase in relative price of skill
- Substantial increase in relative quantity of skill
- Evidence for increased demand for skill

Contribution

What are the implications of skill-biased technological change for the business cycle?

- Construction of a quarterly series of the skill premium (and skill supply)
- Explore the cyclical properties of skill-biased technology shocks
  - A general model with skill-biased technological change
  - Estimation of skill-biased technology shocks
    - What is the nature of skill-biased technology shocks?
    - What are the dynamic responses to skill-biased technology shocks over the business cycle?
    - How important are SBT shocks for the business cycle?

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What are the implications of skill-biased technological change for the business cycle?

- Construction of a quarterly series of the skill premium (and skill supply)
- Explore the cyclical properties of skill-biased technology shocks
  - Permanent technology shocks are skill-biased
  - The fall in hours largely due to skill-biased technology shocks
  - Capital and skilled labor are not complementary over the business cycle
  - SBT shocks contribute little to output volatility, but are important for hours worked

Benchmark Model

- RBC model with skilled and unskilled labor
- Production function

$$Y_t = A_t K_t^{\alpha} L_t^{1-\alpha}$$

with

$$L_t = \left[\beta \left(B_t H_{s,t} \right)^{\frac{\sigma-1}{\sigma}} + (1-\beta) H_{u,t}^{\frac{\sigma-1}{\sigma}} \right]^{\frac{\sigma}{\sigma-1}}$$

- Preferences

$$\max_{\{C_t, \widehat{H}_{s,t}, \widehat{H}_{u,t}\}} E_0 \sum_{t=0}^{\infty} \left(\frac{1}{1+\rho} \right)^t \left(Z_t u(C_t) - S_t \frac{\eta}{\eta+1} \widehat{H}_{s,t}^{\frac{\eta+1}{\eta}} - (1-S_t) \frac{\eta}{\eta+1} \widehat{H}_{u,t}^{\frac{\eta+1}{\eta}} \right)$$

s.t.

$$K_{t+1} = (1-\delta) K_t + D_t \left[R_t K_t + S_t W_{s,t} \widehat{H}_{s,t} + (1-S_t) W_{u,t} \widehat{H}_{u,t} - C_t \right]$$

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Benchmark Model

- Skill demand

$$w_{s,t} - w_{u,t} = \ln\left(\frac{\beta}{1-\beta}\right) - \frac{1}{\sigma}(h_{s,t} - h_{u,t}) + (\frac{\sigma-1}{\sigma})b_t,$$

where σ is EOS high and low skill in production

- Skill supply

$$h_{s,t} - h_{u,t} = \eta(w_{s,t} - w_{u,t}) + s_t,$$

where η is Frisch elasticity of labor supply

- Equilibrium skill premium

$$w_{s,t} - w_{u,t} = \frac{\sigma}{\sigma+\eta}\ln\left(\frac{\beta}{1-\beta}\right) - \frac{1}{\sigma+\eta}s_t + (\frac{\sigma-1}{\sigma+\eta})b_t$$

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Benchmark Model: Long-run effects

	Skill supply	I-Techn.	SBTechnology	N-Techn.	Labor supply
Investment price	0	1	0	0	0
Skill premium	$-\frac{1}{\sigma+\eta} < 0$	0	$\frac{\sigma-1}{\sigma+\eta} > 0$	0	0
Wage low skilled	$\frac{\omega_2}{(\sigma+\eta)} > 0$	$\frac{\alpha}{1-\alpha} > 0$	$\frac{1+\eta}{\sigma+\eta}\omega_2 > 0$	0	
Wage high skilled	$-\frac{(1-\omega_2)}{(\sigma+\eta)} < 0$	$\frac{\alpha}{1-\alpha} > 0$	$\frac{\sigma-1+(1+\eta)\omega_2}{\sigma+\eta} > 0$	$\frac{1}{1-\alpha} > 0$	0
Productivity	$\frac{\sigma(1+\eta)(\omega_2-\omega_1)}{(1+\eta)(\sigma+\eta)}$		$\frac{\sigma(1+\eta)\omega_2-(\sigma-1)\eta\omega_1}{\sigma+\eta}$		
	> 0	$\frac{\alpha}{1-\alpha} > 0$	> 0	$\frac{1}{1-\alpha} > 0$	0
Output	$\frac{\xi_t-1+\omega_2}{1+\eta} > 0$	$\frac{\alpha}{1-\alpha} > 0$	$\omega_2 > 0$	$\frac{1}{1-\alpha} > 0$	$\frac{\eta}{1+\eta} > 0$
Total hours			$-\frac{(\sigma-1)\eta(\omega_2-\omega_1)}{\sigma+\eta}$		
	ambiguous	0	< 0	0	$\frac{\eta}{1+\eta} > 0$
Hours high skilled	ambiguous	0	$\frac{(\sigma-1)\eta}{\sigma+\eta}(1-\omega_2) > 0$	0	$\frac{\eta}{1+\eta} > 0$
Hours low skilled	ambiguous	0	$-\frac{(\sigma-1)\eta}{\sigma+\eta}\omega_2 < 0$	0	$\frac{\eta}{1+\eta} > 0$
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Benchmark Model: Long-run effects

- Use the model to motivate identifying assumptions of the various shocks
- How robust are the long-run effects to generalizations of the benchmark model?

	Skill supply	I-Techn.	SBTechnology	N-Techn.	Labor supply
Investment price	0	> 0	0	0	0
Skill premium	< 0	0	> 0	0	0
Productivity	> 0	> 0	> 0	> 0	0
Output	> 0	> 0	> 0	> 0	> 0
Total hours		0	< 0	0	> 0
Rel. empl. skill	> 0	0	> 0	0	0

Generalizations: Endogenous skill supply

- Law of motion: $S_{t+1} = X_{t+1}\left[(1-\lambda)\, S_t + T_t\right]$
- Cost of training: $g(T_t)$

	Skill supply	I-Techn.	SBTechnology	N-Techn.	Labor supply
Investment price	0	> 0	0	0	0
Skill premium	< 0	0	> 0	0	0
Productivity	> 0	> 0	> 0	> 0	0
Output	> 0	> 0	> 0	> 0	> 0
Total hours		0	< 0	0	> 0
Rel. empl. skill	> 0	0	> 0	0	0

Generalizations: Capital-skill complementarity

- KORV '00 production function

$$Y_t = \left[\beta\left(\gamma K_t^{\frac{\theta-1}{\theta}} + (1-\gamma)\left(B_t A_t H_{s,t}\right)^{\frac{\theta-1}{\theta}}\right)^{\frac{\theta}{\theta-1}\frac{\sigma-1}{\sigma}} + (1-\beta)\left(A_t H_{u,t}\right)^{\frac{\sigma-1}{\sigma}}\right]^{\frac{\sigma}{\sigma-1}}$$

	Skill supply	D-Shock	B-Shock	A-Shock.	Labor supply
Investment price	0	> 0	0	0	0
Skill premium	< 0	$\neq 0$	> 0	0	0
Productivity	> 0	> 0	> 0	> 0	0
Output	> 0	> 0	> 0	> 0	> 0
Total hours			< 0	0	> 0
Rel. empl. skill	> 0	$\neq 0$	> 0	0	0

Generalizations: Capital-skill complementarity

- Capital-skill complementarity $\theta < \sigma$

	Skill supply	D-Shock	B-Shock	A-Shock	Labor supply
Investment price	0	> 0	0	0	0
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Output	> 0	> 0	> 0	> 0	> 0
Total hours			< 0	0	> 0
Rel. empl. skill	> 0	> 0	> 0	0	0

Generalizations: Capital-skill substitutability

- Capital-skill substitutability $\theta > \sigma$

	Skill supply	D-Shock	B-Shock	A-Shock	Labor supply
Investment price	0	> 0	0	0	0
Skill premium	< 0	< 0	> 0	0	0
Productivity	> 0	> 0	> 0	> 0	0
Output	> 0	> 0	> 0	> 0	> 0
Total hours			< 0	0	> 0
Rel. empl. skill	> 0	< 0	> 0	0	0

Generalizations: KORV production function

- $\alpha = \frac{1}{3}$, $\rho = 0.01$, $\eta = 2$, $\delta = 0.025$, $\sigma = 1.67$,
  mean skill supply in population: 47%
- Labor supply shock calibrated to match 20% of time spent working
- Share parameters γ and β to match 30% income share of capital and skilled wages 50% higher than unskilled wages
- Capital-skill complementarity $\theta = 0.67$, substitutability $\theta = 2.67$

	Skill supply	D-Shock	B-Shock	A-Shock	Labor supply
Investment price	0	> 0	0	0	0
Skill premium	< 0	$\neq 0$	> 0	0	0
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Output	> 0	> 0	> 0	> 0	> 0
Total hours			< 0	0	> 0
Rel. empl. skill	> 0	$\neq 0$	> 0	0	0

Generalizations: Two sector model

- Investment-goods sector
- Consumption goods sector

	Skill supply	D-Shock	B-Shock	A-Shock	Labor supply
Investment price	$\neq 0$	> 0	$\neq 0$	0	0
Skill premium	< 0	$\neq 0$	> 0	0	0
Productivity	> 0	> 0	> 0	> 0	0
Output	> 0	> 0	> 0	> 0	> 0
Total hours			< 0	0	> 0
Rel. empl. skill	> 0	$\neq 0$	> 0	0	0

Identification of Shocks

- Structural VAR methodology
  - Long-run restrictions (Blanchard and Quah '89)
  - *Only* technology shocks affect labor productivity in the long run (Galí '99)

	Skill supply	D-Shock	B-Shock	A-Shock	Labor supply
Investment price	$\neq 0$	> 0	$\neq 0$	0	0
Skill premium	< 0	$\neq 0$	> 0	0	0
Productivity	> 0	> 0	> 0	> 0	0
Output	> 0	> 0	> 0	> 0	> 0
Total hours			< 0	0	> 0
Rel. empl. skill	> 0	$\neq 0$	> 0	0	0

Identification of Shocks

- Shocks to the supply of skill invalidate the identifying restrictions
  - Exogenous increase in supply increases the employment of skill
  - Labor productivity increases if high skilled are more productive

	Skill supply	D-Shock	B-Shock	A-Shock	Labor supply
Investment price	$\neq 0$	> 0	$\neq 0$	0	0
Skill premium	< 0	$\neq 0$	> 0	0	0
Productivity	> 0	> 0	> 0	> 0	0
Output	> 0	> 0	> 0	> 0	> 0
Total hours			< 0	0	> 0
Rel. empl. skill	> 0	$\neq 0$	> 0	0	0

Identification of Shocks I

- Skill supply shocks

  ... are the *only* shocks that affect skill supply within the quarter

  ... may affect labor productivity in the long run

- Technology shocks are the *only remaining* shocks that affect labor productivity in the long run

	Skill supply	D-Shock	B-Shock	A-Shock	Labor supply
Investment price	$\neq 0$	> 0	$\neq 0$	0	0
Skill premium	< 0	$\neq 0$	> 0	0	0
Productivity	> 0	> 0	> 0	> 0	0
Output	> 0	> 0	> 0	> 0	> 0
Total hours			< 0	0	> 0
Rel. empl. skill	> 0	$\neq 0$	> 0	0	0

Identification of Shocks I

- Do technology shocks have an effect on the skill premium?

	Skill supply	D-Shock	B-Shock	A-Shock	Labor supply
Investment price	$\neq 0$	> 0	$\neq 0$	0	0
Skill premium	< 0	$\neq 0$	> 0	0	0
Productivity	> 0	> 0	> 0	> 0	0
Output	> 0	> 0	> 0	> 0	> 0
Total hours			< 0	0	> 0
Rel. empl. skill	> 0	$\neq 0$	> 0	0	0

Identification of Shocks II

- Control for skill supply shocks
- Skill-biased technology shocks
  ... are the *only* shocks that affect the relative price of skill in the long run
  ... may affect labor productivity in the long run
- Neutral technology shocks are the *only remaining* shocks that affect labor productivity in the long run

	Skill supply	D-Shock	B-Shock	A-Shock	Labor supply
Investment price	$\neq 0$	> 0	$\neq 0$	0	0
Skill premium	< 0	$\neq 0$	> 0	0	0
Productivity	> 0	> 0	> 0	> 0	0
Output	> 0	> 0	> 0	> 0	> 0
Total hours			< 0	0	> 0
Rel. empl. skill	> 0	$\neq 0$	> 0	0	0

Identification of Shocks III

- Control for skill supply shocks
- Investment-specific technology shocks
  ... are the *only* shocks that affect the relative price of investment in the long run
  ... may affect labor productivity in the long run
- Skill-biased technology shocks are the *only remaining* shocks that affect the skill premium in the long run
- Neutral technology shocks are the *only remaining* shocks that affect labor productivity in the long run

	Skill supply	D-Shock	B-Shock	A-Shock	Labor supply
Investment price	0	> 0	0	0	0
Skill premium	< 0	$\neq 0$	> 0	0	0
Productivity	> 0	> 0	> 0	> 0	0
Output	> 0	> 0	> 0	> 0	> 0
Total hours			< 0	0	> 0
Rel. empl. skill	> 0	$\neq 0$	> 0	0	0

Data

- CPS outgoing rotation groups: 1979:1-2006:2 (110 quarters)
- Wage = weekly earnings / usual weekly hours
  - Workers 16-64 years old, private non-farm business sector
  - topcoding, varying hours, trimming outliers
- Skill = educational attainment
  - 5 categories:
    <HS, HS grad, some college, college grad, >college
  - Consistent over sample period (Jaeger 1997)
- Skill premium
  - log wage differential college over high-school graduates
  - allows for heterogeneity; sampling and hours weights (Autor, Katz and Kearney 2005)

→ plot →correlations

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    <HS, HS grad, some college, college grad, >college
  - Consistent over sample period (Jaeger 1997)
- Skill premium
  - log wage differential college over high-school graduates
  - allows for heterogeneity; sampling and hours weights (Autor, Katz and Kearney 2005)

→ plot →correlations

Data

- CPS outgoing rotation groups: 1979:1-2006:2 (110 quarters)
- Wage = weekly earnings / usual weekly hours
  - Workers 16-64 years old, private non-farm business sector
  - topcoding, varying hours, trimming outliers
- Skill = educational attainment
  - 5 categories:
    <HS, HS grad, some college, college grad, >college
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→ plot →correlations

Estimation and Implementation

- Structural VAR
  - Very little theory imposed, full dynamic impulse responses
  - Implementation via a combination of short- and long-run restriction in VAR
- Estimation of the reduced form VAR
  - Quarterly US data, 1979:1-2000:4
  - Labor productivity and hours worked from the BLS
  - Skill premium and relative skill supply
  - First differences, seasonally adjusted data
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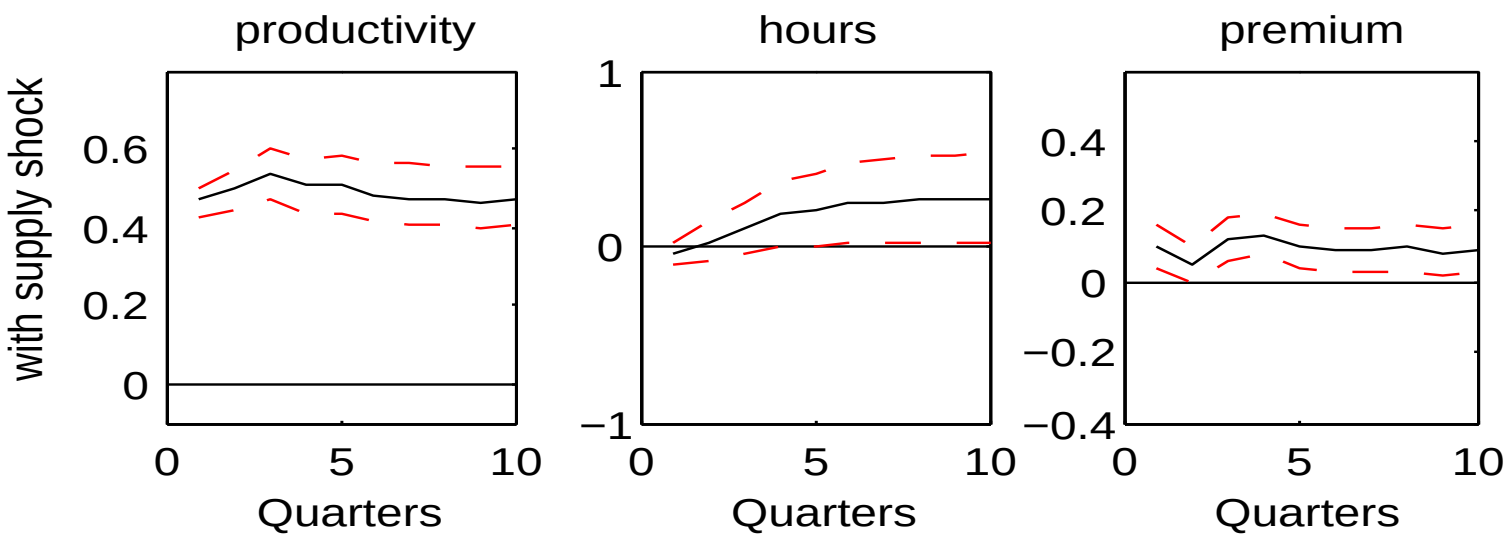
Identification of Shocks I

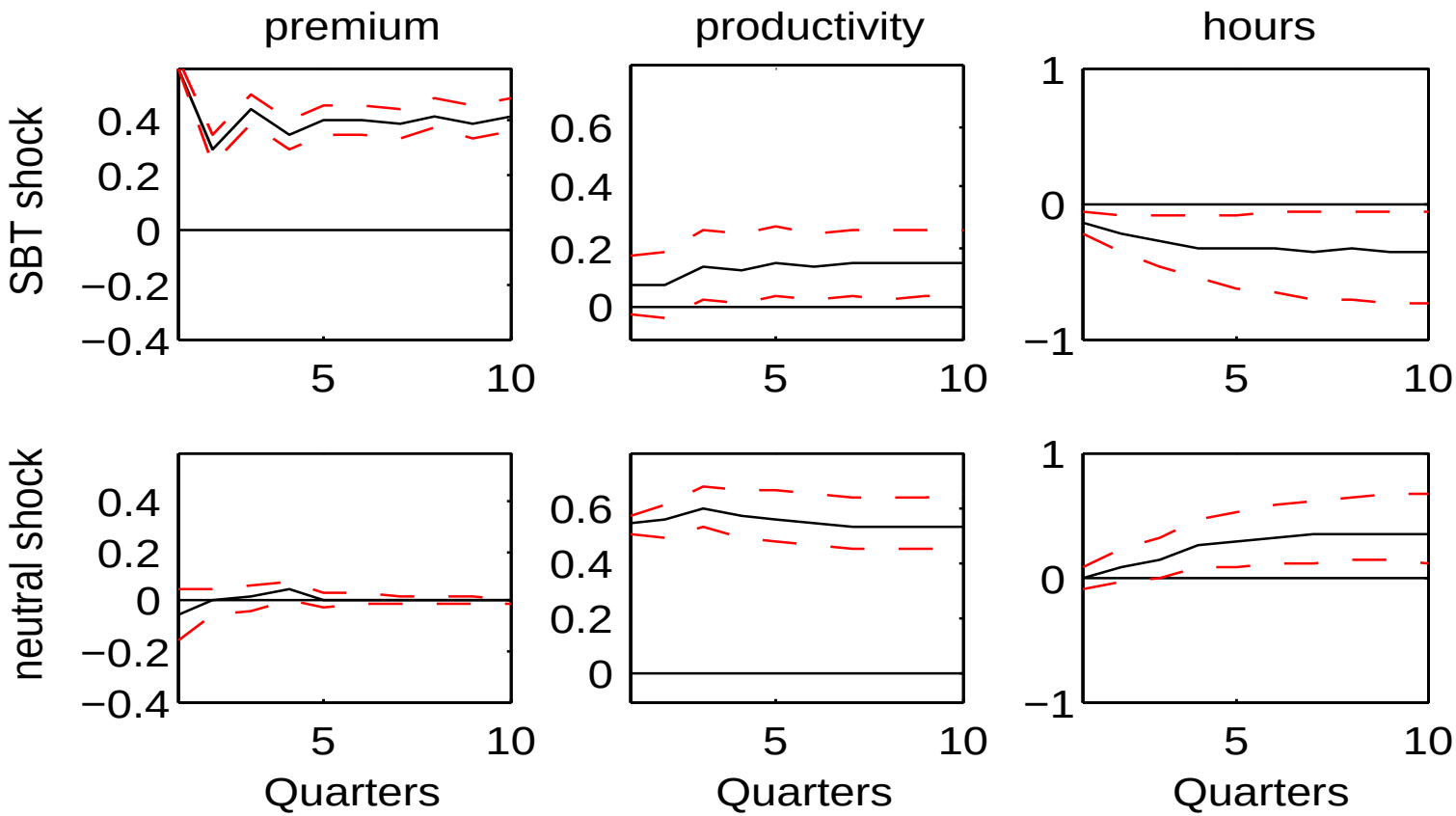
- Identify skill supply and technology shocks
- Skill supply shocks do not affect results significantly



→ Assumptions

Identification of Shocks II

- Identify skill supply, skill-biased and skill-neutral technology shocks



→ Production function decomposition → Assumptions → Dynamics

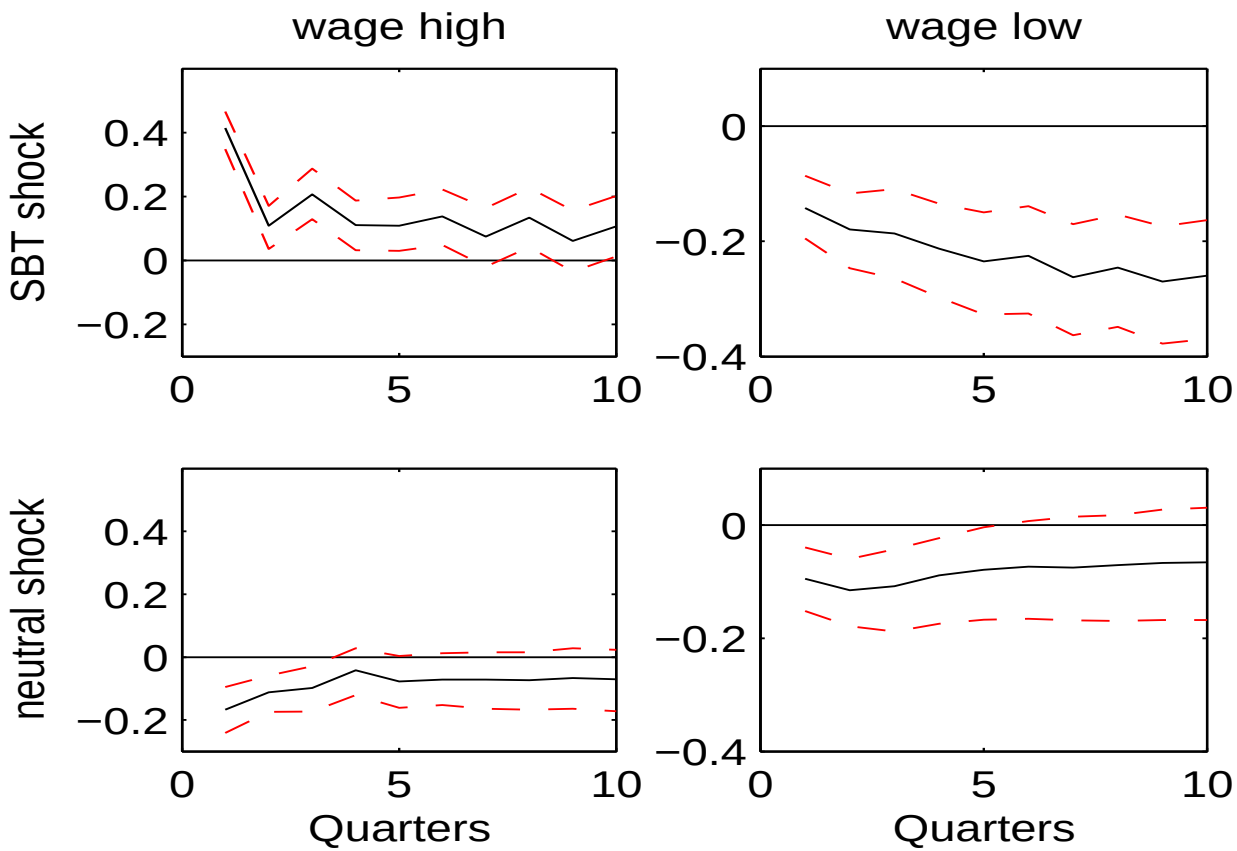
Benchmark Model: Long-run effects

	Skill supply	I-Techn.	SBTechnology	N-Techn.	Labor supply
Investment price	0	1	0	0	0
Skill premium	$-\frac{1}{\sigma+\eta} < 0$	0	$\frac{\sigma-1}{\sigma+\eta} > 0$	0	0
Wage low skilled	$\frac{\omega_2}{(\sigma+\eta)} > 0$	$\frac{\alpha}{1-\alpha} > 0$	$\frac{1+\eta}{\sigma+\eta}\omega_2 > 0$	0	
Wage high skilled	$-\frac{(1-\omega_2)}{(\sigma+\eta)} < 0$	$\frac{\alpha}{1-\alpha} > 0$	$\frac{\sigma-1+(1+\eta)\omega_2}{\sigma+\eta} > 0$	$\frac{1}{1-\alpha} > 0$	0
Productivity	$\frac{\sigma(1+\eta)(\omega_2-\omega_1)}{(1+\eta)(\sigma+\eta)}$ > 0	$\frac{\alpha}{1-\alpha} > 0$	$\frac{\sigma(1+\eta)\omega_2-(\sigma-1)\eta\omega_1}{\sigma+\eta}$ > 0	$\frac{1}{1-\alpha} > 0$	0
Output	$\frac{\xi_t-1+\omega_2}{1+\eta} > 0$	$\frac{\alpha}{1-\alpha} > 0$	$\omega_2 > 0$	$\frac{1}{1-\alpha} > 0$	$\frac{\eta}{1+\eta} > 0$
Total hours	ambiguous	0	$-\frac{(\sigma-1)\eta(\omega_2-\omega_1)}{\sigma+\eta}$ < 0	0	$\frac{\eta}{1+\eta} > 0$
Hours high skilled	ambiguous	0	$\frac{(\sigma-1)\eta}{\sigma+\eta}(1-\omega_2) > 0$	0	$\frac{\eta}{1+\eta} > 0$
Hours low skilled	ambiguous	0	$-\frac{(\sigma-1)\eta}{\sigma+\eta}\omega_2 < 0$	0	$\frac{\eta}{1+\eta} > 0$
Rel. empl. skill	$\frac{\sigma}{\sigma+\eta} > 0$	0	$\frac{(\sigma-1)\eta}{\sigma+\eta} > 0$	0	0

→ Dynamics

Identification of Shocks II

- Identify skill supply, skill-biased and skill-neutral technology shocks



→ Dynamics

Identification of Shocks II

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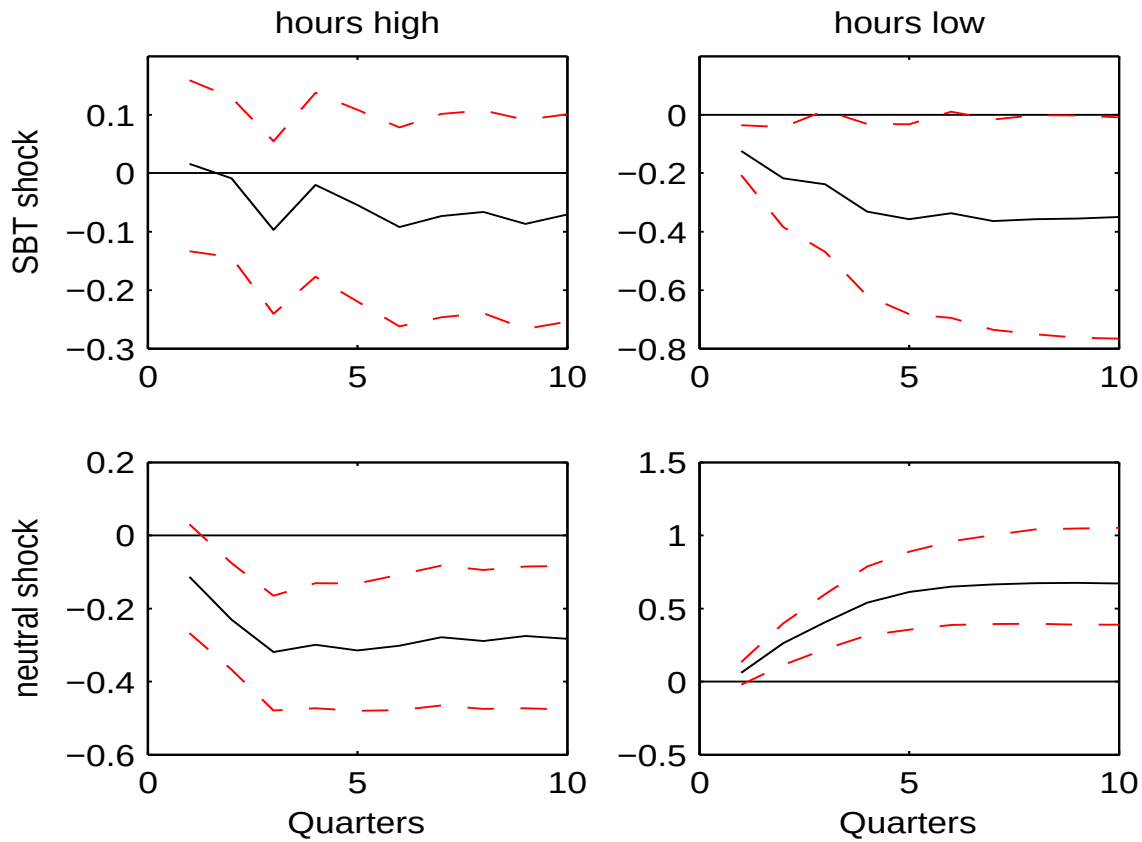
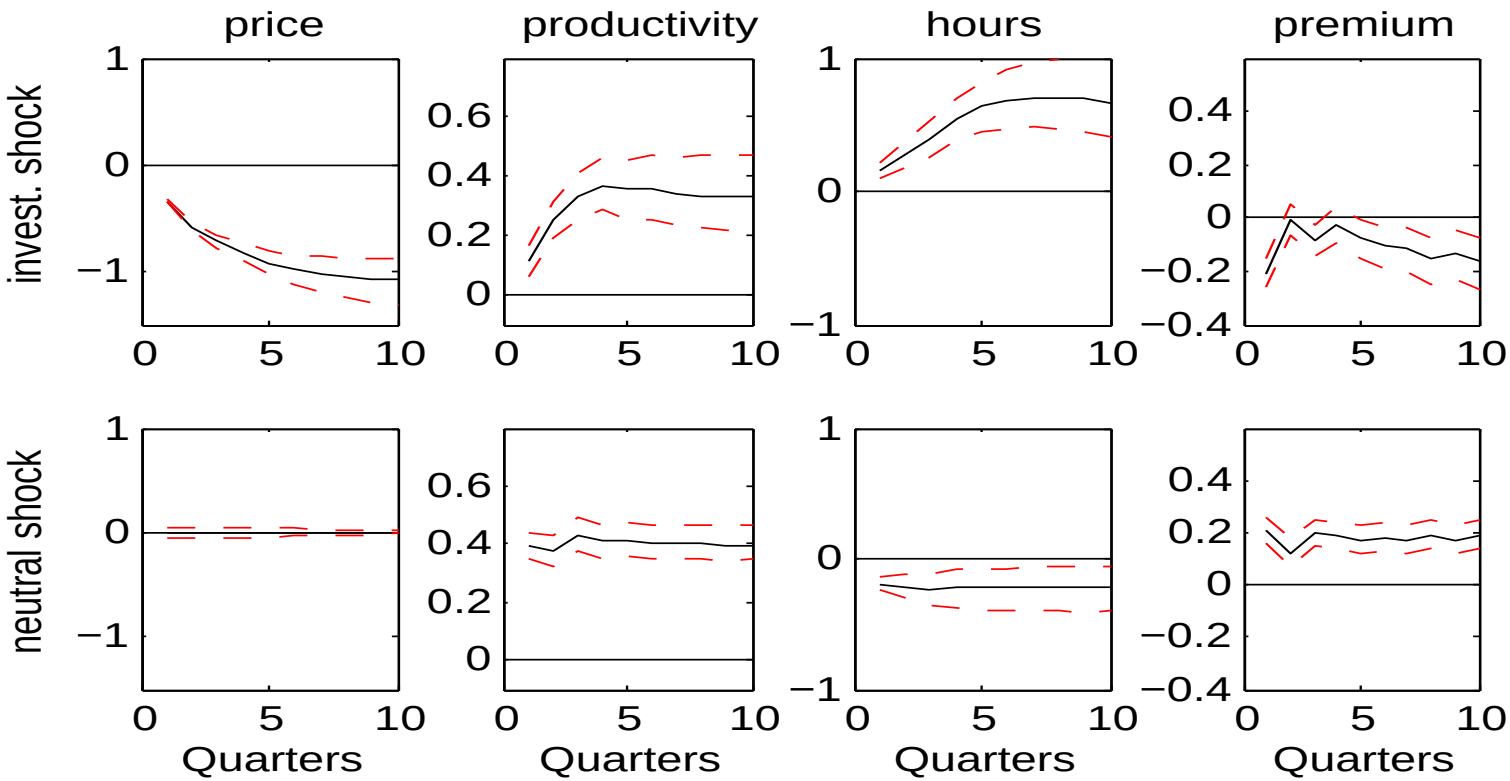


→ Dynamics

Identification of Shocks III

- Identify skill supply, investment-specific and investment-neutral technology shocks



→ SBT with price → Assumptions → Dynamics

Robustness of Capital-skill complementarity

- Can we trust our results on the substitutability of capital and skill?
- Simulation of model with different degrees of capital-skill complementarity and substitutability
- Estimation of our structural VAR with simulated data
  - Can the VAR replicate the model responses of the different technology shocks?
  - What degree of substitutability do we observe in the data?

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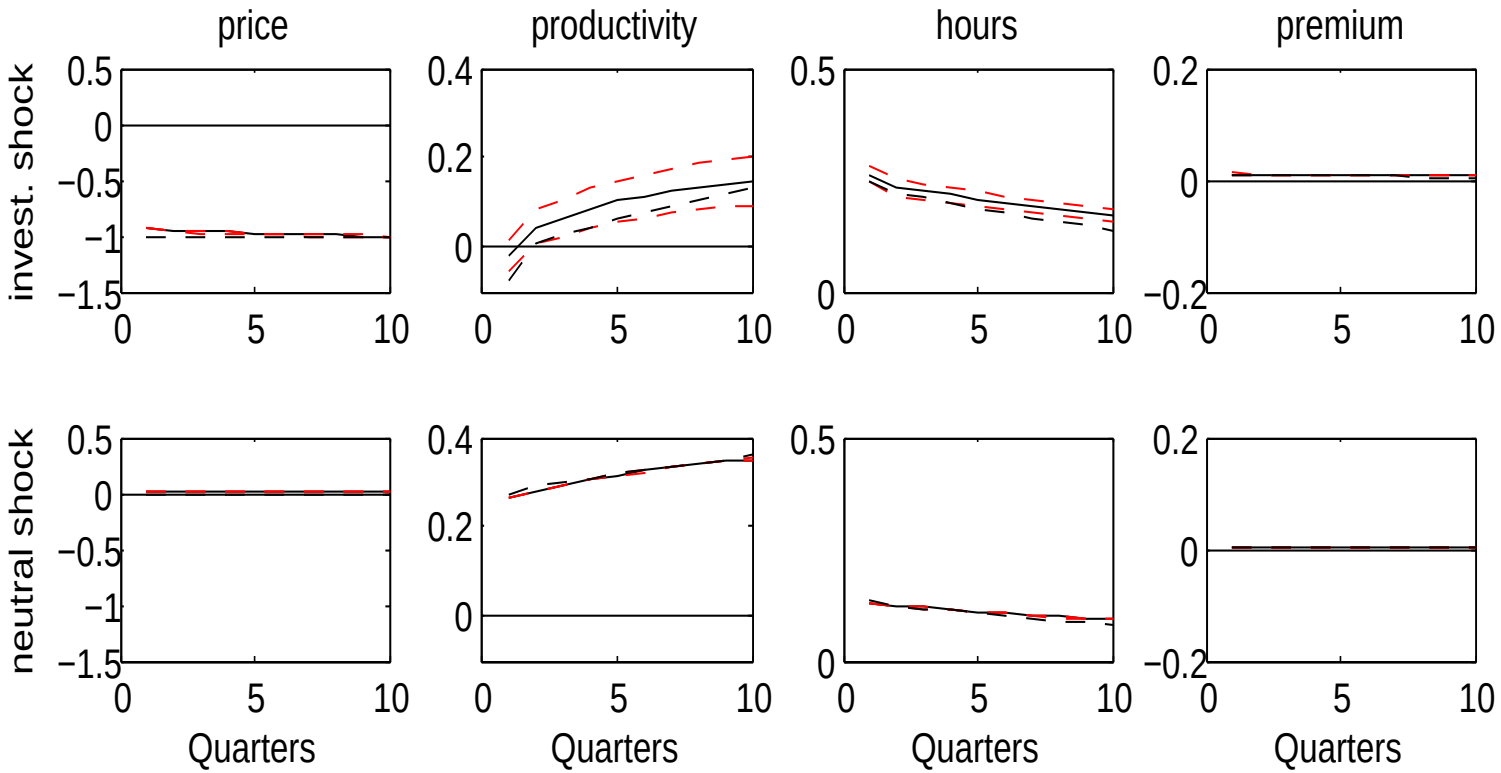
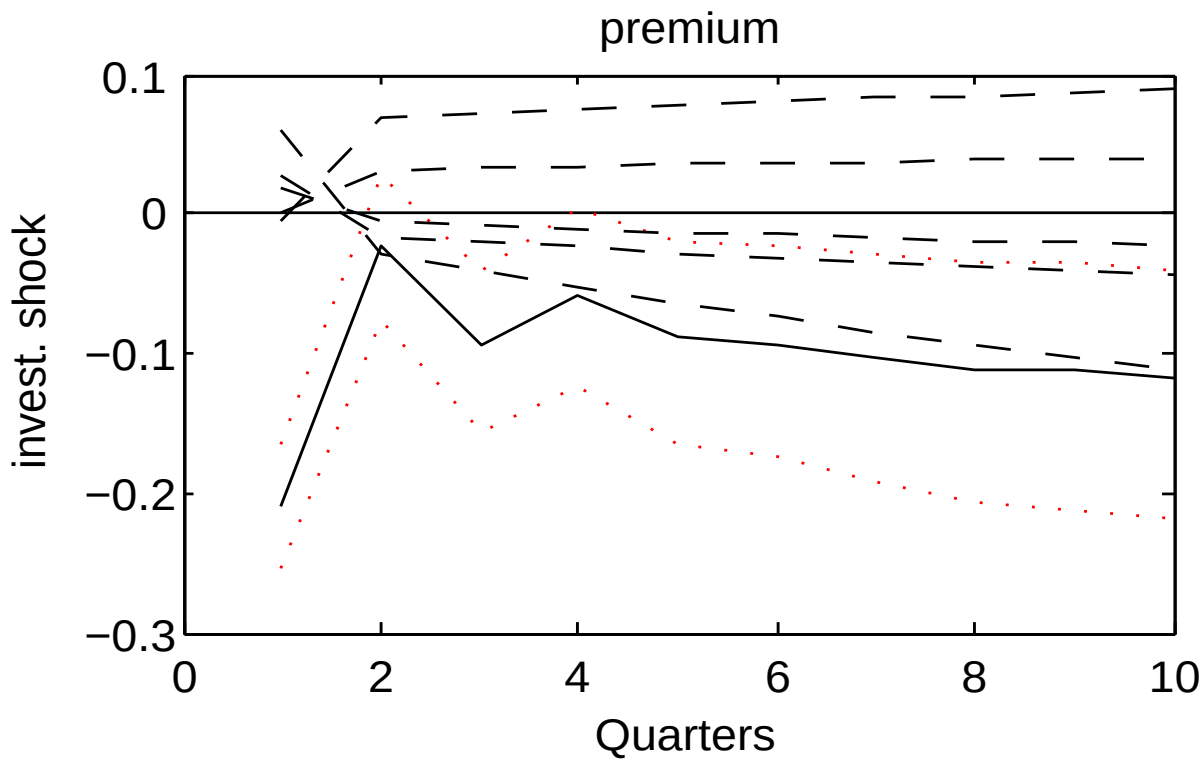
Impulse-responses from Model



Capital and skill are neither complements nor substitutes

Capital-skill complementarity



Dashed lines show responses from the model with depict $\sigma = 1.67$ and $\theta = [0.67, 1.17, 2.17, 2.67, 5]$

Variance Decomposition

- Joint identification of all shocks in order to assess their relative importance over the business cycle
- Skill- and investment-neutral technology shocks are uniquely identified
- Skill-biased and investment-specific technology shocks cannot be entirely separated

Shocks that affect...	Ordering I	Ordering II
... the skill premium	LB: skill-biased inv-neutral	UB: skill-biased inv-specific
... the relative price	UB: inv-spec skill-biased	LB: inv-spec skill-neutral

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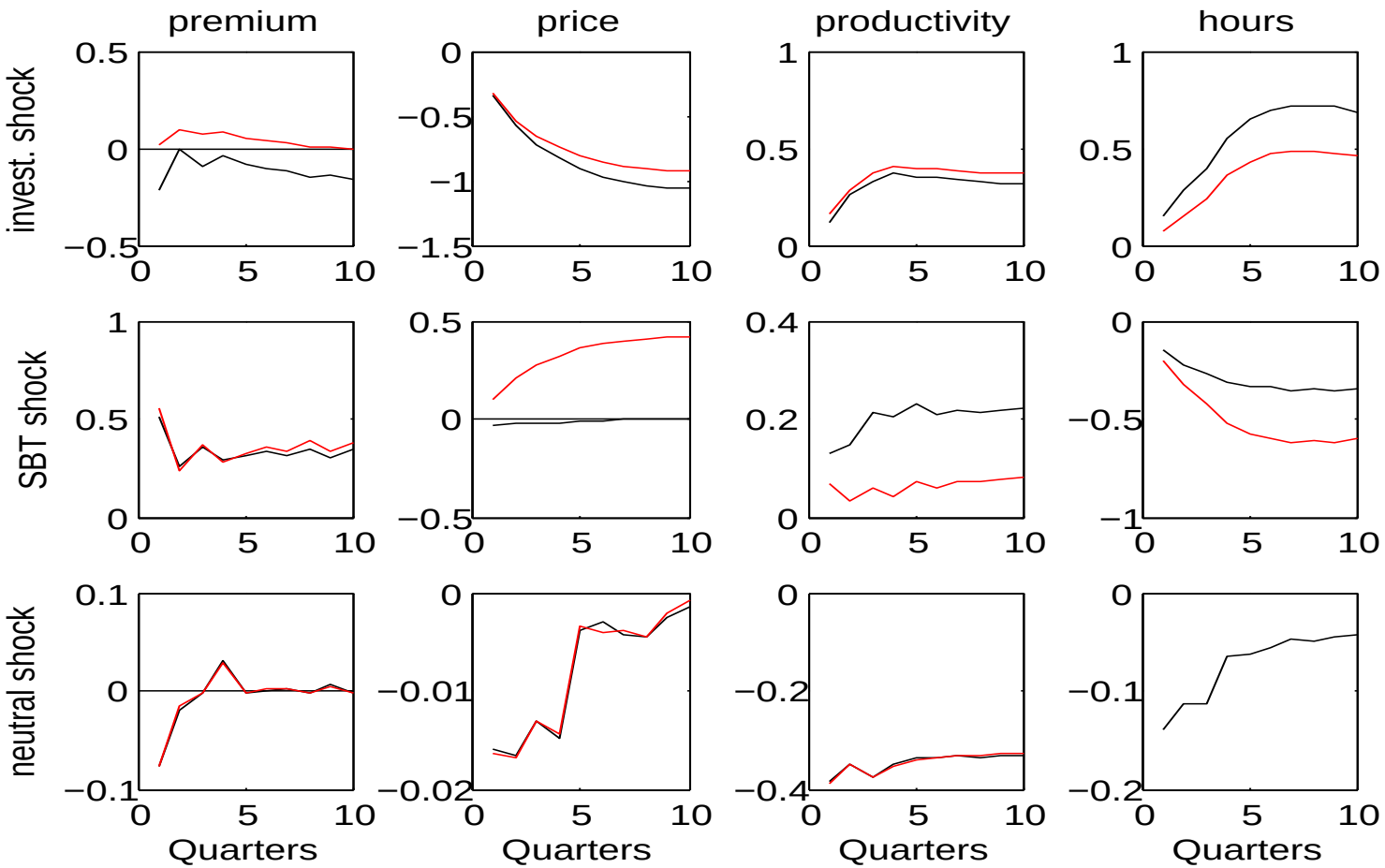
Joint Identification of Shocks



black lines: ordering I, red lines: ordering II

$\longrightarrow$ additional variables

Variance Decomposition

Horizon	8		16		32	
	I	II	I	II	I	II
output						
i-shock (ul,lb)	58.95	45.84	62.40	48.73	63.75	50.4
SBT shock (lb,ub)	0.91	9.99	0.88	10.50	0.84	10.8
neutral shock	6.64	6.44	5.66	5.45	5.29	5.16
hours						
i-shock (ul,lb)	38.89	21.91	42.37	24.24	43.55	25.1
SBT shock (lb,ub)	10.34	25.13	9.11	24.71	8.84	24.47
neutral shock	1.36	1.53	0.91	1.09	0.78	0.91
premium						
i-shock (ul,lb)	8.71	1.65	9.39	0.87	9.65	0.4
SBT shock (lb,ub)	89.57	96.46	89.76	98.17	89.76	99.08
neutral shock	0.52	0.48	0.27	0.25	0.14	0.12

Conclusion

- Technological change is skill-biased at all frequencies
- Fall in hours is largely due to SBT shocks
- Capital and skill are not complementary over the business cycle
  - Investment-specific technology shocks are not skill-biased
  - Volatility in the skill premium is largely explained by (i-neutral) SBT shocks
  - Correlation in trends remains unexplained
- SBT shocks
  - explain almost all of the fluctuations in the skill premium
  - explain up to 25% of fluctuations in hours worked
  - explain little output volatility

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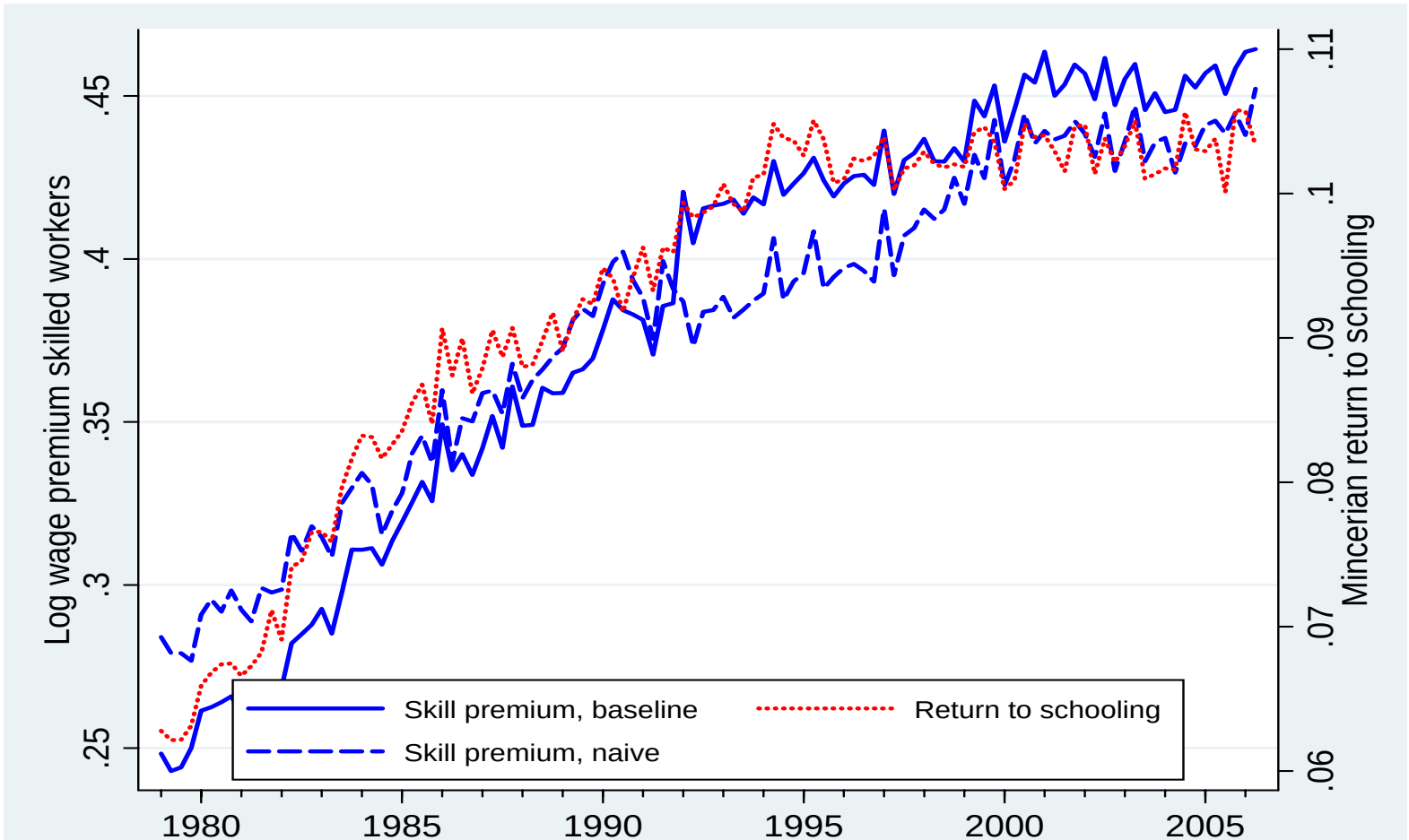
Quarterly Measures of the Price of Skill



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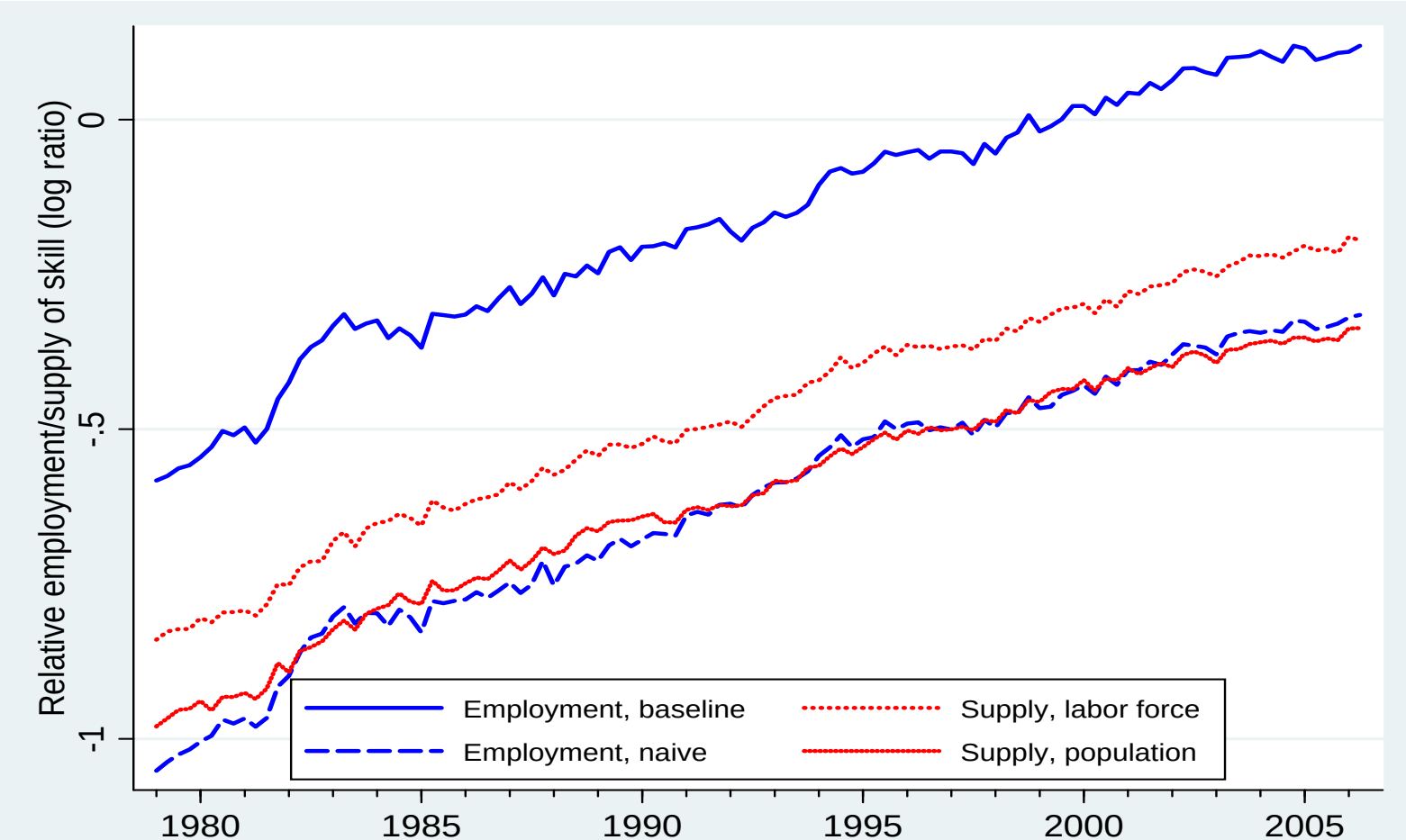
Quarterly Measures of the Quantity of Skill



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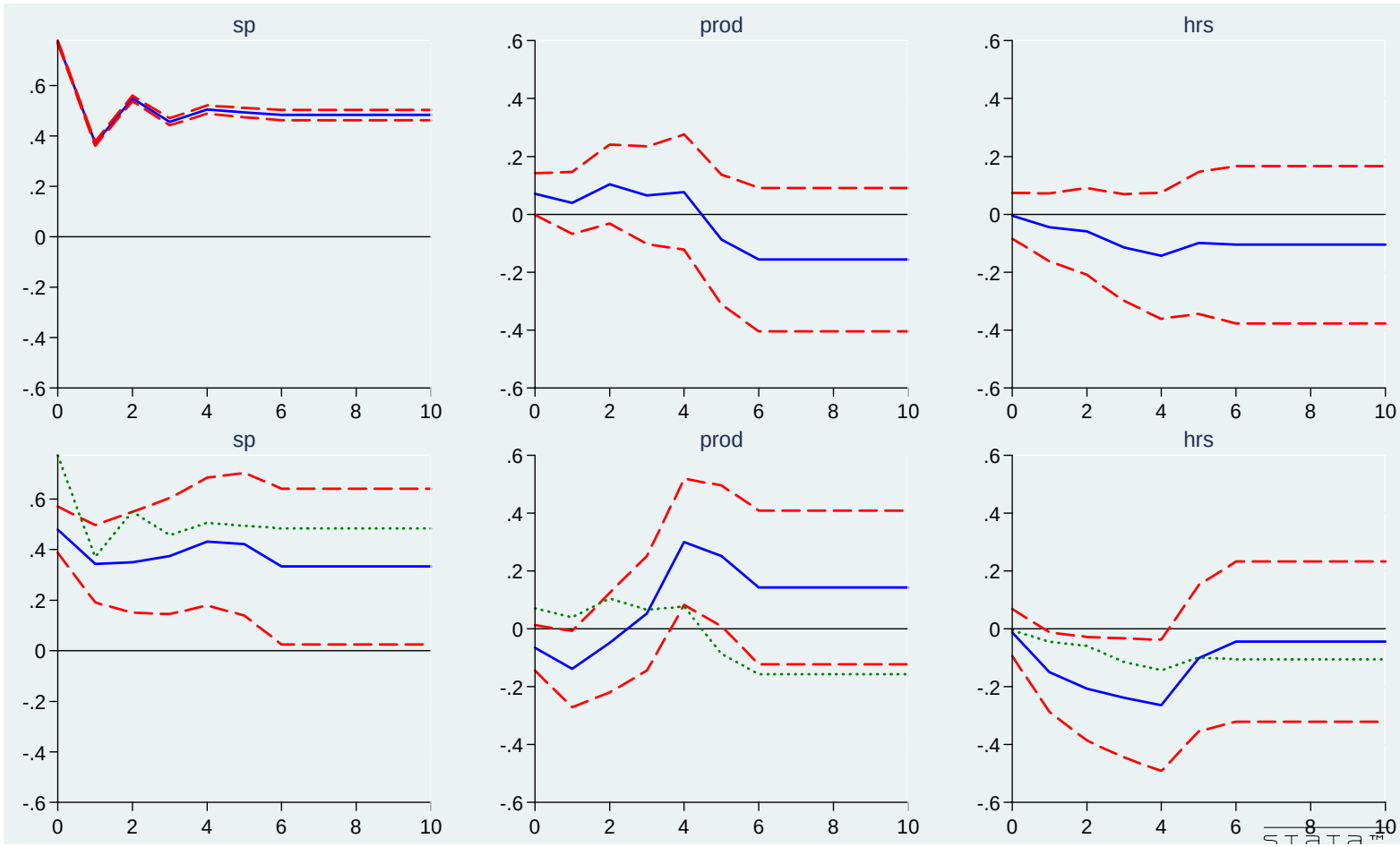
Unconditional Business Cycle Correlations

	Std	Correlation with			
		Output	Hours	Productivity	Price
Baseline measure					
Skill premium	0.0067	0.1189	-0.0685	0.3338*	-0.1571
Relative employment	0.020	-0.4178*	-0.2727*	-0.3452*	0.6257*
Naive measure					
Skill premium	0.0073	0.0506	0.1370	-0.1259	0.0497
Relative employment	0.0173	-0.4160*	-0.3337*	-0.2435	0.6062*
Relative supply	0.0119	0.0320	0.1268	-0.1445	0.3990*

(Notes: HP with $\lambda = 1600$. * indicates significance of at least 10%.)

→ back

Impulse-responses to Solow Residual



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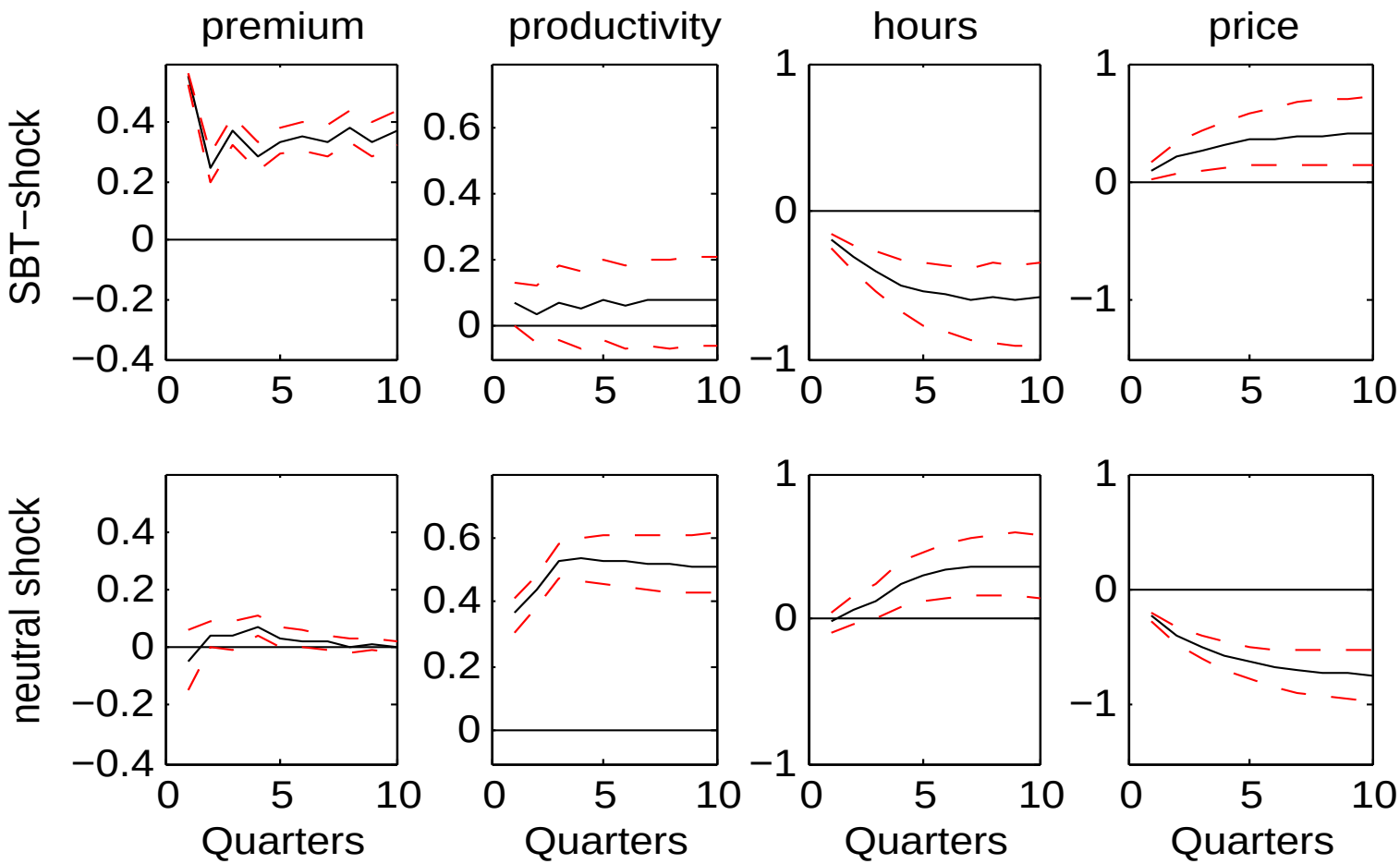
Identification of Shocks III: reverse



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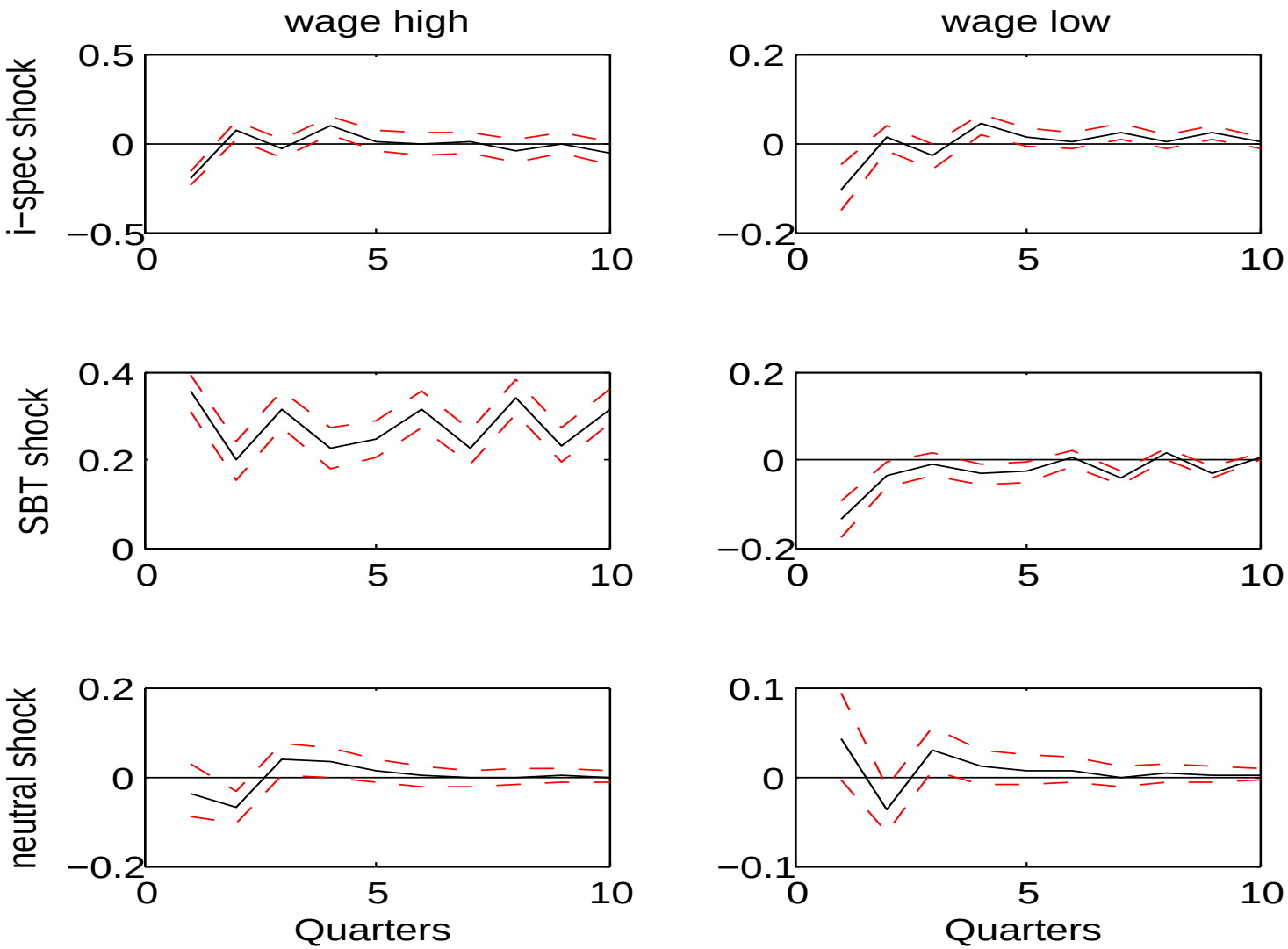
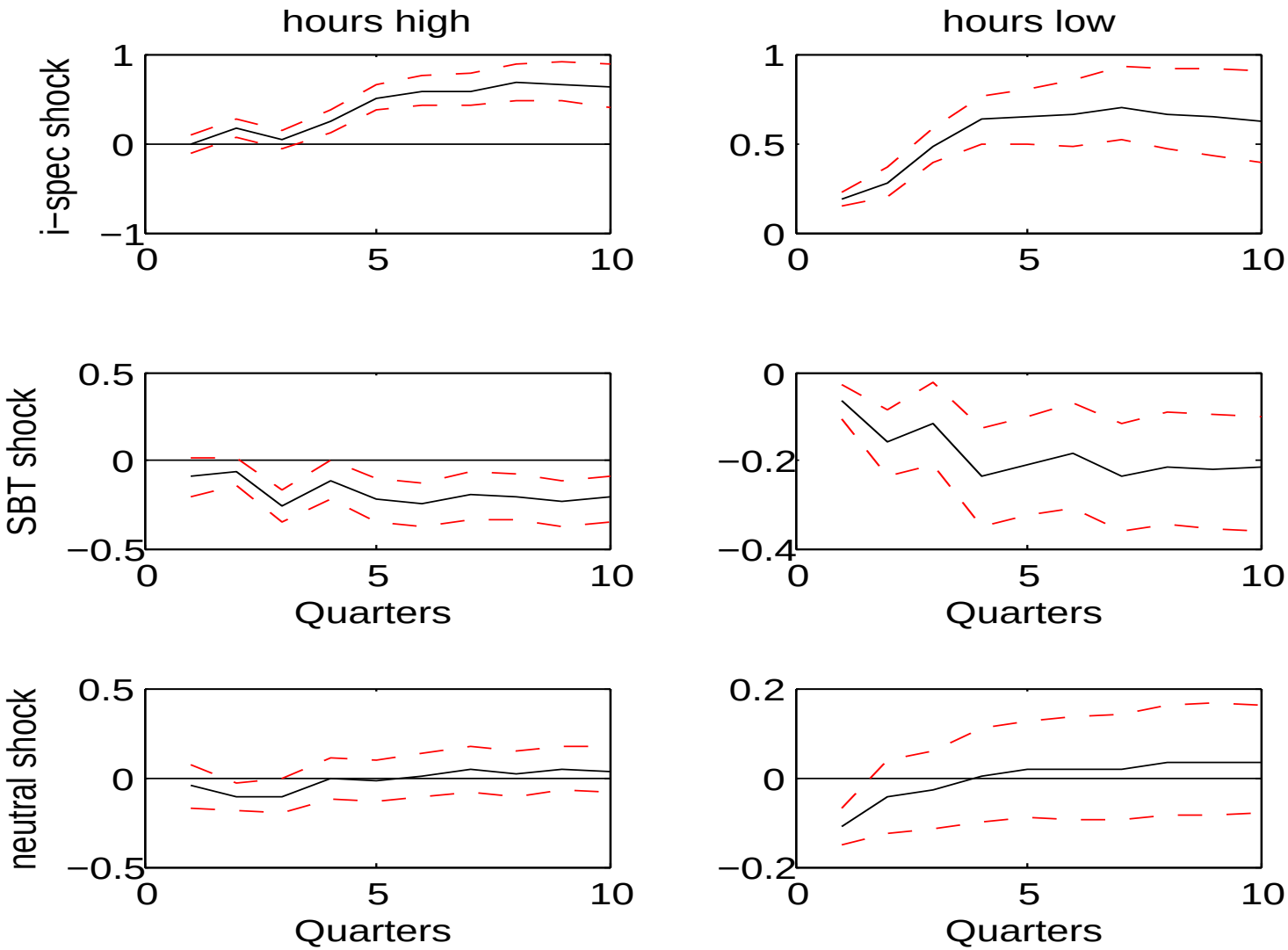
Joint Identification I



Joint Identification I



→ back

Model Dynamics: Benchmark

Calibration

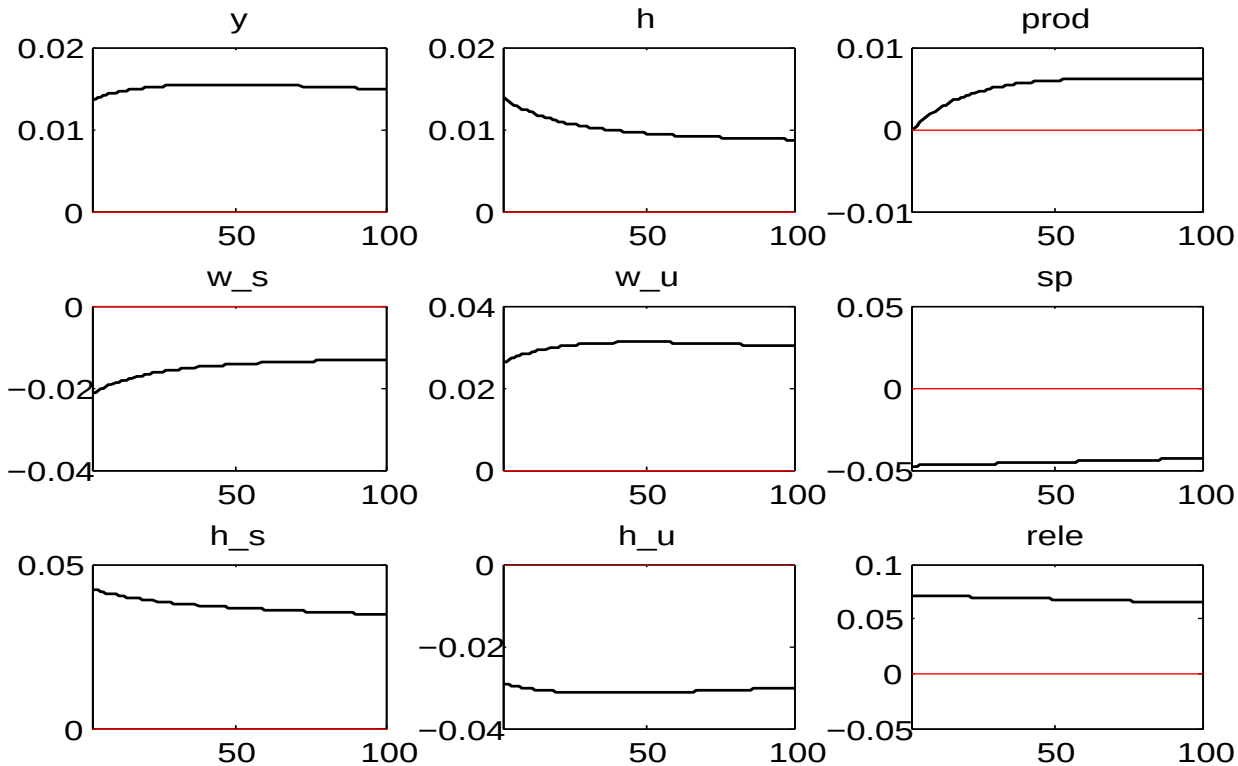
- $\alpha = \frac{1}{3}$, $\rho = 0.01$, $\eta = 2$, $\delta = 0.025$
- $\sigma = 1.67$ and mean skill supply in population: 47%
- Labor supply shock calibrated to match 20% of time spent working
- Share parameter β to match skilled wages 50% higher than unskilled wages

→ back to results

→ back to model

Model Dynamics: Benchmark

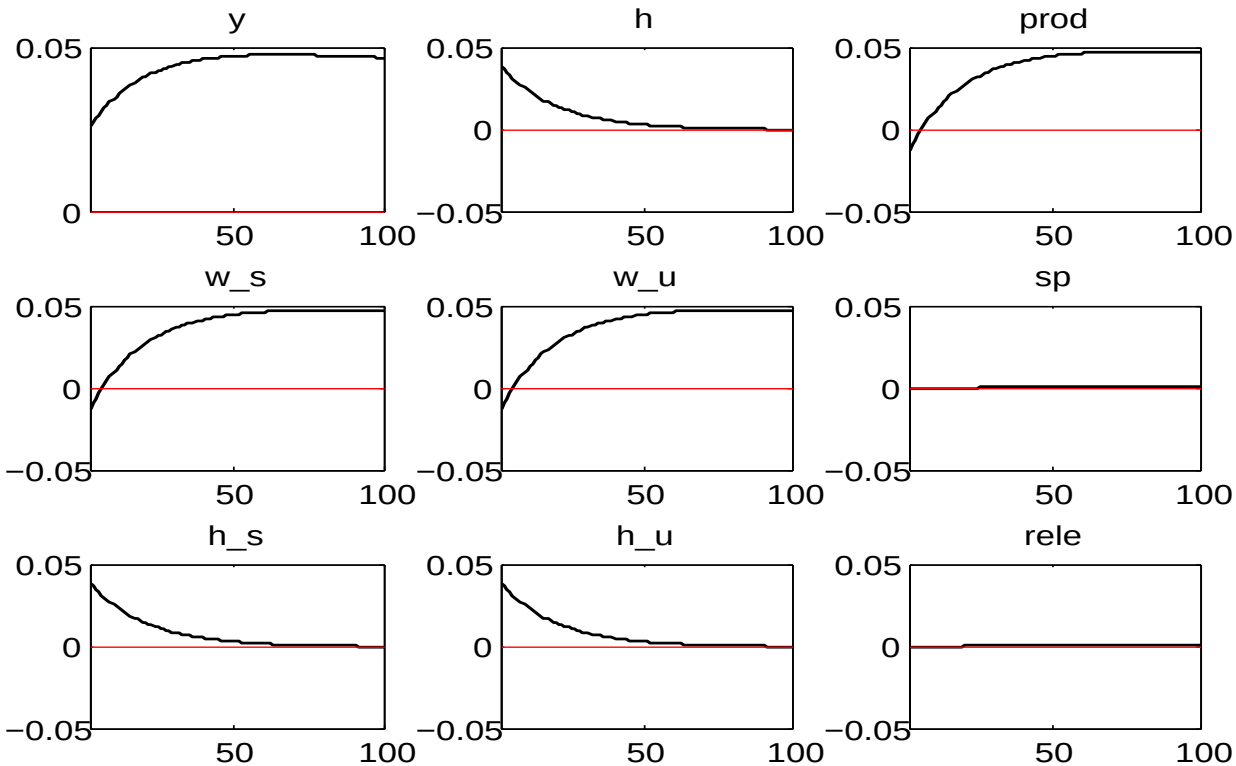
Skill supply shocks



→ back to results → back to model

Model Dynamics: Benchmark

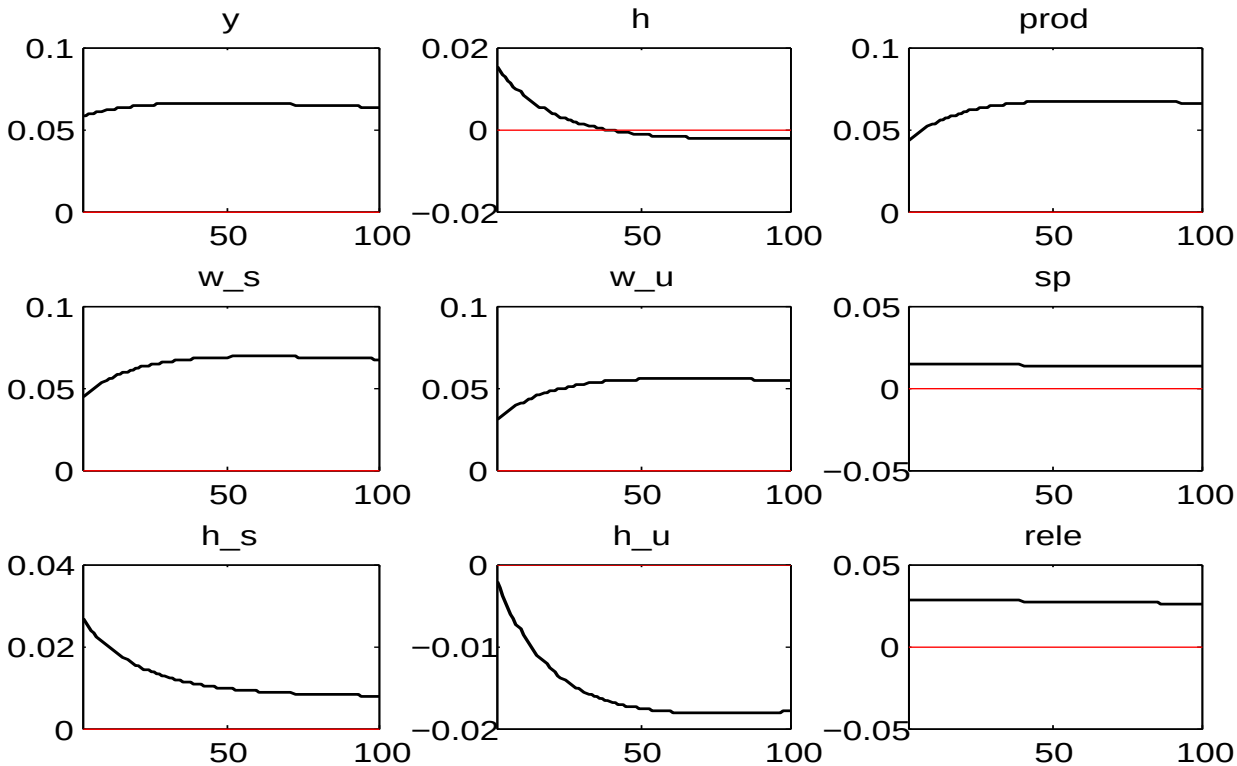
Investment-specific technology shocks



→ back to results → back to model

Model Dynamics: Benchmark

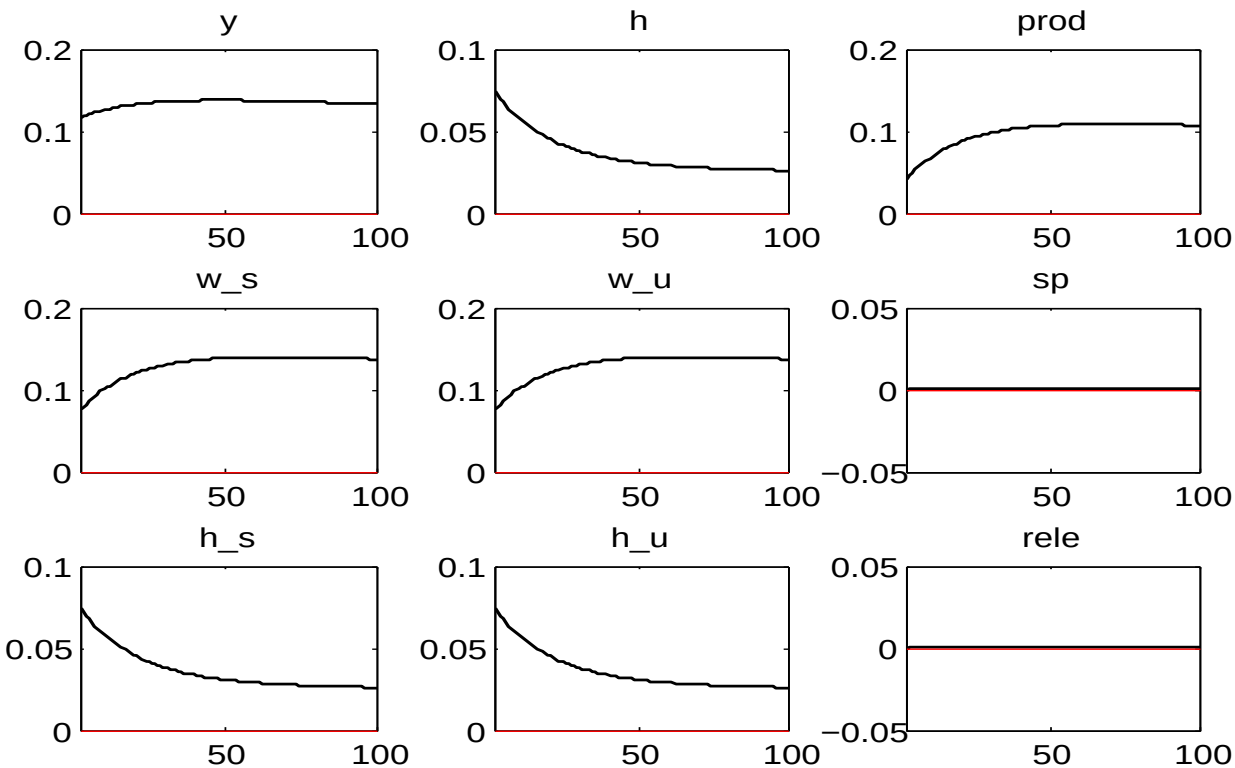
Skill-biased technology shocks



→ back to results → back to model

Model Dynamics: Benchmark

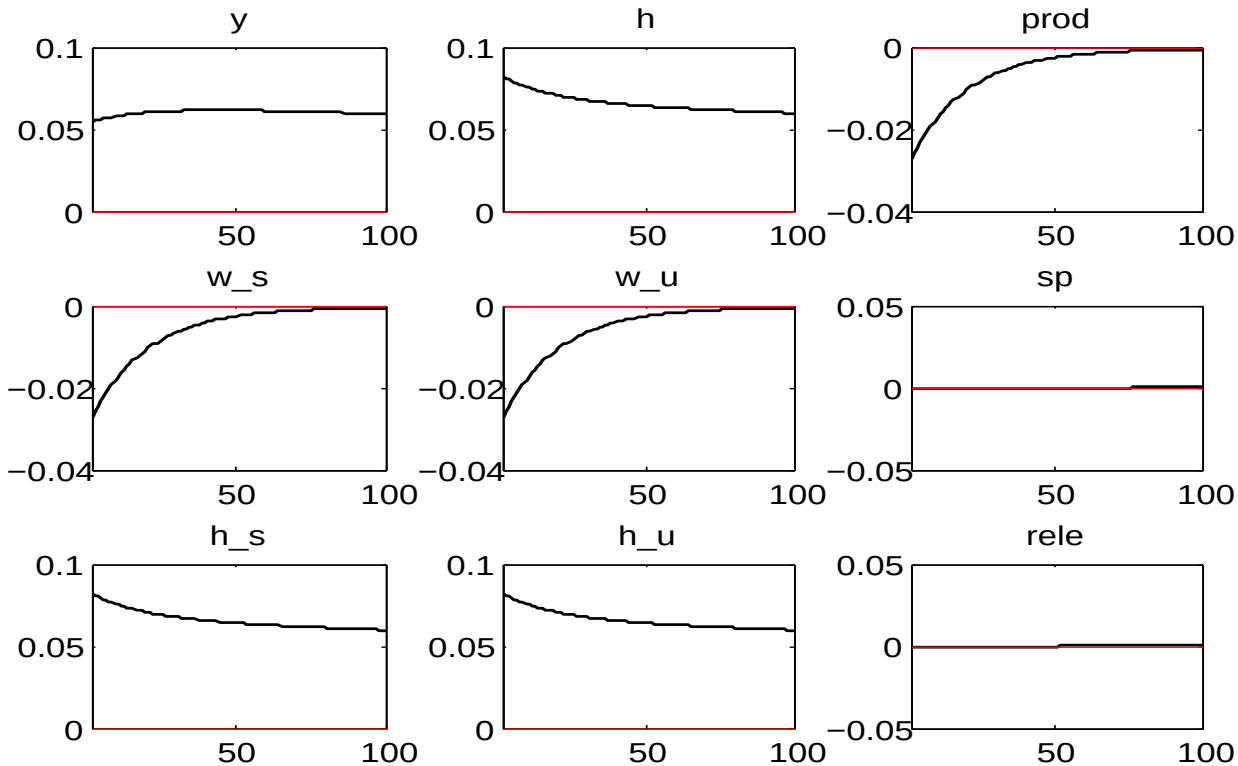
Neutral technology shocks



→ back to results → back to model

Model Dynamics: Benchmark

Labor supply shocks

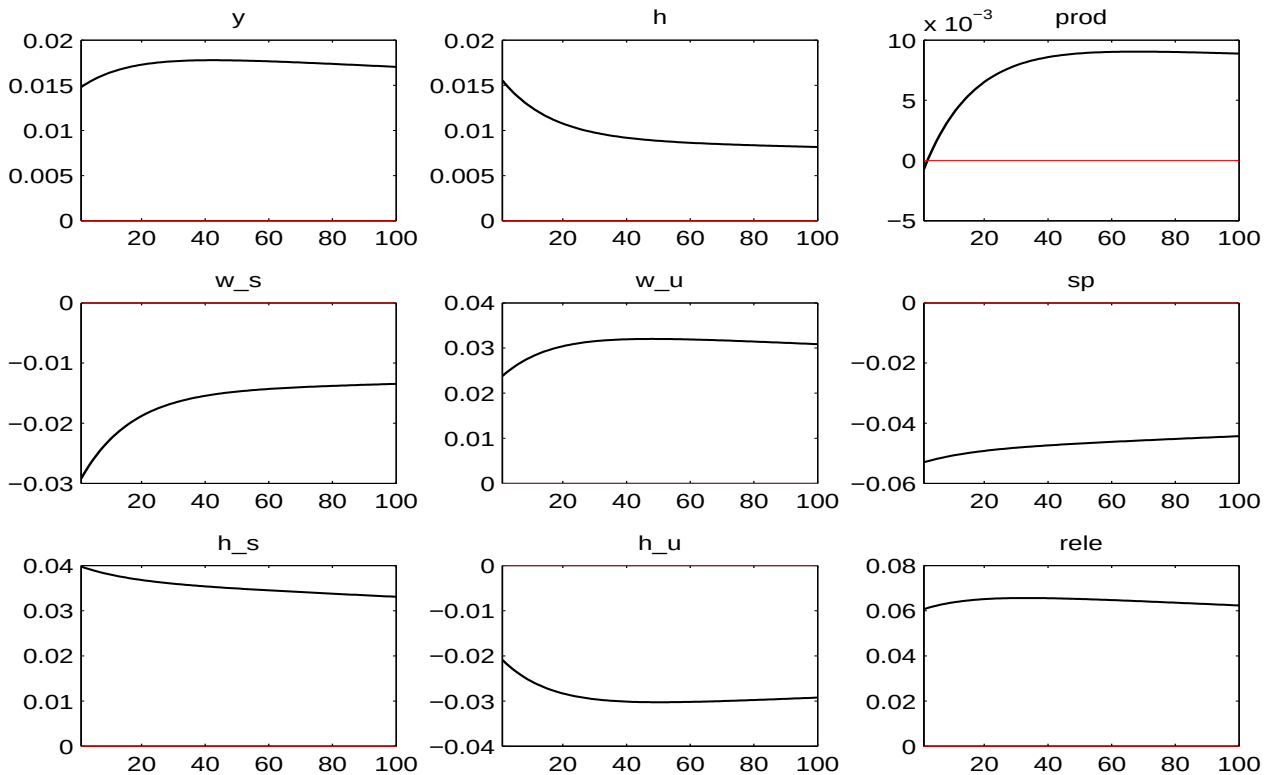


→ back to results

→ back to model

Model Dynamics: Capital-Skill Complementarity

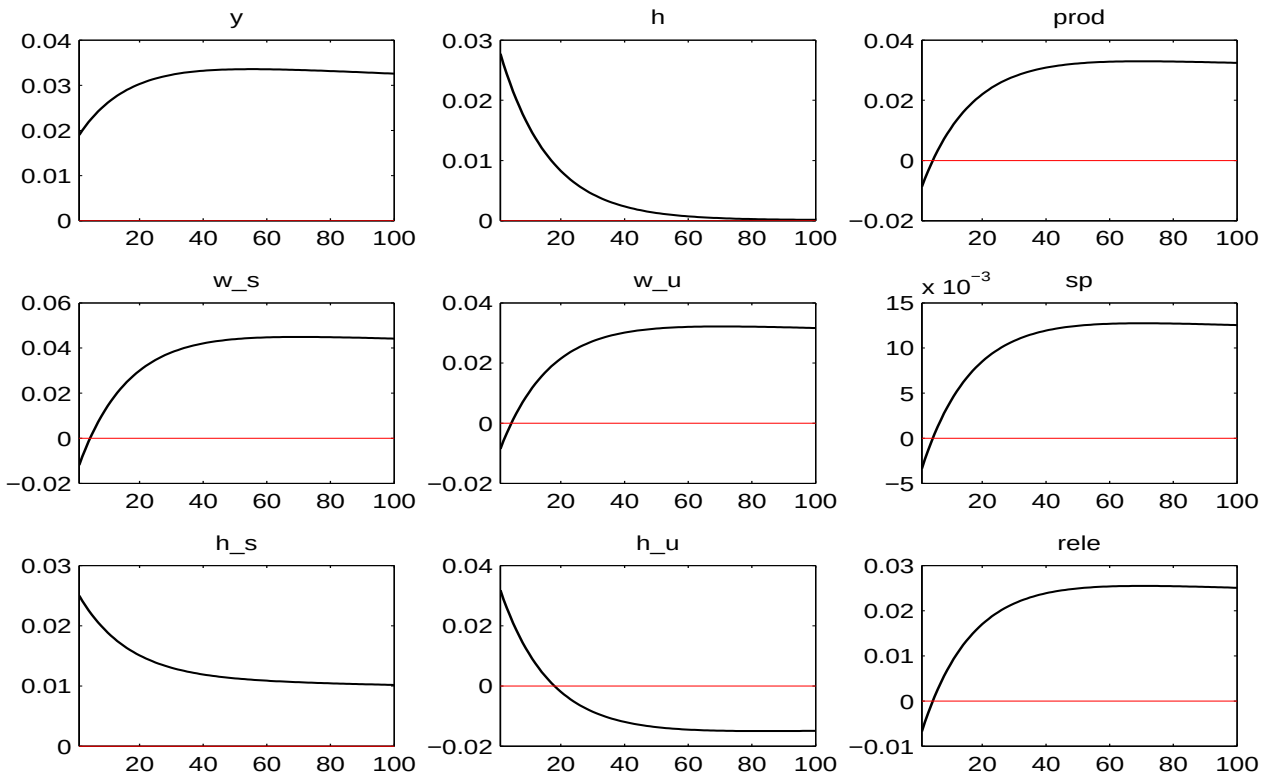
Skill supply shocks



→ back to results → back to model

Model Dynamics: Capital-Skill Complementarity

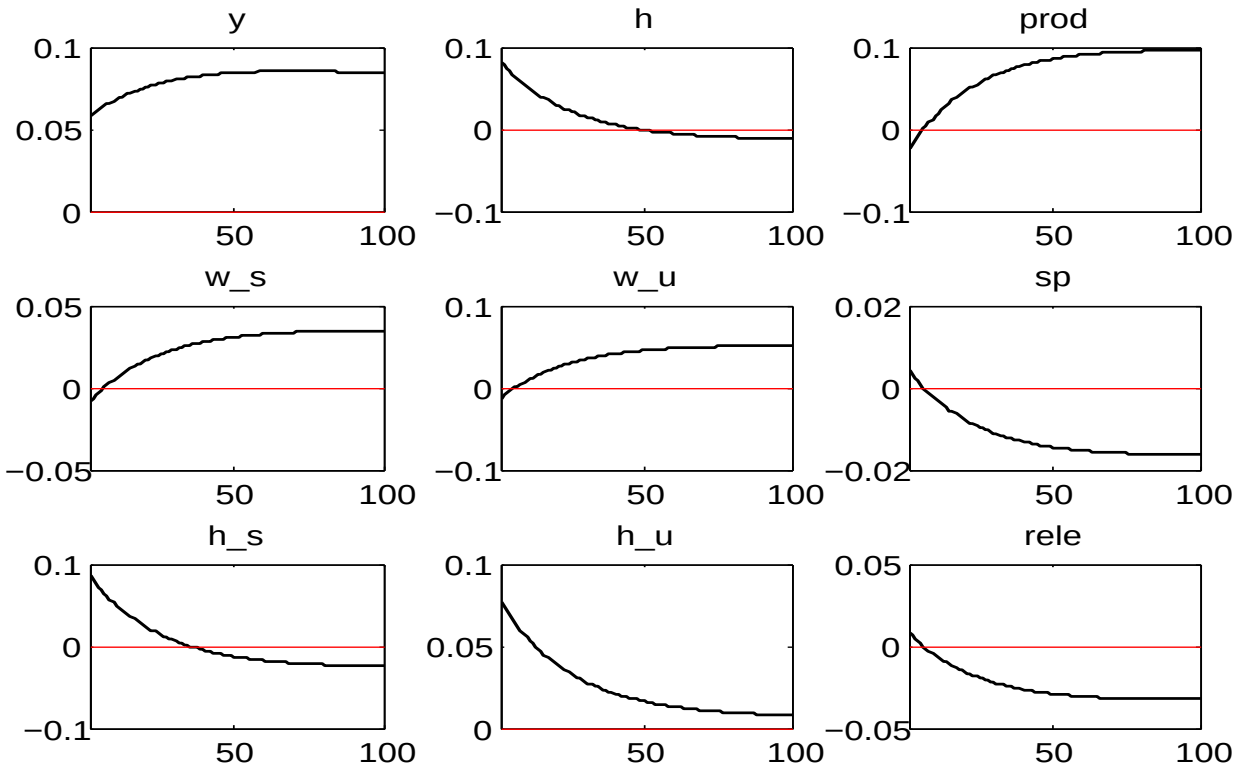
Investment-specific technology shocks



→ back to results → back to model

Model Dynamics: Capital-Skill Substitutability

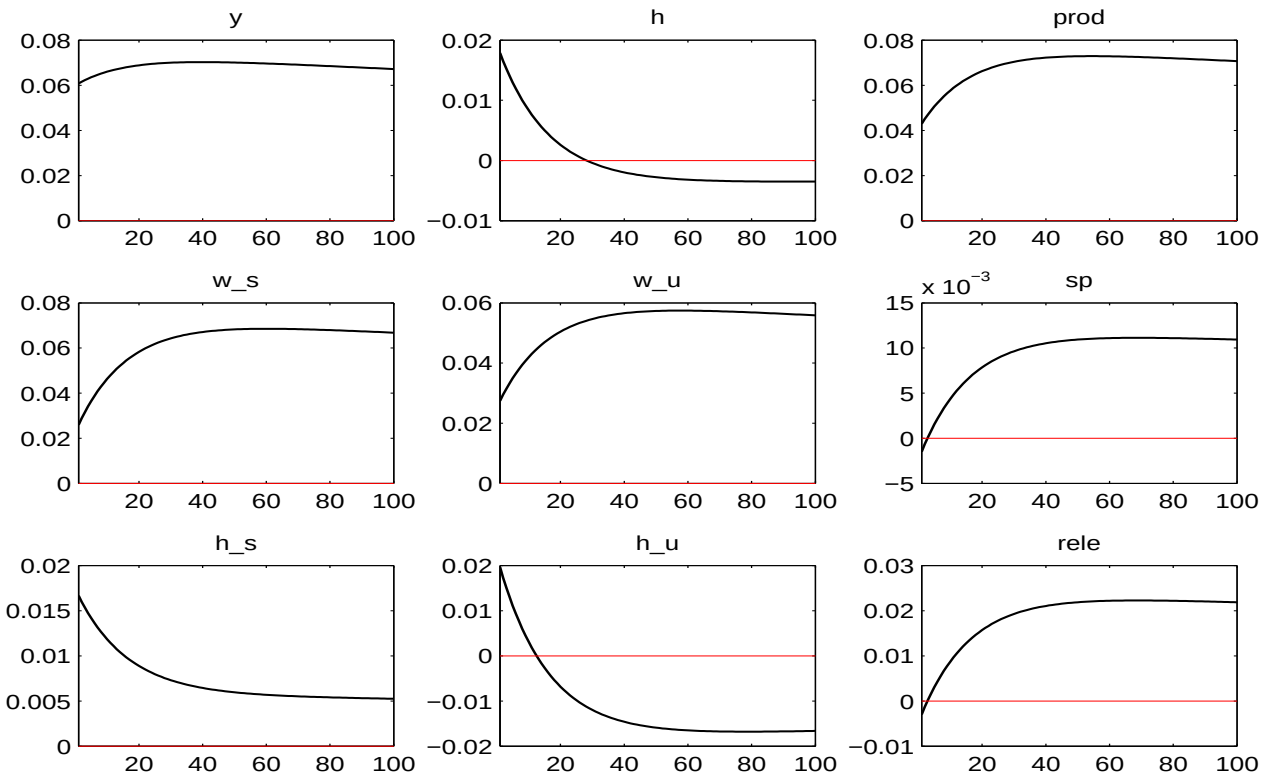
Investment-specific technology shocks



→ back to results → back to model

Model Dynamics: Capital-Skill Complementarity

Skill-biased, investment-neutral technology shocks



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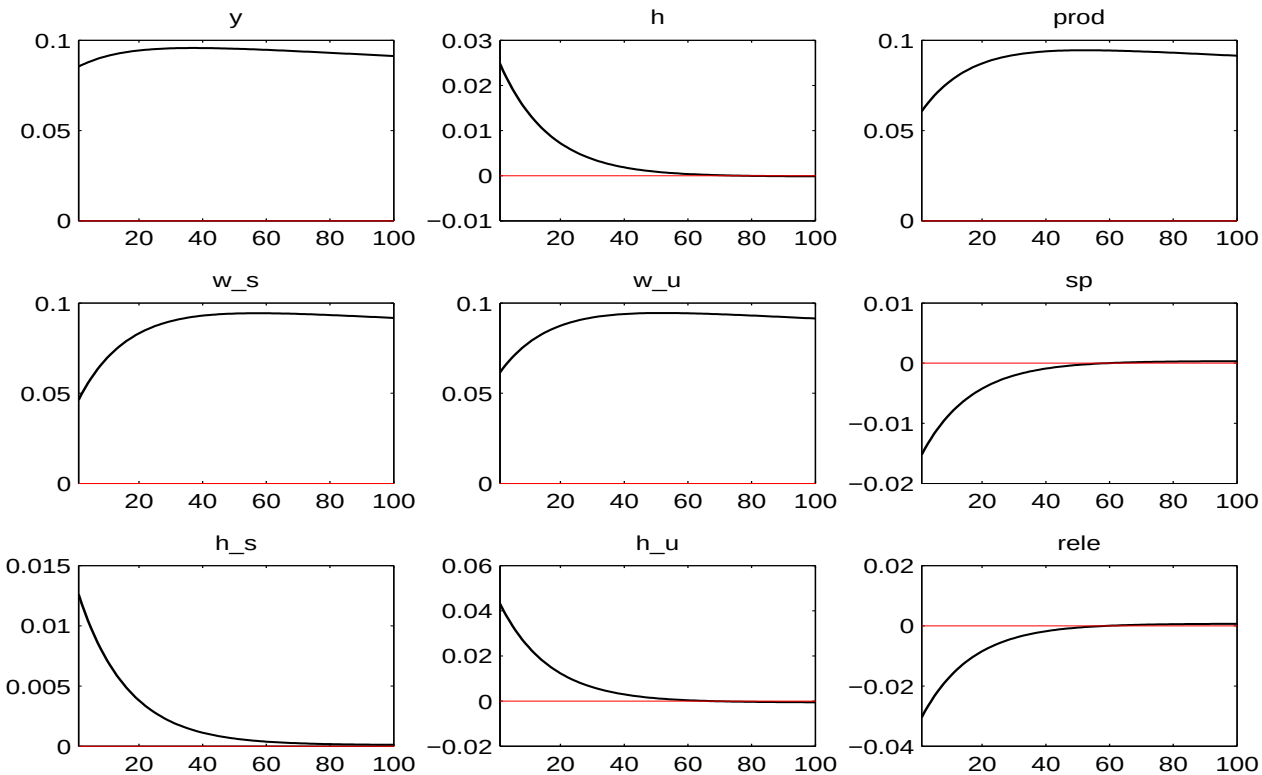
Model Dynamics: Capital-Skill Complementarity

Neutral technology shocks



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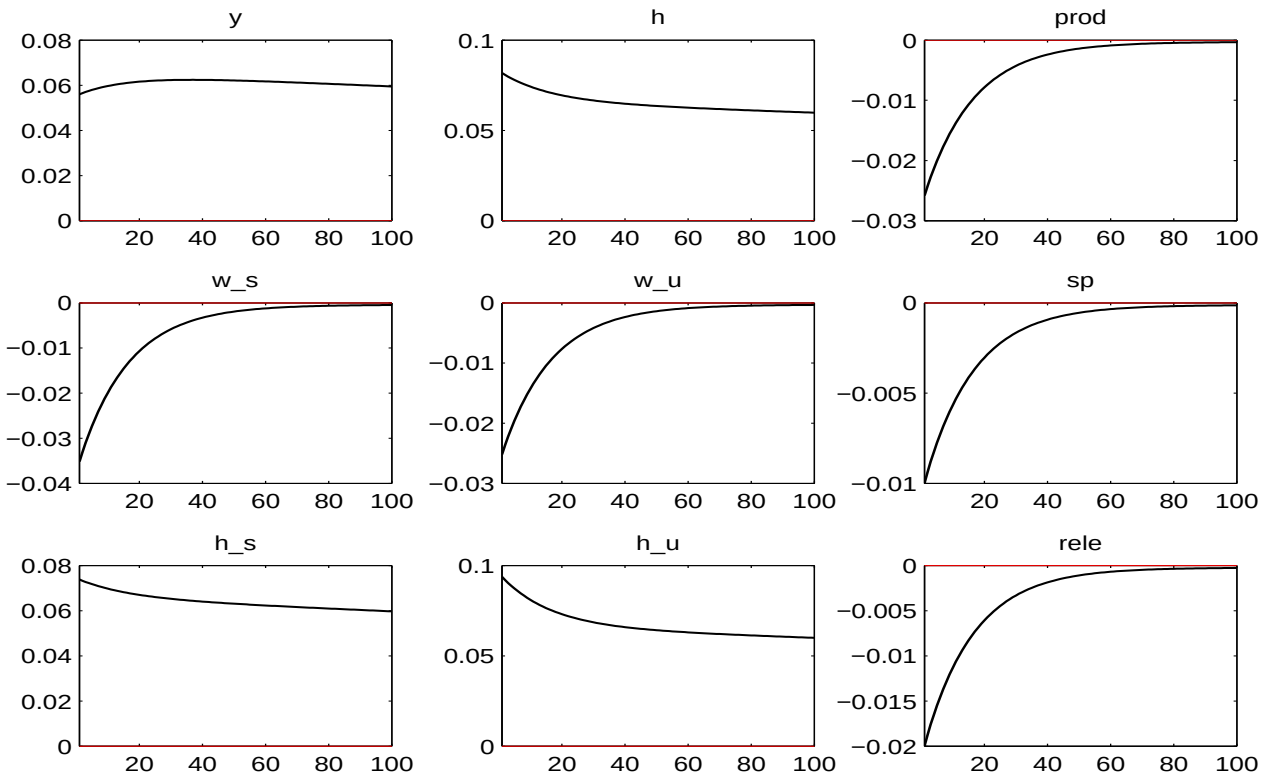
Model Dynamics: Capital-Skill Complementarity

Labor supply shocks



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