Uncertainty Shocks and the Relative Price of Investment Goods

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This paper...

- Study how changes in uncertainty affect macroeconomy.

- Two contributions:

  Empirical side

  - Document how "typical" macroeconomic variables respond to changes in uncertainty by using a standard SVAR.

  - Increases in the relative price of investment goods

  - Comovement among output, consumption, investment, (and hours)

  Theoretical side

  - Focus on two-sector DSGE models with flexible investment prices.

  - Find that factor immobility plays an important role.

Uncertainty

- More predictable or less predictable

- Objective uncertainty: the probabilities are well understood by agents.
  - Macro uncertainty (our focus) Shock Process
  - Micro uncertainty

- Ambiguity: the probabilities are not well understood.

Uncertainty Shocks

- The Great Recession
- A growing number of both theoretical and empirical studies, triggered by Bloom (2009)
- Bloom (2014):
  The rise in uncertainty in 2008 accounts for 1/3 of the total decline of output from 2008 to 2009 (about 3% drop in GDP).

Our Empirical Focus

- Earlier empirical studies focus on *whether* higher uncertainty has an adverse effect on the economic activity or not.
- We further investigate *how* the uncertainty shocks impact the aggregate economy.
- Especially we care about dynamic interaction among:
  - uncertainty
  - macroeconomic variables
  - the relative price of investment goods

Why the Relative Price of Investment?

- A popular story of uncertainty shocks (the real-options effect) suggests a demand-side story.
- Higher uncertainty raises the value of waiting and firms postpone purchases of new capital goods until uncertainty is resolved.
- Wait-and-see behavior
- Expect to see simultaneous drops in investment and its relative price.

Eyeballing Econometrics

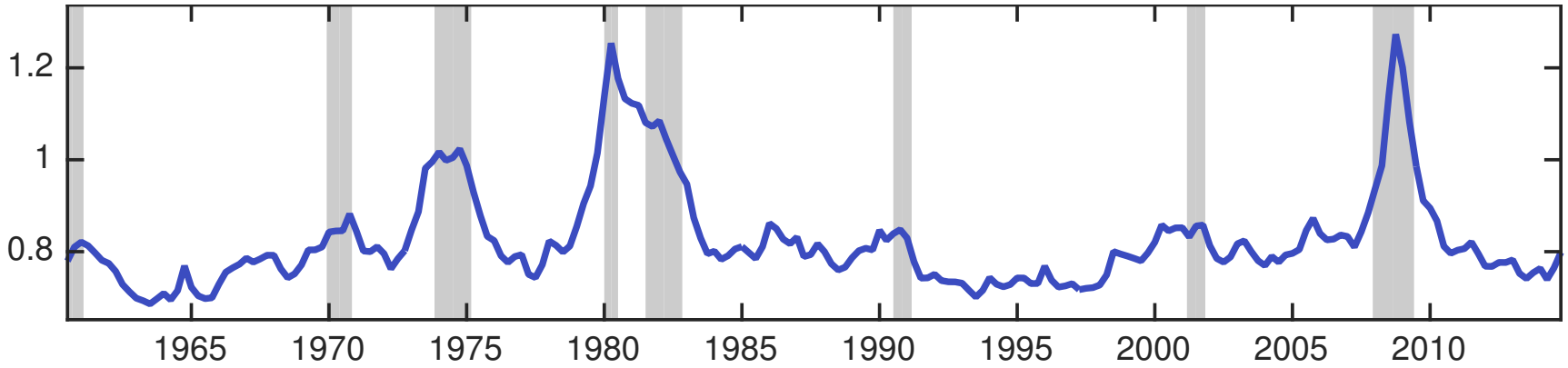

Figure: 3-month-ahead Aggregate Uncertainty Measure

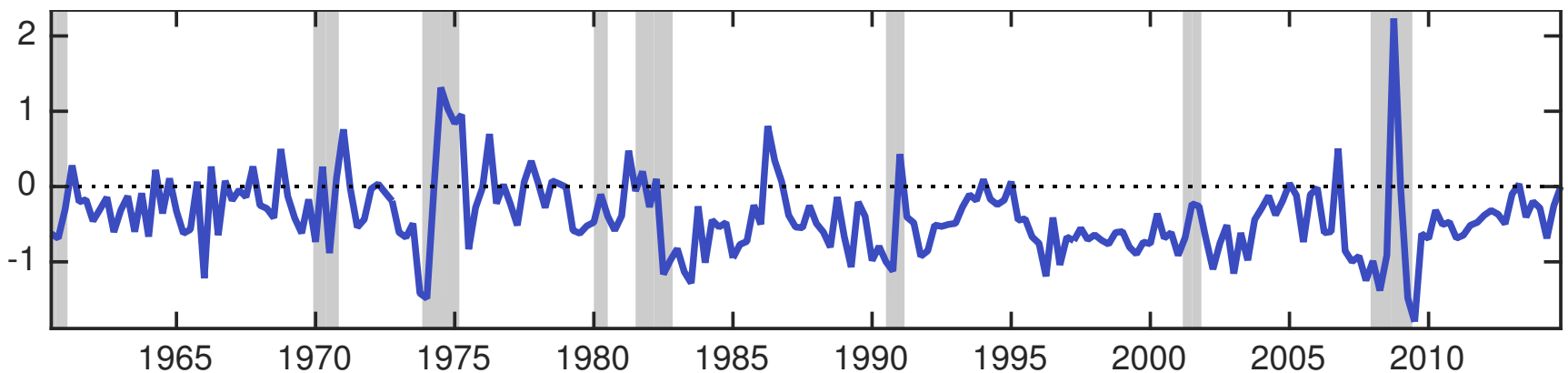

Figure: Percentage Changes in the Relative Price of Investment Goods

Asymmetric Sectoral Price Rigidity

- Sticky consumption-good prices and **flexible** investment-good (long-lived good) prices
- We tend to bargain over big-ticket long-lived items and their prices become effectively flexible (Barsky, House, Kimball, 2007).
- Bils et al. (2013):
  Residential housing and structure are flexibly priced.
- Bouakez et al. (2009) and Kim and Katayama (2013):
  Construction and durable-goods sectors have flexible prices.

Unexpected Outcomes in the Two-sector Setup

- One-sector setup: Basu and Bundick (2012)
  - Counter cyclical markup
  - Precautionary motives $\Rightarrow$ saving $\uparrow$ and labor supply $\uparrow$
- Precautionary labor supply = Favorable cost shocks to firms
- The relative price of investment goods $\downarrow$.
- Higher uncertainty reduces consumption, but raises investment.
  $\rightarrow$ Negative comovement problem
- $\uparrow$ in investment can dominate $\downarrow$ in consumption.
  $\rightarrow$ Uncertainty shocks can be expansionary!

Limited Factor Mobility

- Introduction of limited factor mobility can result in an *increase* in the relative price.
- Negative correlation between price and quantity of investment goods
- We can provide some empirical support for our story.

Proposed Mechanisms

- Real-options effects of uncertainty shocks in the presence of the non-convex nature of adjustment costs (investment and labor)
  - Bloom (2009)
  - Bloom et al. (2012)
- Precautionary motives with nominal rigidities
  - Basu and Bundick (2012): Technology and demand uncertainty shocks
  - Fernández-Villaverde et al. (2013): Fiscal volatility shock
  - Leduc and Liu (2015): Search friction

Empirical Results

"Standard" Quarterly Macro VAR

- Augment the specification of Christiano, Eichenbaum, and Evans (2005) by including the uncertainty measure and the relative price of investment good.
- The uncertainty measure of Jurado, Ludvigson and Ng (2015)
  - Longer time-series observations are available than other uncertainty measures.
  - Data-rich environment
  - Aggregated forecast uncertainties from FAVAR
- The relative price of investment goods to consumption goods as in Justiniano, Primiceri and Tambalotti (2011)

Other Measures

Setup

- VAR(4)
- Sample: 1960:Q3 – 2014:Q4
- Cholesky ordering:

1. The uncertainty measure
2. Per capita real GDP
3. Per capita real consumption
4. GDP deflator
5. Per capital real investment
6. Real wage
7. Labor productivity
8. The federal funds rate
9. Per capita real profits
10. M2 growth rate
11. The relative price of investment

- For the ZLB period (2009:Q1 – 2014:Q4), replace the FF rate by the Wu-Xia shadow rate.

Impulse Response Functions

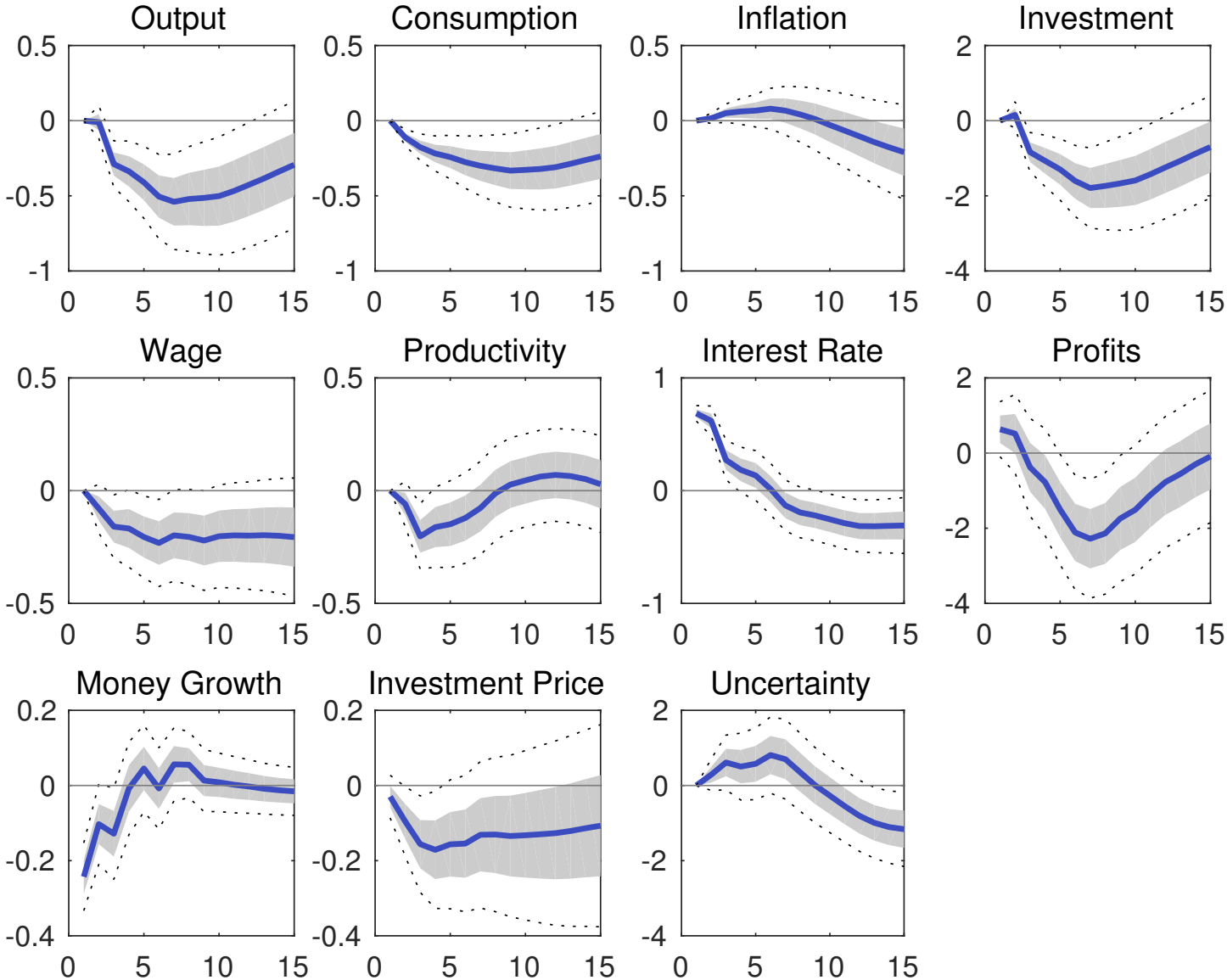

Figure: Responses to the Monetary Shock

Note: Shaded areas and dashed lines indicate ± 1 and ± 2 standard-deviation bands, respectively.

Impulse Response Functions

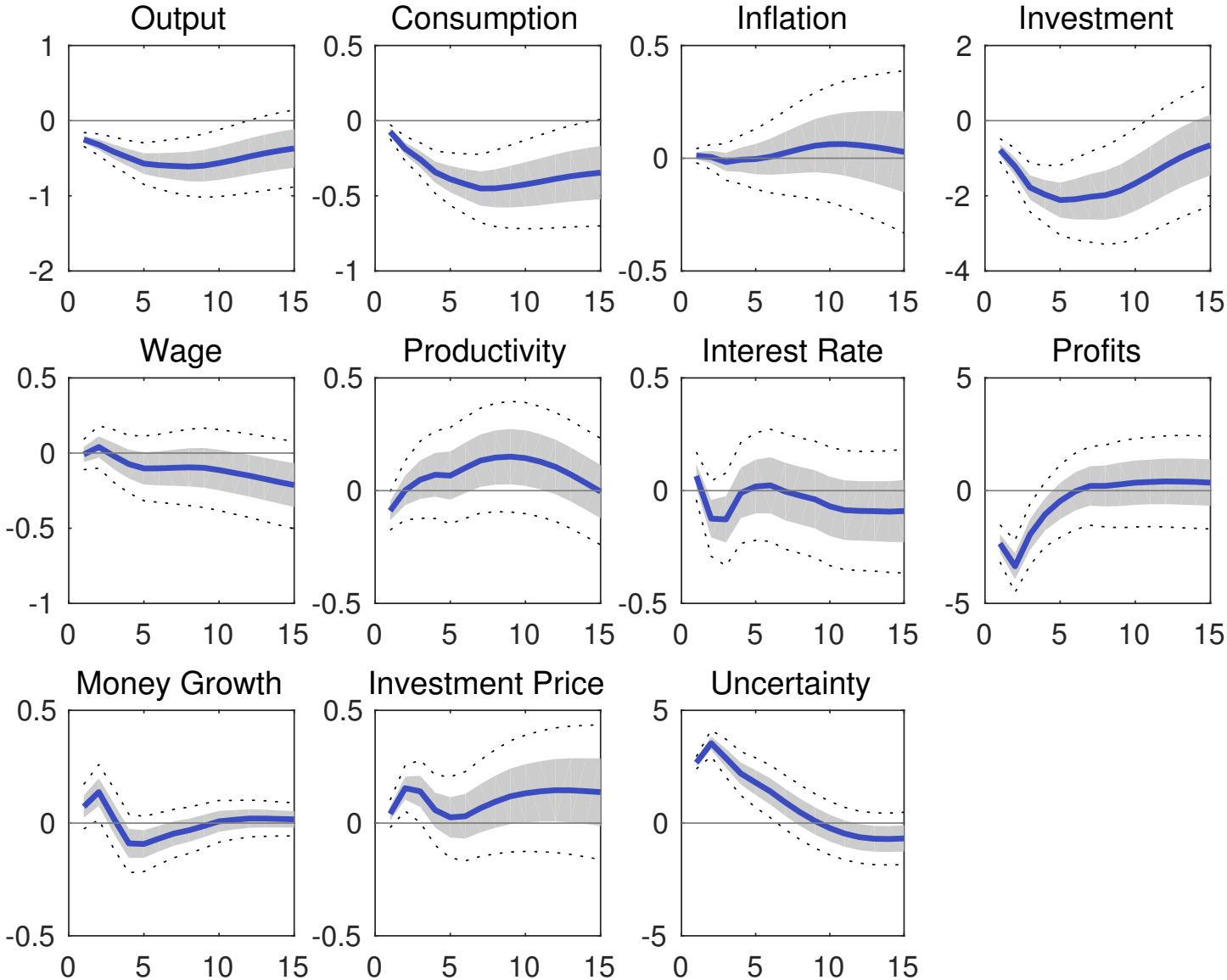

Figure: Responses to the Uncertainty Shock

Note: Shaded areas and dashed lines indicate ± 1 and ± 2 standard-deviation bands, respectively.

Robustness Check #1

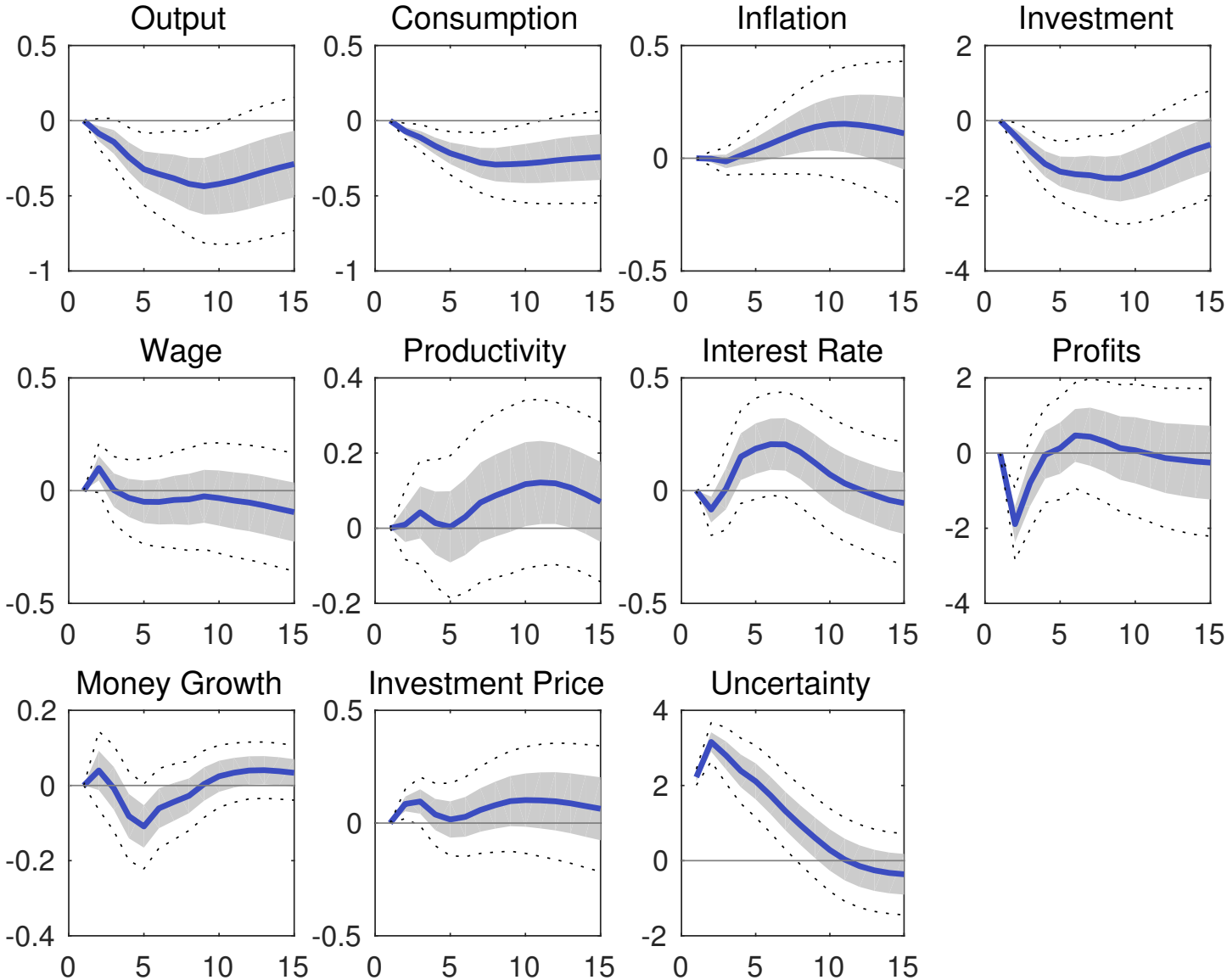

Figure: Response to the Uncertainty Shock (placing the uncertainty measure last)

Note: Shaded areas and dashed lines indicate ± 1 and ± 2 standard-deviation bands, respectively.

Robustness Check #2

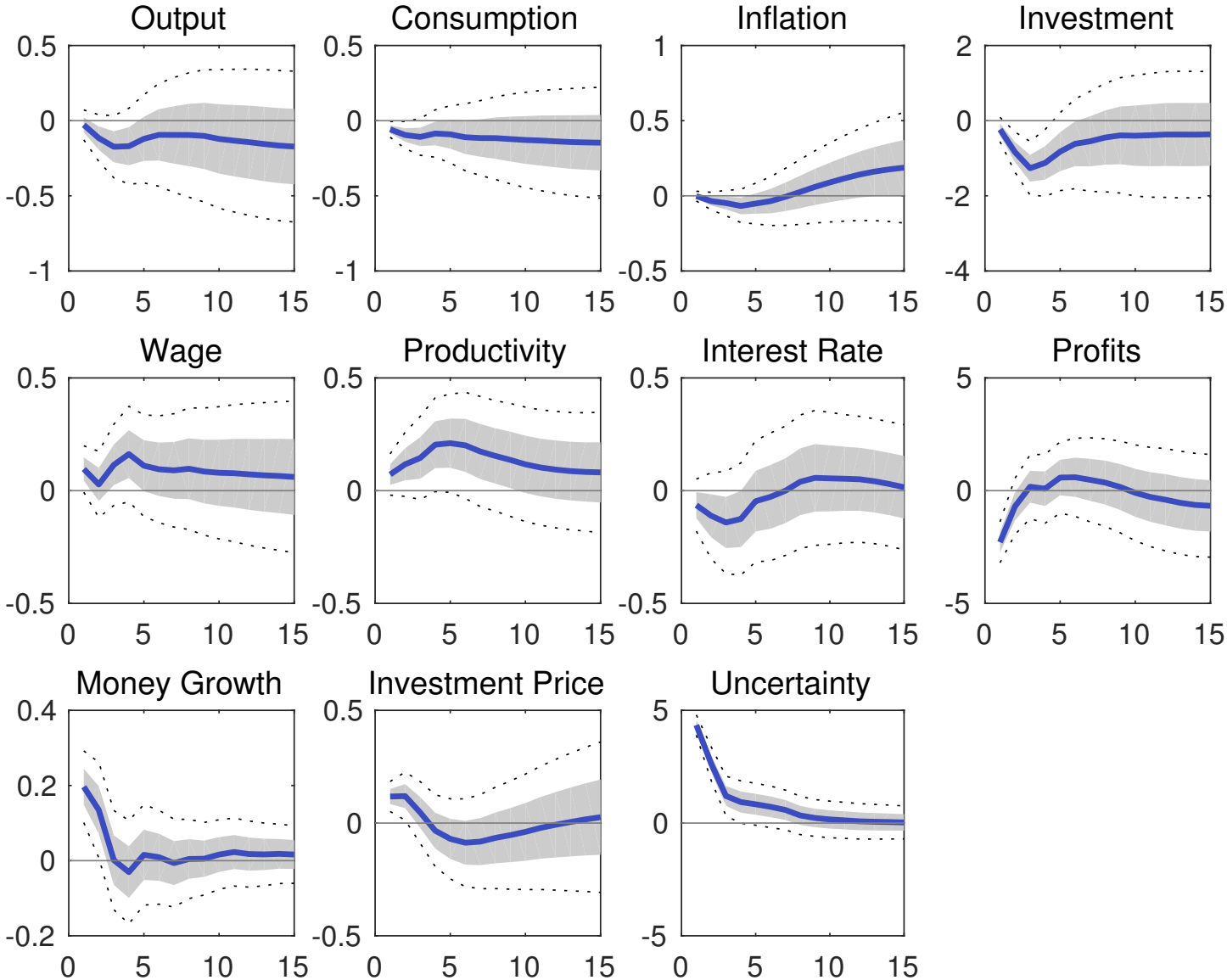

Figure: Response to the Uncertainty Shock with VIX

Note: Shaded areas and dashed lines indicate ±1 and ±2 standard-deviation bands, respectively.

VIX

Robustness Check #3

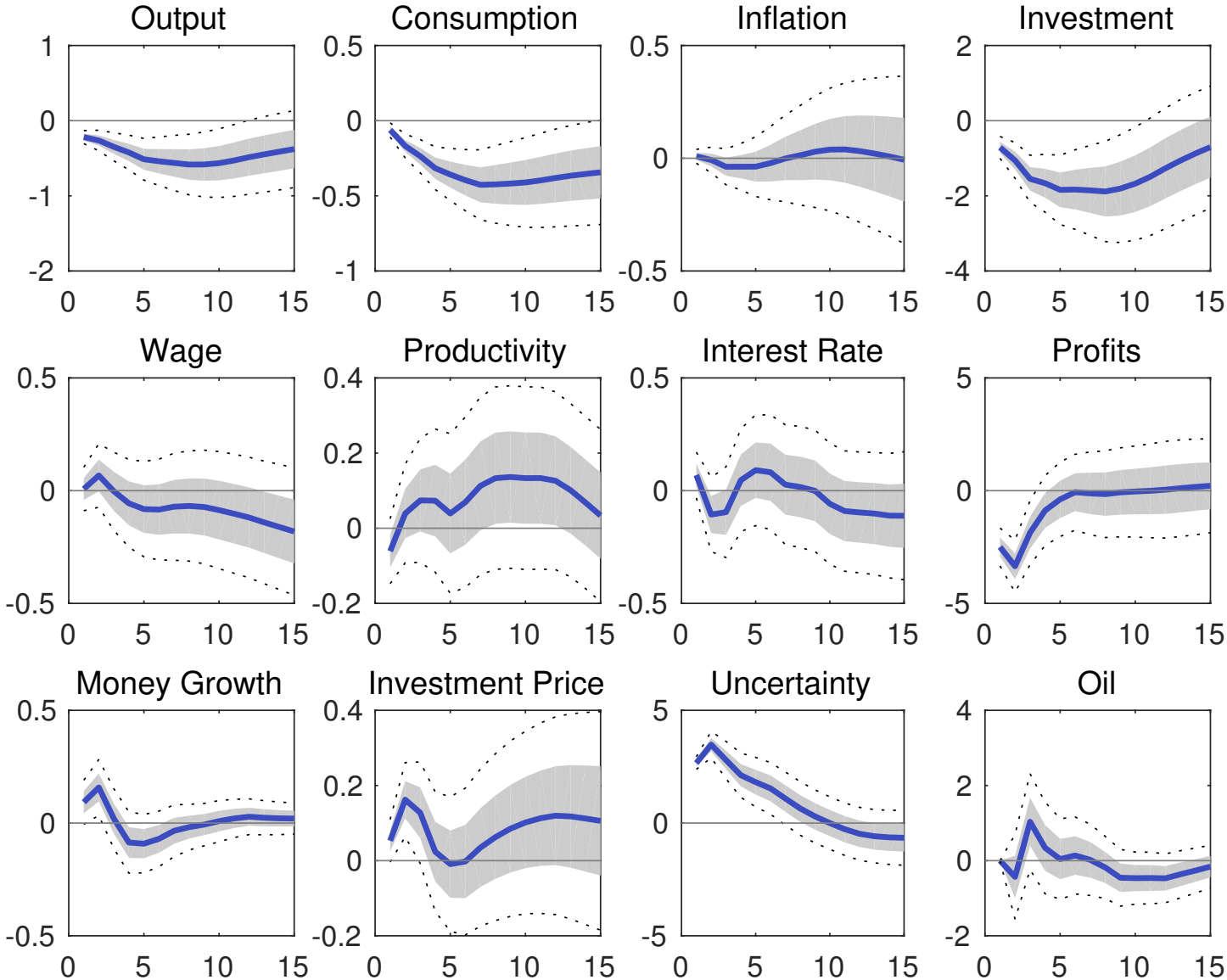

Figure: Response to the Uncertainty Shock with NOPI

Note: Shaded areas and dashed lines indicate ± 1 and ± 2 standard-deviation bands, respectively.

Summary of Empirical Findings

- The relative price of investment goes up.
  $\rightarrow$ Suggesting some heterogeneity in price rigidity

- Output, consumption, and investment (plus hours) show comovement.
  $\rightarrow$ A standard feature of business cycles

- Negative correlation between the price and quantity of investment
  $\rightarrow$ Looks like an adverse supply shock

Model

Overview of the Model

- Two-sector sticky-price model (consumption and investment sectors)
- Imperfect mobility of factor inputs across sectors
- Continuum of monopolistically competitive firms in each sector
- Quadratic price adjustment costs
- Taylor rule

Limited Inter-Sectoral Labor Mobility

- We assume

$$N_t = \left[N_{c,t}^{\frac{\theta+1}{\theta}} + N_{i,t}^{\frac{\theta+1}{\theta}} \right]^{\frac{\theta}{\theta+1}}, \quad \theta \geq 0. \tag{1}$$

- Huffman and Wynne (1999), Horvath (2000), and Katayama and Kim (2015)
- $\theta \geq 0$ controls the degree of inter-sectoral labor mobility.
- $\theta \to \infty$: Sectoral wages must be equalized.
- $\theta < \infty$: Wages are not equalized. Households prefer having diversity of labor.
- MRT

$$\left(\frac{N_{c,t}}{N_{i,t}} \right)^{1/\theta} = \frac{W_{c,t}}{W_{i,t}} \tag{2}$$

Imperfect Capital Mobility

- Sector-specific capital accumulation

$$K_{j,t+1} = I_{j,t}\left[1 - \phi\left(\frac{I_{j,t}}{I_{j,t-1}}\right)\right] + (1-\delta)K_{j,t}, \quad j = c, i,$$

where

$$\phi\left(\frac{I_t}{I_{t-1}}\right) = \frac{\kappa}{2}\left(\frac{I_t}{I_{t-1}} - 1\right)^2$$

is the investment adjustment costs.

Shock Process

- Technology uncertainty
- Stochastic volatility

$$A_t = (1 - \rho_a)A + \rho_a A_{t-1} + \sigma_t \epsilon_t \tag{3}$$
$$\sigma_t = (1 - \rho_\sigma)\sigma + \rho_\sigma \sigma_{t-1} + \sigma_\nu \nu_t \tag{4}$$

where A_t is the aggregate TFP, $\epsilon_t, \nu_t \sim N(0, 1)$

- ϵ_t = standard first-moment shock
- ν_t = second-moment or uncertainty shock

Analytical Discussion

- $P_{j,t} = \mu_{j,t} MC_{j,t} \quad$ for $j = c, i$.
- The relative price of investment goods

$$p_t = \frac{\mu_{i,t}}{\mu_{c,t}} \left(\frac{W_{i,t}}{W_{c,t}} \right)^{(1-\alpha)} \left(\frac{R^k_{i,t}}{R^k_{c,t}} \right)^{\alpha} \tag{5}$$

- Flexible-price investment sector: $\mu_{i,t} = \mu_i$
- Two competing factors:

  (1) $\uparrow$ in uncertainty $\Rightarrow$ precautionary labor supply $\Rightarrow$ $MC \downarrow \Rightarrow \mu_{c,t} \uparrow$

  (2) Lower demand for $C \Rightarrow (W_{i,t}/W_{c,t}) \uparrow$ and $(R^k_{i,t}/R^k_{c,t}) \uparrow$

- Perfect factor mobility: $p \downarrow$ only via **(1)**

More...

Responses with Imperfect Factor Mobility

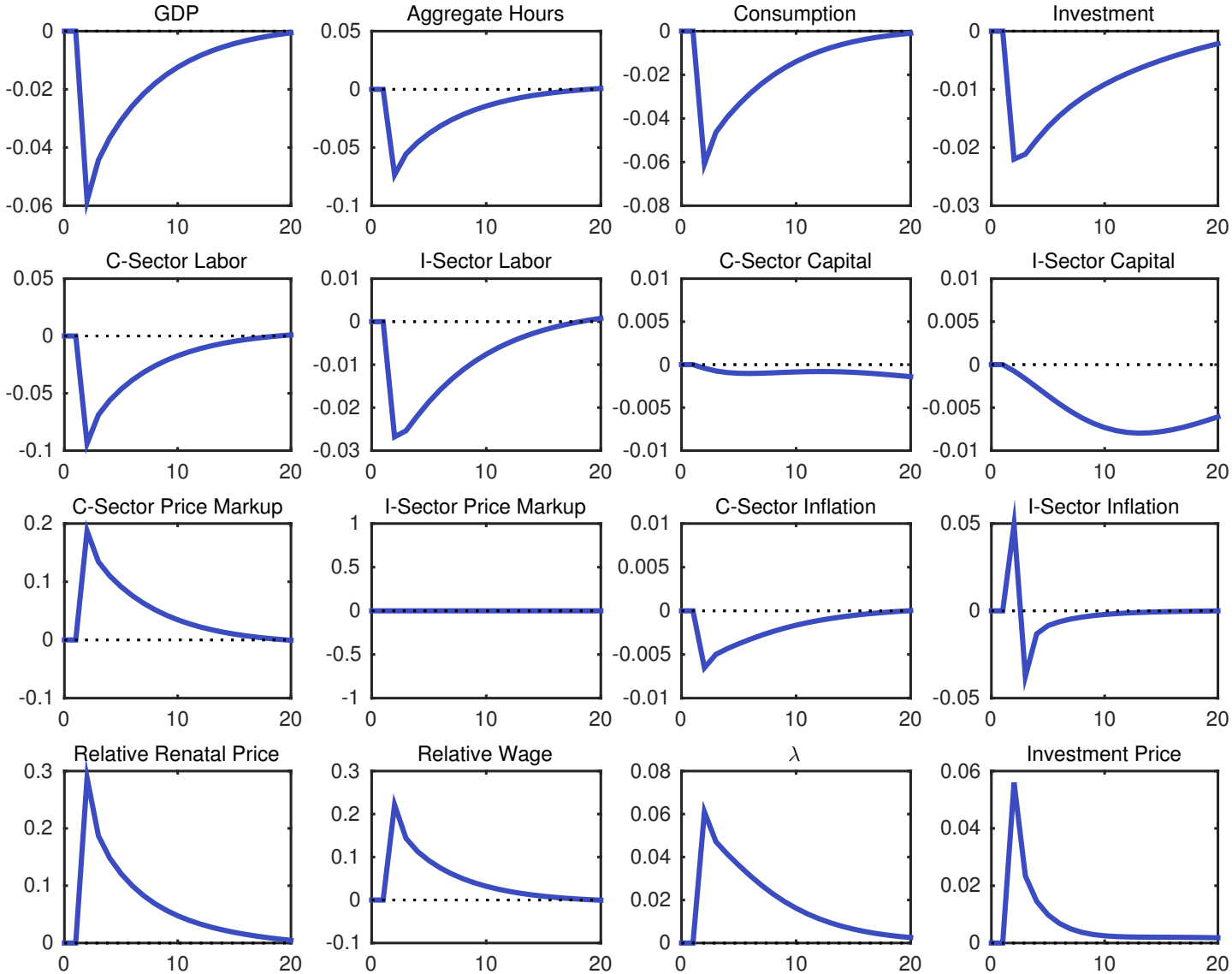

Figure: Responses to an Uncertainty Shock (% Deviation from the Ergodic Mean)

Note: We set $\theta = 0.3030$ based on Katayama and Kim (2015).

Problems with Perfect Factor Mobility

- Marginal costs are the same across sectors.
- Symmetric price rigidity: the relative price does not respond
- Flexible-price investment sector:
  - $\downarrow$ in p
  - Intertemporal substitution
  - Expansion in the investment-good sector
- Uncertainty shocks can be expansionary even when the majority of prices are sticky.
- Negative comovement problem (cf. Barsky, House, and Kimball, 2007)

IRFs with Perfect Factor Mobility

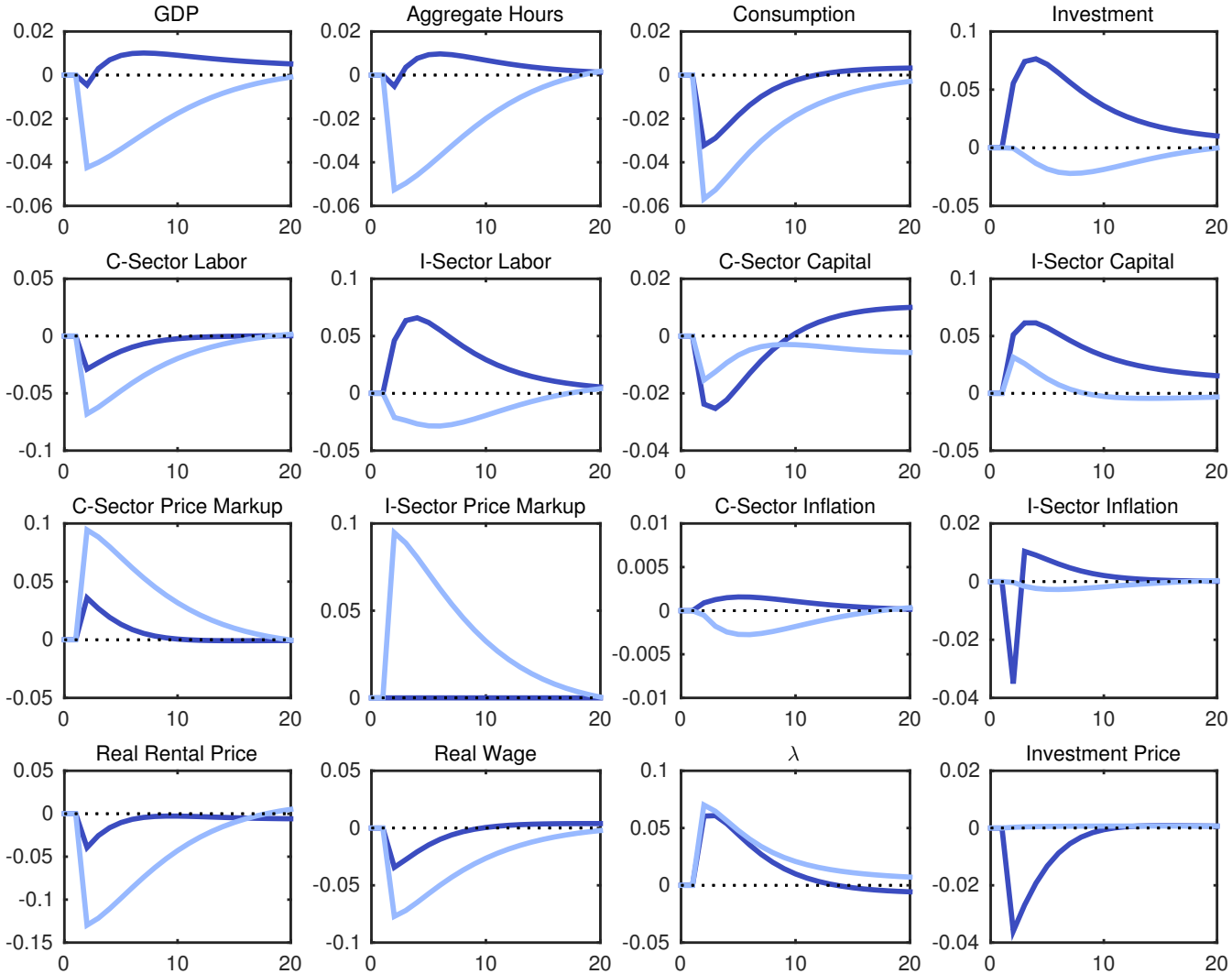

Figure: Responses to Uncertainty Shock (% Deviation from the Ergodic Mean)

Note: Dark blue lines correspond to IRFs with $\phi_{p_c} = 160$ and $\phi_{p_i} = 0$. Light blue lines represent those with $\phi_{p_c} = \phi_{p_i} = 160$.

Robustness Check

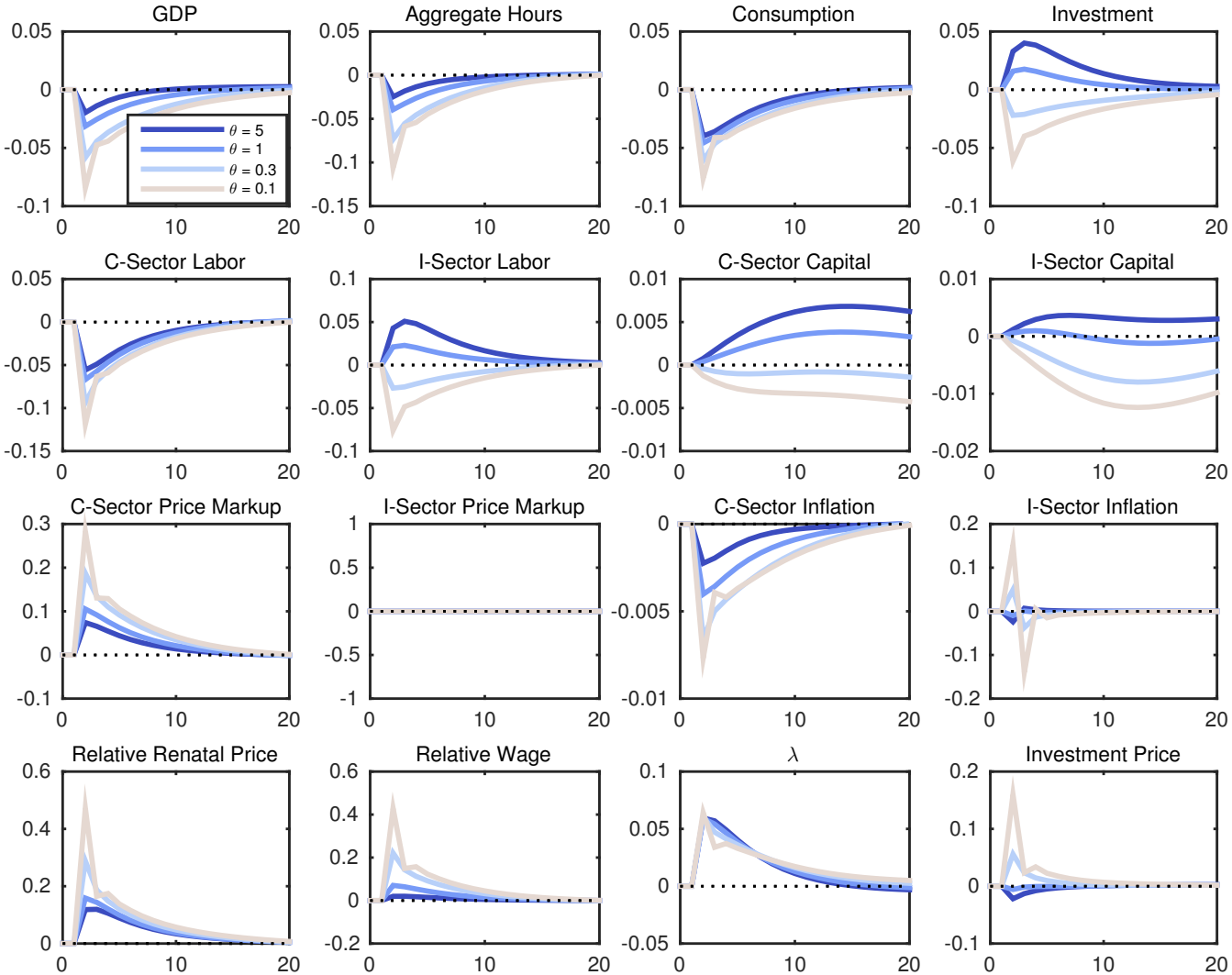

Figure: Responses to Uncertainty Shock (% Deviation from the Ergodic Mean)

Note: The value of θ becomes smaller as the color of lines gets lighter from $\theta = 5$ to $\theta = 0.1$.

Validity Check

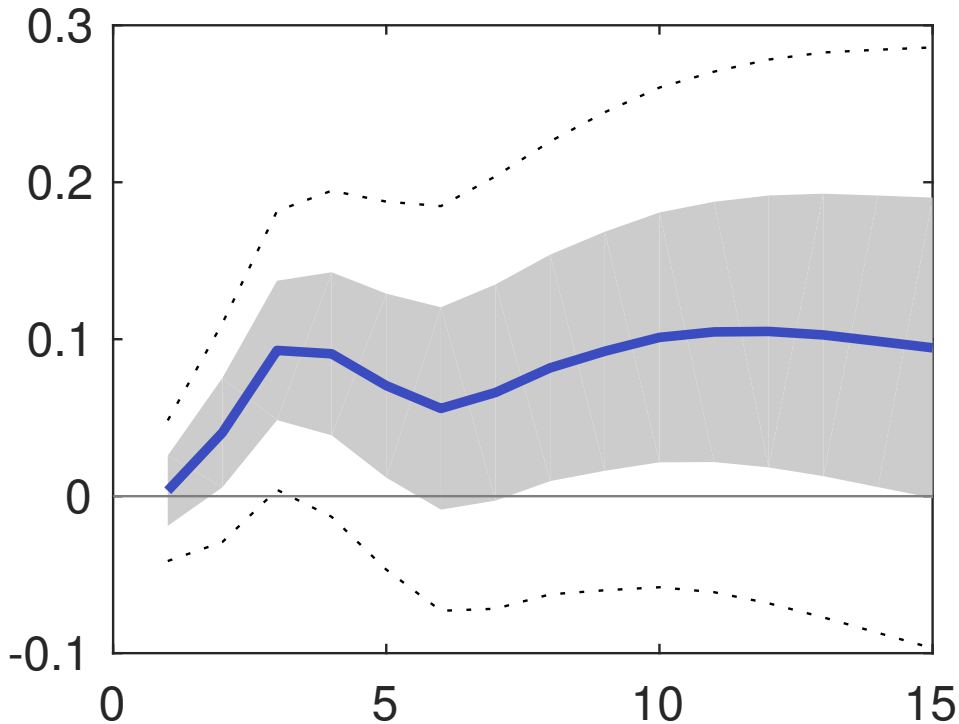

Figure: Estimated Responses of Relative Wage (W_i/W_c)

Note: Shaded areas and dashed lines indicate ± 1 and ± 2 standard-deviation bands, respectively.

Limited Factor Mobility

Limited Labor Mobility:

- Consistent with persistent sectoral wage differential (e.g., Krueger and Summers, 1988; Neumuller, 2015).
- Davis and Haltiwanger (2001): limited labor mobility across sectors in response to monetary and oil shocks
- Horvath (2000) and Katayama and Kim (2015): a relatively low estimate for the elasticity of substitution of labor across sectors
- Beaudry and Portier (2011): the returns to labor between individuals initially attached to different sectors are not equalized.

Limited Capital Mobility:

- Ramey and Shapiro (2001): the high costs associated with reallocating capital across sectors

Remaining Issues

- Investment responds less to the uncertainty shock than consumption.
- Theoretical impulse responses appear to be small and might not be a main driving force of business cycles.
  $\rightarrow$ Need to incorporate the ZLB (cf., Basu and Bundick, 2015)?
- Hump-shaped responses

Conclusion

- The relative price of investment good increases when we face greater uncertainty.
- The negative correlation between price and quantity of investment contrasts with the real-options effect.
- Typical two-sector models fail to replicate the observed patters with flexible investment price.
- Imperfect factor mobility makes uncertainty shocks behave like adverse supply shocks in the two-sector setup.