Investment-specific Technology Shocks, Neutral Technology Shocks and the Dunlop-Tarshis Observation: Theory and Evidence

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INTRODUCTION

The Dunlop-Tarshis observation is key for business cycle research

- near orthogonality between hours worked and real wages, and between hours worked and aggregate labor productivity at the business cycle frequencies
- picture
- often seen as a litmus test of “reasonable” business cycle theories
- appears contrary to much of the technology driven business cycle literature

INTRODUCTION

It is a puzzle for RBC style theories and Keynesian style theories because:

- **RBC style theories** rely on an aggregate productivity shocks: shift labor demand and therefore gives rise to positive hours-productivity (- real wage) comovements
- **Keynesian style theories**: contradicts the simplest sticky wage story which would imply negative real wage comovements

INTRODUCTION

It has been the concern of much research in the recent business cycle literature

- mix of labor demand and labor supply shocks (Christiano and Eichenbaum, 1992, Braun, 1994, McGrattan, 1994): Fiscal impulses
- indivisible labor (Hansen, 1986): High labor supply elasticity
- home-production theories (Benhabib, Rogerson and Wright, 1992): modified labor supply responses to technology shocks

THIS PAPER

Three aims:

1. Look at conditional correlation structures: How do hours and productivity comove conditional on shocks?
    - Neutral permanent technology shocks
    - Investment-specific technology shocks
2. Look at sectoral aspects:
    - Consumption sector vs. investment sector
3. Contrast conditional and sectoral results with economic theory

EMPIRICS

We investigate US quarterly data

- 1960-2003 sample

We use a structural VAR approach to identify two types of technology shocks:

- neutral permanent technology shocks
- investment-specific permanent technology shocks

We then examine the impact of these identified shocks on aggregate and sector level variables

SVAR

We estimate the following VAR:

$$X_t = k + B(L)X_{t-1} + e_t$$

$$X_t = \left[\Delta p_t^{\,i}, \Delta a_t, h_t, c_t^{\,n} - y_t^{\,n}, i_t^{\,n} - y_t^{\,n}\right]'$$

- p_t^i: the log of the investment to consumption price
- a_t: the log of aggregate labor productivity
- h_t: the log of hours worked
- c_t^n-y_t^n: the log of nominal consumption expenditure to nominal output
- i_t^n-y_t^n: the log of nominal investment to nominal output
- k: constants and trends

SVAR

The two shocks are identified assuming

1. Only permanent investment-specific technology shocks can affect long-run level of relative investment price
2. Only permanent investment-specific technology shocks and permanent neutral technology shocks can affect long-run level of aggregate labor productivity

$$\beta_0 X_t = \kappa + \sum_{i=1}^{P} \beta_i X_{t-i} + \varepsilon_t$$

Estimated using Shapiro-Watson 2SLS + triangular 2SLS estimation procedure

SVAR

Having estimated the two shocks, we then estimate their impact on sectoral variables from:

$$\tilde{h}_t^s = \alpha_n + \sum_{i=1}^{P} \beta_i^h y_{t-i} + \sum_{i=1}^{P} \gamma_i^h \tilde{h}_{t-i}^s + \mu_t$$

h_t^s denotes detrended hours worked in sector s

- consumption sector (non-durables)
- investment sector (durables)

y_t denotes the vector of identified shocks

RESULTS

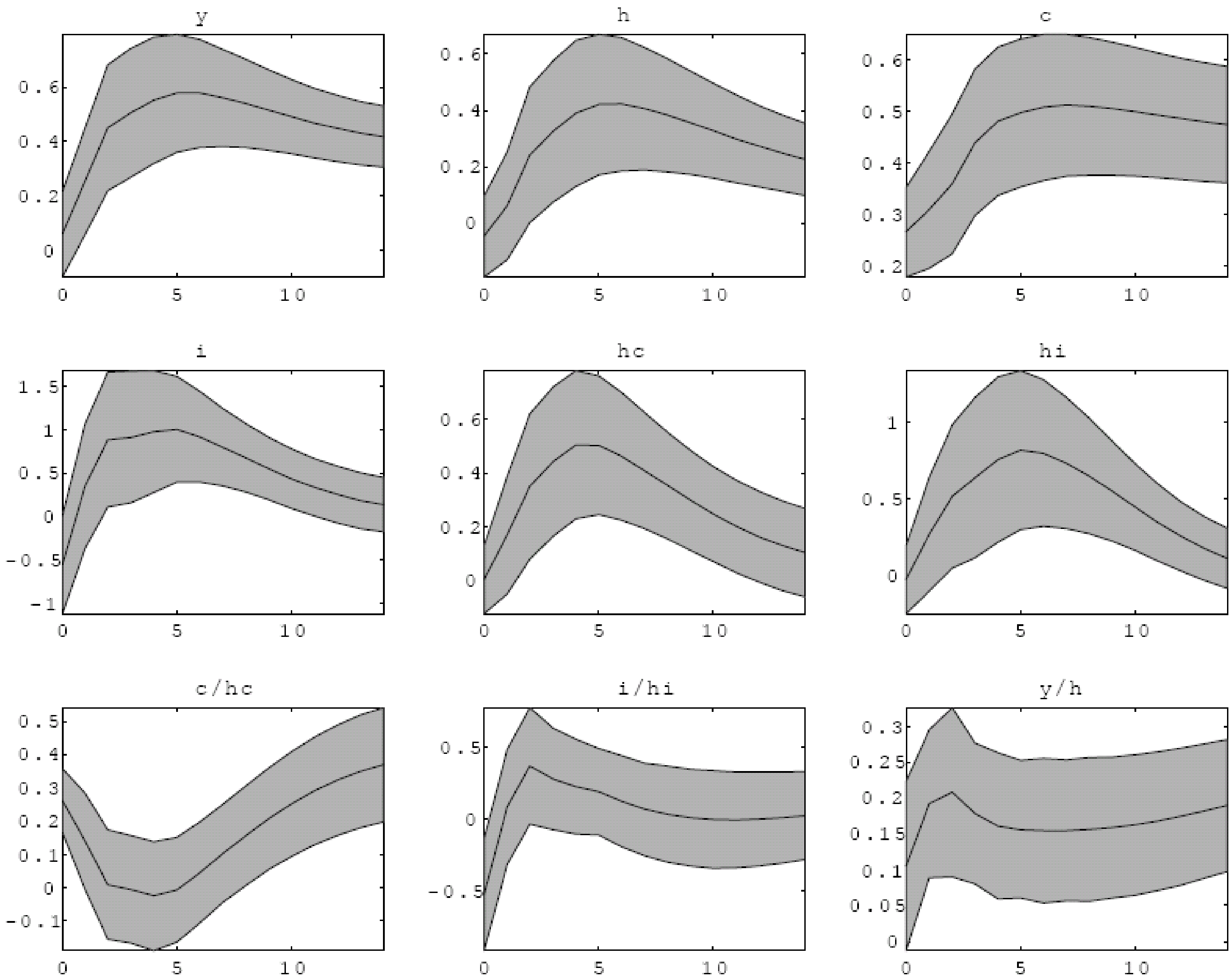
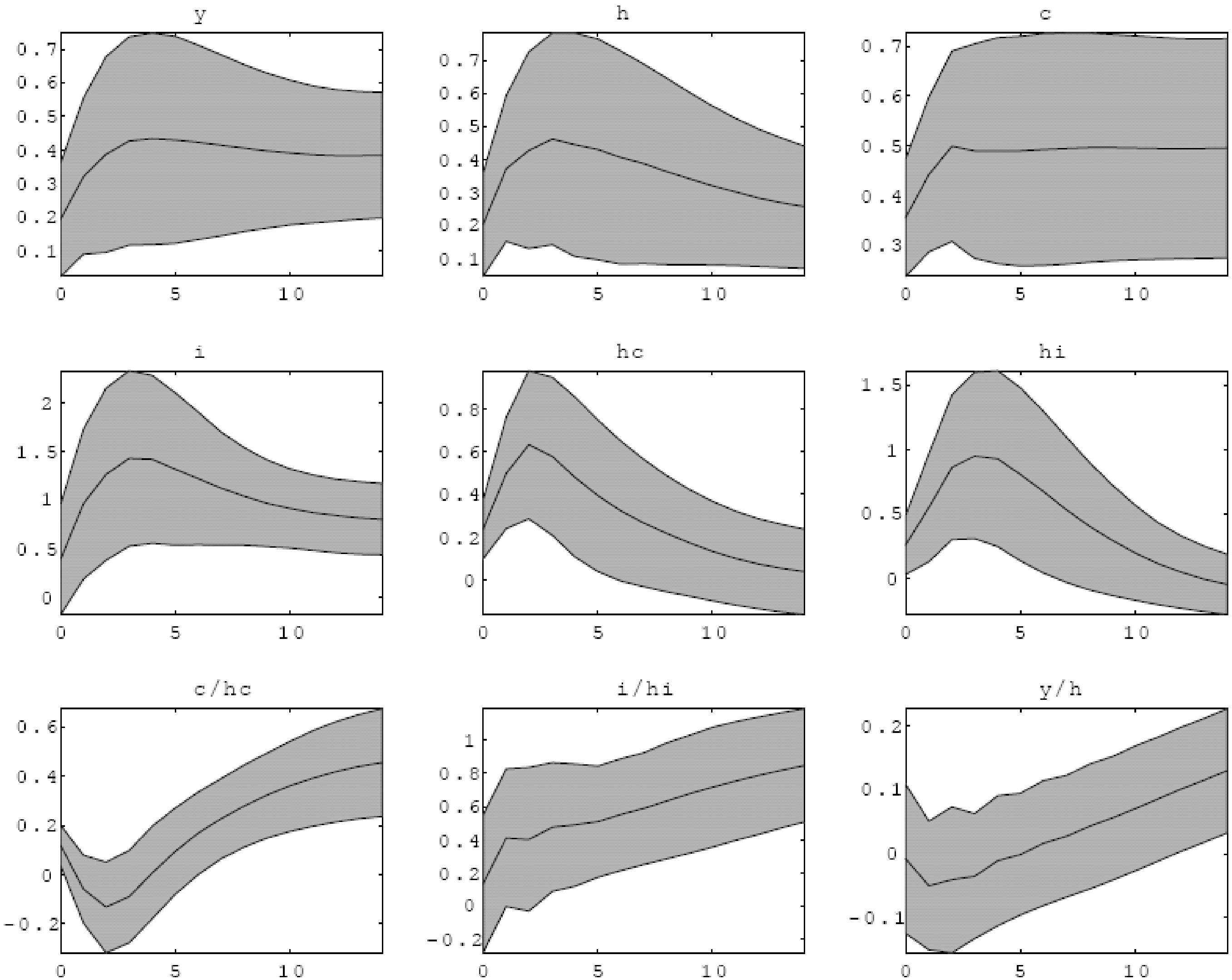


Figure 1: The Impact of a Neutral Technology Shock

RESULTS



The Impact of an Investment Specific Technology Shock

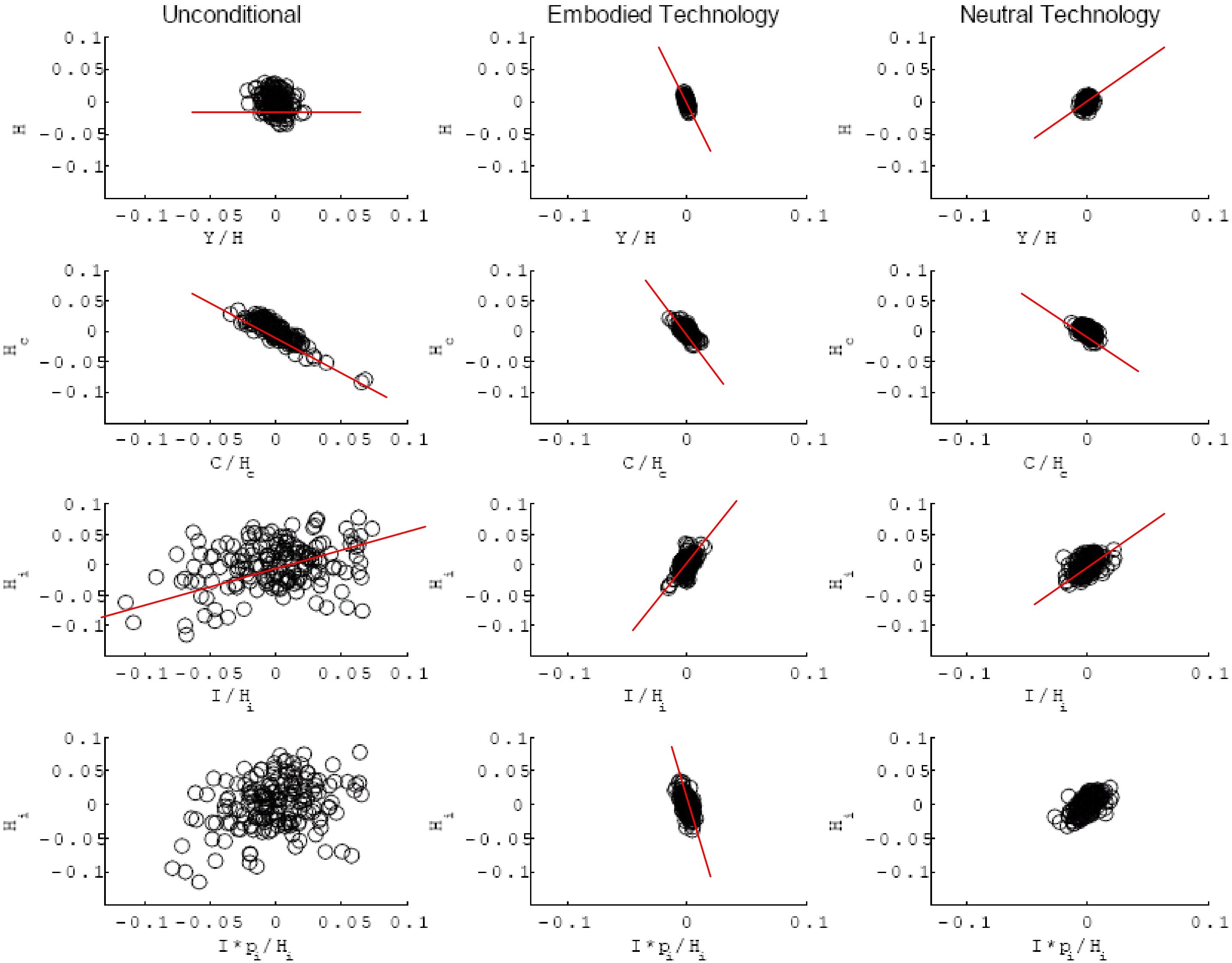
THE HOURS-PRODUCTIVITY RELATIONSHIP

Aggregate

Consumption

Investment in quantities

Investment with relative price adjustment



MOMENTS

Table 2: Hours and Productivity Correlations: US Data

	Unconditional	Conditional upon: Investment specific shock	Neutral shock	Both
Aggregate	-0.09	-0.85	0.47	0.04
Consumption Sector	-0.90	-0.77	-0.65	-0.74
Durables Sector	0.31	0.63	0.47	0.58
Durables sector with price adjustment	0.28	-0.65	0.63	0.21

The numbers refer to Hodrick-Prescott filtered variables. The conditional correlations are computed from simulations of the counterfactuals.

Aggregate:

- Large negative correlation conditional upon investment-specific shocks.
- Large positive correlation conditional upon neutral shocks

Sector level:

Consumption sector: Negative comovements

Investment sector:

- quantities: positive comovements
- with price adjustment: as in the aggregate

EVIDENCE

In summary:

- The Dunlop-Tarshis observation holds unconditionally in the aggregate but:
  - it does not hold unconditionally at the sector level
  - it does not hold conditionally on neutral and investment-specific technology shocks
    - systematic relationships in the aggregate
    - systematic relationships at the sector level
- **Implication**: Theory should not decouple hours and productivity

THEORY

We examine business cycle version of Greenwood, Hercowitz, and Krusell (1997) two-sector economy:

- **consumption goods producing sector** – goods are non-storable
- **investment goods sector** – goods cannot be consumed
  - both sectors are competitive
- **neutral and investment specific technology shocks**
- costs of adjustment related to variations in capital stocks and in hours worked
- variable capacity utilization

PREFERENCES

Households are assumed to be infinitely lived, have rational expectations, and their preferences are given as:

$$V_0 = E_0 \sum_{t=0}^{\infty} \beta^t \left(C_t^{1-\sigma} / (1-\sigma) - \frac{\phi}{1+\kappa} s_{1t}^{1-\sigma} \left(n_{c,t} + n_{i,t} \right)^{1+\kappa} \right)$$

- $1/\sigma$ is the intertemporal elasticity of substitution
- $1/\kappa$ is the inverse of the aggregate labor supply elasticity
- s_{1t} is a growth factor that is included to guarantee the existence of a balanced growth path

TECHNOLOGIES

The production technologies are given as:

$$C_t = A_1 z_t \left(u_{c,t} K_{c,t}\right)^{\alpha_c} \left(h_{c,t}\right)^{1-\alpha_c}$$

$$I_t = A_2 z_t x_t \left(u_{i,t} K_{i,t}\right)^{\alpha_i} \left(h_{i,t}\right)^{1-\alpha_i}$$

z_t: **Neutral technology shock** that affects both sectors simultaneously

x_t: **Investment-specific technology shock** that affects the investment sector only

Investment goods cannot be consumed and consumption goods cannot be invested:

$$I_t = I_{c,t} + I_{i,t}$$

ADJUSTMENT COSTS

We assume that it is costly to vary capital and labor inputs:

$$h_{s,t} = \left(1 - F_s\left(n_{s,t} / n_{s,t-1}\right)\right) n_{s,t}$$

$$K_{s,t+1} = \left(1 - \delta_s - \Lambda_s\left(u_{s,t}\right)\right) K_{s,t} + I_{s,t} - G_s\left(I_{s,t} / K_{s,t}\right) K_{s,t}$$

Where *F* and *G* are assumed to be such that there are no adjustment costs along the balanced growth path

These costs are needed to limit the extent to which factors of production can instantaneously be reallocated across sectors

- the model would be counterfactual without such costs of adjustment

OUTPUT AND TECHNOLOGY GROWTH

Aggregate output and the technology processes are:

$$Y_t = C_t + P_t I_t$$

$$z_t = z_{t-1} \gamma_z^{1-\rho_z} \left(z_{t-1} / z_{t-2} \right)^{\rho_z} \exp\left(\varepsilon_t^{\,z} \right)$$

$$x_t = x_{t-1} \gamma_x^{1-\rho_x} \left(x_{t-1} / x_{t-2} \right)^{\rho_x} \exp\left(\varepsilon_t^{\,x} \right)$$

Growth in technology leads to growth in:

- output and consumption
- investment and capital stocks
- relative investment price

MODEL VS. DATA

In order to assure that only investment-specific shocks have permanent effects on relative investment price we assume:

$$\alpha_c = \alpha_i \ \text{ and } \ \varepsilon_t^{c} \perp \varepsilon_t^{i}$$

However: We still do not know

- Is the model consistent with the dynamic impact of neutral and investment-specific technology shocks on aggregate variables?
- Is the model consistent with the dynamic effects of technology shocks on sector level variables?

STRUCTURAL ESTIMATION

In order to evaluate the model, we need to parametrize it:

- Θ_1: Parameters that we calibrate
- Θ_2: Parameters that we estimate

The estimation is done by limited information approach:

$$\Theta_2 = \arg\min_{\Theta_2} \left(IR^{data} - IR^{theory}\left(\Theta_2 \mid \Theta_2\right)\right)' W \left(IR^{data} - IR^{theory}\left(\Theta_2 \mid \Theta_2\right)\right)$$

IR^{data}: The empirical estimates of the impact of technology shocks

IR^{theory}: The impact of the shocks in the model given the parameters

W: A weighting matrix

PARAMETERS

Table 3: Calibrated Parameters

Parameter	Meaning	Value	Calibration
α	Capital share	0.36	Calibrated to capital income share estimate
γ_z	Steady-state growth rate of neutral technology	1.0004	Calibrated to average trend growth rate of output
γ_z	Steady-state growth rate of inv.spec. technology	1.0076	Calibrated to trend change in relative investment price
β^*	Effective subjective discount factor	0.99	Calibrated to imply 4% annual real interest rate in steady state
ϕ	Utility weight	4.18	Calibrated to be consistent with $\overline{n}_c+\overline{n}_i= 0.30$
$\Lambda_c'(1)$	Marginal impact of utilization rate of depreciation of capital stock in consumption sector	0.048	Calibrated to be consistent with $\overline{u}_c= 1$
$\Lambda_i'(1)$	Marginal impact of utilization rate of depreciation of capital stock in investment sector	0.048	Calibrated to be consistent with $\overline{u}_i= 1$
δ	Depreciation rate at normal rate of capacity utilization	0.025	Calibrated to imply 10 percent annual depreciation in steay state

Table 4: Parameter Estimates

Parameter	Meaning	Estimate	Standard error
σ	Inverse of intertemporal elasticity of substitution	3.322	0.011
κ	Inverse of Frisch elasticity	0.0001	-
$F_c''(\overline{n}_c)$	Adjustment costs of labor, consumption sector	0.001	-
$F_i''(\overline{n}_i)$	Adjustment costs of labor, investment sector	0.421	0.008
$G_c''\left(\overline{K}_c/\overline{I}_c\right)$	Adjustment costs of capital, consumption sector	0.0001	-
$G_i''\left(\overline{K}_i/\overline{I}_i\right)$	Adjustment costs of capital, investment sector	24.07	0.189
$\Lambda_c''(1)/\Lambda_c'(1)$	Elasticity of impact of utilization on depreciation in consumption sector	0.117	0.001
$\Lambda_i''(1)/\Lambda_c'(1)$	Elasticity of impact of utilization on depreciation in investment sector	0.001	-
ρ_z	Persistence of growth rate of neutral technology	0.177	0.001
ρ_x	Persistence of growth rate of inv.spec. technology	0.050	0.002
μ_z	Standard deviation of neutral technology shock innovations	0.069	0.0002
μ_x	Standard deviation of inv.spec. technology shock innovations	0.706	0.002

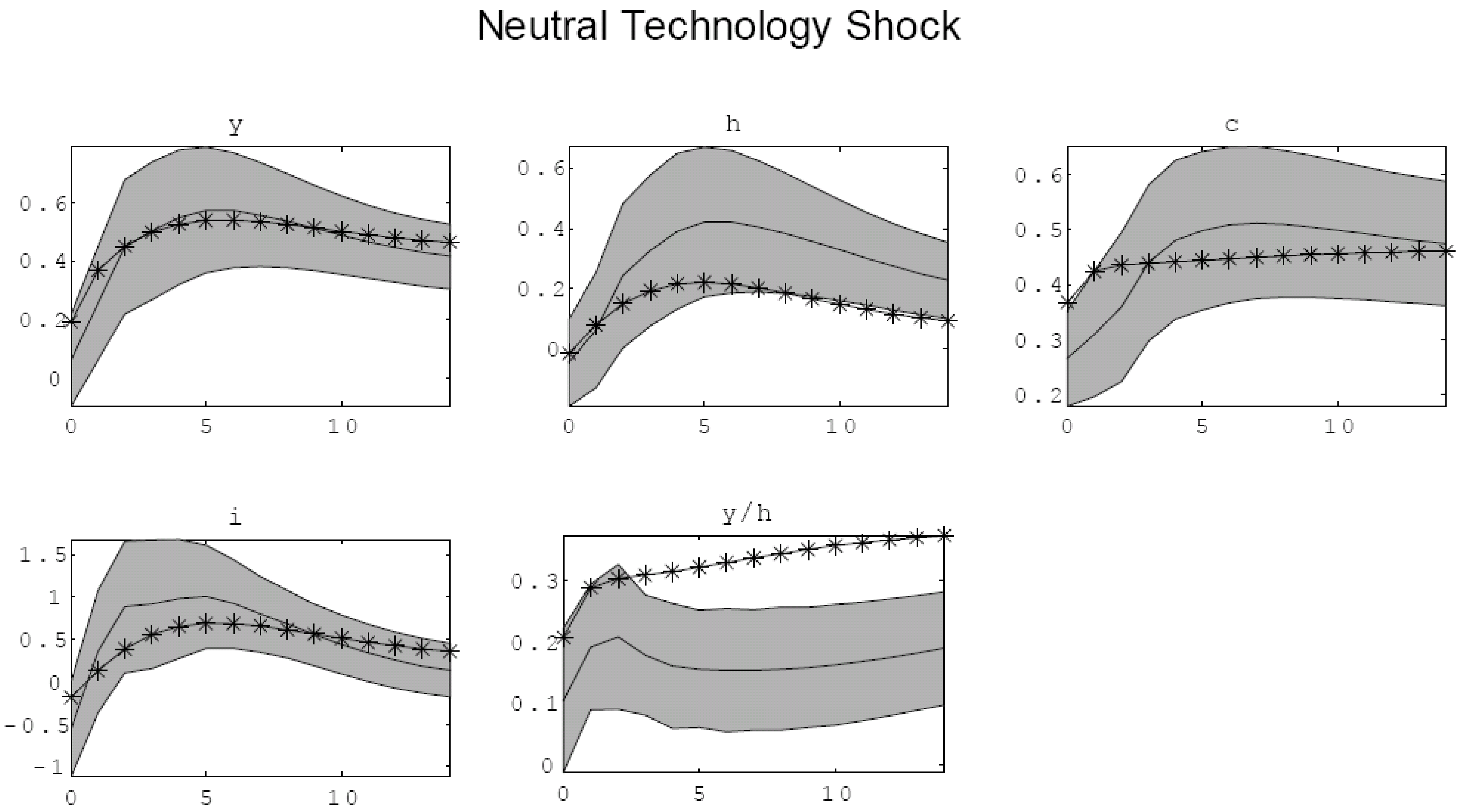
Indivisible labor

High adjustment costs in investment sector

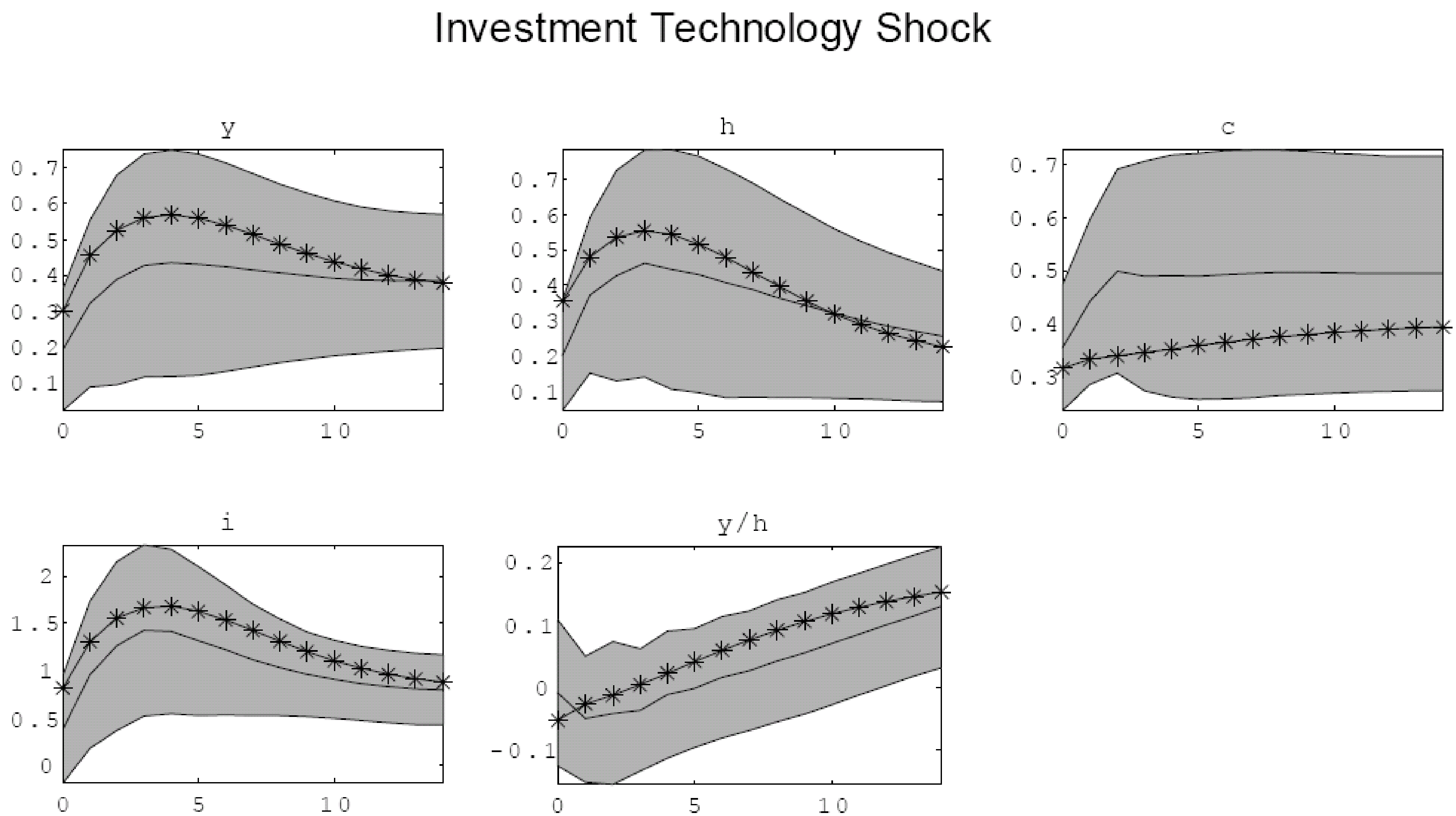
Higher persistence of neutral shocks

Investment-specific shocks much more volatile

THE MODEL VS. DATA



MODEL VS. DATA



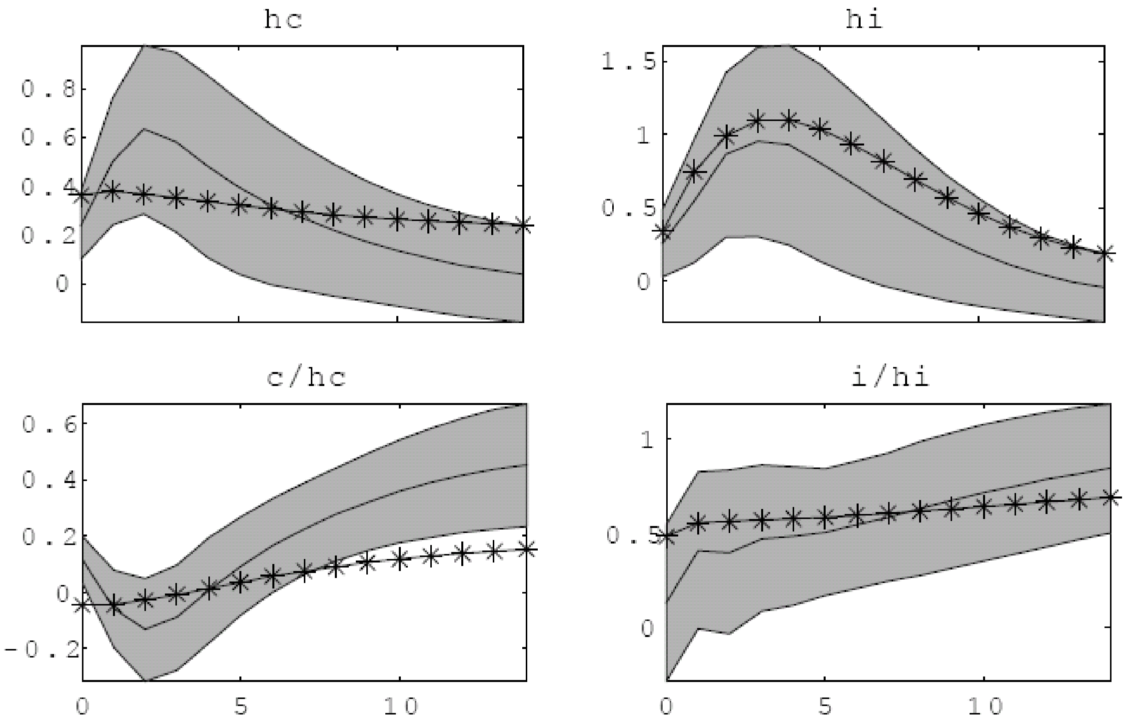
MODEL VS. AGGREGATE DATA

The model does a great job of accounting for most of the aggregate dynamics:

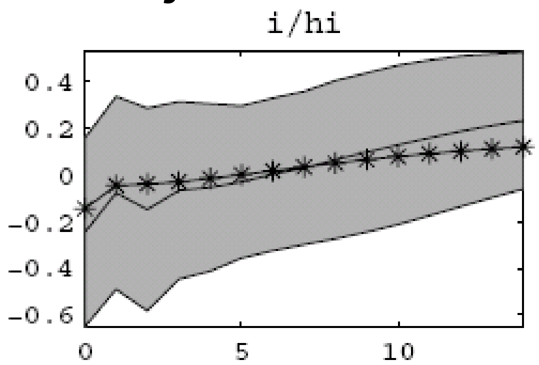
- very precise estimates of the impact of the two technology shocks on
  - output
  - consumption
  - investment
  - hours worked
- slightly worse in terms of neutral technology shocks on labor productivity

MODEL VS. DATA

Investment-specific shock



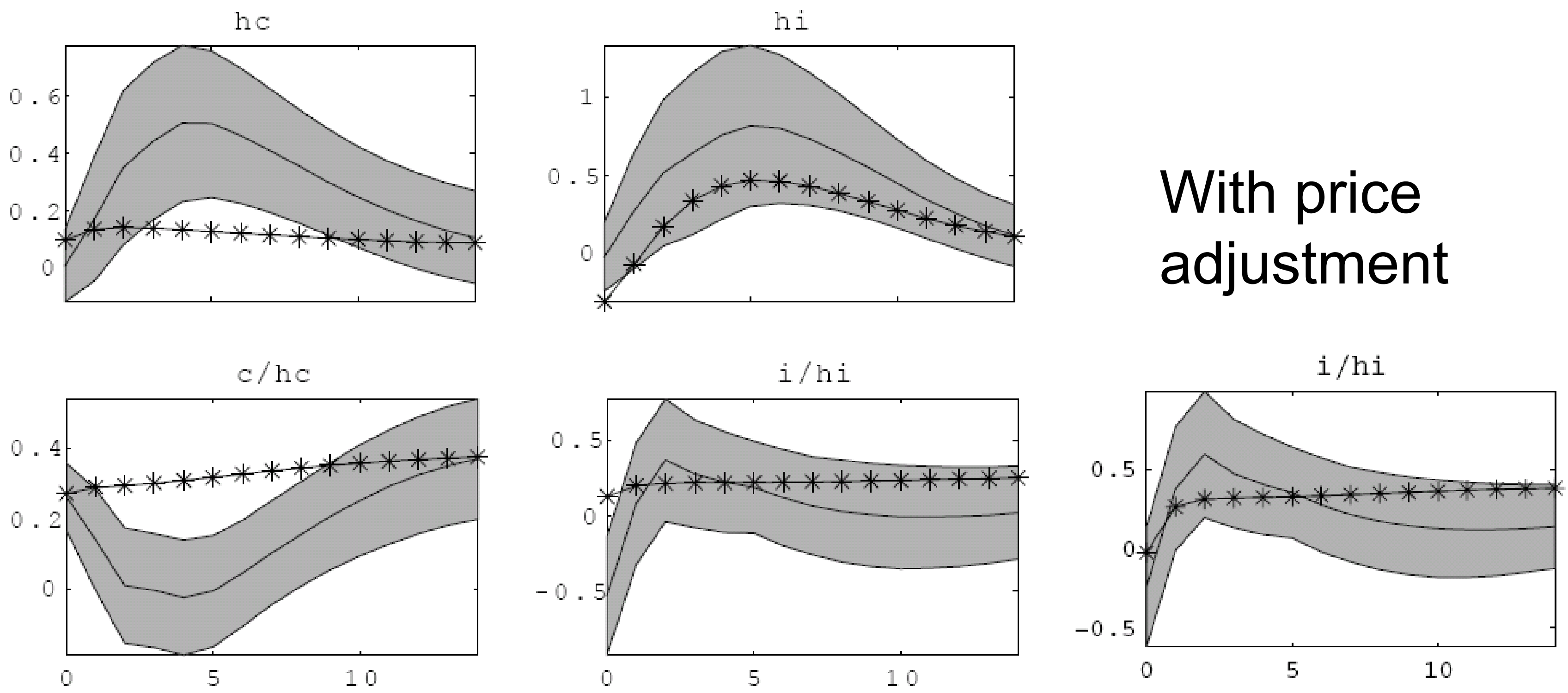
With price adjustment



Precise estimates of the impact of investment-specific shocks

MODEL VS. DATA

Neutral technology shock



With price adjustment

Here the fit is worse in terms of impact on consumption sector

DUNLOP-TARSHIS OBSERVATION

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Table 5: Hours and Productivity Correlations: Benchmark Model

	Conditional upon		
	Investment specific shock	Neutral shock	Both
Aggregate	-0.53	0.75	0.52
Consumption Sector	-0.68	0.93	0.53
Durables Sector	0.83	0.66	0.53
Durables sector with price adjustment	-0.50	0.72	0.52

The numbers refer to Hodrick-Prescott filtered variables. The conditional correlations are computed from simulations of the model.

WHAT’S MISSING?

The model provides a motive for reallocation of labor but:

- does not introduce further sector specificities such as skill differences across sectors
    - durables wages around 15-20 % higher than consumption sector (and sector premium is procyclical)
    - in booms: skilled labor flows from consumption to investment sector
    - left for future research

CONCLUSIONS

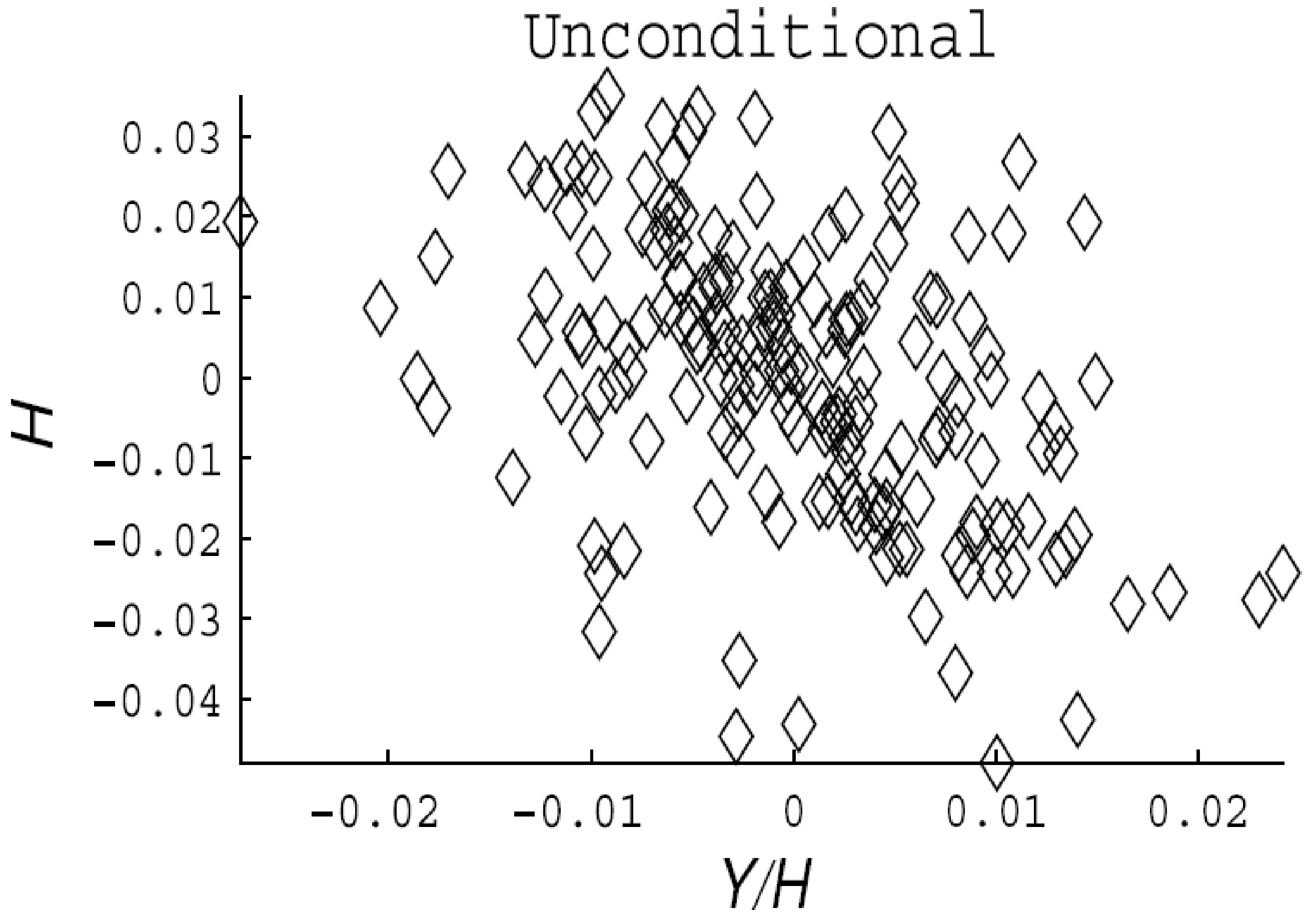
We have shown:

1. While hours and productivity are nearly orthogonal at the business cycle frequencies, the conditional correlation structure does not confirm near orthogonality
    - Neutral shocks: Positive comovements
    - Investment-specific shocks: Negative comovements
2. Systematic differences across sectors
    - Positive productivity-hours comovements in investment sector
    - Negative comovements in consumption sector

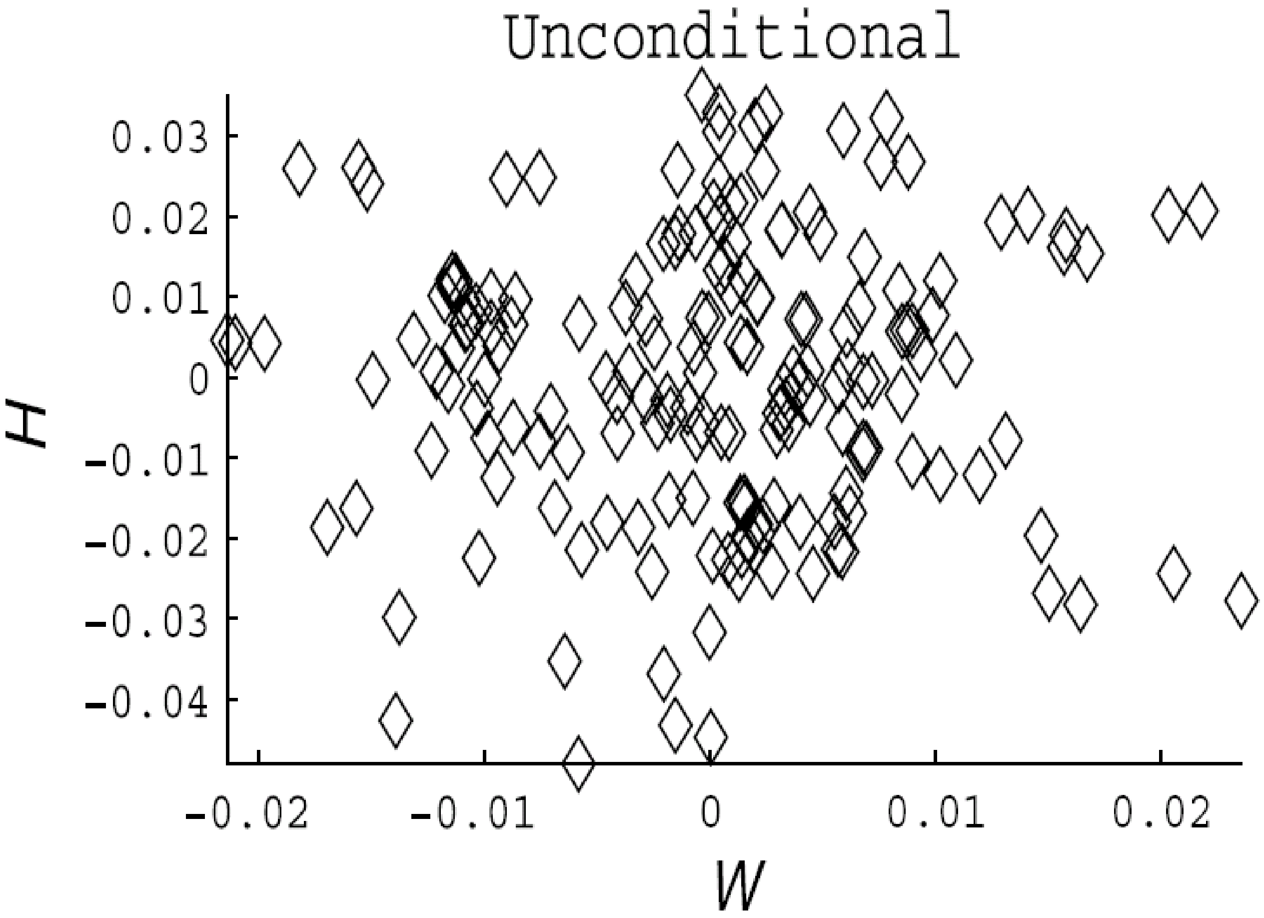
CONCLUSIONS

3. Economic theory can account for aggregate evidence very well.
4. Still work to do in terms of accounting fully for the sectoral evidence but theory does better than expected!

Dunlop-Tarshis



Dunlop-Tarshis



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