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

Morten O. Ravn, European University Institute and the CEPR
Saverio Simonelli, European University Institute and University of Naples
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


- indivisible labor (Hansen, 1986): High labor supply elasticity

- home-production theories (Benhabib, Rogerson and Wright, 1992): modified labor supply responses to technology shocks
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
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
We estimate the following VAR:

\[ X_t = k + B(L)X_{t-1} + e_t \]

\[ X_t = \left[ \Delta p^i_t, \Delta a_t, h_t, c^n_t - y^n_t, i^n_t - y^n_t \right] \]

- \( \Delta p^i_t \): the log of the investment to consumption price
- \( a_t \): the log of aggregate labor productivity
- \( h_t \): the log of hours worked
- \( c^n_t - y^n_t \): the log of nominal consumption expenditure to nominal output
- \( i^n_t - y^n_t \): the log of nominal investment to nominal output
- \( k \): constants and trends
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.
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
Figure 1: The Impact of a Neutral Technology Shock
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

<table>
<thead>
<tr>
<th></th>
<th>Unconditional</th>
<th>Investment specific shock</th>
<th>Neutral shock</th>
<th>Both</th>
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<tbody>
<tr>
<td>Aggregate</td>
<td>-0.09</td>
<td>-0.85</td>
<td>0.47</td>
<td>0.04</td>
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<tr>
<td>Consumption Sector</td>
<td>-0.90</td>
<td>-0.77</td>
<td>-0.65</td>
<td>-0.74</td>
</tr>
<tr>
<td>Durables Sector</td>
<td>0.31</td>
<td>0.63</td>
<td>0.47</td>
<td>0.58</td>
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<tr>
<td>Durables sector with price adjustment</td>
<td>0.28</td>
<td>-0.65</td>
<td>0.63</td>
<td>0.21</td>
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</tbody>
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The numbers refer to Hodrick-Prescott filtered variables. The conditional correlations are computed from simulations of the counterfactuals.

Aggregate:

Consumption sector: Negative correlations upon investment-specific shocks.

Investment sector:
- Large positive correlation conditional upon neutral shocks
- 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
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
Households are assumed to be infinitely lived, have rational expectations, and their preferences are given as:

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

- $1/\sigma$ 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
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:

\[
\begin{align*}
    h_{s,t} &= \left(1 - F_s\left(\frac{n_{s,t}}{n_{s,t-1}}\right)\right)n_{s,t} \\
    K_{s,t+1} &= \left(1 - \delta_s - \Lambda_s\left(u_{s,t}\right)\right)K_{s,t} + I_{s,t} - G_s\left(I_{s,t}/K_{s,t}\right)K_{s,t}
\end{align*}
\]

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.
Aggregate output and the technology processes are:

\[ Y_t = C_t + P_t I_t \]

\[ z_t = z_{t-1} \gamma_z^{1-\rho_z} \left( \frac{z_{t-1}}{z_{t-2}} \right)^{\rho_z} \exp\left( \varepsilon_t^z \right) \]

\[ x_t = x_{t-1} \gamma_x^{1-\rho_x} \left( \frac{x_{t-1}}{x_{t-2}} \right)^{\rho_x} \exp\left( \varepsilon_t^x \right) \]

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:

\[ \alpha_c = \alpha_i \quad \text{and} \quad \varepsilon_t^c \perp \varepsilon_t^i \]

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

- $\Theta_1$: Parameters that we calibrate
- $\Theta_2$: Parameters that we estimate

The estimation is done by limited information approach:

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

$IR^{data}$: 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
Table 3: Calibrated Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Meaning</th>
<th>Value</th>
<th>Calibration</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\alpha$</td>
<td>Capital share</td>
<td>0.36</td>
<td>Calibrated to capital income share estimate</td>
</tr>
<tr>
<td>$\gamma_z$</td>
<td>Steady-state growth rate of neutral technology</td>
<td>1.0004</td>
<td>Calibrated to average trend growth rate of output</td>
</tr>
<tr>
<td>$\gamma_z$</td>
<td>Steady-state growth rate of inv.spec. technology</td>
<td>1.0076</td>
<td>Calibrated to trend change in relative investment price</td>
</tr>
<tr>
<td>$\beta^*$</td>
<td>Effective subjective discount factor</td>
<td>0.99</td>
<td>Calibrated to imply 4% annual real interest rate in steady state</td>
</tr>
<tr>
<td>$\phi$</td>
<td>Utility weight</td>
<td>4.18</td>
<td>Calibrated to be consistent with $\bar{n}_c + \bar{n}_i = 0.30$</td>
</tr>
<tr>
<td>$\Lambda_c^* (1)$</td>
<td>Marginal impact of utilization rate of depreciation of capital stock in consumption sector</td>
<td>0.048</td>
<td>Calibrated to be consistent with $\bar{u}_c = 1$</td>
</tr>
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<td>$\Lambda_i^* (1)$</td>
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<td>0.048</td>
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</tr>
<tr>
<td>$\delta$</td>
<td>Depreciation rate at normal rate of capacity utilization</td>
<td>0.025</td>
<td>Calibrated to imply 10 percent annual depreciation in steady state</td>
</tr>
</tbody>
</table>
Table 4: Parameter Estimates

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Meaning</th>
<th>Estimate</th>
<th>Standard error</th>
</tr>
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<tr>
<td>$\sigma$</td>
<td>Inverse of intertemporal elasticity of substitution</td>
<td>3.322</td>
<td>0.011</td>
</tr>
<tr>
<td>$\kappa$</td>
<td>Inverse of Frisch elasticity</td>
<td>0.0001</td>
<td>-</td>
</tr>
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<td>$F''_c (\bar{n}_c)$</td>
<td>Adjustment costs of labor, consumption sector</td>
<td>0.001</td>
<td>-</td>
</tr>
<tr>
<td>$F''_i (\bar{n}_i)$</td>
<td>Adjustment costs of labor, investment sector</td>
<td>0.421</td>
<td>0.008</td>
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<td>$G''_c (\bar{K}_c/\bar{I}_c)$</td>
<td>Adjustment costs of capital, consumption sector</td>
<td>0.0001</td>
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<td>$G''_i (\bar{K}_i/\bar{I}_i)$</td>
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<td>24.07</td>
<td>0.189</td>
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<td>$\Lambda''_c (1)/\Lambda'_c (1)$</td>
<td>Elasticity of impact of utilization on depreciation in consumption sector</td>
<td>0.117</td>
<td>0.001</td>
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<td>$\rho_z$</td>
<td>Persistence of growth rate of neutral technology</td>
<td>0.177</td>
<td>0.001</td>
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<td>$\rho_x$</td>
<td>Persistence of growth rate of inv.spec. technology</td>
<td>0.050</td>
<td>0.002</td>
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<td>$\mu_z$</td>
<td>Standard deviation of neutral technology shock innovations</td>
<td>0.069</td>
<td>0.0002</td>
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<td>Standard deviation of inv.spec. technology shock innovations</td>
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Indivisible labor

High adjustment costs in investment sector

Higher persistence of neutral shocks

Investment-specific shocks much more volatile
Neutral Technology Shock

THE MODEL VS. DATA
MODEL VS. DATA

Investment Technology Shock

- $y$ vs. time
- $h$ vs. time
- $c$ vs. time
- $i$ vs. time
- $y/h$ vs. time
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
Neutral technology shock

Here the fit is worse in terms of impact on consumption sector
### Table 2: Hours and Productivity Correlations: US Data

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*with price adjustment*

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### Table 5: Hours and Productivity Correlations: Benchmark Model

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<td>0.75</td>
<td>0.52</td>
<td></td>
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<tr>
<td>Consumption Sector</td>
<td>-0.68</td>
<td>0.93</td>
<td>0.53</td>
<td></td>
</tr>
<tr>
<td>Durables Sector</td>
<td>0.83</td>
<td>0.66</td>
<td>0.53</td>
<td></td>
</tr>
<tr>
<td>Durables sector</td>
<td>-0.50</td>
<td>0.72</td>
<td>0.52</td>
<td></td>
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*with price adjustment*

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
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!
Unconditional