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Shiftwork in the Real Business Cycle

Yoram Halevy
Department of Economics, UBC

and

James M. Nason*
Department of Economics, UBC
Research Department, FRB-Atlanta

*The usual disclaimers apply with regard to the Federal Reserve Bank of Atlanta and the Federal Reserve System.

RBC Theory

- Test ability of neoclassical stochastic growth model to replicate U.S. business cycle.

- Observe small variation in measured factor inputs.

- Yields large variation and serially correlation in measured Solow total factor productivity.

- TFP correlated with many macro aggregates but not labor inputs.

  $\Longrightarrow$ Data reject RBC theory.

- But, Woody Allen once said,

  "All men are Socrates. Socrates was a man. Therefore all men are Socrates."

- Claim of rejection gets the motivation of RBC theory all wrong; see King and Rebelo (1999).

- Rather, introduce features into RBC model to understand its failures.

Goals of Paper

- One goal of the paper is to do just this.

  Study the power of some well-known and not so well-known features of a one-sector RBC model to explain several outstanding puzzles of RBC theory.

- We adapt Shiftwork to a RBC environment.

  The impact of Shiftwork on the measurement of technology.

  The implications of Shiftwork for intertemporal substitution.

  The ability of shiftwork to help understand observed aggregate labor market behavior.

Framework of Paper

- Take shiftwork as given.

- Ask about explanatory power of shiftwork within RBC theory.

- Our model of shiftwork is similar to

  Sargent and Hansen (JME, 1988) and Hall (JME, 1996) for straight-time/overtime RBC model.

  Burnside (wp, 2000) RBC model with variation in the number and length of shifts.

  Hornstein (EQ-FRB Richmond, 2002) analysis of impact of shiftwork on measurement of technology.

Micro Evidence on Shiftwork

and the Work Week of Capital

Quantity Evidence:

- Mayshar and Solon (AER, 1993) find that about 1/4 of manufacturing and 1/6 of all employees work swing shifts.

  Swing shift accounts for almost 50 percent of the variation in employment in manufacturing and about 30 percent in aggregate employment.

- Shapiro (BP, 1996) calculates that 42 percent of the variation in aggregate employment is generated by the swing shift.

Quantity Evidence (cont.):

- The impact of recessions on employment falls disproportional on swing shift workers according to Mayshar and Solon.

  In manufacturing, half of the employment loss is in the swing shift. Economy-wide it is about one-third.

- Shapiro (AER, 1993) reports that the work week of capital varies by 14.5 percent in manufacturing over a typical business cycle.

Wage Evidence:

- The shift premium appears to be small.

  Bresnahan and Ramey (QJE, 1994) and Shapiro (wp, 1995) suggest not much more than five percent.

- Kostiuk (JPE, 1990) argues such estimates understate the shift-premium because of worker heterogeneity which raises it to 20 percent.

  Shapiro (wp, 1995) agrees because taking into account ongoing employment relationships takes the premium to 25 percent.

Evidence from Micro Theory:

- Mayshar and Halevy (JOLE, 1997) show that shift-work can be procyclical in a partial equilibrium model of the firm.

- Argue a large shift premium is not necessarily a hindrance to existence of shiftwork.

Current Prototype RBC Model

- Technology: Capacity Utilization in capital.

  Variation in efficiency units of capital greater than in measured capital stock input.

  Measured TFP much less volatile and persistent.

- Preferences: Linear in employment because of Labor Indivisibilities.

  Aggregate labor supply elasticity greater than at household level.

- Also: Allow effort to vary ex post of technology shock realization.

  Creates infinite adjustment cost in labor input that induces a propagation mechanism.

- Ex.: Burnside and Eichenbaum (AER, 1996).

Another Approach to Prototype RBC Model

- Use Work Week of Capital to generate greater variation in efficiency units of capital than in measured capital stock.

- Estimates of industry level technology suggests Capacity Utilization and the Work Week of Capital are important for measuring TFP; Basu and Kimball (NBER WP 5915, 1997)

- Problem with WWC: Bulk of variation in aggregate U.S. labor market is along extensive margin (employment) not intensive margin of hours.

Prototype RBC Model (cont.)

- Requires household to have preferences over hours and employment

  $\Longrightarrow$ costs to entering labor market along with costs of supplying hours.

- Bils and Cho (JME, 1994) and Cooley and Cho (JEDC, 1994)

  $\Longrightarrow$ utility cost to entering labor market because of lost household production.

- Calibration of preference parameters not obvious.

  $\Longrightarrow$ Studies rely on calibrated values typical for RBC models, summary statistics from PSID, and (subjective) judgement.

The Model

- Assume typical firm runs two shifts.

- An A shift and a B shift:

  A shift is standard and B shift is swing.

- Technology is CRS in a shift.

  Shifts at same level of capacity utilization. Allow employment and shift length to vary, but number of non-simultaneous shifts fixed.

- Households play lotteries over opportunity to work in one of two shifts or not work at all.

- Cost of moving from home to market production no matter the shift.

The Household Sector

Preferences:

Daily utility of household

$$U(c, h_A, h_B) = u(c) - [\nu_A(h_A) + \nu_B(h_B)],$$

$u(c)$: increasing and concave,

$\nu_i(h_i)$: disutility of h_i hours in shift i is increasing and convex.

Invoke Inada conditions.

Aggregate Preferences:

Lotteries on shift employment

$\Longrightarrow$ Expected utility:

$$[u(c_A) - \nu_A(h_A)]e_A \;+\; [u(c_B) - \nu_B(h_B)]e_B$$
$$+\; u(c_{NE})(1 - e_A - e_B)$$

where e_i is the probability of working shift i.

Complete income insurance $\Longrightarrow c_A = c_B = c_{NE}$ and

$$u\,(c) - [\nu_A\,(h_A)\,e_A + \nu_B\,(h_B)\,e_B]$$

Average Daily Utility Function:

$\psi_i(e_i)$: fixed cost of working proportion e_i of the days of the period in shift i, $i = A$, B, increasing in e_i along with standard assumptions.

Represents cost to household of lost home production because additional member participates in the labor market.

Total felicity equals utility minus fixed cost to home production of labor market participation

$$
\begin{aligned}
u(c) - [\nu_A(h_A) + \psi_A(e_A)]e_A \\
- [\nu_B(h_B) + \psi_B(e_B)]e_B
\end{aligned}
$$

$\Longrightarrow e_i$ becomes employment rate of shift i.

Utility and Cost Specifications:

(1) $u\,(c_t) = \ln[c_t]$,

(2) $\nu_i\,(h_{it}) = \phi_{1i} h_{it}^{1+\eta}/(1+\eta)$,

(3) $\psi_i\,(e_{it}) = \phi_{2i} e_{it}^{1+\psi}/(1+\psi)$,

(4) and the household discount factor $\beta < 1$.

$\Longrightarrow$ (2) and (3) same as Bils and Cho (JME, 1994), Cooley and Cho (JEDC, 1994), and Hornstein (EQ-FRB-Richmond, 2002).

The Firm

Technology :

$$Y_t = (v_t K_t)^{\theta} \; Z_t^{1-\theta} \left[(e_{At} h_{At})^{1-\theta} + (e_{Bt} h_{Bt})^{1-\theta} \right],$$

where $0 < \theta < 1$.

Y_t : aggregate output.

v_t : capacity utilization.

K_t : capital stock.

$\Longrightarrow v_t \times K_t =$ efficiency units of capital; Greenwood, Hercowitz, and Huffman (AER, 1987) and Burnside and Eichenbaum (AER, 1996).

Z_t : random walk labor-augmenting technology shock.

Motivate Technology :

- Assume output per worker-per hour is CRS

$$\frac{Y_{it}}{N_{it}} = \mathcal{F}\left(K_t \left[\frac{N_{it}}{v_t}\right]^{-1},\ Z_t\right),$$

where $N_{it} = e_{it}h_{it}$ and $N_t = N_{At} + N_{Bt}$.

$\Longrightarrow$ construct aggregate technology summed across shifts A and B.

- Variable capacity utilization same for all shifts.

- Employment and hours vary across shifts rather than being fixed across shifts.

Impact on TFP Measurement :

- Solow-TFP measure

$$\ln STFP_t = \frac{\ln Y_t - \theta \ln (v_t K_t)}{1-\theta} - \ln N_t$$

$$= \ln Z_t + \frac{\ln(1+\mu_t^{1-\theta})}{1-\theta} - \ln(1+\mu_t),$$

where $\mu_t = \frac{N_{Bt}}{N_{At}}$.

$\Longrightarrow$ shocks to composition of labor inputs across shifts yields incorrect measure of TFP.

- When $\mu_t < 1$, $\ln STFP_t > \ln Z_t$.

$\Longrightarrow$ True at or above steady state for N_{At}.

Law of Motion of Capital :

$$K_{t+1} = I_t + \left(1 - \delta_0 - \delta_1 v_t^{\varphi}\right) K_t$$

δ_0 : rust and dust depreciation, $0 < \delta_0 < 1$.

$\Longrightarrow$ emphasized by Basu and Kimball (NBER WP 5915, 1997).

$\delta_1 v_t^{\varphi}$: time-varying or wear and tear depreciation, $0 < \delta_1 < 1$, and $0 < \varphi$.

Larger φ smaller is depreciation cost of increasing capacity utilization. Less of a source of propagation.

Resource Constraint of the Economy :

$$Y_t = C_t + I_t + G_t.$$

G_t : exogenous government spending.

Impulse Structure

Technology Shock :

Z_t: random walk (with drift) technology shock

$$\ln(Z_{t+1}) = \ln(Z_t) + \gamma + \varepsilon_{t+1},$$

$\gamma > 0$: deterministic growth rate of labor-augmented technology.

ε_{t+1} : innovation to technology shock, normally distributed, mean zero, and finite variance σ_ε^2.

Government Spending Shock :

$g_t = \frac{G_t}{Y_t}$, government spending-output ratio shock is a AR(1) process around its steady state g^* :

$$\ln(g_{t+1}) = \left(1 - \rho_g\right) \ln(g^*) + \rho_g \ln(g_t) + \upsilon_{t+1},$$

where $|\rho_g| < 1$.

υ_{t+1} : innovation to technology shock, normally distributed, mean zero, and finite variance σ_υ^2.

Assume $\mathbf{E}\{\varepsilon_{t+j}\upsilon_{t+s}\} = 0$, for all j and s.

Solution Methods

- Construct FONCs of Social Planner's problem.

  Stochastically detrend the FONCs.

  Compute the steady state: $\frac{K^*}{Y^*}, \frac{C^*}{Y^*}, \ldots$

- Detrended optimality and equilibrium conditions

  Linearize around the steady state.

Solution Methods (cont.) :

- Convert to state space system.

  Obtain Kalman filter and its associated likelihood; see Hamilton (1994) and Nason (2002).

- Adapt Sargent (JPE, 1989) and Ireland (JEDC, 2001)

  Add AR(1) measurement error process to measurement equation of state space system.

- Ireland: Soak up misspecification generated by linearization of the model, measurement error of data, and inadequacies of the RBC model.

Optimality Conditions and Equilibrium :

- Labor market optimality

$$\frac{\phi_{1i} h_{it}^{\eta} e_{it}}{c_t^{-1}} = (1-\theta)\left(v_t K_t\right)^{\theta}\left(Z_t e_{it}\right)^{1-\theta} h_{it}^{-\theta},$$

$$\frac{\phi_{1i} \frac{h_{it}^{1+\eta}}{1+\eta} + \phi_{2i} e_{it}^{\psi}}{c_t^{-1}} = (1-\theta)\left(v_t K_t\right)^{\theta}\left(Z_t h_{it}\right)^{1-\theta} e_{it}^{-\theta},$$

where $\quad i = A,\ B,$

Optimality Conditions and Equilibrium (cont.) :

- Optimal capacity utilization choice

$$\frac{\theta}{\varphi}\frac{Y_t}{K_t} = \delta_1 v_t^{\varphi},$$

- Intertemporal optimality in the goods market

$$1 \; = \; \beta \mathbf{E}_t \left\{ \frac{C_t}{C_{t+1}} \left[\theta \frac{Y_{t+1}}{K_{t+1}} \; + \; 1 - \delta_0 - \delta_1 v_{t+1}^{\varphi} \right] \right\},$$

Optimality Conditions and Equilibrium (cont.) :

- Labor market equilibrium

$$N_{it} = e_{it}h_{it}, \quad i = A, B$$

- Goods market equilibrium

$$Y_t = C_t + K_{t+1} - (1 - \delta_0 - \delta_1 v_t^{\varphi})K_t + G_t$$

Anticipate Results

- Estimate some model parameters via MLE and calibrate others.

- Conditional on ML estimates employ the Kalman smoother to construct unobservables:

$$\{Z_t, e_{At}, h_{At}, e_{Bt}, h_{Bt}, v_t\}_{t=1}^{T}.$$

- Examine models implications for TFP, capacity utilization, and shiftwork.

- Construct FEVDs w/r/t to structural shocks.

- Study "tests" that reject RBC models.

State Space System

and the Kalman Filter

- The linearized model yields the state space

$$\begin{aligned}\mathcal{S}_{t+1} &= F\mathcal{S}_t + \lambda_{t+1}, &(1)\\ \mathcal{Y}_t &= H\mathcal{S}_t + \mathcal{V}_t, &(2)\\ \mathcal{V}_{t+1} &= D\mathcal{V}_t + \xi_{t+1}, &(3)\end{aligned}$$

where equation (1) is the state equation, equation (2) the measurement equation, and equation (3) is a AR(1) measurement error process.

- Assume $\mathbf{E}\{\lambda_{t+j}\xi_{t+s}\} = 0$, for all j and s.

- The state space vectors process are

$$\mathcal{S}_t = \begin{pmatrix} \widetilde{K}_t & \tilde{Y}_{t-1} & \varepsilon_t & \tilde{g} \end{pmatrix}',$$

$$\mathcal{Y}_t = \begin{pmatrix} \Delta \ln Y_t & \ln \frac{C_t}{Y_t} & \ln \frac{G_t}{Y_t} & \ln \delta_t & \ln e_t & \ln h_t \end{pmatrix}',$$

$$\lambda_{t+1} = \begin{pmatrix} \varepsilon_{t+1} & \xi_{t+1} \end{pmatrix}',$$

$$\mathcal{V}_{t+1} = \begin{pmatrix} V_{1,t+1} & \dots & V_{6,t+1} \end{pmatrix}', \text{ and}$$

$$\xi_{t+1} = \begin{pmatrix} \xi_{1,t+1} & \dots & \xi_{6,t+1} \end{pmatrix}',$$

where $\widehat{K}_{t+1} = \frac{K_{t+1}}{Z_t}$ and $\widetilde{K}_{t+1} = \ln \widehat{K}_{t+1} - \ln K^*$ and $\widehat{Y}_t = \frac{Y_t}{Z_t}$ and $\widetilde{Y}_t = \ln \widehat{Y}_t - \ln Y^*$.

The Kalman Filter and MLE

- The state system of (1)-(3) implies the VARMA

$$\mathcal{Y}_t = D\mathcal{Y}_{t-1} + H\mathcal{S}_t - DH\mathcal{S}_{t-1} + \xi_t.$$

- Estimating a VAR(1) restricted by theoretical MA(2) process imposed by linearized RBC model.

- Cross-equation restrictions also from AR1 measurement process matrix D.

- Maximize likelihood using Kalman filter as discussed in Hamilton (Chapter 13).

Data

- Estimation Sample: 1955Q1 to 1998Q4.

- NIPAs from FRED at the Federal Reserve Bank of St. Louis.

  $\Longrightarrow$ \$1996, seasonally adjusted at annual rate.

- C : Nondurables and Services.

- I : Real Gross Private Domestic Investment + Gov. Investment + Consumer Durables.

- G : Govt. expenditure (federal, state, local)

- $Y = C + I + G$.

- Labor market data from BLS files.

- e : Civilian employment seasonally adjusted.

  Per capita employment=(civilian employment) $\div$ (civilian labor force).

- h : Total non-agricultural hours.

  Per capita hours=total hours $\div$ (1369 x civilian employment).

Data (cont.): Depreciation

- K : (Stock) BEA's data linearly interpolated from annual to quarterly where net stock of K is residential + non residential + consumer durables.

- δ_t : as in Burnside and Eichenbaum (AER, 1996)

$$\delta_t = 1 - \frac{K_{t+1}}{K_t} + \frac{I_t}{K_t}$$

$\Longrightarrow$ According to Burnside and Eichenbaum,
K_t is measured with error, but not δ_t.

Connect Data to RBC Model Variables

- $Y_t, C_t, G_t, \delta_t, e_t = e_{At} + e_{Bt}, h_t = \frac{e_{At}h_{At} + e_{Bt}h_{Bt}}{e_t}$,

$$\begin{bmatrix} \textbf{DATA} \\ \Delta \ln Y_t \\ \ln\left(\frac{C_t}{Y_t}\right) \\ \ln\left(\frac{G_t}{Y_t}\right) \\ \ln \delta_t \\ \ln e_t \\ \ln h_t \end{bmatrix} = \begin{bmatrix} \textbf{MODEL} \\ \tilde{Y}_t - \tilde{Y}_{t-1} \\ \tilde{C}_t - \tilde{Y}_t \\ \tilde{g}_t - \tilde{Y}_t \\ \textit{constnts} * \tilde{v}_t \\ \left[\frac{e_A^* \tilde{e}_{At} + e_B^* \tilde{e}_{Bt}}{\overline{e}}\right] \\ \frac{e_A^* h_A^* \left(\tilde{e}_{At} + \tilde{h}_{At}\right) + e_B^* h_B^* \left(\tilde{e}_{Bt} + \tilde{h}_{Bt}\right)}{\overline{h}} \end{bmatrix}$$

Calibration

- Calibrate there model parameters

$$(\beta, \eta, \psi, \phi_A, \phi_B, \varphi)$$

- Take $(\eta, \psi, \phi_A, \phi_B)$ from calibrations of Bils and Cho (JME, 1994) and Cooley and Cho (JEDC, 1994).

- Fix φ at Burnside and Eichenbaum (AER, 1996) estimate of 1.56.

  Estimates of depreciation parameters and theoretical $\ln v_t$ series conditional on B&E depreciation elasticity of capacity utilization.

Calibration (cont.): Steady State

- Calibrate $e_A^* = \frac{5}{6}\overline{e}$ and $e_B^* = \frac{1}{6}\overline{e}$ to estimates of Mayshar and Solon (AER, 1993) and other studies of the workweek of capital.

  But e_A^* and e_B^* are "estimated" rather being pre-set.

- h_A^* set to Hall's (JME, 1996) estimate of the lower bound of a fixed length straight time shift, (451.1 - 48.5)/1369.

- Solve for h_B^* in the steady state as a function of e_A^*, e_B^*, and h_A^*.

- $v^* =$ sample average of FRB's capacity utilization series.

- See table 1.

Table 1: Calibration of Model

β	=	$1.03^{-0.25}$	e_A^*	=	$\frac{5}{6}\overline{e}$
$\phi_{1,A}$	=	13.50	e_B^*	=	$\frac{1}{6}\overline{e}$
$\phi_{2,A}$	=	1.40	h_A^*	=	0.29
η	=	2.00	v^*	=	0.82
ψ	=	1.67			
φ	=	1.56			

Additional Restrictions

- Drop measurement error process for $\ln\left(\frac{G_t}{Y_t}\right)$ from AR(1) process of $\mathcal{V}_{t+1}$.

- This implies $\ln\left(\frac{G_t}{Y_t}\right)$is tied to model's predictions for this exogenous shock and the parameters ρ_g and σ_{υ}.

Table 2: Parameter Estimates

Parameter	Estimate	Standard Error
$\phi_{1,B}$	109.3534	36.9390
$\phi_{2,B}$	12.3622	2.9574
θ	0.2903	0.0082
δ_0	0.0003	0.0008
δ_1	0.0281	0.0011
γ	0.0038	0.0009
σ_ε	0.0039	0.0006
g^*	0.1901	0.0020
ρ_g	0.9136	0.0169
σ_ξ	0.0123	0.0007
$\frac{C}{Y}$	0.5869	0.0060
$\frac{K}{Y}$	9.0918	0.5367
δ	0.0208	0.0015
$\overline{e}$	0.9353	0.0068
$\overline{h}$	0.3084	0.0070
h_B^*	0.3802	0.0422

Table 3: Estimates of AR(1) Matrix of Measurement Error Process

	ΔY_t	$\frac{C_t}{Y_t}$	δ_t	e_t	h_t
ΔY_{t-1}	0.4641	-0.4167	1.3253	0.3421	0.2497
	(0.1107)	(0.0934)	(0.5641)	(0.0473)	(0.0614)
$\frac{C_{t-1}}{Y_{t-1}}$	-0.0189	0.8610	0.3631	0.0153	0.0575
	(0.07102)	(0.0628)	(0.3730)	(0.0283)	(0.0388)
δ_{t-1}	-0.0132	0.0112	0.9350	-0.0007	-0.0019
	(0.0081)	(0.0061)	(0.0310)	(0.0024)	(0.0036)
e_{t-1}	-0.1710	-0.442	-0.0025	0.9796	0.0920
	(0.1185)	(0.1082)	(0.6349)	(0.0453)	(0.0607)
h_{t-1}	0.0339	-0.0017	0.0942	0.0023	0.9636
	(0.0457)	(0.0386)	(0.2119)	(0.0164)	(0.0236)

All variables in logs, modulus of largest eigenvalue is 0.9780, and ML standard errors in parentheses.

Table 4: Estimates of Error Covariance Matrix of

Measurement Error Process

	ξ_{1t}	ξ_{2t}	ξ_{3t}	ξ_{4t}	ξ_{5t}
ξ_{1t}	0.0065	-0.00003	0.0002	0.00002	0.00002
	(0.0006)	(0.000006)	(0.00003)	(0.000002)	(0.0000003)
ξ_{2t}		0.0065	-0.0002	-.0.000001	-0.00001
		(0.0004)	(0.000005)	(0.00002)	(0.000003)
ξ_{3t}			0.0339	0.00007	0.00007
			(0.0020)	(0.00003)	(0.00002)
ξ_{4t}				0.0031	0.00006
				(0.0002)	(0.00001)
ξ_{5t}					0.0047
					(0.00003)

Standard deviations along the diagonal, covariances above the diagonal, and ML standard errors in parentheses.

Structural Parameter Estimates

- Technology and impulse parameters similar to estimates of Burnside and Eichenbaum (AER, 1996), Hall (JME, 1996), and Ireland (JEDC, 2001).

- Capital's share is about 30 percent.

- "Rust and dust" component of depreciation is negligible.

  $\Longrightarrow$ Burnside and Eichenbaum (AER, 1996).

- Movements in capacity utilization drives depreciation. Wear and tear depreciation dominates.

- Persistent government spending shock, $\rho_g = 0.91$, and the standard deviation of its innovation is larger than technology's.

Structural Parameter Estimates (cont.)

- There is one exception, $\sigma_\varepsilon = 0.0039$, the standard deviation of the technology shock innovation is low compared to most estimates reported elsewhere.

- Its 95 percent confidence interval $= (0.0027,\ 0.0051)$.

  $\Longrightarrow$ Smaller estimate of standard deviation of TFP innovation than found elsewhere, by 20 percent or more.

- Burnside and Eichenbaum report an estimate of around 0.007.

  $\Longrightarrow$ The 95 percent interval $= [0.006,\ 0.008]$.

Structural Parameter Estimates (cont.)

- Estimate $\phi_{2,B}$ =12.36 is nearly ten times larger than calibrated values of $\phi_{2,A}$.

- Costly to move a member of household out of home production into B shift production.

$\Longrightarrow$ Large shift premium.

$\Longrightarrow$ B shift employment is sensitive to the "stage-of-the-business cycle".

$\Longrightarrow$ Recession falls mostly on B shift workers.

$\Longrightarrow$ B shift employment is more volatile and exhibits peaks and troughs around business cycle peaks and troughs.

Structural Parameter Estimates (cont.)

- Estimate of $\phi_{1,B} = 109.35$ is also nearly ten times larger than calibrated values of $\phi_{1,A}$.

$\Longrightarrow$ B shift workers need substantial shift premium to induce additional hours.

$\Longrightarrow$ Firms ask for these hours only during especially productive states of the world.

Shiftwork's Implications for the

Real Business Cycle

Technology Measurement

- See figure 1.

- Shiftwork results in less volatile and smoother TFP.

- Standard deviation of Solow TFP growth rate is 0.0085.

Technology Measurement (cont.)

- Model estimate of TFP neither exhibits wiggles around

  recession of late 1960s-early 1970s,

  two oil price shocks,

  recession of 1990-1991, nor

  strong recovery from productivity slowdown.

Technology Measurement (cont.)

- Model's TFP power to explain variation in output, consumption, depreciation, employment, and hours

  $\Longrightarrow$ Forecast Error Variance Decomposition.

- See table 5.

- Technology shock explains more than 20 percent of the variation of output, consumption, and employment up to a five year forecast horizon.

Table 5: FEVD with Respect to Technology Innovation

Horizon	Y_t	C_t	δ_t	e_t	h_t
1	40.03	56.55	9.95	23.03	7.62
2	42.16	66.61	14.13	32.96	15.66
3	41.67	67.55	13.86	33.90	16.44
4	29.71	56.01	12.22	34.68	16.35
8	19.45	30.26	1.41	36.55	13.89
12	22.34	22.69	2.88	33.46	13.49
16	23.06	24.14	3.22	27.54	14.62
20	23.20	23.66	1.74	23.47	15.95
40	22.80	22.91	0.39	13.72	19.53

Capacity Utilization

- See figure 2.

- $\ln v_t$ less volatile than FRB-CU series.

  Relative volatility $= 0.71$.

- $\ln v_t$ exhibits no business cycle like FRB-CU.

- Rather, $\ln v_t$ is more persistent

  half-life of its AR1 coefficient is nearly five years, about two years for FRB-CU.

- Importance of $\ln v_t$ for the business cycle?

  Or with shiftwork does capacity utilization operate at lower frequencies?

Shiftwork and the Labor Market

- Employment in figure 3.

- Hours in figure 4.

- Employment and hours in A shift less volatile than in B shift.

  Relative volatilities range from 0.145 to 0.223.

- Employment and hours in A shift about as volatile as aggregates

- B shift employment almost always bottoms at or subsequent to business cycle troughs.

- B shift hours show little relation to business cycle peaks and troughs in second half of sample.

Shiftwork and the Labor Market (cont.)

- Regress $e_{A,t}$ on e_t, slope coefficient $=$ 0.79.

- Regress $e_{B,t}$ on e_t, slope coefficient $=$ 2.12.

- Regress $h_{A,t}$ on h_t, slope coefficient $=$ 0.38.

- Regress $h_{B,t}$ on h_t, slope coefficient $=$ 3.90.

  $\Longrightarrow$ Shiftwork-RBC model captures stylized fact that swing swift varies more with aggregate labor market.

Price of Shiftwork in the Labor Market

- This comes at the price of a high shift premium.

- At the steady state values of $e_A^* = 0.78$, $e_A^* = 0.16$, $h_A^* = 0.29$, and $h_B^* = 0.38$

  $\Longrightarrow$ B shift premium is nearly 50 percent.

- Smaller than the 70 percent shift premium Hornstein (QR-FRB Richmond) reports for his calibration.

- Note B shift is more than 30 percent longer than A shift at steady state.

Shiftwork, the Labor Market, and Technology

- Gali (AER, 1999) argues that RBC theory fails because productivity and employment show little comovement.

- Calculates permanent and transitory components of productivity and employment (or hours worked) in just-identified SVAR.

  Permanent component of productivity is Gali-TFP. Transitory component is $\frac{Y_t}{N_t}$.

  Correlation of permanent components of productivity and hours (employment) $=$ -0.82 (-0.84).

  Correlation of transitory components of productivity and hours (employment) $=$ 0.26 (0.64).

- Shiftwork and the Gali identification scheme yields

  Correlation of the permanent components of productivity and hours (employment) is 0.46 (-0.18).

  Correlation of the transitory components of productivity and hours (employment) is -0.83 (-0.98).

  Correlation of Shiftwork-TFP and sample hours (employment) is 0.03 (0.07).

- Suggests condemnation of RBC theory along this dimension is unwarranted.

Conclusions

- Shiftwork is important for Real Business Cycles.

- Shiftwork contributes to smoother, less volatile technology shocks.

- Shiftwork TFP plays an important role in output, consumption and employment fluctuations.

- Shiftwork weakens role of capacity utilization for explaining business cycle fluctuations.

- Shiftwork highlights the role of the work week of capital for business cycle fluctuations.

- Shiftwork can help to explain the small correlation of productivity and hours (or employment).

- Shiftwork not without its own problems

  Large cost to moving from home production to swing shift.

  Large shift premium.

  Long swing shift.

- As students of dynamic general equilibrium model, want a theory of shiftwork in general equilibrium.

  $\Longrightarrow$ Future research.

Figure 1: Solow Residual and TFP

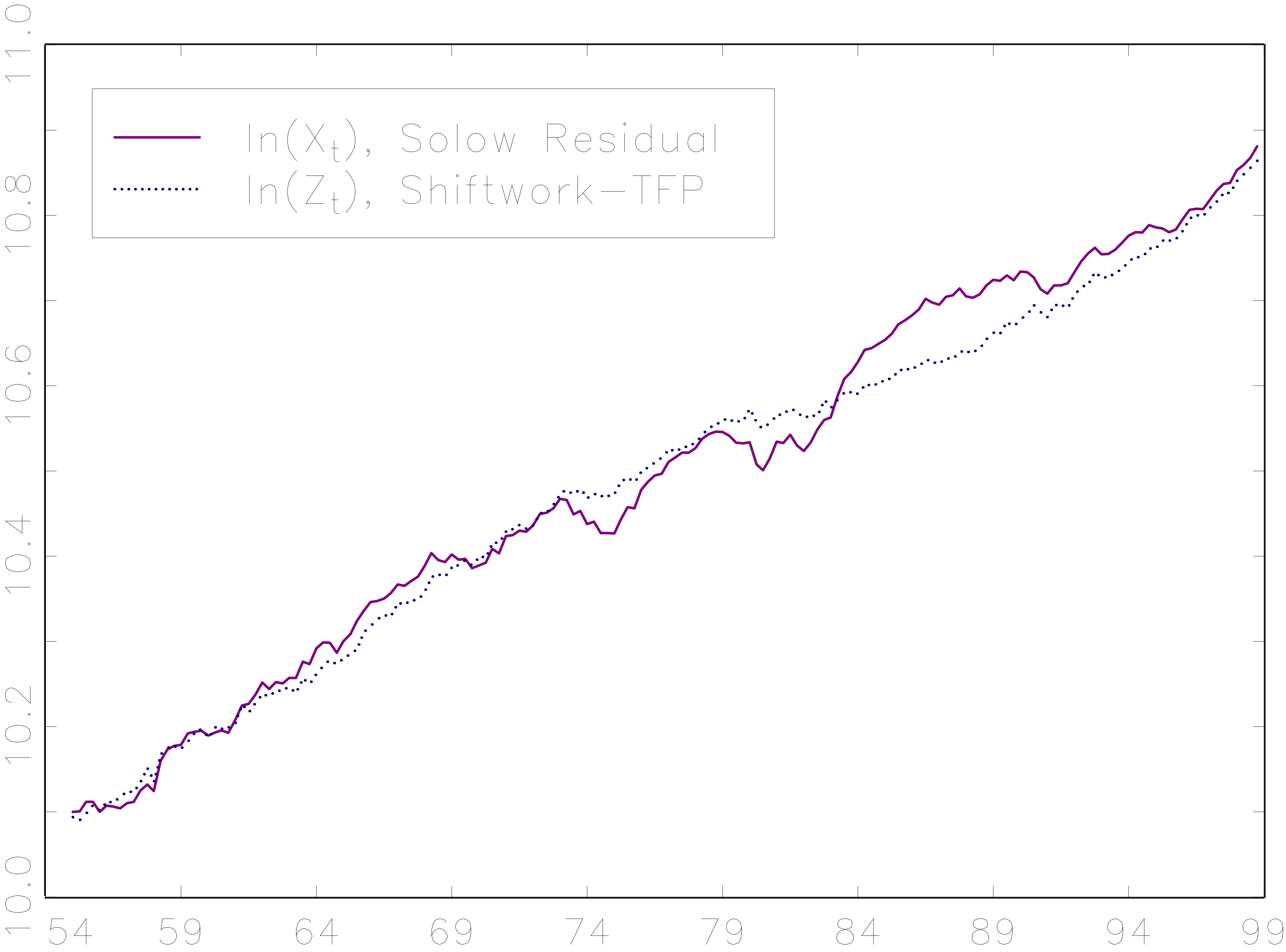

Figure 2: Capacity Utilization under Shiftwork

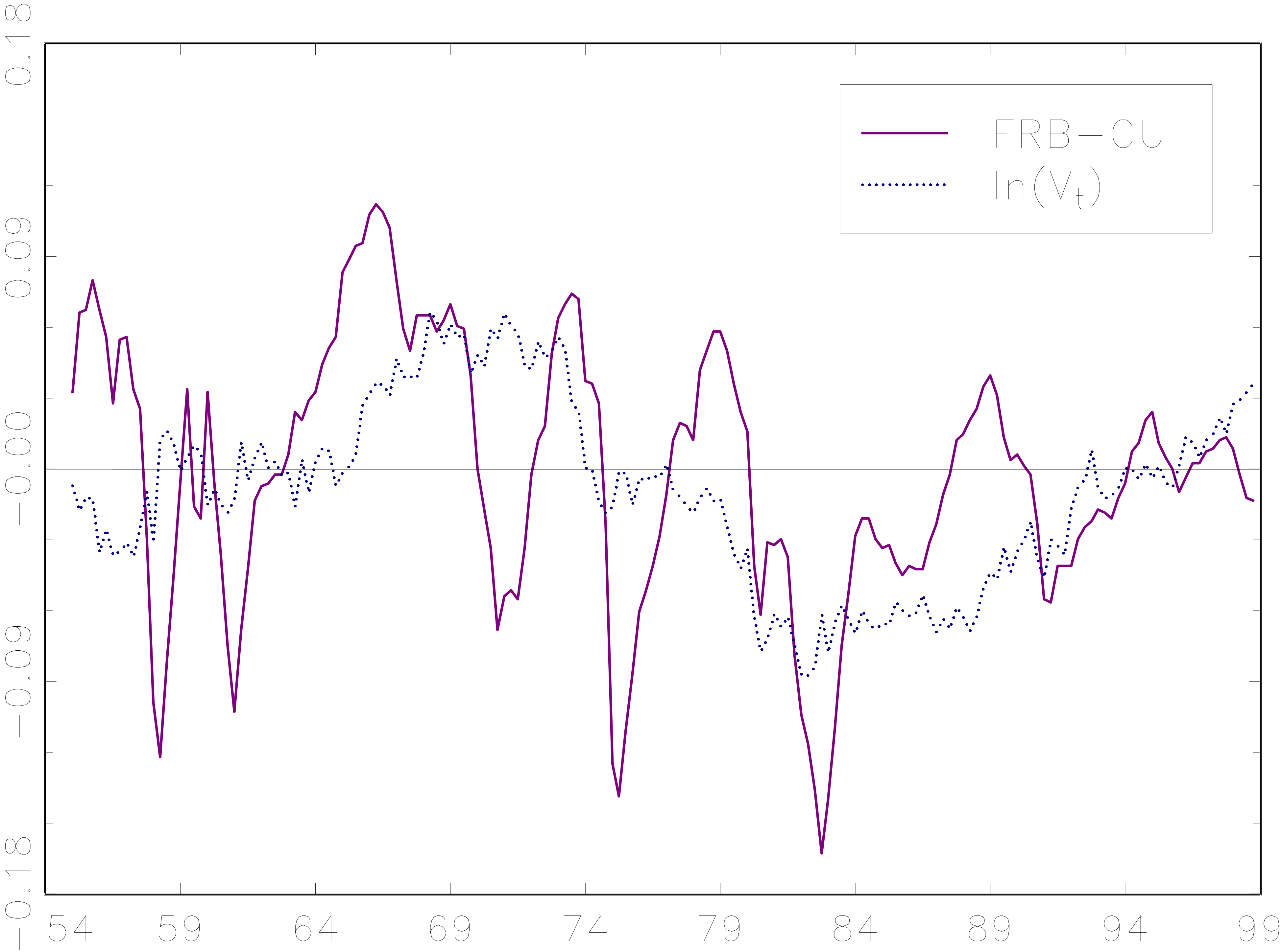

Figure 3: Employment and Shiftwork

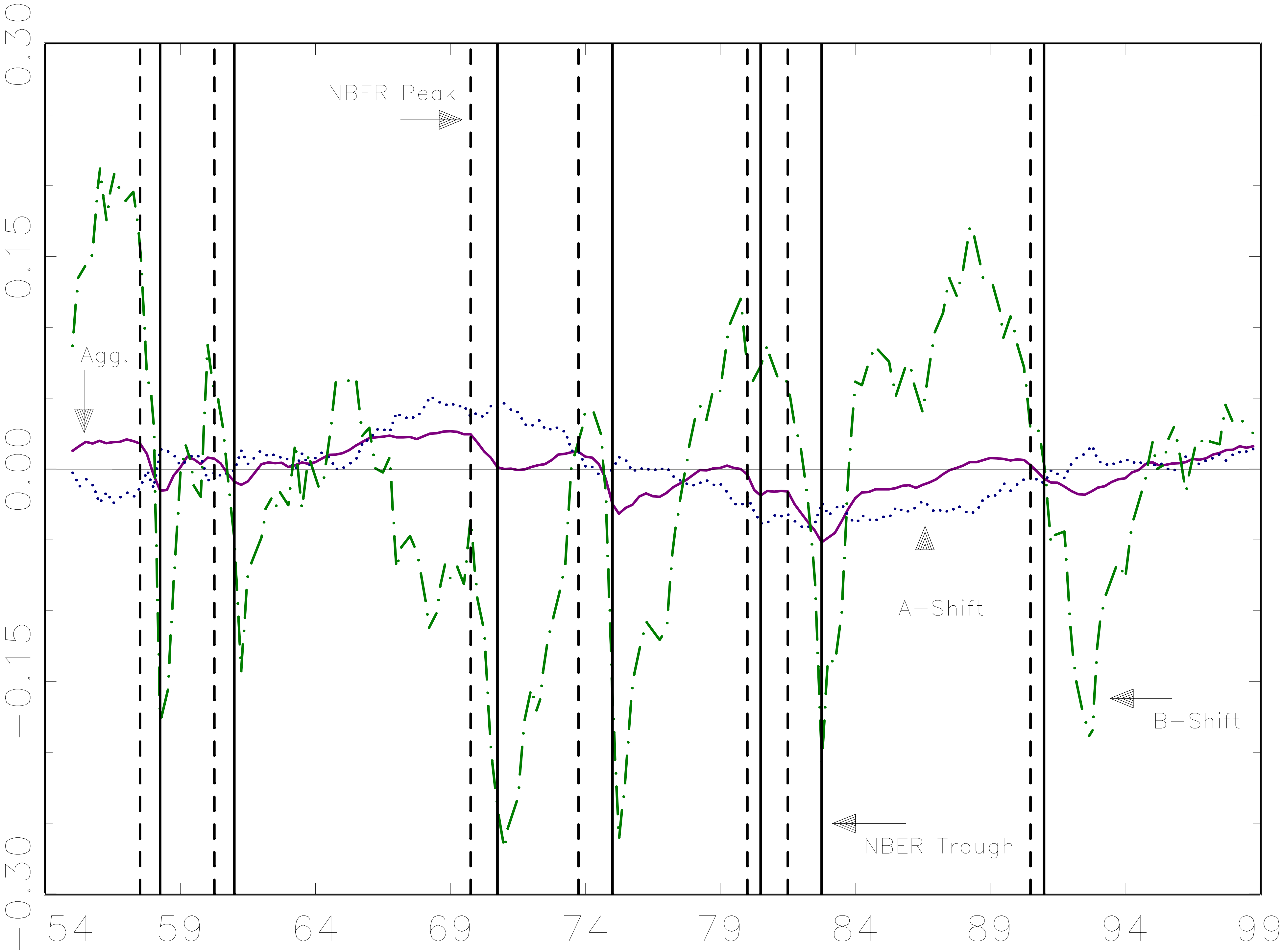

Figure 4: Hours and Shiftwork