

Decoding productivity:
Business cycle properties of labor
productivity growth,
by Arturo Estrella, FRB of NY

Presented and Discussed
By Robert J. Gordon,
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The “Rainbow Connection”

- This is Arturo’s Powerpoint
- This is Bob’s TITLE and text
- Arturo’s Powerpoint is quite terse, so I’ve expanded it quite a bit as part of the exposition
 - ANYTHING PURPLE IS DIRECTLY FROM ARTURO’S PAPER
- The “New Economy” invades CRIW in technicolor!

Presenting vs. Discussing

- Two possibilities
 - #1, present first, discuss at end
 - #2, divide paper into blocks, discuss each in sequence
- This paper deserves to be presented intact, discussion at end
- Insertions consist only of short previews of issues taken up later (watch the color!)

Overview

- Study behavior of labor productivity growth (BLS non-farm) at business cycle frequencies
 - (Note: no discussion of productivity trend, which is of great interest to this audience, this is easily fixed)
- Test hypotheses related to 3 issues from the literature
- Use frequency domain techniques, including definition of business cycle
 - Important contribution of paper, contrast with time domain that has previously dominated this literature
 - “only clear after decoding in frequency domain”

Issues

- Productivity is procyclical
 - positive covariance with output or employment
 - Crucial distinction between growth rates and levels, productivity is not procyclical in the sense of NBER cycle reference dates, and in 2000-2003 was countercyclical in levels. Focus on growth rates is a major positive in Arturo's paper
- Dunlop-Tarshis phenomenon
 - real wage is procyclical in contrast to countercyclical implication of original 1936 Keynesian model
- Reder hypothesis
 - quality of labor force is countercyclical

Procyclical productivity

- Output and employment benchmarks
- Output: Bernanke & Powell (1986), Gali (1999), Basu & Fernald (2000)
 - All of these cites remark on the close positive correlation of productivity GROWTH with output GROWTH, which is very different from the NBER cycle.
- Employment: Bernanke & Parkinson (1991), Christiano & Eichenbaum (1992), Basu (1996), Gali (1999)
 - This literature is about productivity vs. employment growth, not different if employment and output growth are highly correlated.
 - Conventional literature doesn't treat lags adequately as does Arturo

Reasons for Procyclical Productivity

- Labor hoarding
 - Bernanke-Parkinson (1991) reject technology shocks, adopt a combo of labor hoarding (variable labor utilization) and increasing returns to scale
 - Basu (1996) mix of exogenous technology shocks and variable factor utilization.
 - Basu-Fernald (2000) downplay tech shocks and emph variable factor utiliz and resource reallocation.
- Oops, no cites to Oi, Okun, Hultgren (1960-62).
Okun's Law, Labor as a "quasi-fixed factor"

Why the y - n , n Correlation Should be Surprising

Covariances

$$b_{yn} = \frac{\text{cov}(y, n)}{\text{var}(n)}$$

$$c_{xn} = \text{cov}(y - n, n) = \text{var}(n)(b_{yn} - 1)$$

$$c_{xy} = \text{cov}(y - n, y) = \text{var}(n) \left(\frac{\text{var}(y)}{\text{var}(n)} - b_{yn} \right)$$

Explanation of Equations

- The signs of the two covariances, $y-n$ with n and $y-n$ with y , are completely determined by the value of the regression coefficient b_{yn} .
- Productivity is procyclical with employment only if $b_{yn} > 1$
- Productivity is procyclical with output if $b_{yn} < v$ (where $v = \text{var}(y)/\text{var}(n)$) which we should assume is > 1 .

Range of values $1 < b_{yn} < v$ for which both covars may be positive

Procyclical productivity, in grad school this was the “SRIRL Paradox”

Cobb-Douglas case

$$y = \alpha k + \beta n + \varepsilon$$

$$b_{yn} = \beta + \alpha b_{kn}$$

Interpretation

- CRS, $\alpha + \beta = 1$
- $b_{yn} = \beta + \alpha b_{kn}$
 - Assuming k, n positively correlated, that means estimator of β is upward biased, so that theoretical value of $\beta < 1$ is compatible with $b_{yn} > 1$. (should distinguish between K stock and utilized K, link to Eichenbaum, Basu, etc.)
- If K and N used in fixed prop and CRS, then implied $b_{yn} = 1$ and $c_{xn} = 0$ and $c_{xy} > 1$ if $v > 1$

Hypotheses for Empirical Research

- x positively correlated with y ?
- x positively correlated with n ?
- y positively correlated with n ?

- These questions will be addressed at the frequency domain so the crucial issue of leads and lags will be implicitly addressed

Dunlop-Tarshis

- Keynes (1936): real wage countercyclical
 - agreed with classics
 - labor demand curve
 - “. . . In general, an increase in the employment can only occur to the accompaniment of a decline in the rate of real wages” (1936, p. 17)

Cyclical Productivity in the Original Keynesian Model

- Competitive factor pricing and Cobb-Douglas implication for labor's share (S)

$$\frac{W}{P} = \frac{\partial Y}{\partial N}$$

$$\frac{\partial Y}{\partial N} = \beta \frac{Y}{N}$$

$$S = \frac{WN}{PY} = \beta \frac{YN}{NY} = \beta$$

Dunlop-Tarshis

In general

If $Y = f(N)$ with $f'(N) > 0$ and $f''(N) < 0$,

profit max. implies $\frac{w}{p} = h\left(\frac{Y}{N}\right)$, $h'(X) > 0$.

E.g., Cobb-Douglas $w/p = \partial Y / \partial N = \beta Y / N$

CES $\log(w/p) = \log((1 - \delta)\gamma^{-\rho}) + (1 + \rho)\log(Y/N)$

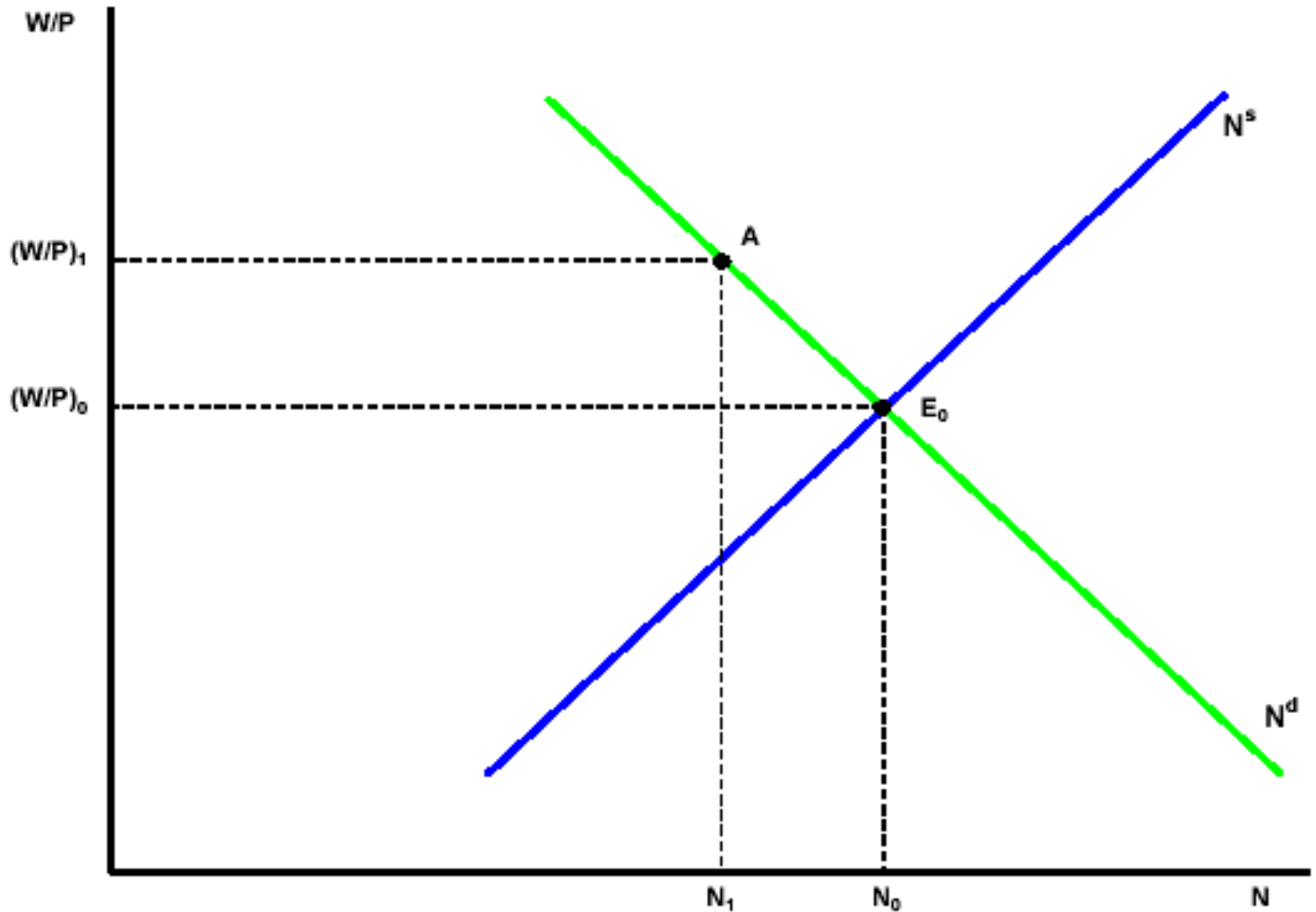
Alternative with CES

- Real wage is a simple power function of productivity
- Relation is linear in logs and correlation is perfect
- Further Hypotheses based on interpretation of Keynes (1936) directly contradictory to #1, #2, and #3
 - #4: $\Delta(y-n)$ negatively correlated with Δy
 - #5: $\Delta(y-n)$ negatively correlated with Δn

The Countercyclical Real Wage Hypothesis

- Dunlop (1938) and Tarshis (1939) found contrary evidence
- Preponderance of collected evidence still favours Dunlop-Tarshis
 - Abraham & Haltiwanger (1995) JEL review
- How can these guys cite macro from 1936 to 1939 without citing anything written from 1956 to 1981??
 - The “Missing Link” in American macro graduate education!

Labor Market



Reder hypothesis

- Quality of labor force declines in booms, increases in recessions
- Reder (1955)
 - high demand for low skilled labor at peak increases relative wage
 - evidence that wage differential lowest
- Bils and McLaughlin (2001) confirm

Relation of Reder Hypothesis to Rest of Paper is Obscure

- First, problem, Reder hypothesis involves cyclical wage behavior across groups, but no relative wage data are included in paper
- McLaughlin and Bils (2001) find high wage industries have more cyclical employment and less cyclical wages.
 - No evidence in paper, could be unions, any other source of wage rigidity. Let's drop it, that's another paper.

Suddenly the U Rate Appears

- Table 1 shows U a better predictor of NBER-defined recessions than either output or hours
- But the author forgets here the distinction between levels and rates of change. All the rest of the paper is about the rate of change of productivity, so the correlation between the LEVEL of U and the NBER dates is irrelevant.

Dropping into the Cauldron of Irrelevancy

- Hyp #6. Productivity is pos correlated with U rate
- Hyp #7. Productivity GROWTH is pos correlated with the U rate.
- Failure to relate U rate to basic economic variables y , n , $y-n$. Ignores the output identity that ties all these variables together.

In general, earlier results

- Almost all in time domain
 - Bernanke & Powell (1986) is the exception
- Procyclicality: evidence of everything
 - positive, negative, zero
 - mostly positive
- Reder hypothesis tested with real wage data
- Most of the criticism of time domain results rests on the lack of attention to lags, ignoring the best existing research in the time domain in which lags and leads are central.

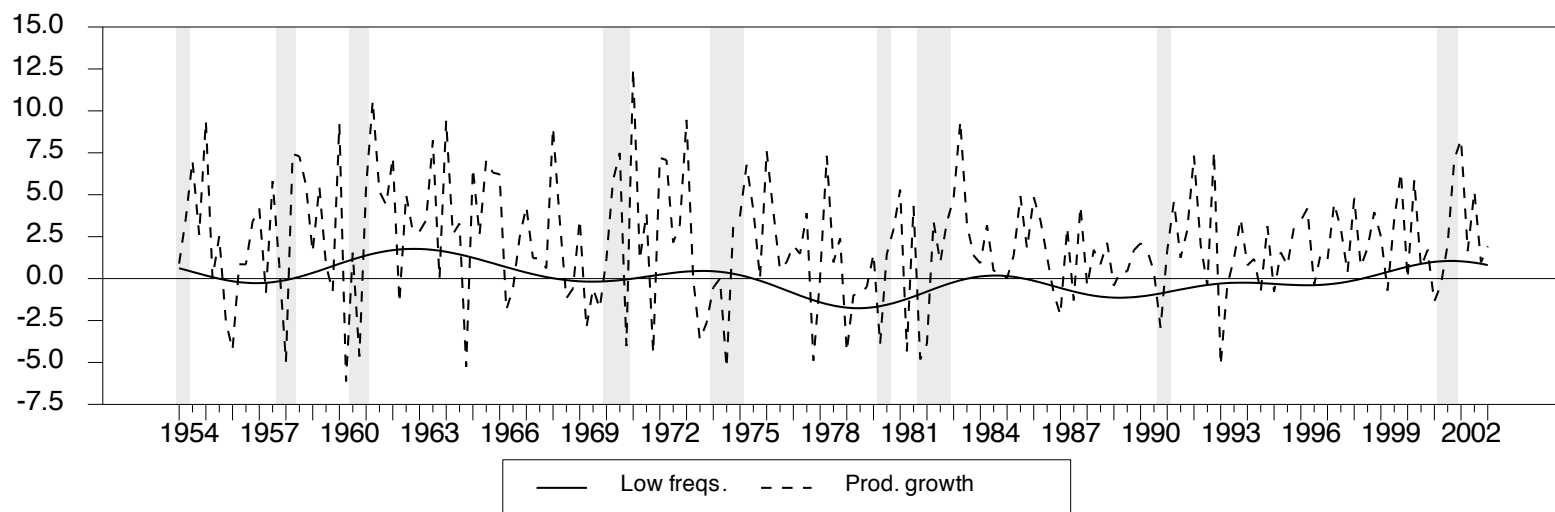
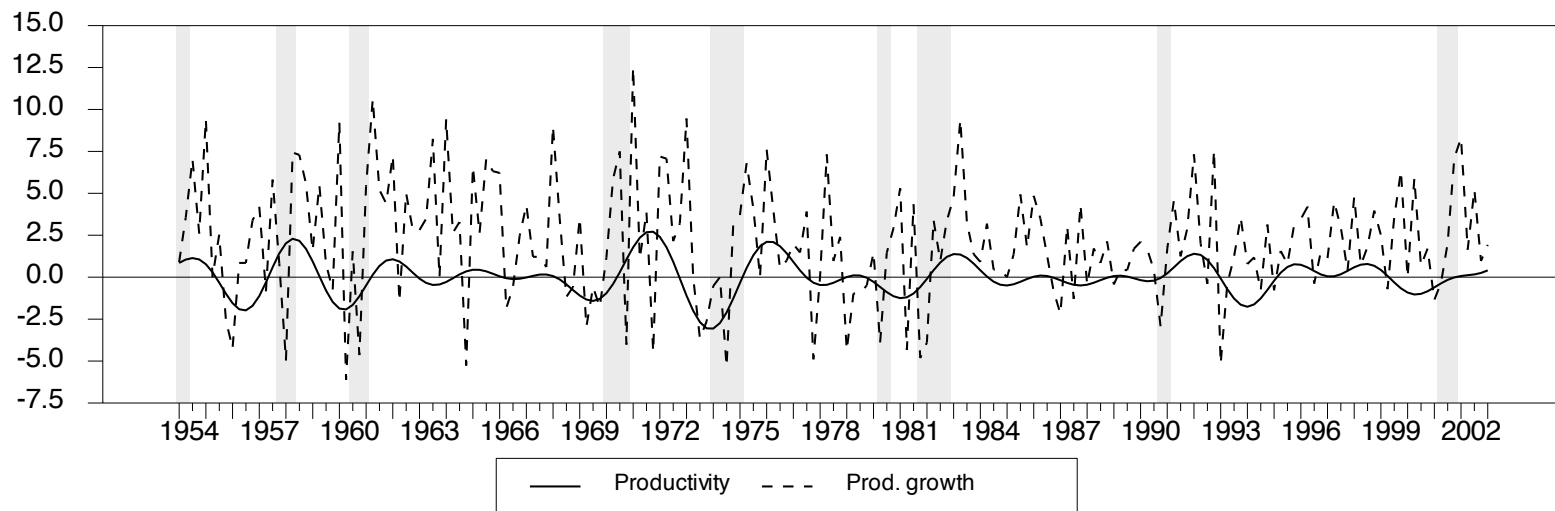
Frequency domain methods

- More accurate than time domain approximations
 - e.g., Baxter-King, Hodrick-Prescott
 - less obligatory differencing
- I could not find any convincing argument that we should prefer freq domain to time domain, Arturo is invited to explain. Paper would be better if he did frequency vs. time domain results side by side and showed us what frequency gives us that time does not.
- Empirical definition of business cycle
 - coherence maximin
 - consistent window
- “Cycles of length 3 to 7 years, what about 1980s (9 years) and 1990s (10 years)??”

Frequency domain measures

- Reference frequency (-ies)
- Coherence
- In-phase correlation
 - cf., dynamic correlation, Croux et al. (2001)
- In-phase regression
 - coefficient, R squared
- Phase lead
- Sample period 1954:Q1 to 2003:Q1, similar to Gordon (BPEA, 2003).

Productivity growth, low frequency and business cycle frequency components

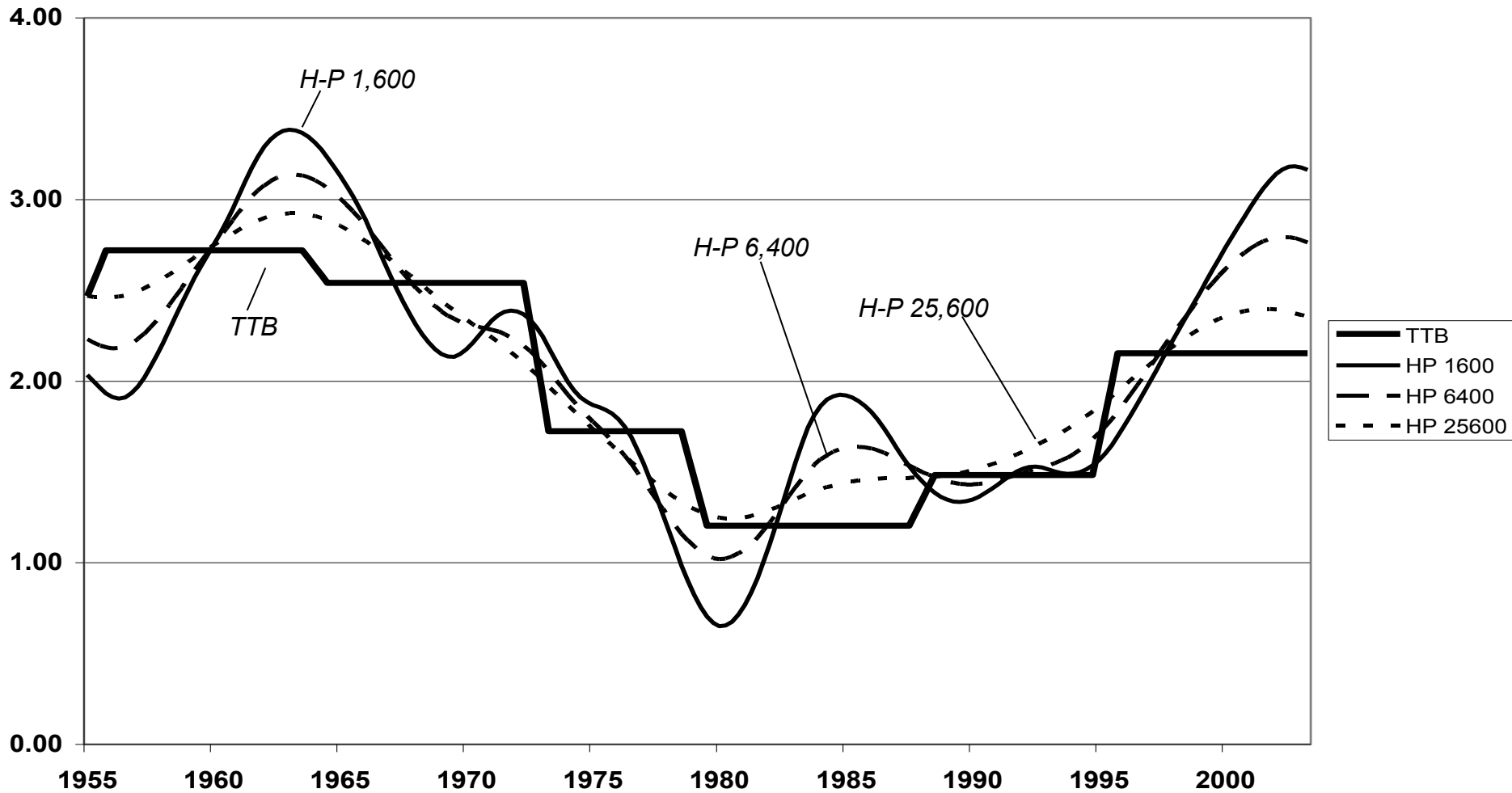


The Paper's Explanation of Figure 1

- The business cycle frequency (solid line) accounts for 9% of the variance of the series.
- The frequency domain analysis indicates correlations among variables at cyclical frequencies that automatically takes account of lags and leads (which has to be done consciously in time domain).

Alternative H-P trends

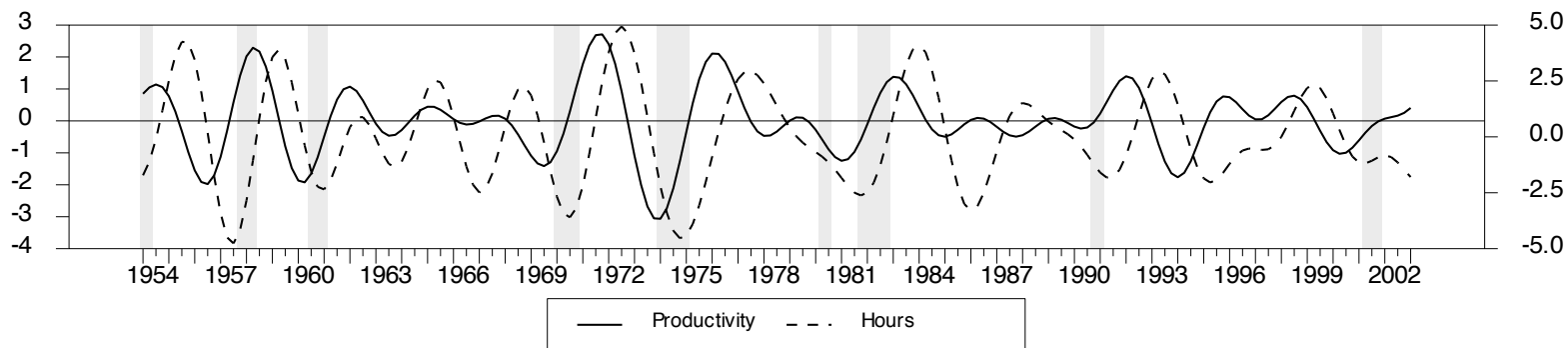
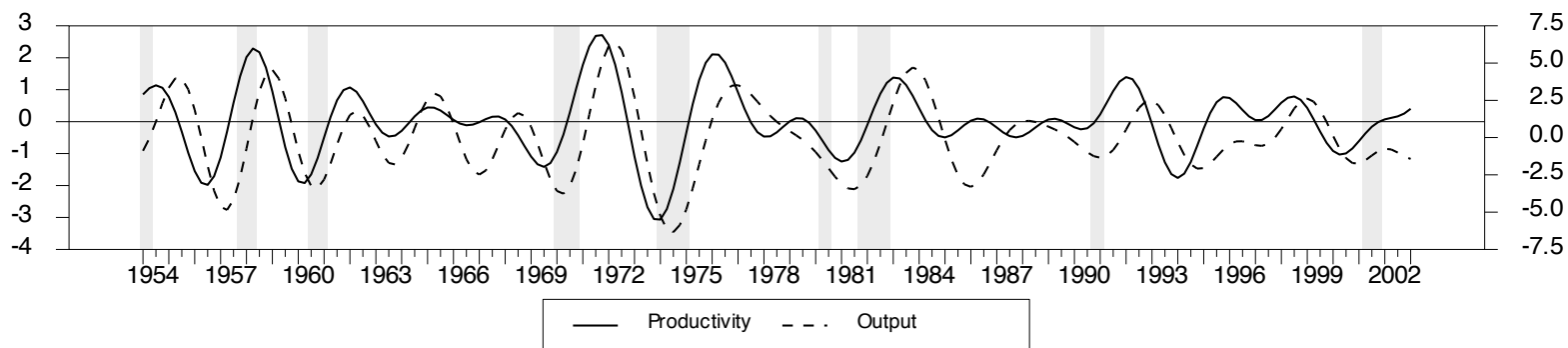
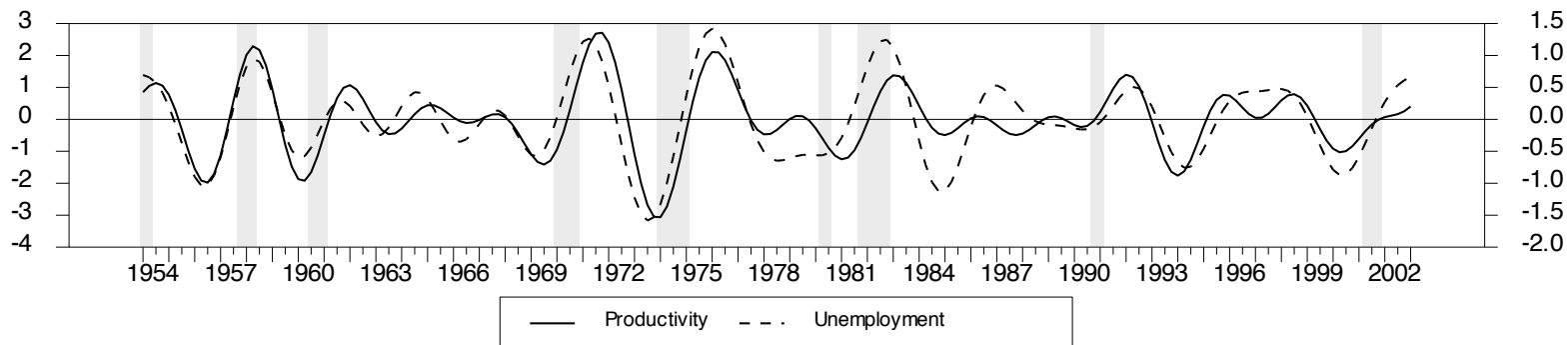
TTB and H-P methods



Before Looking at Figure 2

- Convincing evidence that hours lag output, which implies logically that productivity leads output and leads hours even more.
- You don't need frequency domain to understand this, which everyone knew back in the early 1960s in the era of Oi, Okun, and Hultgren

Business cycle frequency components of productivity growth, output growth and hours growth



The Lag of Hours Behind Productivity, Dramatized in Time Domain

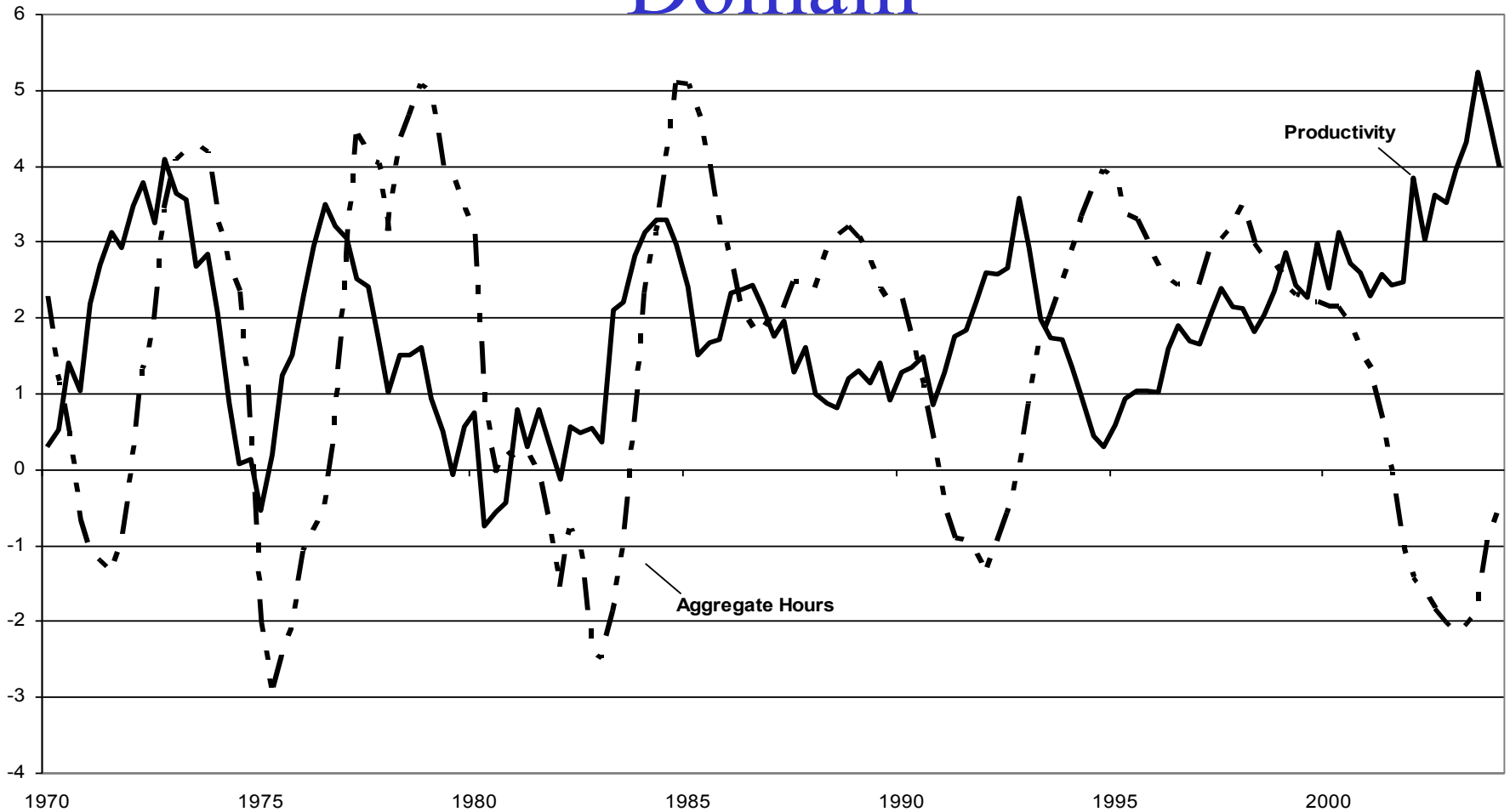


Table 2, Everything is Correlated with Everything

Look at all those high coherences, this says that everything is correlated with everything at the business cycle frequency in the frequency domain, which automatically allows for the obvious lags.

What about 2002-2003, really unusual, not mentioned in paper

Table 2. Coherences
1954 Q1 to 2003 Q1

Var. 1	Var. 2 Δ_x	Δ_y	Δ_n	u
Δ_y	.878 (6.42)	-		
Δ_n	.839 (5.71)	.972 (9.99)	-	
u	.852 (5.93)	.947 (8.44)	.941 (8.20)	-
Δ_u	.848 (5.86)	.960 (9.15)	.977 (10.48)	.946 (8.39)

Table 3. In-phase correlation, proportion in-phase
1954 Q1 to 2003 Q1

Var. 1	Var. 2			
	Δ_x	Δ_y	Δ_n	u
Δ_y	.481 (.300)	-		
Δ_n	.055 (.004)	.902 (.860)	-	
u	.805 (.892)	.180 (.036)	-.192 (.042)	-
Δ_u	-.044 (.003)	-.876 (.833)	-.977 (.999)	.224 (.056)

As We Would Expect, Zero In-phase Correlation of productivity with hours

- Look at next slide with results of Table 3
- Notice very small in-phase (contemporaneous) correlation of productivity with labor market variables
- Why is this interesting? Some naïve investigator could claim no positive, or even negative relation between $y-n$ and n

Table 4. In-phase regression coefficients
1954 Q1 to 2003 Q1

		Regressor:			
Dep. Var.	Δ_x	Δ_y	Δ_n	u	
Δ_x	-	.21 (.11)	.03 (.15)	1.39 (.31)	
Δ_y	1.12 (.61)	-	1.03 (.15)	.72 (1.19)	
Δ_n	.11 (.61)	.79 (.11)	-	-.67 (1.04)	
u	.47 (.10)	.04 (.07)	-.05 (.08)	-	

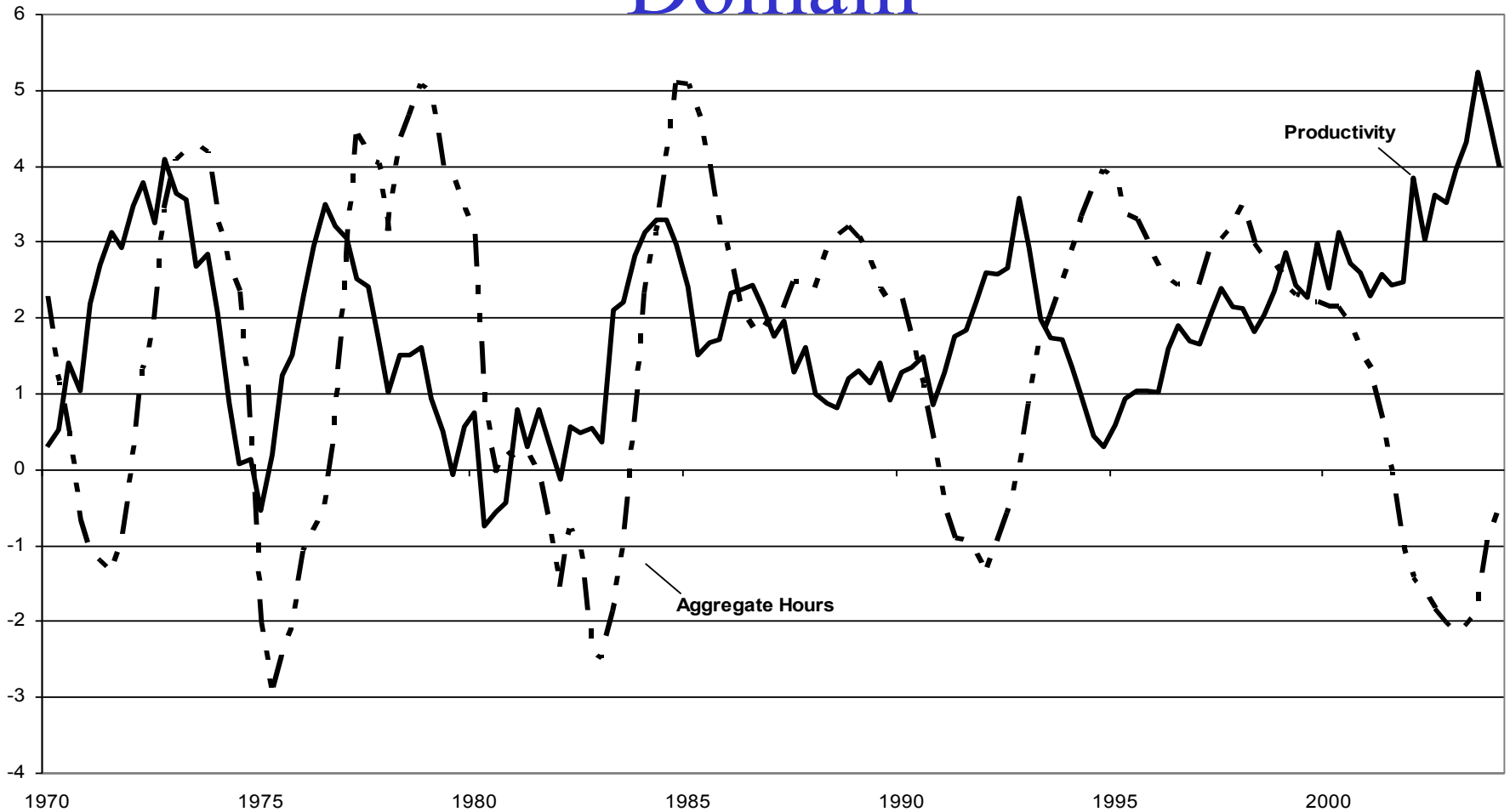
Table 5. Phase: number of periods by which variable 1 leads variable 2
1954 Q1 to 2003 Q1

Var. 1	Var. 2			
	Δ_x	Δ_y	Δ_n	u
Δ_y	-2.60 (.96)	-		
Δ_n	-3.95 (1.14)	-1.01 (.43)	-	
u	.88 (1.08)	3.62 (.60)	4.67 (.63)	-
Δ_u	4.26 (1.10)	7.14 (.51)	8.17 (.38)	3.50 (.61)

Best Part of Empirical Results: Phase Leads and Lags

- Everything looks plausible and sensible
 - Lead of output ahead of hours
 - Lead of productivity ahead of output
 - (Double) lead of productivity ahead of hours
- Go back to my graph

The Lag of Hours Behind Productivity, Dramatized in Time Domain



Conclusions

- Productivity is procyclical
 - positive covariance, but must account for lags
- Dunlop-Tarshis phenomenon
 - theoretical link, apply productivity evidence
- Reder hypothesis (extended)
 - productivity growth is very countercyclical vis a vis unemployment rate

Discussion: Praise

- Cyclical Behavior of Productivity depends on getting the phase right
- Positive correlation of productivity with output is in RATES OF CHANGE not in LEVELS
- Phase discussion exactly right, productivity change leads output change leads hours change
- Not clear what frequency domain adds to ample evidence in time domain
 - Gordon (2003, Table 5) has Δn regressed on current and lagged Δy AND $\Delta(y-n)$ regressed on LEADS of Δy

The “Output Identity” Organizational Tool for Trends, Cycles, and Residuals

- The Output Identity
- In its Simplest Form Makes Output (Q) Equal to the product of:
 - Productivity (Q/A)
 - Hours per Employee (A/E)
 - Employment Rate (E/L), that’s just $(1 - U/L)$
 - Labor-force Participation Rate (L/N)
 - Working-age Population (N)
- Hiding Inside the Output Identity are Numerous Useful Trend and Cyclical Relationships, including
- *OKUN’s Law*. Recall the original 1962 breakdown. For every three percentage points of change in detrended output, 1 point for E/L , 1 point for productivity, $\frac{1}{2}$ point for A/E , and $\frac{1}{2}$ point for L/N .

Five-term Output Identity Cannot be Used for Empirical Analysis

- Productivity data for the NFPB sector
- Expand the identity (equation 2) to identify NFPB variables and links to total economy:

$$Q \equiv \frac{Q^B}{A^B} \cdot \frac{A^B}{E^B} \cdot \frac{E}{L} \cdot \frac{L}{N} \cdot N \cdot \frac{Q/E^P}{Q^B/E^B} \cdot \frac{E^P}{E}$$

- Mix effect – ratio of output per employee: total/NFPB sector
- Employment ratio of payroll to household

Keynes, Dunlop, Tarshis, Arturo's Astonish Literature Lapse

- Holy Grail, RJG “Output Fluctuations and Gradual Price Adjustment,” *JEL*, June 1981, pp. 502-03
- #1 Keynes rejected countercyclical interpretation in *EJ* March 1939
 - “. . . Short-period changes in real wages are usually so small compared with the changes in other factors that we shall not often go far wrong if we treat real wages as substantially constant in the short period” (Keynes, 1939, pp. 42-43)

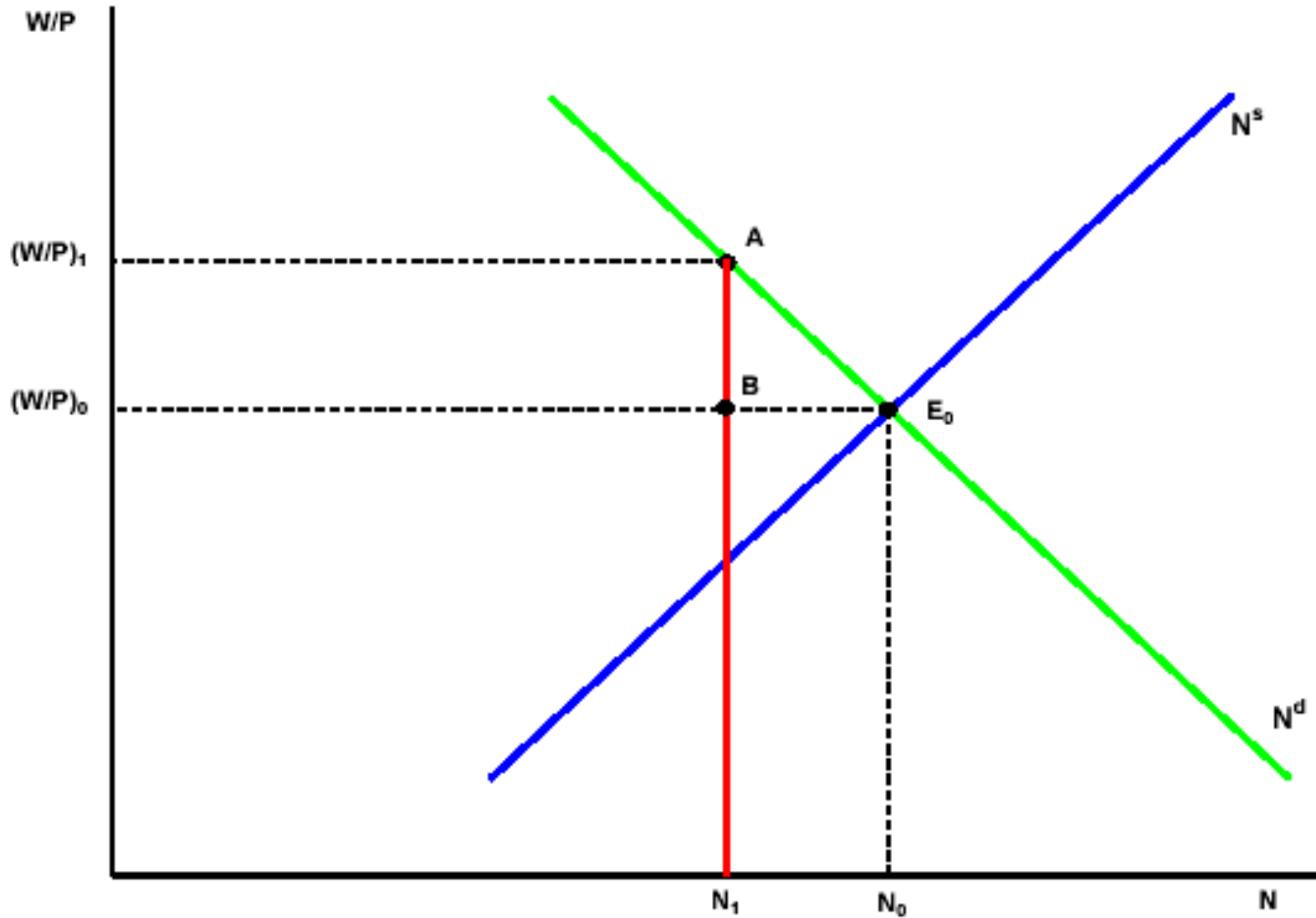
What is Left Out of Graduate Macro Education Today, but not in 1980?

- Non-market-clearing models
- Patinkin (1956, chapter 13)
 - Firms recognize a sales constraint on output at a given level of W/P that forces them to operate off their classical Labor Demand curve
- The central non-market-clearing question. Are firms able to sell all they want at the market real wage? NO!!

Patinkin did the labor market, Clower did the expenditure market

- Clower coined the “effective demand curve” to describe firms which were unable to obtain their preferred combination of wage and employment in the labor market
- Patinkin (1956) and Clower (1965) were synthesized by Barro-Grossman (1971).
- The graph: why there is no presumption in Keynesian economics of a negative correlation between employment and the real wage

Labor Market 2



Going Beyond Paper, What About Labor's Share?

- Assumed in false-Keynesian interpretation to be constant over the cycle

$$S^* = \frac{W^*/P^*}{Y^*/N^*} = \frac{W^*/P^*}{X^*}$$

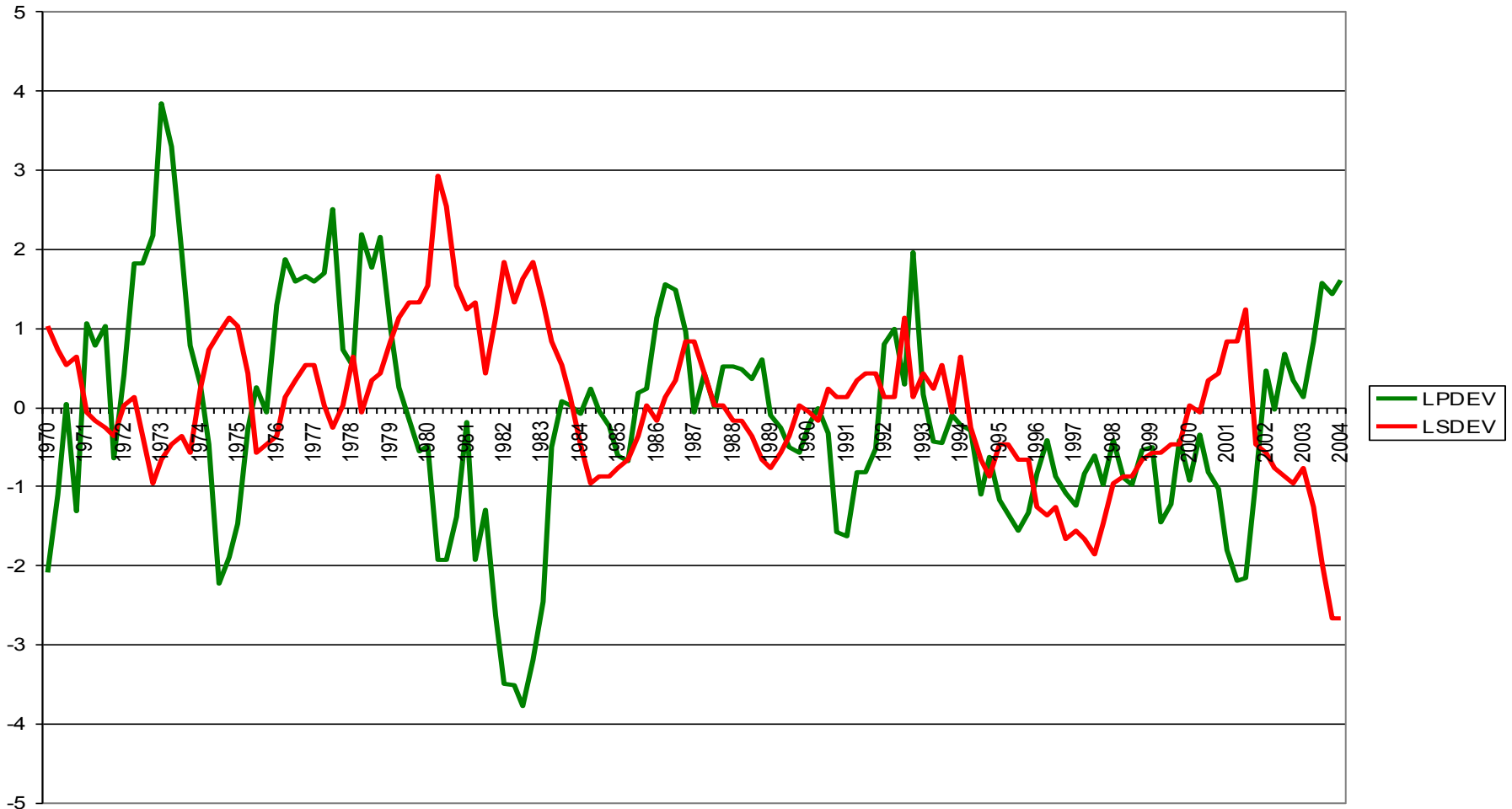
- A start at an interpretation

$$P = P^* \left(\frac{X}{X^*} \right)^{-\gamma} Z$$

- Unique about price: partial adjustment to productivity

$$\frac{S}{S^*} = \left(\frac{W/W^*}{(P/P^*)(X/X^*)} \right) = Z^{-1} \left(\frac{X}{X^*} \right)^{-(1-\gamma)}$$

How is Labor's Share Related to Cyclical Productivity?



Regression Results

- ** drop lags
- Linear Regression - Estimation by Least Squares
- Dependent Variable C1LSHR
- Quarterly Data From 1970:01 To 2004:01
- Usable Observations 137 Degrees of Freedom 133
- Centered R**2 0.264691 R Bar **2 0.248105
- Uncentered R**2 0.264693 T x R**2 36.263
- Mean of Dependent Variable 0.0007299270
- Std Error of Dependent Variable 0.4330969784
- Standard Error of Estimate 0.3755465201
- Sum of Squared Residuals 18.757680107
- Regression F(3,133) 15.9588
- Significance Level of F 0.00000001
- Durbin-Watson Statistic 2.072539

Variable	Coeff	Std Error	T-Stat	Signif

1. Constant	-0.000579057	0.032086045	-0.01805	0.98562839
2. C1LPDEV	-0.272623889	0.040989557	-6.65106	0.00000000
3. CC1FAE	0.006115405	0.002978082	2.05347	0.04198668
4. CC1RELIMP	0.013260474	0.004978166	2.66373	0.00868337

Conclusions

- Empirical analysis has it exactly right, study relation of changes to changes, not levels to levels
- Need to compare frequency to time domain to provide more convincing case of payoff to frequency domain
- Reder hypothesis can't be tested without micro data
- Read Patinkin (1956) Chapter 13 and/or Barro-Grossman *AER* (1971). Keynesian model has NO implications for cyclical behavior of real wage or productivity