KEYNES RE-INTERPRETED – AN ECONOMETRIC INVESTIGATION OF KEYNES' CONSUMPTION FUNCTION THEORY IN POST-WAR AMERICA

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Using econometrics, this essay examines John Maynard Keynes' consumption function hypothesis and its applicability to the US economy over the last half-century. Employing income and interest rates as explanatory variables, Michael Curran seeks to examine their effects on consumption expenditure, encountering non-stationarity, autocorrelation and non-normality along the way.

Introduction

"The fundamental psychological law … is that men are disposed … to increase their consumption as their income increases, but not by as much as the increase in their income."[1]

Although recent emphasis has focused on the marginal propensity to consume (MPC) of permanent income and of wealth, e.g. Modigliani and Brumberg (1955), Friedman (1957), Kimball (1990), Carroll (2000, 2001a, 2001b), in this paper I will investigate Keynes' consumption function hypothesis. I will examine the effects of real income per person employed, and nominal interest rates on real consumption expenditure per person employed concentrating on consumers in the USA between the first quarter of 1949 and the third quarter of 2006.

[1] Keynes 1936, p.96

Figure 1. PCE against PDI

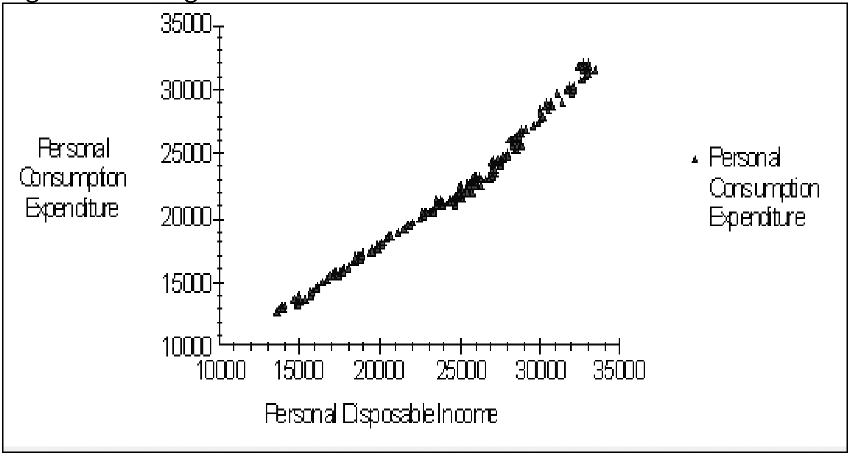


Figure 1 illustrates a rising trend and close relationship between the two variables, personal consumption expenditure (PCE) and personal disposable income (PDI). It is harder to identify any clear relationship in Figure 2 between PCE and bank prime loan rate (PRIME). As most of the observations for *quarterly changes* in PDI and *quarterly changes* in PRIME are scattered around the origin (Figure 3), it appears that there is no multicollinearity between these two explanatory variables.

Figure 2. PCE against PRIME

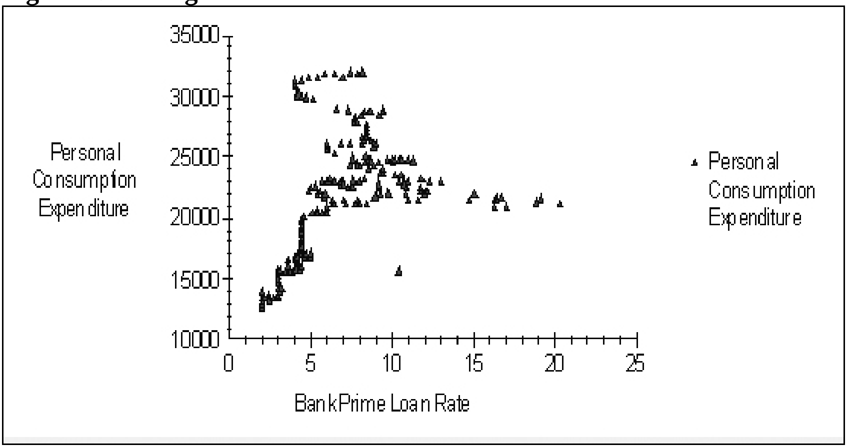
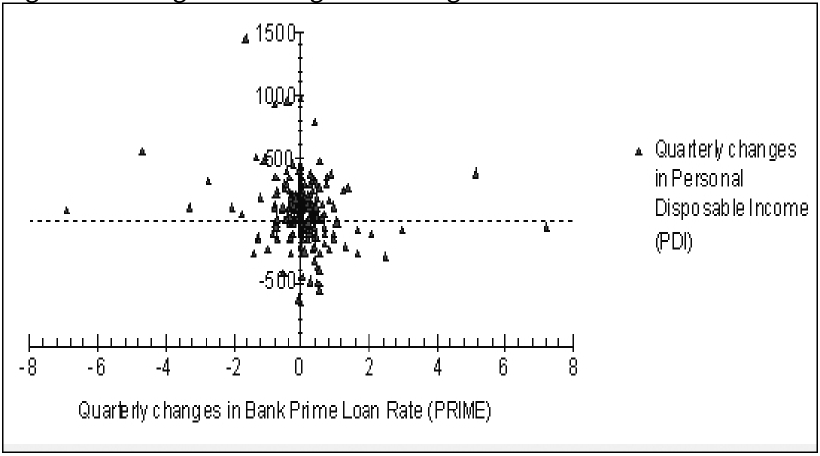


Figure 3. Changes in PDI against Changes in PRIME



Keynes' General Theory

Keynes approximated the discount rate using the interest rate, which he hypothesised led to short period changes, only if there were unusually large variations in this rate; else it was part of a separate determinant of consumption, *viz.* windfall changes of capital values: 'consumption of wealth owning classes may be extremely susceptible to unforeseen changes in the money-value of its wealth' (Keynes, 1936:92-3) He concluded that real income is 'the principal variable upon which the consumption-constituent of the aggregate demand function will depend' (ibid.:96).

I could have chosen the real rate of interest and transformed my second explanatory from PRIME (nominal) to the real value:

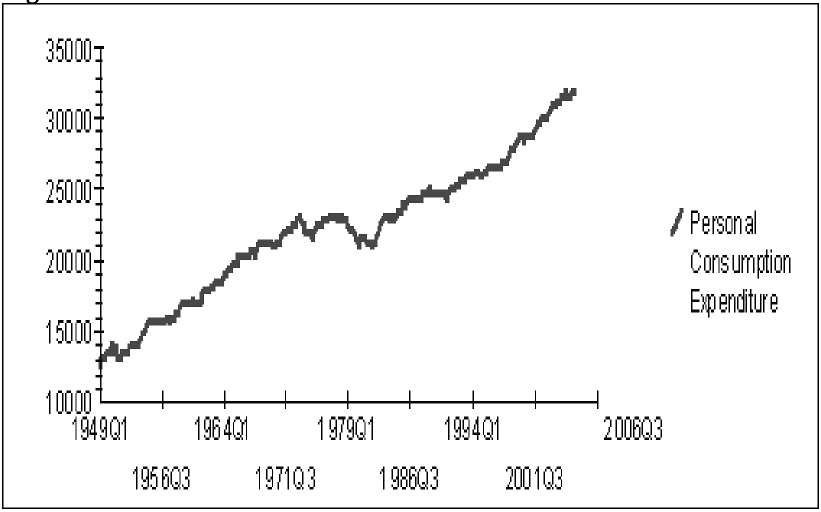
$$\frac{1 + \mathrm{PRIME}}{1 + (Pt+1 - Pt)/Pt} - 1$$

However, the *nominal* interest rate is more appropriate to my investigation – Keynes refers to the nominal interest rate, which will have greater impact on my variables.

Econometric Models & Estimation

The following graphs illustrate that the time series variables – PCE, PDI and PRIME are non-stationary[2]; in Figures 4 and 5, the means of PCE and PDI, respectively rise over time. First differencing produces stationary time series', removing stochastic trends. Figure 6 shows that the variability of PRIME changed over time. Again first differencing induces stationarity.

Figure 4. PCE over Time



[2] Although not presented (due to space constraints), individual unit root tests for PCE, PDI and PRIME confirm this; an augmented Engle-Granger (1987) co-integration test inferred residuals are nonstationary – nonstationary variables and residuals imply that levels regression is spurious.

Figure 5. PDI over Time

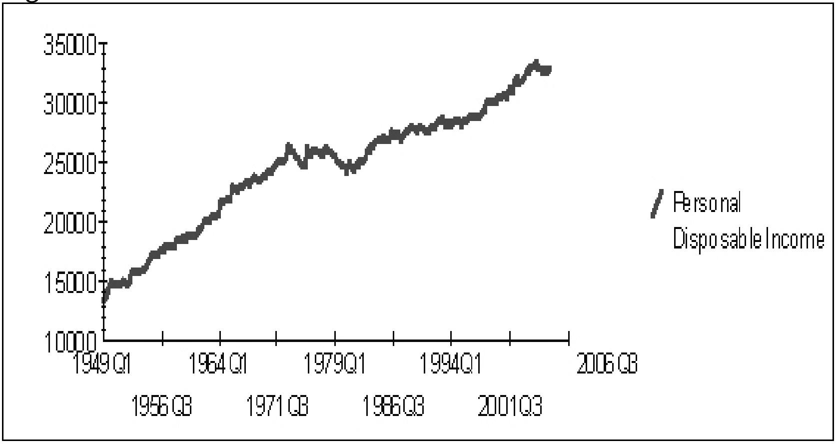
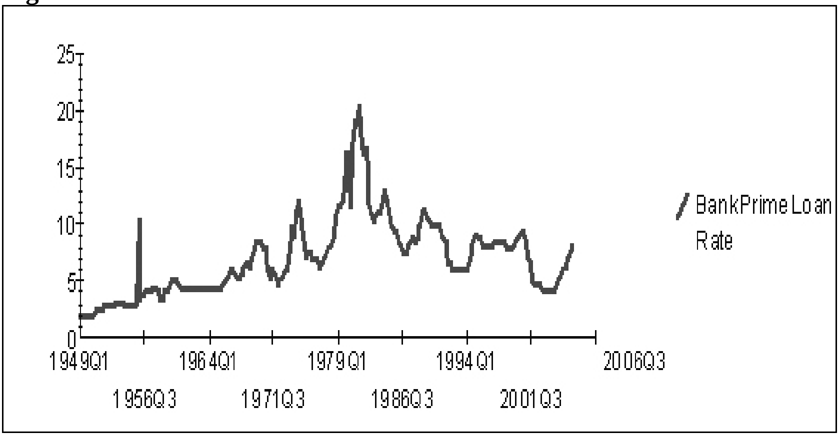


Figure 6. PRIME over Time



A lower Durbin Watson (DW) statistic (.24511) than R^2 (.98818) would suggest that the estimation method of OLS provides spurious[3] results (Granger and Newbold, 1974) – we should not take the results of the regression too seriously. The DW statistic produced under first differencing is 2.3422, which is greater than R^2 = .30257; we fail to reject the hypothesis of non-spurious regression.

[3] Even when sample size is large, spurious correlation can persist in nonstationary time series (Yule, 1926).

The above discussion advocates a revised model: *quarterly changes in (real) PCE (per person employed) depends linearly on quarterly changes in (real) PDI (per person employed) and quarterly changes in nominal interest rates*. Hence, I shall estimate the following equation[4]:

$$\mathbf{\Delta PCE_t = \beta_0 + \beta_1\, \Delta PDI_t + \beta_t\, \Delta PRIME_t + u_t}^{5}$$

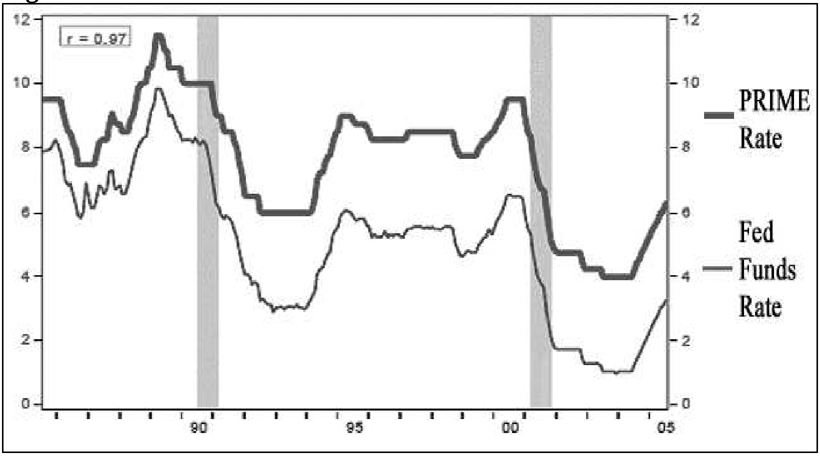
where

ΔPCE	= quarterly change in real personal consumption expenditure per person employed.
ΔPDI	= quarterly change in real personal disposable income per person employed.
ΔPRIME	= quarterly change in bank prime loan rate.
u	= residual.

PCE and PDI are level variables and PRIME is a nominal, percentage variable. I chose *real* PCE *per person employed* to be a proxy of consumption expenditure, as PCE is an aggregate figure that could rise due to an increase in employment levels and/or with inflation. The reasoning behind my selection of real PDI per person employed as a proxy for real income was similar to that for real PCE per person employed; ‘other objective attendant circumstances’ determining consumption include changes in fiscal policy, which affect disposable income, so I chose income net of taxes (Keynes, 1936:91). As a proxy for the interest rate, I chose the Bank Prime Loan Rate, which is a short term reference/base rate that US domestic commercial banks use to set the interest rates on many of their commercial bank loans and loans to consumers. Unlike deposit rates, it is usually uniform across all banks and is similar to an upper-bound on interest rates. Figure 10[6] shows that the prime rate very closely follows the federal funds rate – the interest rate that banks charge each other on overnight loans.

4 Retrospection on introducing a trend term revealed a similar adaptation by Smithies (1945).
5 $\beta_0 \equiv$ Constant
6 See http://www.frbsf.org/education/activities/drecon/2005/0506.html

Figure 7. Bank Prime Loan Rate and Federal Funds Rate



Adapted from the Federal Reserve Bank of San Francisco

My model is linear in form (in the parameters and variables). I postulate an increase in PCE, when ΔPDI and ΔPRIME are simultaneously zero and a 'positive and less than unity' β_1 (partial regression coefficient[7] of ΔPDI) – a slight variation to Keynes' model (Keynes, 1936:96). The partial coefficient of ΔPRIME measures the change in the mean value of ΔPCE, per unit change in ΔPRIME holding ΔPDI constant; I anticipate an inverse[8] relationship between ΔPRIME and ΔPCE.

Data

231[9] quarterly observations were taken for PCE and PDI from the first quarter of 1949 to the third quarter of 2006. The data for PRIME was transformed from a frequency of monthly to that of quarterly. I adjusted PCE and PDI from nominal, aggregate level variables in billions of US dollars to

[7] My substitute for Keynes' MPC measures the change in the mean value of ΔPCE, per unit change in ΔPDI, holding the value of ΔPRIME constant. Ceteris paribus, I envision that similar to the MPC (although in terms of changes), variations in ΔPDI will lead to less than proportional variations in ΔPCE, albeit in the same direction.

[8] Fixing ΔPDI, an increase in growth of PRIME slows down the growth of PCE, or if PCE is constant, it should start to fall.

[9] 230 observations are used for first difference estimation: sample size minus first observation.

real[10], per person employed[11] variables in US dollars. All data has been taken from the website of the St. Louis Federal Reserve Bank.

Table 1. Summary Statistics for Level Variables for Sample Period

Variable	PCE (US$)	PDI (US$)	PRIME (%)
Maximum	31,895.80	33,483.40	20.3233
Minimum	12,654.10	13,619.20	2
Mean	22,166.20	24,551.40	7.1076
Std. Deviation	4,904.80	5,101.00	3.4355
Avg. Growth[12]	0.004079	0.003881	0.015892

Table 1 shows summary statistics for the three *level* variables. The maximum value of PRIME was in the third quarter of 1981 – the chairman of the Federal Reserve at this time was Paul Volcker, an 'inflation hawk' (Bernanke, 2004).

Results

Table 2. Regression Results

Regressor	Coefficient	Standard Error	T-Ratio	[Prob]
CONSTANT	52.9116	11.7046	4.5206	[.000]
ΔPDI	0.38058	0.043485	8.7521	[.000]
ΔPRIME	-34.5743	10.8581	3.1842	[.002]

Table 3. Relevant Statistics

Statistic	Value
R-Squared	0.30257
R-Bar-Squared	0.29643
F-Statistic F(2,227):	49.2406 [.000]
DW-statistic	2.3422

[10] Dividing nominal variables by the Consumer Price Index (CPI) divided by 100 (since the base period CPI had a value of 100). The base period index was 1982-84. I averaged CPI data for each quarter.

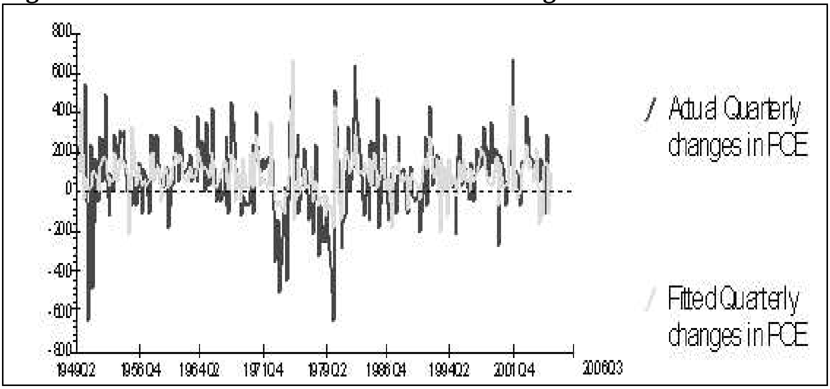
[11] Actually, per civilian employed – a proxy for total employment. I assumed (hoped for) inter-temporally an approximately constant ratio of civilian to military employment, of purchasing power of civilian employees to military employees and of consumer expenditure of civilian employees to military employees in order to justify my choice of surrogate for employment. I averaged this data for each quarter.

[12] Average *quarterly* growth expressed in percentages.

Multiple Coefficient of Determination (R^2)

The R^2 value of .30257 is statistically significantly different from zero since the *F* statistic (49.2406 for 2 numerator and 227 denominator degrees of freedom) has a *p*-value of less than .001: the true population parameters are not identically zero. This R^2 value means that over 30% of the variation in ΔPCE is explained by ΔPDI and ΔPRIME. The fitted line and the actual line in Figure 8 depart from each other to some extent, but there is sufficient visual evidence of closeness of fit.

Figure 8. Plot of Actual and Fitted Values of Regression



T-tests

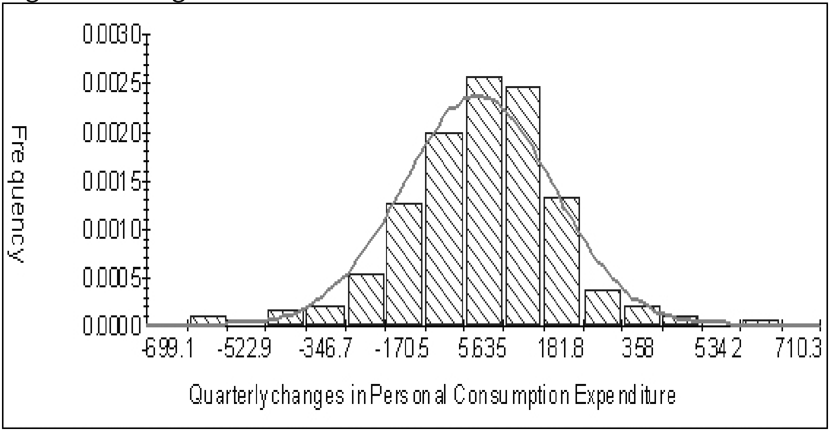
All partial regression coefficients, β_0, β_1 and β_2 are statistically significantly different from zero as the accompanying *p*-values to their estimated *t*-values are sufficiently small. Their signs are in accordance with prior considerations. When PDI and PRIME are constant, on average, PCE is increasing quarterly by just over US$52.91. Fixing ΔPRIME, a 10% increase in ΔPDI will lead to a $3.8 rise in ΔPCE. Holding ΔPDI constant, raising ΔPRIME by 1% will lead to a decline in ΔPCE of almost $34.6.

Table 3: Diagnostics Results

Diagnostic Tests	CHSQ	T-Statistic	P-Value
Serial Correlation	4	11.9365	[.018]
Functional Form	1	0.55487	[.456]
Jarque-Bera Test	2	47.6336	[.000]
Heteroscedasticity	1	0.028538	[.866]

A histogram of residuals (Figure 9) shows that the residuals from the regression may not be symmetrically distributed. The Jarque-Bera (*JB*) statistic is about 47.6336 with a *p*-value of less than 0.1%. The sample size should be large enough for us to be reasonably confident that we are not making a Type I error – we reject the hypothesis that residuals are normally distributed.

Figure 9. Histogram of Residuals



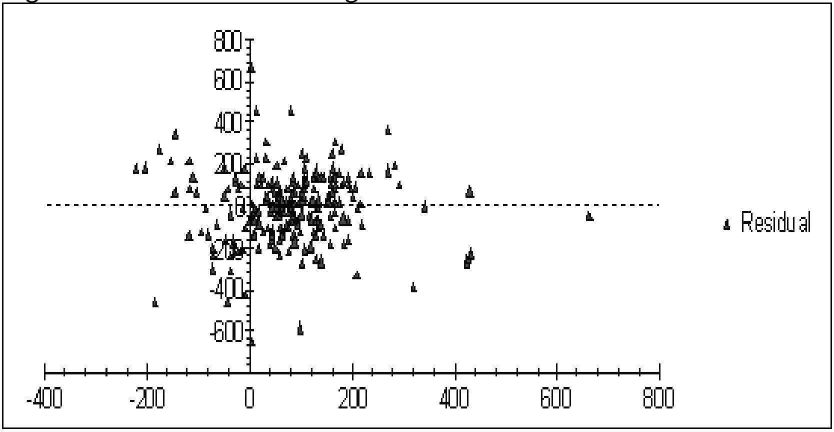
The value of 0.55487 with a *p*-value of .456 from the Ramsey RESET test of functional form results in a failure to reject the null hypothesis that the model is correctly specified. This test is validated because of the relatively large sample size.

For a 1% significance level, 230 observations and two explanatory variables, $d_u \approx 1.693$ and $d_l \approx 1.653$. A Durbin-Watson statistic for autocorrelation between residuals of 2.3422 displays evidence of negative autocorrelation[13]. Unlike the *DW* test, the Breusch-Godfrey serial correlation test relies on large sample sizes. The *p*-value accompanying the *BG* statistic is about 0.018 – we conclude that serial correlation is present in our model.

The Koenker-Bassett test for heteroscedasticity is valid even if the residual term in the model is not normally distributed; Microfit produces 0.028538 with a *p*-value of .866 – we fail to reject the null hypothesis that the residuals exhibit the same conditional variances. The graph (Figure 10) of residuals on the fitted values of ΔPCE confirms the roughly equal spread.

[13] Since the regressors are stochastic, the DW or d test will be valid in neither small samples, nor in large samples (Davidson, 2000).

Figure 10. Estimates for Changes in PCE and Residuals



Confidence Interval for β_1

A confidence interval for β_1 will take the form:

$$\beta_1 \pm (t_{\alpha/2}^{\upsilon=n-3})(\mathrm{SE}(\beta_1))$$

For a 95% confidence level, $\alpha = 0.05$, *t*-tables show $t_{0.025}^{227} \approx 1.96$; thus we get:

$$.38058 \pm (1.96)(0.043485)$$

This yields a confidence interval of:

$$[0.2953494, 0.4658106]$$

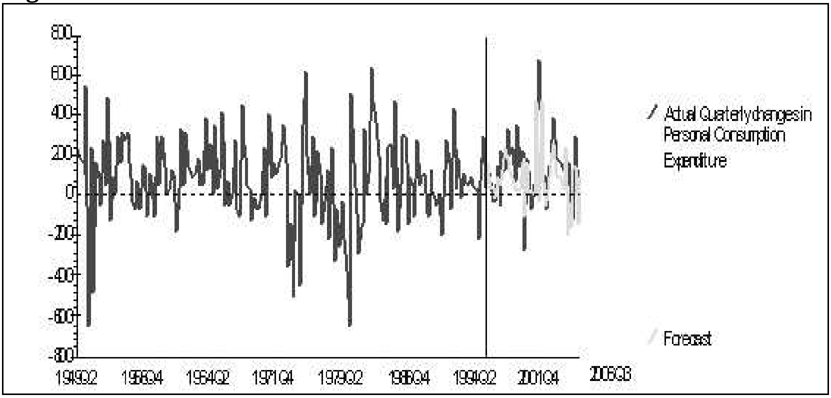
Therefore if this test was carried out an infinite number of times, the true value of β_1 would lie between 0.2953494 and 0.4658106 ninety-five percent of the time.

Forecast

Forecasting tests the model's accuracy. Running the regression, without the last 43 quarters (i.e. from the first quarter of 1949 to the last quarter of 1995) resulted in a graph (Figure 11) of the observed ΔPCE and the forecasted values. The forecast seems to follow the general trend and the Chow predictive failure *F*-test returns a value of 0.92562 with a *p*-value of 0.606 –

we fail to reject the null hypothesis of accurate forecasting properties of the model.

Figure 11. Plot of Actual and Forecasted Values



Conclusion

The problem of non-stationarity means that first differencing is necessary. On inspection of the correlogram for PRIME we see it cuts off at lag j = 52, so further research may propose using a MA(52) model. The correlograms for PCE and PDI do not cut off, so one could look at the Partial Autocorrelation Function of each variable to determine whether we should assume an AR or an ARMA model.

Data on total employment may be explored. As mentioned in footnote 11, I have looked at civilian employment in this investigation, i.e., per civilian (not per person) employed.

The presence of autocorrelation suggests the use of a Feasible Least Squares estimation such as the Cochrane-Orcutt method. The adoption of this process (also the addition of a trend variable) delivers improved results.[14]

Non-normality is a worrying consequence as the *F* and the *t* tests both assume normal distribution of variables. However, the model appeals due to an equal spread of errors (homoscedasticity), correct functional form, and good forecasting ability, in addition to meeting prior considerations discussed earlier. On the assumption that Keynes would agree to my reinterpretation, he would be proud of the results!

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[14] Space considerations do not permit the inclusion of these findings.

Data Sources

Federal Reserve Bank of St. Louis:

PCE:	http://research.stlouisfed.org/fred2/series/PCEC/downloaddata?&cid=110
PDI:	http://research.stlouisfed.org/fred2/series/DPI/downloaddata?&cid=110
CPI:	http://research.stlouisfed.org/fred2/series/CPIAUCSL/downloaddata?&cid=9
PRIME:	http://research.stlouisfed.org/fred2/series/MPRIME/downloaddata?&cid=117
Figure 7:	http://www.frbsf.org/education/activities/drecon/2005/0506.html
Emp.:	https://alfred.stlouisfed.org/fred2/series/CE16OV/downloaddata?&cid=10

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