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RESEARCH ARTICLE

The Dynamic Phillips Curve Revisited: An Error Correction Model

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Abstract

In this paper, we apply different unit root tests on five macroeconomic variables. Nearly all our data exhibit unit root phenomenon, confirming results well-known in the literature. Co-integration tests indicate that there exists one set of co-integration relation in the unemployment- inflation equation. The VAR error correction model explains the expected short-term behavior of changes in unemployment rate on the inflation rate on inflation two years later.

Keywords: *Correction model, Phillips Curve, Vector autoregression.*

Introduction

In 1958, economist A.W. Phillips [1] used British data from 1861 to 1957 to examine the relationship between nominal wage growth and unemployment rate. His results were the now famous finding of a stable inverse relationship between the two variables. Later economists used inflation in place of nominal wage growth to re-examine the relationship and again found a stable inverse relationship. The relationship appeared to break down during the stagflation of the 1970's, when both inflation and unemployment rate increased. Even before the stagflation of the 1970s, Friedman [2] and Phelps [3] questioned the validity of the Phillips curve, arguing that changes in levels and changes in rates of growth, and the expectations of such changes, account for the tradeoff, rather than them being due to the relationship between levels. By delineating expected (Πe) and unexpected inflation (Π-Πe) on the one hand, and actual (μ_t) and natural rate (μ_n) of unemployment on the other, the Phillips curve phenomenon can be better understood by regressing actual inflation Π on $\Pi_e - m(\mu_t - \mu_n)$, or the expectations–augmented Phillips curve as in Sargent [4].

While regression around means or fixed values (Πe and μ_n) better explains economic behavior than simple levels, new trends in econometrics starting 1980's have rendered regression using difference(s) an even better choice than that around means or around levels. In what it follows, section 1 examines the unit root properties and section 2 illustrates the co-integration and error correction models. Section 3 provides a conclusion.

Data and Unit Root Tests

Granger and Newbold [5] found a significant but spurious relationship in their regression model using levels. Such models reveal a high R squared, significant t statistics and a low Durbin-Watson statistic. The spurious regression indicates the t statistic is unusually large. Granger and Newbold suggest using t=11.2 instead of t=1.96. Correct regression on levels requires examination of the stationary property of variables involved. If a variable exhibits I (1), integrated of order 1 or higher (I (d)) for d>1, taking differences is recommended. Nelson and Plosser [6], followed by Mankiw and Shapiro [7], Campbell and Mankiw [8] and Perron and Phillips [9], showed that many macroeconomic variables are of I (1) or I (2). Therefore, taking first difference is necessary before performing regression analysis. Unit root tests such as Augmented Dickey–Fuller [10] are available on many statistical software packages. We first perform such tests on the following variables

INF = Inflation rate from 1967 to 2006 (base year=1987)

GINIGAP = Gap of the Gini ratios between African Americans and White Americans

RGDP = Real GDP using 1987 as base year

RMIN = Real minimum wage rate using 1987 as base year

UNEMP = Unemployment rate

We report the results on the three tests, Augmented Dickey-Fuller (ADF), Phillips-Perron (PP), and Kwiatkowski-Phillips-Schmidt-Shin (KPSS) in Table 1.

Table 1: Unit root test results[1]

Unit root models / variable	ADF	PP	KPSS
INF	-1.683	-1.943	0.466**
GINIGAP	-2.132	-2.04	0.301
RGDP[2]	-1.542	-1.484	0.203**
RMIN	-0.962	-0.874	0.706**
UNEMP	-2.592	-1.804	0.171

We fail to reject the null hypothesis of a unit root for all the variables via the ADF and PP tests. Results of the KPSS test lead us to reject the null hypothesis of a stationary variable in 3 of 5 cases (INF, RGDP, RMIN) indicating the prevalence of a unit root in nearly all the variables. It is well known that not all the unit root models give the same conclusion especially in finite (medium sized) samples.

Co-Integration Test and Error Correction Model of the Dynamic Phillips Curve

It is known that if two or more variables are co-integrated, they must obey some long-run equilibrium relationship regardless of the order of each variable I (1) or higher order or not [11] [12]. An existence of a co-integration for Yt and Zt implies that the error correction model (ECM) is a viable approach in describing the short-run variation (in first difference) around the long-run relationship (in level). Before applying the ECM, we need to test for co-integration between the variables. Table 2 reports the co-integration result using the maximum likelihood estimation by Johansen and Juselius [13].

Note that the null hypothesis is Ho: r=o, against HA: r=1, where r is number of co-integration relations. When the null is rejected, as is the case here (P values are 3.84% for the trace test and 3.76% for the maximum eigenvalue test), we proceed to the maximum eigenvalue tests where Ho: r=1 against HA: r=2. Because the calculated p values are 37.97% and 63.49%, we fail to reject the null hypothesis.On this basis, we conclude there exists one co-integration relation, or that the co-integration rank equals one. Both trace and maximum eigenvalue tests give consistent results, which enable us to transform the five variables to stationarity via first differences.

We employ the vector autoregression (VAR) framework to model the dynamic Phillips curve; that is, a five-variable VAR model with some lagged dependent variables to ensure the iid nature of the residuals. The error correction terms from the long-run equilibrium equation are assumed to be I (0). With the optimum lag set at 2, we formulate the model as:

ΔINFt=c + b1ΔGINIGAPt-1 + b2ΔGINIGAPt-2 + b3ΔRGDPt-1 + b4ΔRGDPt-2

-0.393	-44.156	-2.629	-0.005
(-0.53)	(-1.525)	(-0.1)	(0.559)

+ b5ΔRMIN t-1 + b6ΔRMINt-2 + b7ΔUNEMPt-1 + b8ΔUNEMPt-2

-1.474	-4.114	0.239	-1.05
(0.889)	(-2.594)	(0.45)	(-1.886)

+ b9ΔINFt-1 + b10ΔINFt-2 + b11ecmt-1 + εt **(1)**

0.654	-0.3111	89.891
(3.97)	(-1.981)	(3.393)

Note that we present only the ΔINF equation, and do not report the other 4 equations in the VAR. The t values are in parentheses and the log likelihood function = -127.974. We perform all estimations using the statistical package Eview 6. The advantage of the ECM is that it provides an adjustment process to a long-run equilibrium, which is analogous to the expectation theory regarding the Phillips curve. The ecmt-1 term is the bridge that links long-run equilibrium and short-run fluctuation: if $ecm_{t-1} = \Delta INF_{t-1} - \Delta\widehat{INF}_{t-1}$ is positive (actual inflation exceeds expected inflation in year t-1), we expect ΔINFt to be negative after one year's adjustment. As such we expect the coefficient on ecmt-1 to be negative (other variables in first difference are held constant) in order to restore the system to the long-run equilibrium. However, the estimated coefficient 89.891 (t = 3.393) is positive, signaling that if last year's inflation is higher than expected, (ecmt-1 >0), this year's inflation will even be higher (ΔINFt >0) ceteris paribus. Such an expectation, if left unchecked, can be harmful to an economy. The phenomenon manifests again in the positive coefficient of ΔINFt-1(0.645): higher inflation begets more inflation after one year. However, the estimated coefficient on ΔINFt-2 is negative (-0.311), indicating a reversal of direction in year two. Not only can we feel the ultimate impact on ΔINFt two years ago, but the effect also hinges on other lagged variables. For instance, ΔUNEMPt-2, two years ago does have a significant negative impact (t = -1.886) on ΔINFt as does ΔRMINt-2 (t = -2.594). This suggests that

[1] Ho for both ADF and PP Test is: the variable has a unit root
Ho for the KPSS is: the variable is stationary
[2] RGDP is tested with the addition of a trend and a drift while other variables are tested with a drift- term
**= significant at 5% level

Table 2: Results of the johansen co-integration test

	Co-integration	Rank test	(Trace)	
Hypothesized # of co-integration relations	**Eigenvalue**	**Trace statistic**	**0.05 Critical value**	**Prob.**
None*	0.610653	71.23695	69.81889	0.0384
At Most 1	0.357379	36.33538	47.85613	0.3797
At Most 2	0.251798	19.974	29.79707	0.4246
At Most 3	0.143813	9.240941	15.49471	0.3436
At Most 4	0.090161	3.496061	3.841466	0.0615

Trace test indicates 1 cointegrating eqn(s) at the 0.05 level
* denotes rejection of the hypothesis at the 0.05 level
**MacKinnon-Haug-Michelis (1999) p-values

	Co-integration	Rank Test	(Maximum	Eigen value)
Hypothesized # of co-integration relations	**Eigenvalue**	**Max. eigen statistic**	**0.05 Critical value**	**Prob.**
None*	0.610653	34.90157	33.87687	0.0376
At Most 1	0.357379	16.36138	27.58434	0.6349
At Most 2	0.251798	10.73306	21.13162	0.6739
At Most 3	0.143813	5.74488	14.2646	0.6462
At Most 4	0.090161	3.496061	3.841466	0.0615

Max-eigenvalue test indicates 1 cointegrating eqn(s) at the 0.05 level
* denotes rejection of the hypothesis at the 0.05 level
**MacKinnon-Haug-Michelis (1999) p-values

if real minimum wages are on the decline, we expect ΔINFt to increase. At first glance, this result is counterintuitive. However, real minimum wage is a proxy for party domination. Declining real wage (and higher inflation levels) occurred most often when Republicans were in power, as for example the 1980s. To describe the phenomenon of a dynamic inflation-unemployment relationship, we produce Fig. 1 as shown below.

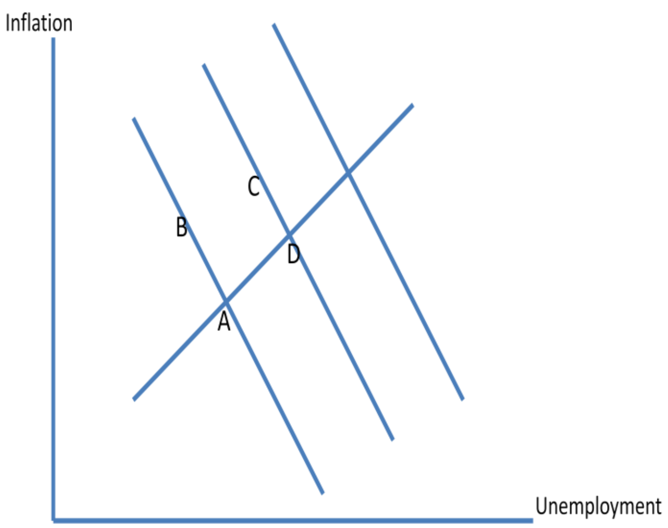

Fig. 1: Long-run phillips curve

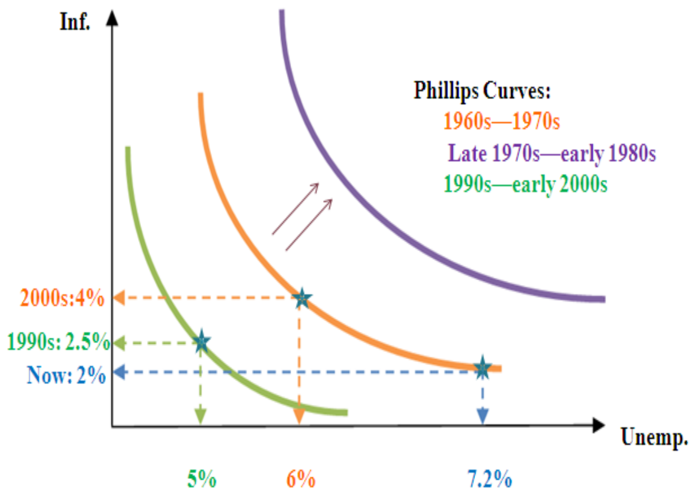

Fig. 2: In 1970's, the natural rate was higher than it is now due to stagflation. In contrast, in most of the 1990's and early 2000's, low inflation accompanied low unemployment rates, due perhaps, to substantial advances in information technology

The vertical gap between A and B in Fig. 1, represents the error term in the static inflation-unemployment equation. When actual inflation exceeds the expected rate (A to B), consumers and producers anticipate even higher inflation one year after (t+1) via the error correction term ecmt+1, (B to C) However, such a deviation reverts itself in the next year (t+2) from C to D. Notice that our analysis is not the same as that of a long- term Phillips curve where a vertical natural rate of unemployment line around which expectations are built. When other lagged variables exert their impacts on INFt in the VAR error correction model, the variations are along the dynamic Phillips curve in Fig. 1. Changing economic conditions dictate the correct current natural rate of unemployment. In 1970's, the natural rate was higher than it is now due to stagflation. In contrast, in most of the 1990's and early 2000's, low inflation accompanied low unemployment rates, due perhaps, to substantial advances in information technology, as in Fig. 2. Consequently, we expect that long-run Phillips (Fig. 1) curve is positively sloped. We verify this via the long-run inflation-unemployment relationship estimated by OLS with variables in levels.

Conclusion

In this paper, we apply different unit root tests on the five macroeconomic variables. Nearly all our data exhibit unit root phenomenon, in confirmation of results well-known in the literature. Co-integration tests by Johansen and Juselius [13] indicate that there exists one set of co-integration relation in the unemployment-inflation equation. The VAR error correction model explains the expected short-term behavior of change in the inflation rate; unemployment rate two years ago exacts negative impact on ΔINFt. The error correction term ecmt-1 has positive sign (along with that of ΔINFt-1) indicating an existence of a divergent expectation. However, in year two, we show that ΔINFt is dampened in order to restore to a new equilibrium. The dynamic Phillips curve is different from the vertical long-run Phillips curve in which expectations are built around a given natural rate of unemployment. In this paper, we have three sets of natural rate of unemployment as our sample extends nearly four decades. The traditional short-run Phillips curve seems to have disappeared since the stagflation of the 1970's. The unit root tests of the 40 years worth of data in our model may have low power in the presence of a structural break, which is a topic to be investigated in the future.

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