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EFFECTS OF UNPREDICTABLE PRICES ON THE  
AVERAGE UNEMPLOYMENT RATE.

CITY UNIVERSITY OF NEW YORK, PH.D., 1978

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1978

EFFECTS OF UNPREDICTABLE PRICES ON THE  
AVERAGE UNEMPLOYMENT RATE

by

NURHAN HELVACIAN

A dissertation submitted to the Graduate  
Faculty in Economics in partial fulfillment  
of the requirements for the degree of Doctor  
of Philosophy, The City University of New York.

1978

This manuscript has been read and accepted for the Graduate Faculty in Economics in satisfaction of the dissertation requirement for the degree of Doctor of Philosophy.

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TO MY PARENTS MIKAEL AND VARTUHI HELVACIAN,  
AND TO MY SISTER EVA YAZIDJIAN.

## Abstract

EFFECTS OF UNPREDICTABLE PRICES ON  
THE AVERAGE UNEMPLOYMENT RATE

by

Nurhan Helvacian

Advisor: Professor Alvin Marty

Two alternative hypotheses are formulated that can explain increasing average unemployment in terms of an increasing variance of inflation. These hypotheses are then tested with fourteen country time series data. The first hypothesis -- based on the convexity of the short run Phillips curve -- is rejected. The second hypothesis -- based on the Lucas (1973) thesis that increasing variance of inflation serves the information conveyed by the absolute prices useless-- is confirmed by the sample data.

ACKNOWLEDGEMENTS

Professor Alvin Marty was the supervisor of the thesis, and I am grateful for his vision and guidance. Professors Michael Grossman and Elliot Zupnick patiently read and commented on the earlier drafts; I am also grateful for their valuable guidance. Furthermore, I would like to thank Dr. James Lothian for first suggesting the need for further research in explaining the positive correlation between inflation and unemployment rates; Professor Phil Cagan for reading an earlier version of the thesis; Professor Damodar Gujurati, Professor I. Harold Kellar and Dr. Arthur Gandolfi for their suggestions. I would also like to thank my friends Ates Dagli, Anthony Cassese and Jacob Gesthalter for the time they devoted to discussing the problems frequently encountered at the different stages in the development of the thesis. My appreciations to Miss Jane House and Mr. Phil Bosakowski for valued typing and editing.

And foremost, I am grateful to Dr. Anna Schwartz for the opportunity to work as her research assistant at the National Bureau of Economic Research. Without her constant encouragement and guidance the completion of this thesis would still remain an unrealized ideal.

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## INTRODUCTION

The average unemployment rate rose for the United States, the United Kingdom and other Western countries through the sixties and the early seventies. The purpose of this study is to examine how the inflationary process can cause the secular increase in the unemployment rate.

Historically, the inflation rate, or percentage change in the price level, has been associated inversely with the unemployment rate. Irving Fisher was the first economist to relate cyclical changes in the unemployment rate to the inflation rate.<sup>1</sup> It was not until the Phillips' study of the long term negative correlation between the inflation and unemployment rates for Great Britain that so much debate was generated on the inflation unemployment trade-offs.<sup>2</sup> More recently, M. Friedman noted in his Nobel Lecture that the unemployment rate is positively correlated with the inflation rate in seven countries.<sup>3</sup> Friedman attributes the positive correlation to the changes in the "natural rate" as a result of increasing volatility of the inflationary process. His two reasons why the "natural rate" can be affected are:<sup>4</sup>

First, increased volatility shortens the optimum length of unindexed commitments and renders indexing more advantageous. . . . In addition, indexing is, even at best, an imperfect substitute for the stability of the inflation rate. . . . These developments clearly lower economic efficiency. It is less clear what their effect is on recorded unemployment. . . . About all one can say now is that the slow adjustment of commitments and the imperfections in indexing may contribute to the recorded increase in unemployment. . . . A second related effect of increased volatility of inflation is to render prices a less efficient system for coordinating economic activity. . . . The more volatile the rate of

general inflation, the harder it becomes to extract the signal about the relative prices from the absolute price. . . . At the extreme, the system of absolute prices becomes nearly useless, and economic agents resort to alternative currency, or to barter, with disastrous effects on productivity.

The direction of the first effect on the unemployment rate is ambiguous. The direction of the second effect is to shift the intercept of the Phillips curve to the right under extreme conditions.

The average unemployment rate, however, can increase as a result of increasing volatility of the actual inflation without affecting the "natural rate". First, the average unemployment rate rises if in the short run, expectations held constant, Phillips curve is negative and convex to the origin. Second, increasing variance increases the slope of the Phillips curve for Friedman's second reason: decisions affecting the real sector of the economy will be made independently of the changes in the absolute price level.

The empirical tests of the first hypothesis--increase in the secular unemployment rate because the Phillips curve is convex--is refuted by the fourteen country quarterly data from 1957 I to 1974 IV (Chapter II). The short run inflation unemployment trade offs are found to be negative but not convex. The empirical tests of the second hypothesis--increase in the secular unemployment rate is a result of the increase in the slope of the Phillips curve--on the other hand, are confirmed by the sample data (Chapter III).

The two hypotheses that are formulated and tested in this study in no way exhaust the range of macroeconomic theories explaining the positive trend in the unemployment rate. There are those who contend that the structural changes in the economy, such as increased unemployment compensation and other social benefits, increase the optimum

unemployment rate for the United States.<sup>5</sup> Others contend that unanticipated disturbances in the commodity supplies increase the average unemployment rate.<sup>6</sup> No attempts are made in this study to test these two alternative hypotheses. The empirical evidence presented in Chapter I, however, strongly suggests that the secular rise in the unemployment rate predates the unexpected rise in the commodity prices in the last quarter of 1973. The unemployment rate began to rise as early as 1959 in France, and is increasing throughout the sample period in the United Kingdom. The use of international cross sectional data in testing the proposed hypothesis, on the other hand, is an attempt to abstract from changes affecting the labor force participation rates in various countries. Unless the social benefits increase universally, structural changes cannot be the only factor responsible for the trend in the unemployment rate.

Chapter I presents empirical correlations between actual inflation, variance of inflation and the unemployment rate. Chapter II presents the results of the tests of the convexity assumption of the Phillips curve. Chapter III formulates and empirically tests the hypothesis that the slope of the short run Phillips curve increases over time.

Footnotes for Introduction

<sup>1</sup>Fisher, Irving, "A Statistical Relation between Unemployment and Price Changes," Journal of Political Economy, (March/April, 1973): 452-502.

<sup>2</sup>Phillips, A.W., "The Relation between Unemployment and the Rate of Change of Money Wage Rates in the United Kingdom, 1961-1957," Economica, (November, 1958): 283-99.

<sup>3</sup>Friedman, Milton, "Nobel Lecture: Inflation and Unemployment," Journal of Political Economy, (June, 1977): 451-72. Also for a most complete review of the literature in the subject see his Price Theory, Aldine Publishing Company, (Chicago, 1976): 213-36.

<sup>4</sup>Friedman's first reason is based on J. Gray's (1976) article on optimum indexation. His second reason is based on works by Hayek (1945), Lucas (1973) and Harberger (1976).

<sup>5</sup>For example, see Feldstein, Martin, "Temporary Layoffs in the Theory of Unemployment," Journal of Political Economy, (October, 1976): 937-58.

<sup>6</sup>For example, see Phelps, Edmund, "Commodity--Supply Shock and Full--Employment Policy," unpublished Columbia University Discussion Paper: 77-7306 (October, 1977), and also Gordon, Robert J. "Recent Developments in the Theory of Inflation and Unemployment," Journal of Monetary Economics, (April, 1976): 185-220.

CHAPTER I  
INFLATION, UNEMPLOYMENT AND  
PRICE UNCERTAINTY IN  
FOURTEEN COUNTRIES

A. Time Trend of the Inflation and the  
Unemployment Rates

The inflation rate, defined as the logarithmic first difference of the quarterly Consumer Price Index, and the unemployment rate, defined as the percentage of the idle labor force, are both increasing for most Western countries and Japan.<sup>1</sup> To measure the extent of the acceleration in the inflation and the unemployment rates, I estimated the following quarterly non-linear trend functions for each country:

$$1 \quad \dot{P}_t = a_0 + b_0 \cdot t + c_0 \cdot t^2 + v_t$$

$$2 \quad U_t = a_1 + b_1 \cdot t + c_1 \cdot t^2 + u_t \quad t = 1, 2, \dots, 72$$

where  $\dot{P}$  is the inflation rate

$U$  is the unemployment rate

$t$  is time

$u, v$ 's are the random error terms with the usual assumptions.

Tables 1.1 and 1.2 give the ordinary least square estimation results. For the early period, where the values for time variable are small, the slope is negative for both functions. For the later periods, however, the slope changes signs and is positive. Austria is the only exception to this general rule, since its inflation rate has a positive trend

while the unemployment rate has a negative trend throughout the sample period. For Norway, the magnitude of the upswing in the unemployment rate is very small and toward the end of the sample period. One other exception is that the unemployment rate has a continuous positive trend for the U.K.

In Table 1.3, I estimate the take-off stages of the acceleration of the inflation and the unemployment rates by substituting the estimated coefficients into the trend functions and finding the first order condition for minimization, and then solving for the values for  $t$ .

$$3 \quad \frac{dP}{dt} = \hat{b}_0 + 2\hat{c}_0 \cdot t^* = 0$$

$$\frac{dU}{dt} = \hat{b}_1 + 2\hat{c}_1 \cdot t^* = 0$$

$\hat{\phantom{x}}$  indicates estimated coefficients.

It is evident that the trend in both rates has its trough in the middle sixties, in general the trough in inflation leading the trough in the unemployment rate. These findings can also be confirmed by examining the Charts A1.1 to A1.14 in the Data Appendix.

The unambiguous conclusion that is drawn from these empirical observations is that the acceleration of the inflation and the unemployment rates is a worldwide phenomenon beginning from the middle sixties. Furthermore, although each country has a different acceleration rate and a different take-off period, the worldwide inflationary trend predates the sudden and sharp increases in the relative price of the raw materials in 1973.

Table 1.1 Trend in the Inflation

$$\dot{P} = a + b.t + c.t^2 + v$$

From 1957 II to 1974 IV

	<u>Country</u>	<u>a<sub>0</sub></u>	<u>b<sub>0</sub></u>	<u>c<sub>0</sub></u>	<u>R<sup>2</sup></u>	<u>DW</u>	<u>F</u>
1.	U.S.	.0061*	-.0003*	.000007*	.66	1.13	65.8
2.	Canada	.0056*	-.0002*	.000007*	.58	1.5	46.6
3.	Japan	.008*	-.0001	.000007*	.30	1.39	14.5
4.	U.K.	.008*	-.0003*	.000009*	.52	2.08	36.5
5.	France	.027*	-.0011*	.000017*	.31	1.29	15.1
6.	Germany	.006*	-.0001	.000004*	.23	1.78	10
7.	Italy	.01*	-.0005*	.0000125*	.44	.92	26.4
8.	Belgium	.005*	-.0002	.000007*	.49	1.53	33.0
9.	Netherlands	.006**	-.0001	.000004	.15	2.07	6.1
10.	Sweden	.008*	-.0001	.000004*	.21	2.12	9.3
11.	Norway	.008*	-.0001	.000005**	.22	1.91	9.8
12.	Denmark	.007	-.00003	.000006	.20	2.07	8.6
13.	Austria	.004	.00001	.000003	.11	2.10	4.184
14.	Ireland	.012*	-.0005*	.0000125*	.45	1.84	28.06

D.O.F. 68

\* significant at 5% one tail test

\*\* significant at 10% one tail test

Table 1.2 Trend in the Unemployment Rate

$$U = a_1 + b_1 t + c_1 t^2 + v$$

From 1957 II to 1974 IV

<u>Country</u>	<u>a<sub>1</sub></u>	<u>b<sub>1</sub></u>	<u>c<sub>1</sub></u>	<u>R<sup>2</sup></u>	<u>F</u>	<u>D.W.</u>
1. U.S.	6.29*	-.08*	.00096*	.185	7.85	.18
2. Canada	6.88*	-.096*	.00121*	.198	8.52	.16
3. Japan	1.52*	-.034*	.0005*	.544	41.1	.98
4. U.K.	1.98*	.02	.0003**	.61	54.7	.22
5. France	.98*	-.012*	.0005*	.79	131	.33
6. Germany	1.91*	-.09*	.0012*	.69	77.8	.19
7. Italy	7.49*	-.19*	.002*	.58	47	.87
8. Belgium	3.46*	-.07*	.0009*	.36	19.1	.09
9. Netherlands	1.84*	-.07*	.0012*	.67	71.1	.22
10. Sweden	.78*	-.02*	.0004*	.64	62.1	.40
11. Norway	2.01*	-.04*	.0004*	.62	10.9	1.74
12. Denmark	10.37*	-.37*	.004*	.37	20.2	1.56
13. Austria	5.06*	-.09*	.0007**	.28	13.2	1.94
14. Ireland	9.24*	-.18*	.0023*	.46	29.7	1.24

D.O.F. 68

\* 5% significance with one tail test

\*\* 10% significance with one tail test

Table 1.3  
 Estimated Take-off Stage  
 of Inflation and Unemployment

<u>Country</u>	<u>Inflation</u>	<u>Unemployment</u>
1. U.S.	61 IV	67 II
2. Canada	61 I	66 IV
3. Japan	59 I	65 IV
4. U.K.	60 IV	INCREASING
5. France	65 II	59 IV
6. Germany	60 IV	66 I
7. Italy	62 I	68 III
8. Belgium	60 II	67 II
9. Netherlands	58 III	64 II
10. Sweden	60 III	63 I
11. Norway	59 III	71 I
12. Denmark	57 II	67 IV
13. Austria	INCREASING	74 I
14. Ireland	61 IV	66 II

B. Average Inflation, Unemployment and  
Uncertainty of Inflation

Two different measures of uncertainty of the inflation rate are used in recent literature. First is the standard deviation of the inflation rate, used by Klein (1975) and Parkin (1977) among others; the other is the coefficient of variation used by Salant (1977). While the standard deviation of the inflation rate is rising for most countries in the sample, the mean of the inflation rate is rising at a much faster rate. As a result, the coefficient of variation, which is the ratio of standard deviation to the mean, is falling for almost all the countries. I prefer Parkin and Klein's definition of uncertainty--the standard deviation of the inflation rate--since the time trend in the average inflation is relatively stable and readily predictable at any instant in time. The coefficient of variation, as a measure of uncertainty, therefore, understates the unpredictability of changes in the price level. I use the following two variations of the measure of dispersion from the expected value:

$$4 \quad \sigma_{1t} = \frac{\sum (\dot{P}_{t-i} - \bar{\dot{P}}_t)^2}{11}$$

$$5 \quad \sigma_{2t} = \frac{\sum |\dot{P}_{t-i} - \hat{\dot{P}}_{t-i}|}{12} \quad i=0, \dots, 11$$

where  $\bar{\dot{P}}$  is the three-year moving average of the inflation

$\sigma_{1t}$  is the three-year moving standard deviation of inflation

$\hat{\dot{P}}$  is the estimated trend value of inflation

$\sigma_{2t}$  is the moving average of the absolute values of the deviations from the trend.

Okun (1971), Gordon (1970), Jaffee and Kleiman (1975), and Logue and Willett (1976) previously compared the mean rate and the variance of the inflation across countries. Jaffee and Kleiman also show diagrammatically that when two countries have different accelerations of the inflation rate, the one with the higher acceleration will have larger variance, even though they may have the same average inflation.<sup>2</sup> In other words, say that there are two countries ( $i=0,1$ ) with two different acceleration rates:

$$\begin{aligned} \text{i} \quad \dot{P}_0 &= a_0 + b_0 \cdot t \\ \dot{P}_1 &= a_1 + b_1 \cdot t \end{aligned}$$

where  $a$ 's are the two intercepts

$b$ 's are the acceleration rates

assuming  $a_1 > a_0$  and  $b_1 < b_0$  and taking the expected values

$$\begin{aligned} \text{ii} \quad \bar{\dot{P}}_0 &= a_0 + b_0 \cdot \bar{t} \\ \bar{\dot{P}}_1 &= a_1 + b_1 \cdot \bar{t} \\ \text{iii}' \quad \bar{\dot{P}}_0 &= \bar{\dot{P}}_1, \text{ iff } (a_1 - a_0) = (b_0 - b_1) \cdot \bar{t} \end{aligned}$$

assume  $a$ 's and  $b$ 's are such that  $\text{iii}'$  holds

$$\text{iii} \quad \bar{\dot{P}} = \bar{\dot{P}}_0 = \bar{\dot{P}}_1$$

Finding the variance of (i)

$$\begin{aligned} \text{iv} \quad \sigma_0 &= E(\dot{P}_0 - \bar{\dot{P}})^2 = b_0^2 \cdot E(t - \bar{t})^2 = b_0^2 \cdot \sigma_T \\ \sigma_1 &= E(\dot{P}_1 - \bar{\dot{P}})^2 = b_1^2 \cdot E(t - \bar{t})^2 = b_1^2 \cdot \sigma_T \\ \text{v} \quad \sigma_T &= \frac{\sigma_0}{b_0^2} = \frac{\sigma_1}{b_1^2} \end{aligned}$$

Since  $b_1$  is  $< b_0$  by assumption, therefore  $\sigma_1$  must be  $< \sigma_0$  for the equality (v) to hold.

The variance of the inflation rate is positively correlated with the acceleration of inflation. The second measure (5) of uncertainty holds the rate of acceleration constant over time; therefore the correlations between the average inflation rate and the uncertainty will not be biased.

To test whether the measure of uncertainty is correlated with the average inflation and the average unemployment rate over time, I ran the following two simple regressions:

$$\begin{aligned} \sigma_i &= a_0 + b_0 \cdot \bar{P} \\ \sigma_i &= a_1 + b_1 \cdot \bar{U} \end{aligned}$$

where  $\bar{U}$  is the average unemployment rate and

$\sigma$  is either of the two measures of uncertainty.

The results of these two regressions are summarized in Table 1.4. There is no significant difference in the results obtained using either one of the two measures. In fact from here on (5) will be the only measure of price uncertainty, since it holds the time trend constant. The average inflation rate is positively correlated with price uncertainty for ten countries and negatively with four; however, it is only with Austria that this negative correlation is significantly different than zero.

On the other hand, uncertainty is positively correlated with the average unemployment rate in only seven countries. This result is not very surprising. To obtain better estimates of the effect of uncertainty on the average unemployment rate one must hold the average inflation rate constant; this is deferred until Chapter 3.

Table 1.4

Correlation between the Two Measures of Price Uncertainty,  
Average Inflation and Average Unemployment from 1957 to 1974

<u>Country</u>	$\sigma = a + b_1 \bar{P} + v$		$\sigma = a + b\bar{u} + v$	
	$\sigma_1$ b	$\sigma_2$ b	$\sigma_1$ b	$\sigma_2$ b
1. U.S.	.269*	.231*	.024	.025
2. Canada	.147*	.12*	.021	.009
3. Japan	.358*	.321*	.332	.413
4. U.K.	.034	.05*	.039*	.043*
5. France	.619*	.42*	-.21	-.17
6. Germany	.089**	.09**	-.01	-.001
7. Italy	.333*	.19*	+.023	-.026
8. Belgium	.214*	.144*	-.171	-.164
9. Netherlands	-.235	-.26*	-.27	-.26
10. Sweden	.27*	.13*	.428*	.387*
11. Norway	.21	-.06	.139	.216**
12. Denmark	.66*	.32*	-.08	-.05
13. Austria	-.68	-.51*	.398*	.284*
14. Ireland	-.01	-.05	-.01	-.034

D.O.F. 68

\* 5% significance with one tail test

\*\* 10% significance with one tail test

In general, the average inflation rate is significantly and positively correlated with the measure of price uncertainty about the inflation rate over time. On the other hand, for half the countries under observation average unemployment is positively correlated with the price uncertainty.

### C. Phillips Curve Revisited

Since the majority of countries have positive trends in both the inflation and the unemployment rates over a decade, can one conclude that the two rates are positively, rather than negatively, related to each other?<sup>3</sup>

I estimated a Phillips curve,<sup>4</sup> unadjusted for expectation,<sup>5</sup> of the following form for each country:

$$7 \quad \dot{P} = a + b.U^{-1} + v$$

Equation (7) was estimated over the entire sample and for the period from 1962 through 1974. These regressions are summarized in Table 1.5. Over the entire period, the unemployment and the inflation rate are negatively correlated for merely half the sample countries. For the period from 1962 on, eleven of the fourteen countries have positive slope coefficients, of which six are significantly greater than zero.

In charts 1.1 to 1.4 the Phillips curves are plotted for each country. A general pattern seemed to emerge: most countries display short run downward sloping Phillips curves which are shifting to the right over time, tracing a positive relationship between the inflation and unemployment rates over time. In figure 1.1, SR1, SR2 and SR3 are short-run curves, where SR3 corresponds to the 1970's. UU\* depicts the

natural rate of unemployment hypothesis; along this line the actual inflation is equal to the expected inflation rate. It also represents a "run", where all the institutional arrangements are fully adjusted to the inflationary process and the variance of the inflation rate is zero. LR is the general expansion path of the SR curves. It has a positive slope, implying that the public's inflationary expectations are less than perfect predictors of the actual inflation over an extended period.

I am not arguing that inflation and unemployment will be positively related in the steady state equilibrium, since that implies a long run where all social structures are fully adjusted and the expected inflation is fully anticipated. Second, there is no evidence that the Phillips curve is positive in the short run. This would correspond to a perverse relationship where excess demand for commodities results in increased inventories and idleness.<sup>6</sup> Third, there can be other structural changes that are shifting the average unemployment over time. Increasing social benefits, changing composition of the labor force, and the effects of the minimum wage laws on the labor force participation rates are examples of such structural changes.

#### D. Summary of Chapter I

Both the inflation rate and the unemployment rate are increasing for most countries in the Western World and Japan. Furthermore, there is a positive correlation between the inflation and the unemployment rates from 1962 through 1974. The uncertainty about the inflation rate is positively correlated with the average inflation and the average unemployment rates. Why then is the average unemployment rising over

time? Are the positive trends in the inflation rate and the uncertainty about the inflationary process systematically related, causing the rise in the average unemployment rate? Is the inflationary process neutral in its impact on the real sector over the long run, or does it affect the long run level of employment? In the following Chapters, I will try to answer these questions.

Table 1.5 Phillips Curves

$$\dot{P} = a + b \frac{1}{u}$$

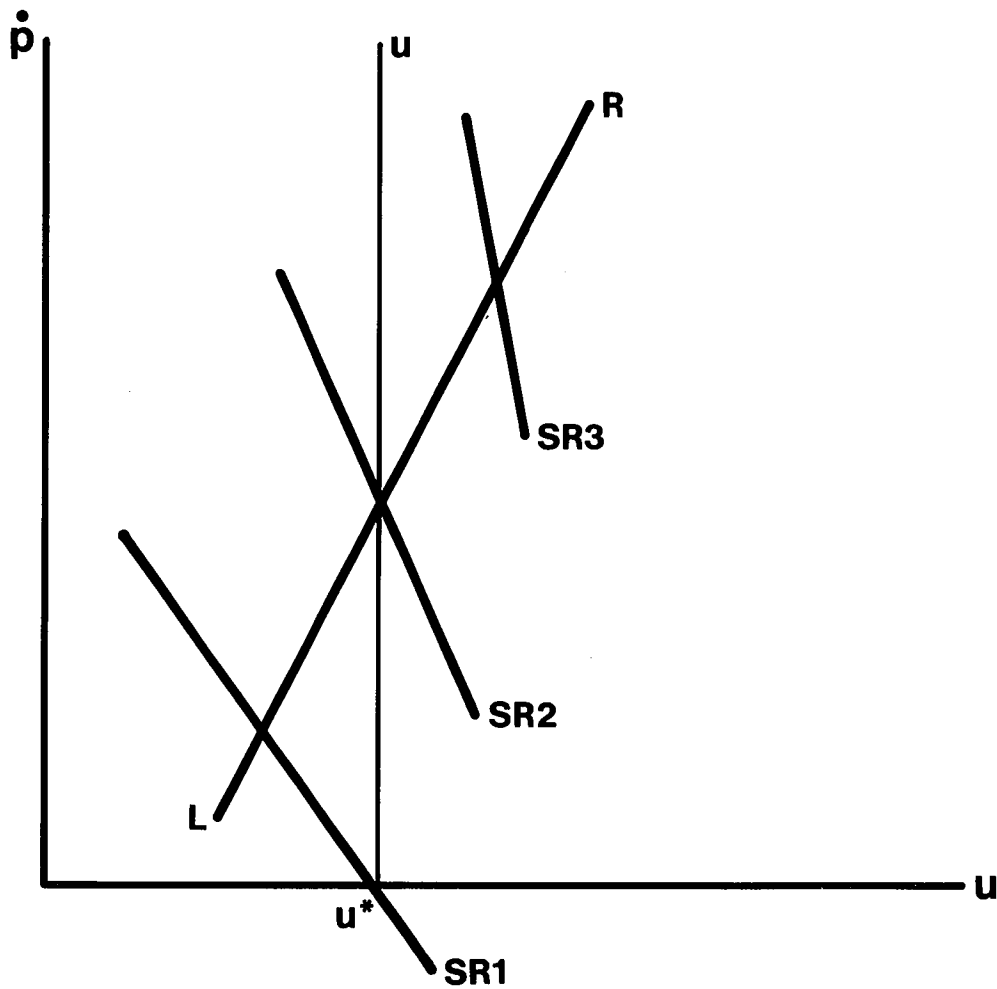
Annual Data

Country	1958 - 1974		1962 - 1974	
	<u>constant</u>	<u>b</u>	<u>constant</u>	<u>b</u>
1. U.S.	1.9	7.45	5.22	-5.67
2. Canada	2.4	5.71	7.12**	-15.22
3. Japan	8.5**	-2.44	17.74*	-10.65*
4. U.K.	12.1*	-21.03*	12.54*	-21.86*
5. France	7.5*	-2.26	8.57*	-4.11*
6. Germany	3.7*	-.23	4.81*	-.53
7. Italy	-5.8	40.31*	-7.04	45.6**
8. Belgium	2.5	2.62	9.6*	-9.81
9. Netherlands	7.1*	-2.8*	8.8*	-3.55*
10. Sweden	7.42*	-1.87*	7.9*	-1.89**
11. Norway	-1.31	6.13*	-2.45	7.26*
12. Denmark	4.27	6.19	11.04*	-11.32
13. Austria	2.81*	2.54**	3.9*	1.3
14. Ireland	14.35	-58.82	26.7*	-131.6*

\* Significant with 5% confidence 1 tail test

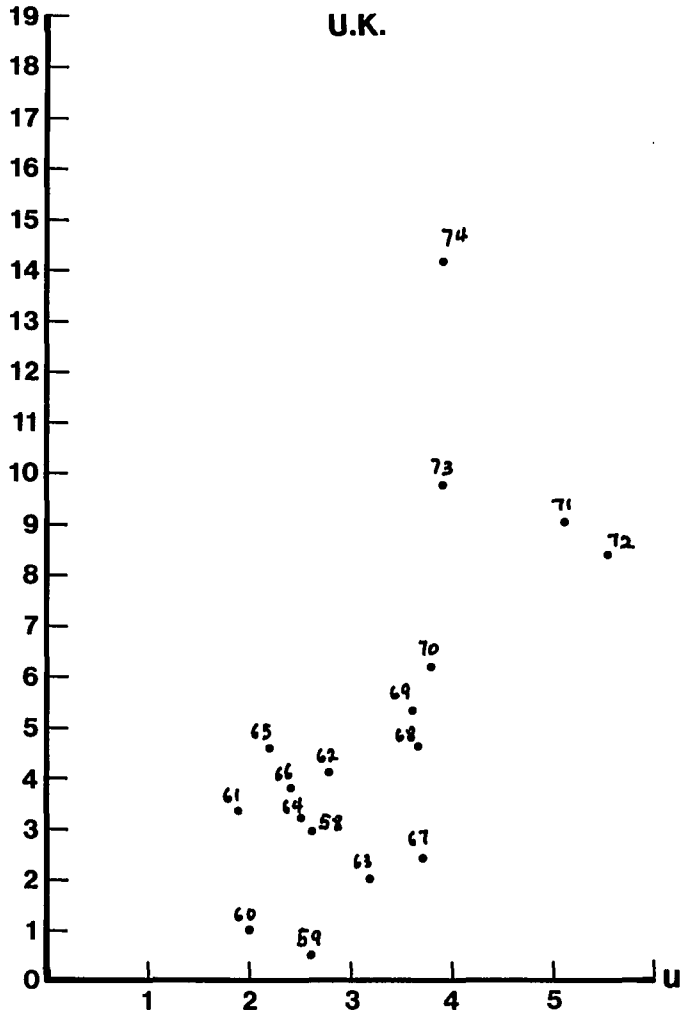
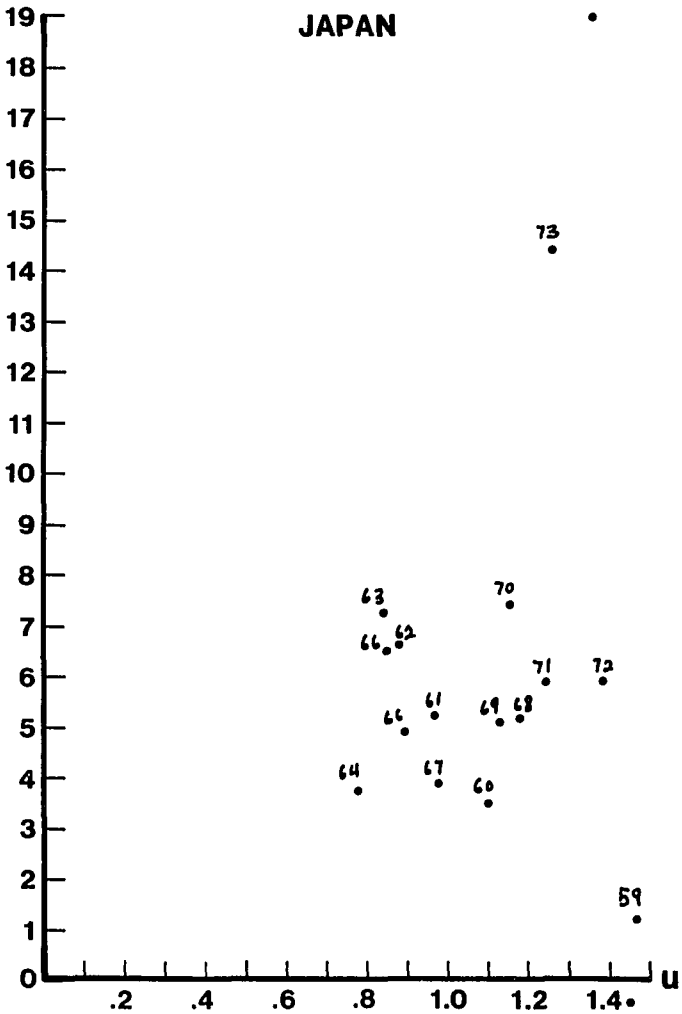
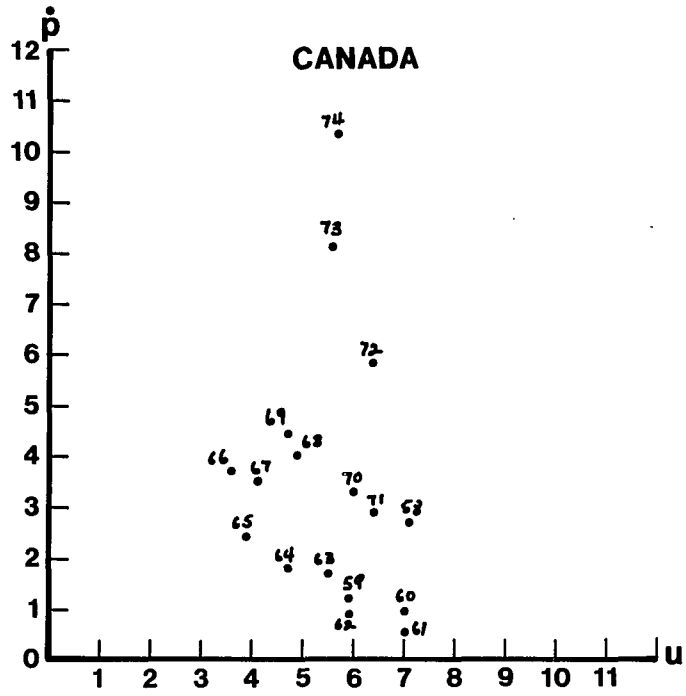
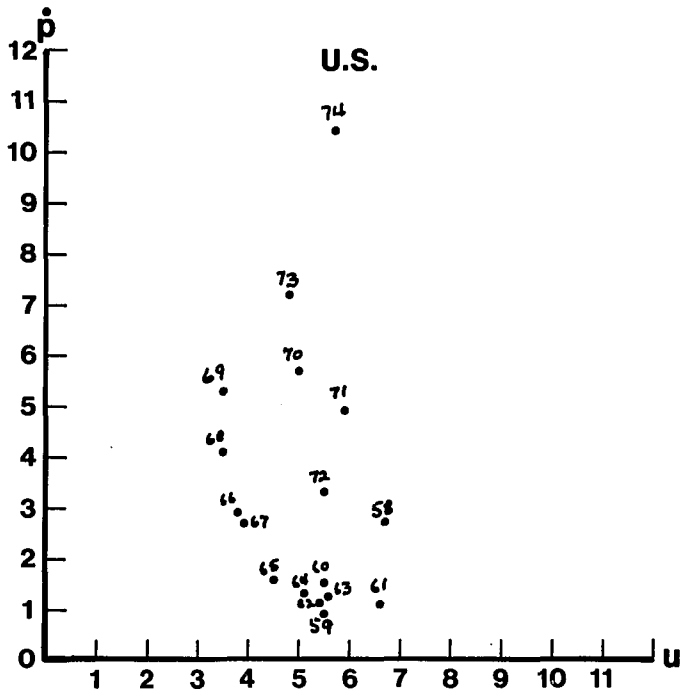
\*\* Significant with 10% confidence 1 tail test

**FIGURE 1.1**  
Phillips Curves, natural rate of  
unemployment and the long run relationship  
between inflation and unemployment rates over time.



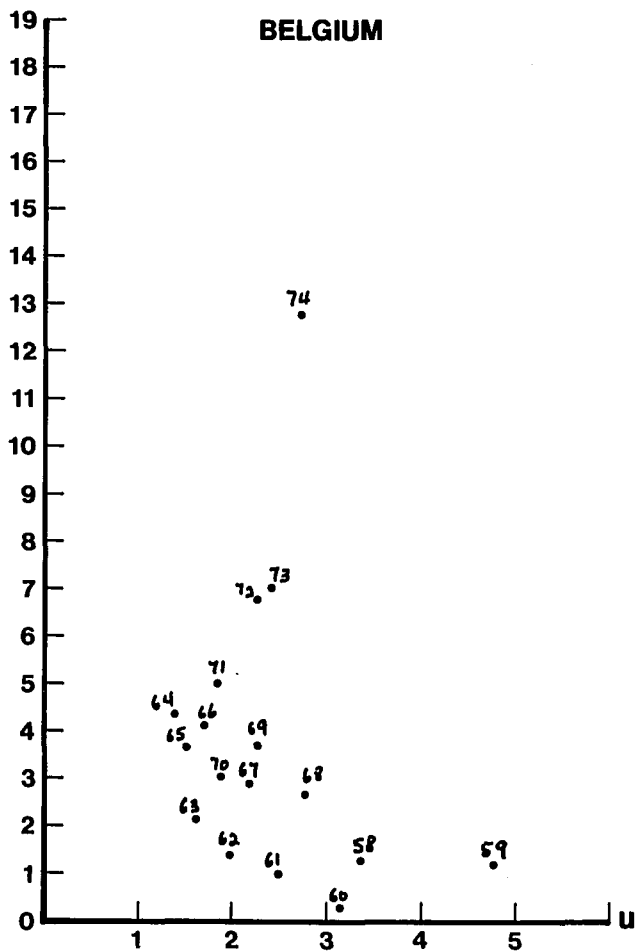
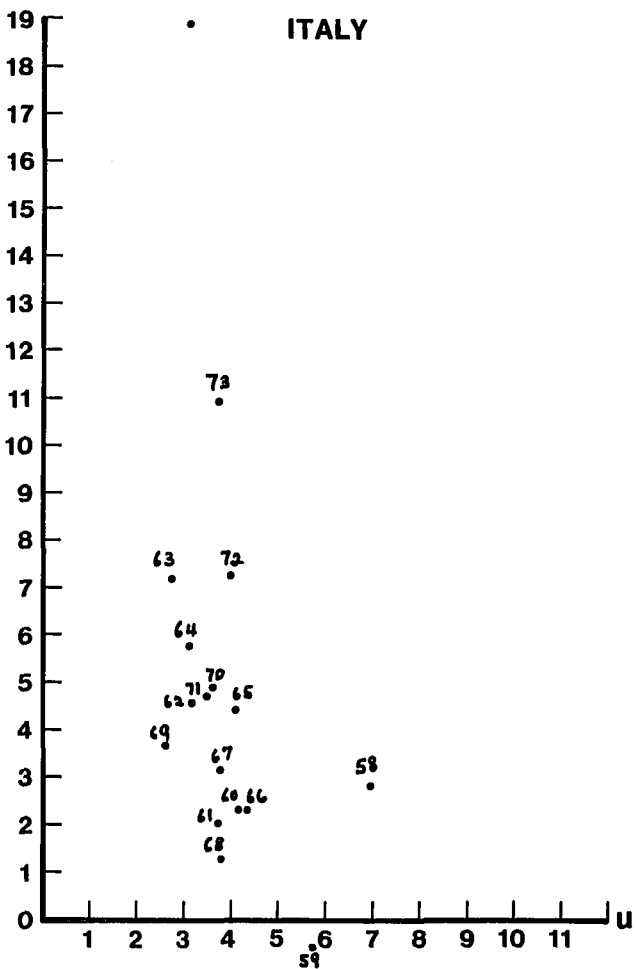
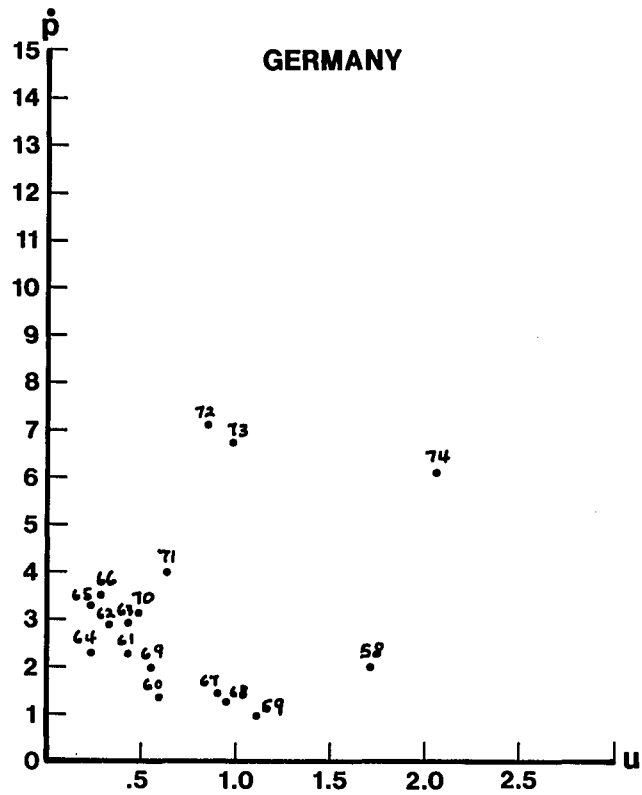
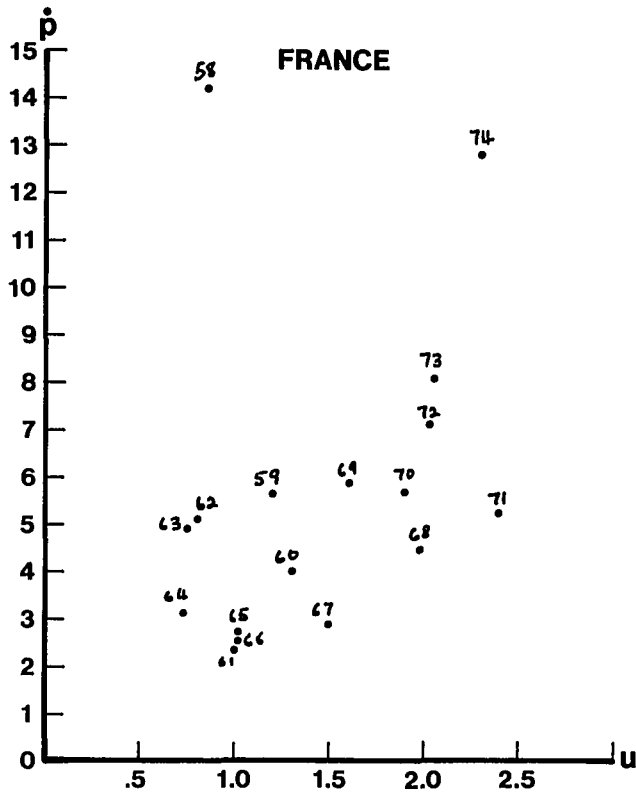
# CHART 1.1

## Phillips Curves for each country

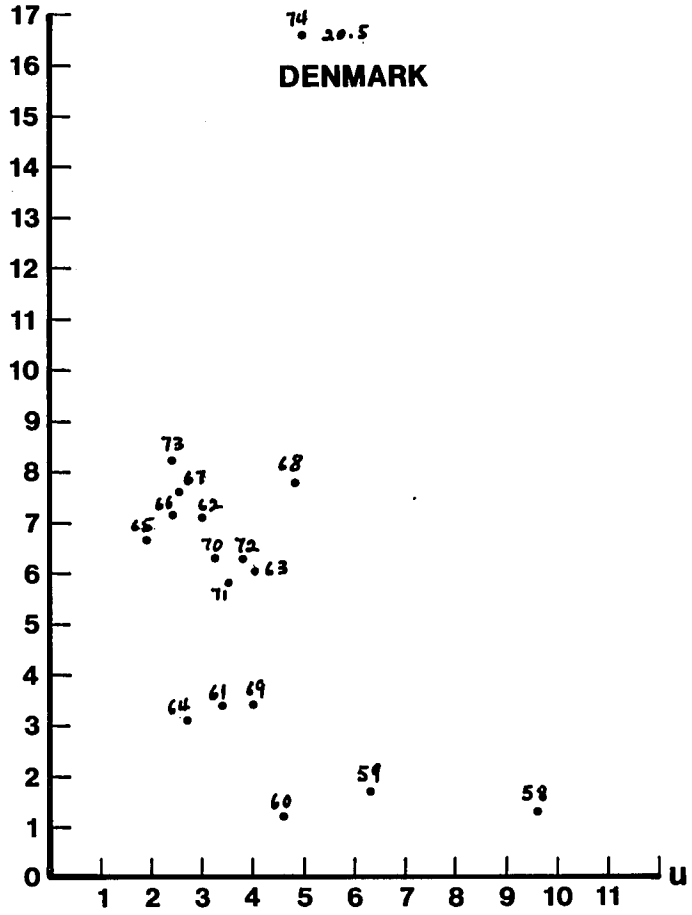
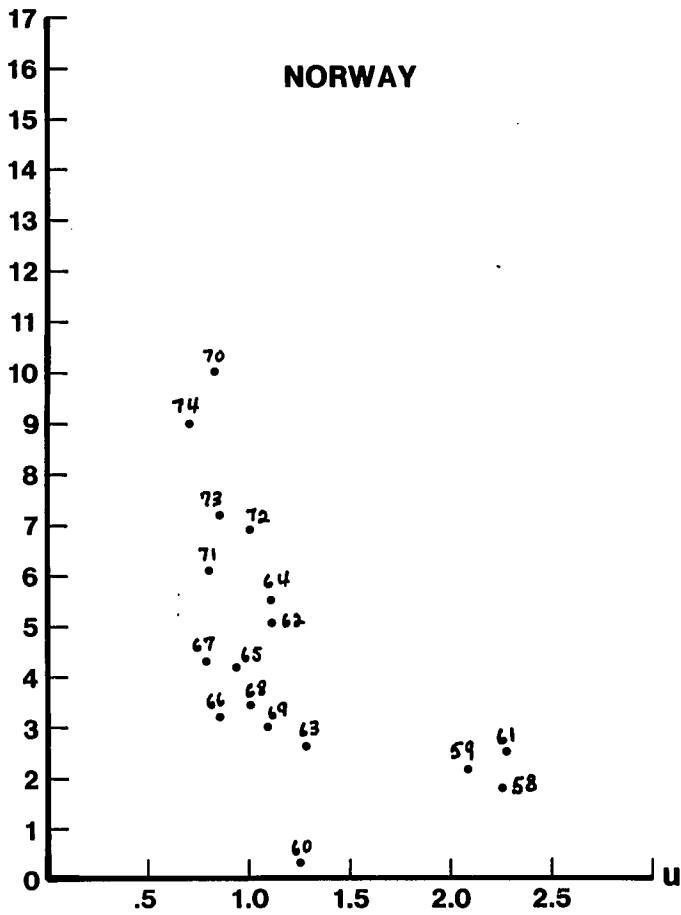
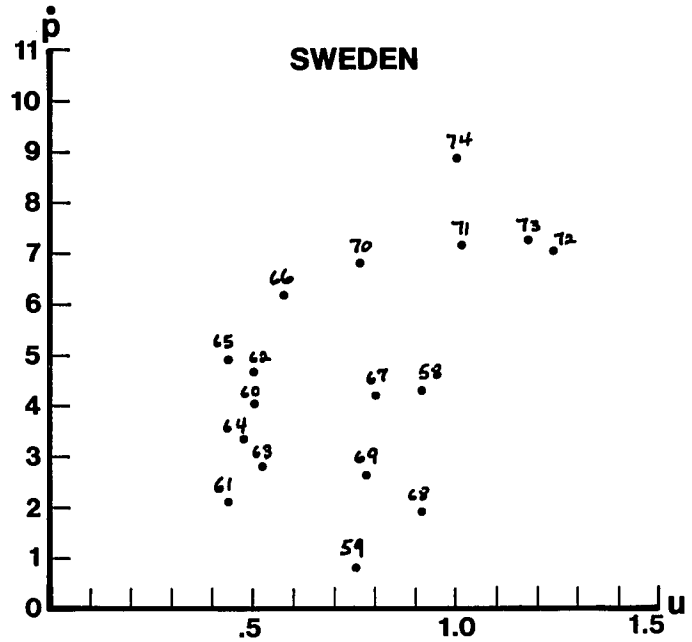
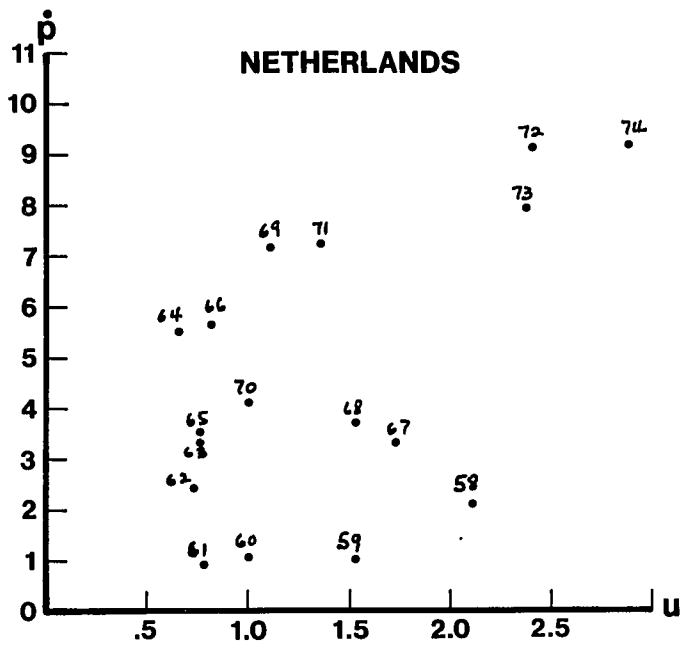


# CHART 1.2

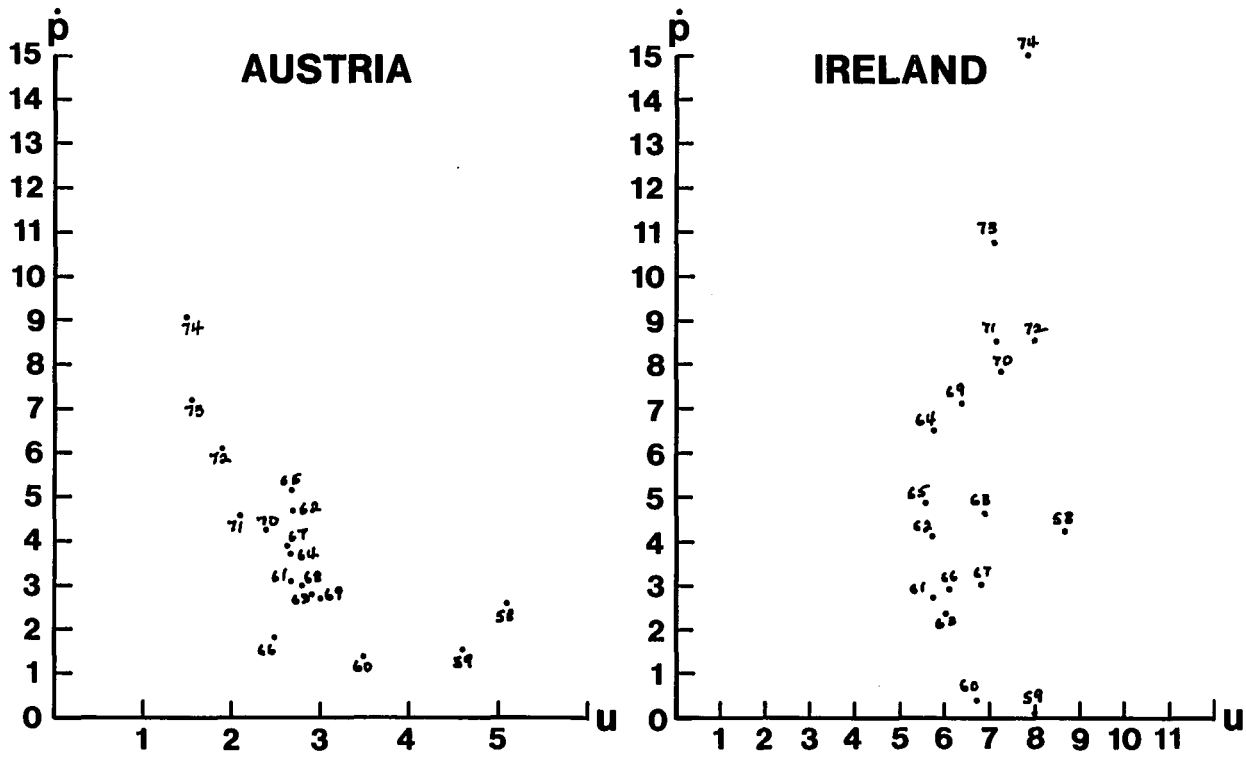
## Phillips Curves for each country



**CHART 1.3**  
Phillips Curves for each country



**CHART 1.4**  
Phillips Curves for each country



Footnotes for Chapter I

<sup>1</sup>The data set is from the University of Manchester--S.S.R.C. Research Programme, "Inflation: its causes, consequences and cure". For more detailed information on the sources of the data, see the Data Appendix. The fourteen countries in the sample are United States, Canada, Japan, United Kingdom, France, Germany, Italy, Belgium, Netherlands, Sweden, Norway, Denmark, Austria and Ireland.

<sup>2</sup>See Figure 2.b in Jaffee and Kleiman, "The Welfare Implications of Uneven Inflation," I.E.A. Conference of Inflation Theory and Anti-Inflation Policy (1975).

<sup>3</sup>Friedman, Milton, "Nobel Lecture", pp. 451-72.

<sup>4</sup>The actual Phillips curve estimated by Phillips (1958) was:

$$\dot{w} = a + bU^{-8}$$

where  $\dot{w}$  is the rate of change of nominal wages  
 $U$  is the unemployment rate

Subsequently, Lipsey (1960) estimated:

$$\dot{w} = a + b.U^{-1} + cU^{-2}$$

<sup>5</sup>In Chapter III, I present more refined estimates of the Phillips curve that take account of the process by which expectations are formed.

## CHAPTER II

CONVEXITY OF THE PHILLIPS CURVE  
AND THE AVERAGE UNEMPLOYMENT RATE

The first hypothesis relating the increasing variation of the inflation rate to the increasing unemployment rate was stated by Phillips (1958), and more recently restated by P. Cagan (1977). It assumes that there is a stable short run trade off between unemployment and inflation rates, and that this negative trade off is convex to the origin around the relevant range of the two variables. If the short run Phillips curve is convex to the origin and the variance in the rate of price changes increases as a result of increasing nominal shocks to the economy, then the unemployment rate will also increase.

A. Hypothesis

Phillips, looking at time series data for the United Kingdom, first observed that ". . . Workers are reluctant to offer their services at less than the prevailing wage rates when the demand for labor is low and unemployment high, so that wage rates fall only very slowly. The relationship between the unemployment rate and the rate of change of wage rates therefore is likely to be highly non-linear."<sup>1</sup>

As a result of nominal wage rigidities, a unit increase in the variation of the unemployment rate over time results in more than a proportional increase in the variance of the rate of change of the nominal wages. In other words, for a given range of unemployment rates,

the arithmetic average of the nominal wage rates is higher than the median wage.

Lipsey demonstrated this proposition for a two market economy where each market has an identical relationship between the rate of change of market wages ( $\dot{w}$ ) and the market unemployment rate ( $u$ ).<sup>2</sup> Initially assume that the two equal-sized markets have the same  $\dot{w}$  and  $u$ ; therefore, the aggregate rate of change of wages ( $\dot{W}$ ) and the aggregate unemployment rate ( $U$ ), which are the arithmetic averages of the market rates, are also identical to the market rates. Holding the average unemployment rate constant, let the variance of the unemployment rate increase. Wages will increase proportionately faster for the market where  $u$  decreases and fall proportionately lower for the market where  $u$  rises, since the relationship between  $\dot{w}$  and  $u$  is convex. As a result, the distribution of  $U$  between the two markets is made unequal. As the variation in  $u$ 's increases,  $\dot{W}$  will take larger and larger values. Conversely, an equiproportional but opposite change in  $\dot{w}$  would result in less than proportional decline in  $u$  for the market with increased  $\dot{w}$ , and more than proportional rise in  $u$  for the market with decreased  $\dot{w}$ . As the variance of  $\dot{w}$  increases across markets, the aggregate unemployment rate rises.

This proposition is demonstrated graphically in the case of two equally sized markets' economy. Each has an identical Phillips curve, initially  $\dot{w}_0 = \dot{w}_1$  and  $u_0 = u_1$ , where subfixes indicate each market. Holding average rate of change of nominal wages constant, an equiproportional opposite change in  $\dot{w}$  results in smaller reduction in  $u_0$  than the increase in  $u_1$ . The arithmetic average of  $u$ 's will be larger than before, although the average wage change remained constant.

Phillip Cagan restated the Lipsey proposition in a recent article:

If convexity could be established, it would suggest that greater inflation has increased the long run average unemployment rate and that future policy should be conducted more cautiously to avoid producing inflation in the long run. However, the lack of evidence as to the convexity of the Phillips curve leaves uncertain whether the variability of the higher average inflation rates has contributed to a long-run rise in unemployment.<sup>3</sup>

We can summarize these arguments in the following way. The unemployment rate for a market, *ceteris paribus*, is a function of the rate of change of the market prices.

$$1) \quad u_i = u(\dot{p}) \quad u' < 0$$

where  $\dot{p}$  is the inflation rate common in each market

Holding average rate of change of prices ( $\bar{\dot{p}}$ ) constant, we use the Taylor expansion to write the unemployment rate as:

$$2) \quad u_i = u(\bar{\dot{p}}) + (\dot{p}_i - \bar{\dot{p}}) * u'(\bar{\dot{p}}) + (1/2) * (\dot{p}_i - \bar{\dot{p}})^2 * u''(\bar{\dot{p}}) + \text{higher terms}$$

Taking the expected value and dropping the higher terms,

$$3) \quad E(u_i) = u(\bar{\dot{p}}) + u'(\bar{\dot{p}}) * E(\dot{p}_i - \bar{\dot{p}}) + (1/2) * u''(\bar{\dot{p}}) * E(\dot{p}_i - \bar{\dot{p}})^2$$

since  $E(\dot{p}_i - \bar{\dot{p}}) = 0$  and  $E(\dot{p}_i - \bar{\dot{p}})^2 = \sigma^2$

$$4) \quad E(u_i) = U = u(\bar{\dot{p}}) + (1/2) * u''(\bar{\dot{p}}) * \sigma^2$$

If  $u''(\dot{p}) > 0$ , then the Phillips curve is convex and the variance of the inflation rate will have a positive impact on the average unemployment rate.

### B. Test of the Hypothesis

To test the hypothesis that the increasing variance of the rate of change of the prices has a positive impact on the unemployment rate if the Phillips curve is convex, the two crucial assumptions of this hypothesis must be investigated. First, there must be a short run negative Phillips curve, and secondly, this curve must be convex to the origin.

I estimated short run Phillips curves using three different functions for quarterly data:

$$5) \quad \hat{P}(t) = a + b.U(t) + c.\hat{P}(-1) + e(t)$$

$$\hat{P}(t) = a + b.\ln U(t) + c.\hat{P}(-1) + e(t)$$

$$\hat{P}(t) = a + b.(1/U(t)) + c.\hat{P}(-1) + e(t)$$

The first is a linear function, while the other two are non-linear. The slope coefficient should be negative in the first two equations and positive in the third. The lagged value of the inflation rate on the right hand side of these equations controls for shifts in the Phillips curve over time. This test is similar to the one by Lucas Papademos for U.S. annual data from 1957 to 1971.<sup>4</sup> That function which minimizes the standard error of the estimate is selected as the one that best estimates the relationship between the inflation and the unemployment rates.

In Table 2.1, the results of this test are summarized. Of the fourteen countries, nine have the correct sign for the slope coefficient (b). The linear function minimizes the standard error of the estimate for eleven countries, of which eight also have negative slopes. The observed positive slope for U.K., France and others is the

result of the inadequacy of the lagged dependent variable to hold vertical movements constant.

A second and more direct test to measure the convexity is to incorporate a non-linear unemployment rate variable to the RHS of the equation.<sup>5</sup>

$$6) \quad \dot{P} = a + b.U + c.U^2 + d.\dot{P}(-1)$$

The first derivative of the inflation rate with respect to the unemployment rate should be negative if the short run Phillips curve is negative; and the second derivative, the sign of the coefficient c, positive, if the Phillips curve is convex to the origin.

### C. The Excluded Variable Bias

If the Phillips curve is convex and the variance of the inflation rate increases over time, then the exclusion of the variance of the inflation rate from the right hand side of the equation (6) will not bias the estimated coefficients by time series data. The estimated coefficients of (6), however, will be biased when the variance of the inflation rate over various markets at any moment in time is excluded from the right hand side of (6).

If the unemployment rate is a function of the inflation rate and the variance of the inflation rate, then (6) must include the variance of the inflation rate over markets:

$$7) \quad U_t = a_0 - a_1.\dot{P}_t + a_2.\dot{P}_t^2 + a_3.\sigma_t^2$$

Assume that the variance  $\sigma_t^2$  is positively related to  $p_t$  and  $p_t^2$ , then:

$$8) \quad \sigma_t^2 = b_0 + b_1 \cdot \dot{p}_t + b_2 \cdot \dot{p}_t^2$$

and

$$9) \quad U_t = a + b \cdot \dot{p}_t + c \dot{p}_t^2$$

where  $a = a_0 + a_3 \cdot b_0$

$$b = a_3 b_1 - a_1$$

$$c = a_2 + a_3 b_2 > a_2$$

If (9) rather than (7) is fitted, then the square term  $a$  will be overstated since  $c > a_2$ .

The coefficient on  $P_t$  is underestimated in absolute value

$$|b| = a_1 - a_3 b_1 < a_1$$

As a result of the excluded variable bias one will tend to reject the hypothesis that the Phillips curve is linear. Accepting a linear Phillips curve, based on this test, in spite of the excluded variable bias, is a powerful conclusion.

#### D. Results

Table 2.2 summarizes the results obtained when (6) is estimated by OLS. The first and second derivative are negative for nine countries. This means that despite the positive bias the short run Phillips curve is negatively sloped for nine countries. The negative relationship is not convex, however, since the second derivative is not positive, despite the positive bias. While the Durbin-Watson statistics are around 2.00 and show absence of autocorrelation, low  $t$

values for the coefficients may be attributed to the high degree of multicollinearity in the U terms." The results presented here, therefore, show no evidence of convexity.

The first assumption that the short run Phillips curve is negatively sloping is confirmed, while the convexity assumption is rejected by this quarterly and cross sectional sample. Therefore, the hypothesis that the average unemployment rate increased as a result of convex Phillips curve is rejected.

Table 2.1 Tests of the Convexity of the Phillips Curve - Quarterly 1957 II to 1974 IV

31

Value in the parentheses are t stats.

Country	a for u(t)	a for lmu(t)	a for 1/u(t)	c	constant	s.e.e.	R <sup>2</sup>	D.W.
1.* U.S.	-.1184(-2.34)			.79(11.28)	.785 (2.83)	.4157	.6797	2.02
		-.529(-2.11)		.79(11.23)	1.032 (2.47)	.4186	.6752	2.01
			2.26(1.9)	.79(11.19)	-.28 (-1.13)	.4211	.6712	2.00
2.* Canada	-.062(-.99)			.67 (7.55)	.631 (1.69)	.568	.477	2.11
		-.29(-.87)		.68 (7.61)	.773 (1.33)	.569	.4753	2.11
			1.27(.76)	.68 (7.65)	.04 (.12)	.5698	.4738	2.12
3.* Japan	-.246(-.378)			.52 (4.92)	1.02 (1.37)	1.337	.2656	2.05
		-.176(-.242)		.52 (4.91)	.76 (3.27)	1.338	.2647	2.05
			.076(.097)	.52 (4.89)	.68 (.87)	1.338	.2642	2.05
4.* U.K.	.264(2.13)			.39 (3.39)	-.05 (-.14)	.9772	.2961	2.17
		.812(2.03)		.4 (3.48)	-.12 (-.28)	.9803	.2917	2.18
			-.209(-1.79)	.42 (3.67)	1.48 (3.01)	.9864	.2828	2.19
5.* France	.078 (.39)			.53 (5.14)	.58 (1.84)	.9881	.3027	1.59
		.072 (.252)		.54 (5.24)	.67 (3.44)	.9887	.3018	1.60
			-.003 (-.01)	.54 (5.33)	.69 (1.901)	.9892	.3011	1.60
6. Germany	-.03 (-.19)			.31 (2.70)	.57 (3.34)	.7194	.0978	1.96
		.009 (.07)		.31 (2.68)	.56 (3.85)	.7196	.0974	1.95
			-.0146(-.21)	.31 (2.68)	.58 (3.07)	.7194	.0979	1.95
7.* Italy	-.058(-.68)			.711(8.31)	.63 (1.53)	.9296	.5486	1.69
		-.249(-.64)		.713(8.34)	.73 (1.25)	.93	.5482	1.70
			.808 (.52)	.717(8.44)	.17 (.408)	.9309	.5473	1.69
8.* Belgium	-.171(1.27)			.591(6.13)	.79 (2.27)	.746	.3881	2.15
		-.346(-1.08)		.60 (6.21)	.67 (2.26)	.7484	.3842	2.15
			.613 (.88)	.60 (6.27)	.1 (.29)	.7506	.3805	2.15
9.* Netherlands	.321(1.25)			.085 (.7)	.627 (1.61)	1.418	.0369	1.88
		.421 (1.16)		.09 (.76)	.974 (4.31)	1.421	.0337	1.89
			-.45 (-1.03)	.1 (.82)	1.46 (3.09)	1.424	.0298	1.89

\* minimum s.e.e.

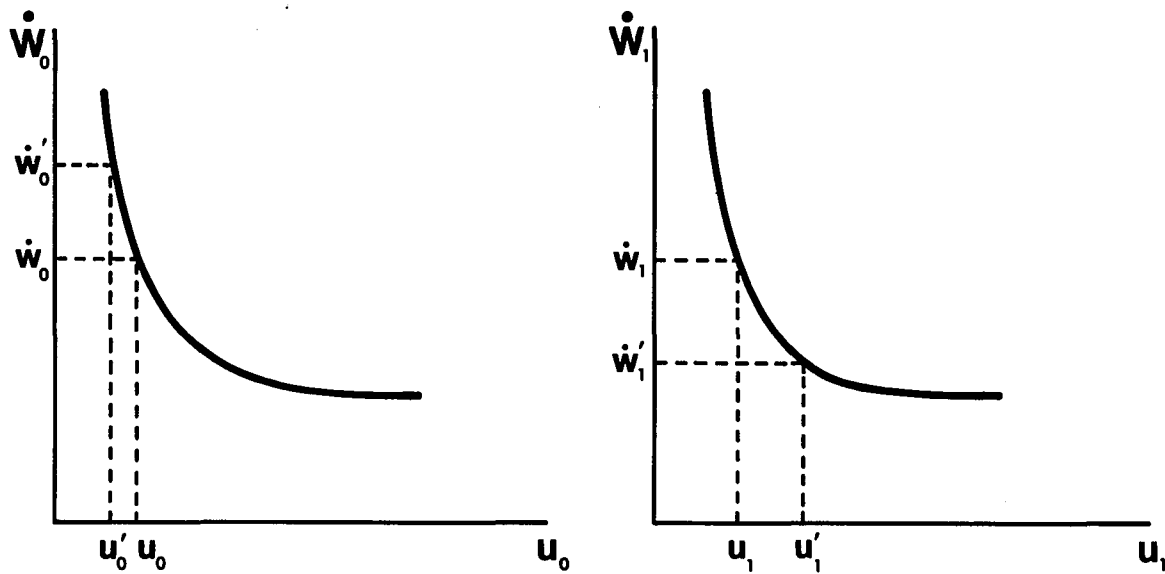
<u>Country</u>					<u>constant</u>	<u>s.e.e.</u>	<u>R<sup>2</sup></u>	<u>D.W.</u>
10.* Sweden	.822(1.91)			.1 (.83)	.4429(1.31)	.9316	.0765	1.99
		.577(1.80)		.11 (.90)	1.252 (5.49)	.9345	.0706	1.99
			-.36(-1.64)	.12 (.98)	1.584 (3.95)	.938	.0637	2.00
11.* Norway	-.122(-.64)			.22 (1.75)	1.07 (3.33)	1.046	.0651	2.01
		-.074(-.33)		.24 (1.88)	.91 (4.78)	1.048	.0609	2.01
			.026 (.15)	.25 (1.99)	.88 (3.23)	1.049	.0597	2.01
12.* Denmark	-1.02(-1.42)			.12 (1.02)	1.81 (4.3)	1.78	.0507	1.99
		-.303(-1.04)		.13 (1.10)	1.73 (3.85)	1.792	.0377	1.98
			.41 (.7)	.14 (1.17)	1.2 (3.25)	1.8	.0292	1.97
13. Austria	-.305(-2.39)			.09 (.762)	2.3 (4.81)	1.734	.0988	2.03
*		-1.0 (-2.44)		.07 (.6)	2.37 (4.8)	1.732	.1017	2.01
			2.24 (2.24)	.06 (.49)	.45 (.92)	1.743	.0902	2.00
14. Ireland	.278 (2.3)			.486(4.55)	-1.15 (-1.34)	1.209	.2814	2.14
		2.02 (2.42)		.482(4.53)	-3.08 (-1.93)	1.204	.2871	2.15
*			-13.8(-2.51)	.479(4.51)	2.85 (3.32)	1.201	.2914	2.16

\* minimum s.e.e.

Table 2.2 Test of Convexity of the Phillips Curve ii  
Quarterly 1957 II to 1974 IV

	<u>Country</u>	<u>b</u>	<u>c</u>	<u>d</u>	<u>constant</u>	<u>s.e.e.</u>	<u>R<sup>2</sup></u>	<u>D.W.</u>
1.	U.S.	.75 (1.66)	-.085 (-1.93)	.80 (11.55)	-1.34 (-1.18)	.4075	.6968	2.07
2.	Canada	.58 (.98)	-.058 (-1.09)	.65 (6.98)	-1.02 (-.66)	.5672	.4863	2.10
3.	Japan	7.33 (1.12)	-3.28 (-1.16)	.52 (4.99)	-3.17 (-.86)	1.333	.2804	2.06
4.	U.K.	.3 (.45)	-.004 (-.05)	.39 (3.36)	-.1 (-.09)	.9846	.2961	2.17
5.	France	.23 (.22)	-.047 (-.15)	.53 (4.98)	.48 (.48)	.9954	.3029	1.59
6.	Germany	.28 (.53)	-.135 (-.61)	.31 (2.69)	.45 (1.7)	.7228	.1029	1.96
7.	Italy	-.102 (-.21)	.004 (.09)	.71 (8.25)	.73 (.63)	.9366	.5486	1.70
8.	Belgium	.74 (.8)	-.18 (-1.0)	.565 (5.67)	-.25 (-.23)	.746	.3972	2.13
9.	Netherlands	-.09 (-.07)	.126 (.33)	.079 (.634)	.908 (.974)	1.428	.0385	1.88
10.	Sweden	-.86 (-.3)	1.03 (.6)	.091 (.75)	1.06 (.98)	.936	.0816	2.00
11.	Norway	.32 (.53)	-.13 (.78)	.23 (1.78)	.80 (1.7)	1.049	.0736	2.03
12.	Denmark	-.015 (-.08)	-.007 (.47)	.12 (.99)	1.63 (2.86)	1.791	.0539	2.00
13.	Austria	-.59 (-1.3)	.03 (.66)	.805 (.675)	2.76 (3.28)	1.742	.1047	2.02
14.	Ireland	1.37 (1.3)	-.077 (-1.08)	.46 (4.3)	-4.9 (-1.37)	1.208	.2938	2.19

**FIGURE 2.1**  
Effects of an equiproportional opposite change in  
the nominal wage growth on the unemployment rate when  
Phillips Curve for each market is convex.



Footnotes for Chapter II

<sup>1</sup>Phillips, op. cit., p. 283.

<sup>2</sup>Lipsey, Richard, "The Relation between Unemployment and the Rate of Change of Money Wage Rates in the United Kingdom, 1862-1957: A Further Analysis," Economica, (February, 1960): 1-31.

<sup>3</sup>Cagan, Phillip, "The Reduction of Inflation and the Magnitude of Unemployment," in A.E.I. Studies of Contemporary Economic Problems, edited by W. Fellner, (A.E.J., 1977): 15-42.

<sup>4</sup>Papademos, Lucas, Optimal Aggregate Employment Policy, Section 8.C., unpublished Ph.D. dissertation, (M.I.T., 1977).

<sup>5</sup>The results summarized here are unaffected if we regress  $U(t)$  on  $\dot{P}(t)$  and  $\dot{P}(t)^2$  and  $U_{t-1}$ . The problems of including  $U_{t-1}$  on the right hand side are discussed in detail in Chapter III. Assuming, however, that the following equation can be estimated, we rewrite equation (6) as:

$$6a) \quad U_t = a + b \cdot \dot{P}_t + c \dot{P}_t^2 + U_{t-1}$$

then

$$\frac{U}{P} = b + 2c \cdot \dot{P}_t \quad \text{should be} \quad 0$$

and

$$\frac{U}{\dot{P}^2} = 2c \quad \text{should be} \quad 0$$

for a convex Phillips curve. The partial of  $\dot{P}$  with respect to  $U_t$  in equation (6) is:

$$\frac{\dot{P}}{U} = b + 2cU_t \quad \text{should be} \quad 0$$

or

$$\frac{U}{\dot{P}} = (b + 2cU_t)^{-1} \quad \text{should be} \quad 0$$

$$\frac{U}{\dot{P}^2} = (-2c)(b + 2cU_t)^{-2} \cdot \frac{U}{\dot{P}}$$

$$\frac{U}{P^2} \text{ is } 0, \text{ iff } \frac{U}{\dot{P}} \text{ is } 0$$

Therefore, the predicted signs are unaffected by estimating either (6) or (6a).

CHAPTER III  
THE EFFECTS OF THE VARIANCE  
OF INFLATION ON THE SLOPE OF  
THE PHILLIPS CURVE

In this chapter a second hypothesis relating the increasing mean and the variance of the inflation rate to the increasing average unemployment rate is formulated based on the Lucas (1973) model and statistically tested. This hypothesis also assumes that there is a short run negative linear relationship between the unemployment rate and the deviation of the actual from the expected inflation rate. Furthermore, it assumes that the expected inflation rate is formed by rational and not by adaptive expectations.

If the variance of the inflation rate increases as a result of government's active stabilization policy, then the increasing absolute prices will be perceived as an increase in the price level. The expected inflation will adjust to the actual inflation at a faster rate and the slope of the short run Phillips curve will be steeper. Over time, increasing variance of the inflation rate will be associated with steeper sloped Phillips curves and higher average unemployment.

A. The Model

The unemployment rate at any moment in time ( $t$ ) has two components: a permanent component,  $U^P(t)$ , and a cyclical component  $U^C(t)$ . The total unemployment rate,  $U(t)$ , is therefore written as:

$$3.1) \quad U(t) = U^P(t) + U^C(t)$$

$U^P(t)$  is analogous to Friedman's "natural rate" or Phelps' "optimum rate" of unemployment.<sup>1</sup> It is determined by the cost minimization conditions similar to those determining the optimum inventories or capital idleness. If one can assume that over a long time the society develops an economic structure to minimize its costs, then  $U^P(t)$  is determined by the structural parameters of a country. What, then, are the forces that can affect the  $U^P(t)$ ?

The forces affecting the factors that determine the labor force participation rate are the main source of variation in  $U^P$ .<sup>2</sup> They would include increasing birth rate lowering the average age of the population, increasing years of schooling, increasing labor participation rates among the secondary workers, increasing personal value of the household activities and increasing leisure time.  $U^P$  undoubtedly increased for the United States as a result of increased unemployment benefits and other social services over the last decade and a half.

In this chapter, however, I am concerned with the determinants of the cyclical components of the unemployment rate. The two main sources of the variation in the  $U^C(t)$  are unanticipated changes in the inflation rate and random supply shocks to the economy. While the former source is due to government's active stabilization policy, the latter can be the result of strikes, boycotts and other temporary changes in the supply of factors of production. Throughout this chapter, I assume that the expected value of the supply shocks is zero and the variance constant over time. Furthermore, I assume that supply shocks are independent of the government's monetary policy.

In the tradition of the neo-classical theory, I thus divide the total unemployment rate into a long term component, which is only

affected by permanent changes in the real variables, and a short term component, which is mainly affected by changes in the nominal variables.

Why is the cyclical component of the unemployment rate affected by changes in the nominal variables? And, can  $U^c(t)$  be considered a short run phenomenon?

The cyclical component of the unemployment rate is affected by nominal variables if the changes in the nominal variables are not perceived by the public to be changes in the nominal variables. The reason changes in the price level affect the unemployment rate is that nominal wages are rigid. If contracts are written for an expected inflation rate, the actual inflation exceeds the expected, and contracts cannot be renegotiated at will, then the rigidity in the nominal wages results in the increased level of employment.<sup>3</sup> R. Barro, in his defense of the rational expectations formulation of the determinants of the unemployment rate, denies the rigidity of the nominal wages, but offers no alternative theoretical explanation of the economic cycles.<sup>4</sup>

The  $U^c$  can be considered short run or transitory, since the average duration of a post World War II reference phase in the United States is 2.08 and in the United Kingdom 2.2 years.<sup>5</sup> The Great Depression of the thirties, on the other hand, lasted over seven years and no doubt cannot be considered a transitory phenomenon. The measured unemployment rate in that decade remained well over ten percent and did not decline until the start of the war. However, that was a unique period in the economic history of the United States, where repeated policy errors by the Federal Reserve System kept the actual unemployment rate at an unusually high level.<sup>6</sup> The measured

unemployment rate, on the other hand, was erroneously high as a result of a statistical mistake in counting persons gainfully employed by federal, state and local governments' work-relief programs as unemployed.<sup>7</sup>

$U^c(t)$  can therefore be expressed as a function of this and past periods' deviation of the actual from the expected inflation rate.

$$3.2) \quad U^c(t) = -b \sum_{i=0}^{\infty} \lambda^i (\dot{P} - E(\dot{P}))_{t-i} + e(t)$$

$e_t$  are all other exogenous shocks that can affect the cyclical unemployment rate. It is assumed to be normally distributed with zero mean and constant variance.  $\lambda$  is a constant between zero and unity. It measures the effects of the past deviation of the expected from the actual inflation on the unemployment rate.

Substituting 3.2 in 3.1 and performing a Koyck transformation, I obtain

$$3.3) \quad U^c(t) = -b_0 (\dot{P} - E(\dot{P}))_t + \lambda U^c(t-1) + e(t)$$

The expected inflation rate  $E(\dot{P})$  is formed rationally, based on the information conveyed from the changes in the relative price of commodities and the past behavior of the price level. The Bayesian formulation of the posterior distribution of the inflation rate to determine the expected inflation rate is the dynamic version of the derivation in Lucas' (1973) article.<sup>8</sup>

First, I assume that the prior distribution of the actual inflation rate is normally distributed with known mean and variance.

$$3.4) \quad \text{prob} (\dot{P}_t) \sim N(t-1\dot{P}, t-1\sigma^2)$$

The actual inflation rate deviates from the percentage change in the absolute price of a commodity by an amount which is also distributed normally with a known mean of zero and constant variance.

$$3.5) \quad \dot{P}_t(z) = \dot{P}_t + z_t$$

where  $z$  is the deviation of the percentage change of the price of commodity  $z$  from the actual inflation rate.

The prior distribution of  $z$  is:

$$3.6) \quad \text{prob}(z_t) \sim N(0, \tau^2)$$

I assume that  $\tau^2$  is constant over time and independent of  $\sigma^2$ .<sup>9,10</sup>

My objective is to derive the posterior distribution of the inflation rate from the known prior distribution of inflation and the absolute price of the commodities using Bayesian method. The first moment of the posterior distribution is the expected inflation, and the second moment is the variance of the inflation rate. (See Statistical Appendix for the derivation of the expected inflation.)

The expected inflation rate is:

$$3.7) \quad E(\dot{P}_t | \dot{P}_t(i)) = \theta_{t-1} \bar{\dot{P}}_t + (1 - \theta_{t-1}) \dot{P}_t$$

where  $\theta_t = \tau^2 / (\tau^2 + \sigma^2)$

$\bar{\dot{P}}$  is the average inflation rate over time

$\dot{P}$  is the average inflation rate across markets at time (t)

This formulation of the expected inflation is preferred to the one with constant coefficients as in the adaptive expectations.<sup>11</sup> First, there is no a priori reason for assuming geometrically declining weights summing to unity. Secondly, the adaptive expectations are irrational

in the sense that the attached weights are constant and independent of the inflationary process itself.

Since I assume that the variance of the changes in the absolute commodity prices around the change in the price level is constant over time,  $\sigma$  is constant,  $\theta_{t-1}$  can be written as a function of the standard deviation of the inflation rate.

$$\theta_{t-1} = \theta(\sigma; \tau)$$

The first derivative of  $\theta$  with respect to the standard deviation of the inflation rate is negative.

$$\frac{\partial \theta}{\partial \sigma} = \frac{\sigma \tau^2}{\tau^2 + \sigma^2} < 0$$

A large variance of the inflation rate over time implies a small  $\theta_{t-1}$ . Changes in the price of commodities, then, are perceived to be changes in the price level, and the expected inflation rate quickly adjusts to the actual inflation rate. Conversely, if the variance of the inflation rate is small, an increase in the change in the commodity prices is perceived as a change in the relative prices and the public is fooled to expect an inflation rate based on the past behavior of the price level, and the unemployment rate is affected. Furthermore, as the variance of the inflation rate is increasing over time due to government's efforts to control the unemployment rate by changes in the inflation rate, the increasing prices are perceived as changes in the absolute and not the relative price of commodities. The slope of the Phillips curve will be steeper and the average unemployment rate higher over time. Substituting the expected inflation into  $U^c(t)$  and solving

for  $U(t)$ , we obtain the following reduced form for the unemployment rate:

$$3.8) \quad U_t^c = -b_o(t-1)^\theta (\dot{P}_t - \bar{P}_t) + \lambda (U_{t-1} - U^P) + e_t$$

$$U_t = (1 - \lambda)U^P - b_o(t-1)^\theta (\dot{P}_t - \bar{P}_t) + \lambda U_{t-1} + e_t$$

#### B. Implications of the Model

This model predicts that the cyclical unemployment rate and the measured unemployment will rise as the variance of the inflation rate increases over time. Defining,

$$\pi_t = \dot{P}_t - t-1 \cdot \bar{P}$$

$$a = (1 - \lambda)U^P$$

$$t-1^\theta = 1 - b_1(t-1 \cdot \sigma) \quad \text{where } b_1(t-1 \cdot \sigma) < 1$$

Rewriting  $U_t$ ,

$$U_t = a - b_o[1 - b_1(t-1 \cdot \sigma)] \cdot \pi_t + \lambda U_{t-1} + e_t$$

$$U_t = a - b_o \cdot \pi_t + b_o \cdot b_1(t-1 \cdot \sigma) \cdot \pi_t + \lambda U_{t-1} + e_t$$

The first partial derivative of  $U_t$  with respect to  $\pi_t$  is negative.

$$\frac{\partial U}{\partial \pi} = b_o \cdot b_1(t-1 \cdot \sigma) - b_o = -b_o(1 - b_1(t-1 \cdot \sigma)) < 0$$

The first partial derivative of  $U_t$  with respect to  $\sigma$  is positive if the inflation rate is accelerating, negative if decelerating over time.

$$\frac{\partial U}{\partial \sigma} = b_o \cdot b_1 \pi_t$$

$$\text{if } \pi_t > 0, \text{ then } \frac{\partial U}{\partial \sigma} > 0$$

$$\text{if } \pi < 0, \text{ then } \frac{\partial U}{\partial \sigma} < 0$$

The second partial derivative with respect to  $\sigma$  is positive.

$$\frac{\partial^2 U}{\partial \sigma \partial \pi} = b_0 \cdot b_1 > 0$$

The unemployment rate initially declines when the inflation rate is accelerating. However, accelerating inflation rate increases the variance of the inflation rate and the unemployment rate at an increasing rate. The initial effect of the accelerating inflation is offset by its affect on the variance of the inflation rate. The absolute value of the slope of the short run Phillips curve increases as a result of the increasing variance.

$$U_t = a_0 + b_0 \cdot t^{-1} \pi_t + \lambda U_{t-1} + e_t$$

$$\frac{\partial \pi}{\partial U} = -b_0^{-1} (1 - b_1 \cdot \sigma)^{-1} < 0$$

$$\frac{\partial^2 \pi}{\partial U \partial \sigma} = -b_0^{-1} (1 - b_1 \cdot \sigma)^{-2} (-b_1) = b_1 \cdot b_0^{-1} (1 - b_1 \cdot \sigma)^2 < 0$$

$\frac{\partial \pi}{\partial U}$  becomes more negative as  $\sigma$  rises. In other words, the slope of the Phillips curve becomes steeper.

The model reduces to the usual Phillips curve if the variance of the inflation rate is constant over time. However, if the variance is increasing, the slope of the Phillips curve becomes steeper.

Figure 3.1 demonstrates this prediction of the model. The short run

Phillips curves swerve around  $U^P$  clockwise, each steeper curve corresponding to a higher  ${}_{t-1}\sigma$ . At a very high level of  $\sigma$ ,  $\theta$  approaches its lower limit, zero, and the Phillips curve is vertical even in the short run. On the other hand, if  $\sigma$  is very small, then  $\theta$  approaches its upper value, unity, and small deviation of the actual inflation affects the unemployment rate. If higher  $\sigma$ 's are also associated with increasing time, the steeper Phillips curves correspond to later periods. Over a given range of the deviation of the actual from the average inflation rate, steeper curves imply higher average unemployment rates. Therefore, increasing average unemployment rate is explained by increasing variance of the inflation rate over time.

To summarize the implications of this model: if the variance of the inflation rate is increasing as a result of either unstable inflation rate or constantly accelerating inflation, there will be two separate movements in the unemployment rate. If the actual inflation rate is greater than the average inflation over time, the movement along the Phillips curve will reduce the unemployment rate. However, increasing variance of the inflation rate will shift the short run Phillips curve to the right, increasing the unemployment rate. The net effect of the inflationary process on the unemployment rate is ambiguous, depending on which of the two movements dominates. If the clockwise shift is dominant, then the unemployment rate increases in the short run, even with accelerating inflation.

### C. Estimation of the Model

The expected inflation  $E(\dot{P})$ , under the assumption of constant variance of the change in the relative prices, is estimated by

$$E(\dot{P}) = \dot{P}^t - b_1 ({}_{t-1}\sigma) (\dot{P} - \dot{P}^t)$$

where  ${}_{t-1}\sigma$  is the moving average of the absolute values of the actual from the trend value of  $\dot{P}$  lagged one period.

Both the trend and the measure of the dispersion are calculated by the method described in Chapter I.

$$\dot{P}^t = a_0 + a_1 t + a_2 \cdot t^2$$

$${}_{t-1}\sigma = \frac{\sum |\dot{P} - \dot{P}^t|_{t-i}}{12}$$

$$t=1, 2, 3, \dots, 72$$

The  $\dot{P}^t$  is used in place of  $\dot{P}$ , since the trend value holds the acceleration of the inflation rate constant over time. (See Chapter I for the proof of the resulting bias when the inflation rate has varying acceleration over time.)

#### 1. OLS Estimation

The equation 3.8 cannot directly be estimated because the dependent variable  $U_t$  is highly correlated with the lagged dependent variable on the RHS. If we can assume that  $U_t$  follows a first order autoregressive scheme, then

$$U_t = \rho U_{t-1} + \varepsilon$$

$\varepsilon_t$  has zero expected value and constant variance. If  $\rho = 1$ , then

$$U_t - U_{t-1} = dU_t$$

$$U_{t-1} = U_t - dU_t$$

Substituting  $U_{t-1}$  in 3.8, defining  $R = \pi \cdot t_{-1}^\sigma$ , solving for  $U_t$ :

$$U_t = A + B \cdot \hat{\pi}_t + C \cdot R_t + D \cdot dU_t + E_t$$

where  $A$  is the estimated value of the permanent unemployment;

$b_1 = C/B$  is the estimate of the effects of the actual from the expected inflation rate (it must be negative);

$C$  is the coefficient measuring the change in the slope of the Phillips curve due to increasing variance (it is predicted to be positive).<sup>12</sup>

## 2. Instrumental Variable Estimation

A consistent method of estimating the parameters of 3.8 is by first predicting the lagged dependent variable  $U_{t-1}$  by those variable of the model which are correlated with  $U$  but are independent of the error term. Such instruments are the other two independent variables,  $R$  and  $\pi$ . In the first stage,  $U$  is regressed only on  $R$  and  $\pi$ . In the second stage, the lagged predicted value  $U_{t-1}^*$  is substituted in place of  $U_{t-1}$  and the equation is estimated.<sup>13</sup>

1st stage 
$$U_t^* = \hat{a}_0 + \hat{a}_1 \cdot \pi_t + \hat{a}_2 \cdot R_t$$

2nd stage 
$$U_t = A + B \cdot \pi_t + C \cdot R_t + D \cdot U_{t-1}^* + e_t$$

where D is the estimate of  $\lambda$

$A/1-D$  is the estimate of permanent unemployment rate. It should be positive.

$C/B$  is the estimate of  $b_1$ . It is predicted to be negative.

### 3. Maximum Likelihood Estimates

The  $U_t$  can also be written as

$$U_t = U^P - b_0 \Sigma \lambda^i \pi_t + b_0 \cdot b_1 \Sigma \lambda^i R_t + e_t$$

The likelihood function is given in Dhrymes<sup>14</sup>

$$L(\lambda; U, \pi, R) = \frac{1}{\pi \cdot \sigma} e^{\left\{ -\frac{1}{2} \cdot \sigma \left\{ U_i^{-\alpha - \beta_1} (\pi_i^* - \bar{\pi}^*) - \beta_2 (R_i^* - \bar{R}^*) \right\}^2 \right\}}$$

$$i=1, 2, \dots, 72$$

where

$$\alpha = \begin{bmatrix} A \\ A_1 \end{bmatrix}$$

$$\pi_t^* = \lambda \pi_{t-1}^* + \pi_t, \quad \pi_1^* = \pi_1$$

$$R_t^* = \lambda R_{t-1}^* + R_t, \quad R_1^* = R_1$$

$$A = U^P$$

$$A_1 = \text{coefficient of } \lambda^i$$

The likelihood function is maximized if the standard error of the estimate of the following equation is minimized with respect to  $\lambda$ .

$$U_t = A + A_1 \lambda^t + B_0 \pi_t^* + B_1 R_t^* + e_t$$

A costly search process for  $\lambda$  is conducted between the a priori values of zero and one. The value of  $\lambda$  that minimizes the sum of the squared residuals is selected as that which maximizes the likelihood function.

The ML estimates have the desired properties of asymptotic unbiasedness and consistency. The major difficulty encountered in using this method is that for three countries, United Kingdom, Austria and Sweden, no value of  $\lambda$  within the assumed range minimized the sum of the squared residuals. In these three cases, extreme values of  $\lambda$ , either 0 or 1, were superimposed as the coefficient of  $U_{t-1}$ , and 3.8 was estimated by OLS. The failure of the model to find estimates of  $\lambda$  for all countries, no doubt, is an indication that the model as specified is not universal in the lag structure and encounters difficulties in cross sectional tests. Nevertheless, the likelihood function was maximized,  $\lambda^*$  was successfully estimated for eleven of the fourteen countries, including the United States, Canada, Japan and West Germany.

#### D. Results and Conclusions

The main purpose of this chapter is to test the hypothesis that increasing variance of the inflation rate increases the slope of the Phillips curve and the unemployment rate over time. This hypothesis is

confirmed if the estimates of  $b_1$  are negative, and rejected if they are not significantly different than zero or positive.

The second hypothesis that is also tested in this chapter is that there is an inverse relationship between the unemployment rate and the deviation of the actual from the expected inflation rate. This hypothesis is confirmed if the estimates of  $b_0$  are significantly negative.

The model also attempts to estimate the number of adjustment periods necessary for each country when the actual inflation rate deviates from the expected.

The empirical tests based on quarterly data for fourteen countries, using three different estimation methods, find that  $b_1$  is negative for almost all countries. The  $b_1$  is significantly negative for the countries in Table 3.3A using the maximum likelihood estimation method. The magnitude and the signs of the OLS or ML estimates are similar to the estimates obtained by IV.

The instrumental variable estimates of  $b_0$  are negative as predicted for ten countries, and ML estimates are negative for nine countries. It can therefore be concluded that, *ceteris paribus*, when the actual inflation exceeds the expected inflation, the unemployment rate declines. Conversely, when the actual is less than the expected, the unemployment rate rises.

The last conclusion deduced from these empirical tests is that the effects of the deviation of  $\dot{P}$  from  $E(\dot{P})$  on the unemployment rate vary in duration depending on each country. The estimates of  $\lambda^*$  range from .03 for Denmark to .998 for Norway. For the United States,  $\lambda^*$  is .4, implying that the unemployment rate adjusts over five quarters.

For Canada, this adjustment is over seven quarters.

Tables 3.1 to 3.4 summarize the results of the tests.

The results and conclusions of this chapter can now be restated.

1. The larger the variance of the inflation rate, the steeper the slope of the Phillips curve, and the higher the average unemployment rate over time.
2. The deviation of the actual from the expected inflation rate can only reduce the unemployment rate when the movement along the Phillips curve dominates the clockwise cross movement in the curves themselves. In other words, then the variance of the inflation rate is small, then the public interprets changes in the absolute prices as changes in the relative price of commodities, and the unemployment rate as well as other real variables will be affected by changes in the nominal variables.
3. The unemployment rate takes well over two years to adjust to the deviation of the actual from the expected inflation rate for most countries in the sample.

Table 3.1

Testing the Effects of the Uncertainty about  
the Inflation Rate on the Unemployment Rate

## OLS Estimates

<u>Country</u>	<u>A</u>	<u>B</u>	<u>C</u>	<u>D</u>	<u>R<sup>2</sup></u>	<u>s.e.e.</u>	<u>D.W.</u>
1. U.S.	4.99 (51.3)	-3.6 (-5.12)	6.24 (3.79)	1.00 (2.99)	.4371	.7421	.72
2. Canada	5.50 (40.56)	-3.05 (-2.33)	6.22 (1.73)	.40 (.97)	.2030	1.01	.33
3. Japan	1.07 (39.46)	-.1 (-1.37)	.08 (1.03)	.53 (3.58)	.2221	.206	.30
4. U.K.	3.38 (23.5)	-.36 (-.26)	.15 (.06)	.50 (1.17)	.0574	1.077	.13
5. France	1.45 (17.7)	.30 (1.13)	-.27 (-.84)	1.58 (3.20)	.1589	.5858	.16
6. Germany	.58 (12.65)	-.6 (-1.55)	.84 (1.10)	2.29 (7.43)	.528	.3443	.61
7. Italy	3.61 (49.9)	-.2 (-.81)	-.46 (-.001)	.46 (5.88)	.4146	.5482	1.12
8. Belgium	2.17 (31.3)	.0002 (.001)	-.39 (-.57)	-.18 (-.04)	.0753	.5191	.16
9. Nthrlnds	1.25 (14.5)	-.095 (-.41)	.04 (.165)	1.94 (3.56)	.1845	.6526	.14
10. Sweden	.75 (19.7)	-.153 (-.78)	.22 (.63)	.60 (1.59)	.0534	.2881	.10
11. Norway	.98 (18.7)	.13 (.47)	-.18 (-.39)	.45 (5.58)	.3640	.4029	1.35
12. Denmark	3.42 (15.9)	-.82 (-1.17)	.77 (1.02)	.51 (6.84)	.4763	1.641	1.33
13. Austria	2.51 (20.3)	-.47 (-1.08)	.73 (1.88)	.58 (7.99)	.5355	.948	1.16
14. Ireland	6.58 (55.3)	.007 (.009)	.09 (.1)	.55 (4.27)	.2718	.9065	.50

Table 3.2

Testing the Effects of the Uncertainty about  
the Inflation Rate on the Unemployment Rate

Instrumental Variables Estimates  
Quarterly 1960 I to 1974 IV

<u>Country</u>	<u>A</u>	<u>B</u>	<u>C</u>	<u>D</u>	<u>R<sup>2</sup></u>	<u>s.e.e.</u>	<u>D.W.</u>
1. U.S.	2.71 (2.68)	-2.52 (-3.33)	4.1 (2.41)	.46 (2.3)	.4031	.7642	.41
2. Canada	1.80 (1.19)	-2.60 (-2.1)	5.46 (1.61)	.68 (2.44)	.2686	.9676	.39
3. Japan	-.04 (-.06)	-.10 (-1.22)	.09 (1.07)	1.04 (1.56)	.0815	.2239	.83
4. U.K.	1.27 (.48)	-.33 (-.24)	.12 (.05)	.64 (.81)	.0453	1.084	.15
5. France	6.01 (.85)	-.11 (-.42)	.16 (.44)	-2.96 (-.64)	.008	.636	.09
6. Germany	.29 (.76)	-.46 (-.84)	.61 (.56)	.57 (.99)	.0706	.483	.21
7. Italy	-.25 (-.1)	.08 (.26)	-.22 (-.52)	1.06 (1.46)	.082	.687	1.80
8. Belgium	1.1 (1.02)	.25 (.71)	-.8 (-1.2)	.49 (.98)	.089	.495	.15
9. Nthrlnds	5.77 (.51)	-.014 (.05)	.007 (.03)	-3.38 (-.40)	.003	.728	.06
10. Sweden	-.11 (-.11)	-.08 (-.42)	.10 (.29)	1.15 (.87)	.02	.295	.13
11. Norway	1.64 (1.33)	.11 (.33)	-.10 (-.18)	-.72 (-.57)	.017	.482	1.79
12. Denmark	4.06 (1.86)	-1.27 (-1.42)	1.28 (1.33)	-.2 (-.32)	.038	2.076	1.73
13. Austria	11.06 (2.96)	-.35 (-.64)	.37 (.76)	-3.45(-2.32)	.10	1.205	1.89
14. Ireland	5.17 (1.1)	.91 (1.17)	-1.08(-1.07)	.21 (.30)	.03	1.017	.81

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Table 3.3A

Testing the Effects of the Uncertainty about  
the Inflation Rate on the Unemployment Rate

Maximum Likelihood Estimates  
Quarterly 1959 I to 1974 IV

Countries with Significant Coefficients for  $\pi^*$  and  $R^*$

	<u>Country</u>	<u>Constant</u>	<u>B<sub>0</sub></u>	<u>B<sub>1</sub></u>	<u>A<sub>1</sub></u>	<u>R<sup>2</sup></u>	<u>SSR</u>	<u><math>\lambda^*</math></u>
1.	U.S.	5.01 (51.1)	-2.59 (-5.83)	5.29 (4.54)	.7 (.7)	.451	29.55	.4
2.	Canada	5.57 (53.8)	-2.81 (-5.82)	6.47 (4.67)	2.5 (4.78)	.6922	21.92	.8
3.	Japan	1.21 (51.0)	- .10 (-7.54)	.88 (5.06)	-.09 (-1.60)	.6594	1.028	.96
4.	France	2.06 (10.5)	.13 (1.59)	.19 (1.68)	.05 (.32)	.5918	9.166	.98
5.	Germany	.88 (12.9)	-1.04 (-6.96)	2.15 (7.33)	-.28 (-2.42)	.5251	6.558	.997
6.	Belgium	2.17 (32.3)	.46 (2.1)	-1.14 (-2.6)	2.46 (5.5)	.4452	9.055	.7

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Table 3.3B

Testing the Effects of the Uncertainty about  
the Inflation Rate on the Unemployment Rate

Maximum Likelihood Estimates  
Quarterly 1959 I to 1974 IV

Countries with Insignificant Coefficients for  $\pi^*$  and  $R^*$

<u>Country</u>	<u>Constant</u>	<u>B<sub>0</sub></u>	<u>B<sub>1</sub></u>	<u>A<sub>1</sub></u>	<u>R<sup>2</sup></u>	<u>SSR</u>	<u><math>\lambda^*</math></u>
1. Italy	3.58 (39.16)	-.08 (-.25)	-.94 (-.23)	39.7 (3.99)	.2534	26.72	.1
2. Netherlands	1.61 (18.7)	.33 (1.92)	-.07 (-.47)	.11 (.49)	.4303	16.66	.994
3. Norway	.94 (15.12)	.10 (.30)	-.08 (-.14)	very large (2.385)	.1019	12.84	.998
4. Denmark	3.37 (12.33)	-1.19 (-1.37)	1.19 (1.28)	very large (3.05)	.1751	237.5	.03
5. Ireland	7.01 (33.8)	-.37 (.95)	.15 (.315)	-1.2 (-1.89)	.2036	50.26	.94

Table 3.3C

Testing the Effects of the Uncertainty about  
the Inflation Rate on the Unemployment Rate

Countries for which  $\lambda^*$  was not Found  
between the Values of 0 and 1

OLS using extreme values of  $\lambda$ , either 0 or 1.

<u>Country</u>	<u>Constant</u>	<u>B<sub>0</sub></u>	<u>B<sub>1</sub></u>	<u>R<sup>2</sup></u>	<u>SSR</u>	<u><math>\lambda</math></u>
1. U.K.	.028 (.644)	-.011 (-.026)	.6855 (.119)	.0088	6.388	1
2. Sweden	.0012 (.089)	.082 (1.207)	-.137 (-1.12)	.0262	.584	1
3. Austria	2.50 (14.1)	-.26 (-.41)	.28 (.501)	.0061	107.7	0

Table 3.4

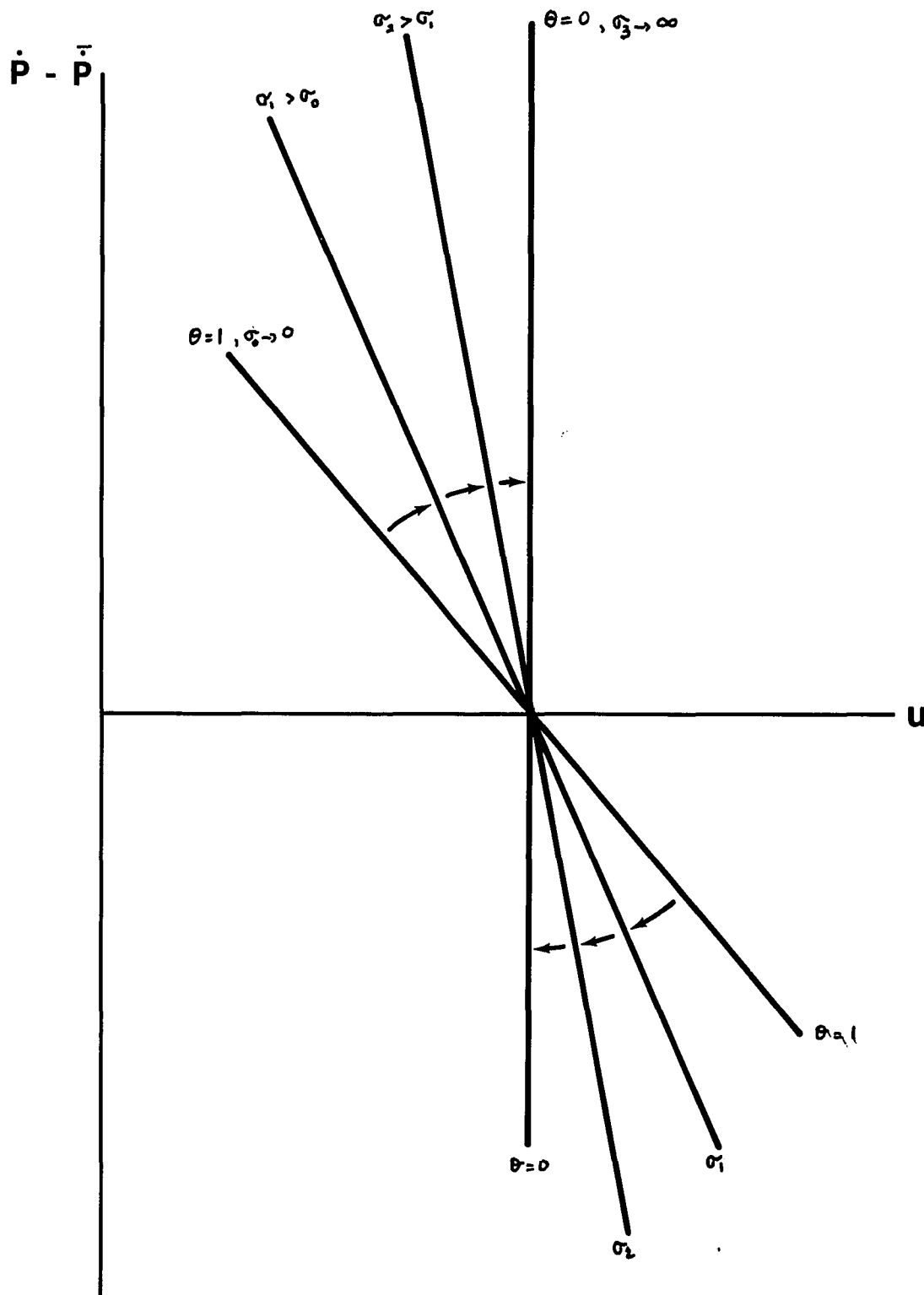
## Estimates of the Model

Quarterly 1959 I to 1974 IV

Country	U <sup>P</sup>			b <sub>0</sub>		b <sub>1</sub>			λ	
	OLS	IV	MLE	IV	MLE	OLS	IV	MLE	IV	MLE
1. U.S.	4.99	5.02	5.01	-2.52	-2.59	-1.73	-1.63	-2.04	.46	.4
2. Canada	5.50	5.63	5.57	-2.60	-2.81	-2.04	-2.10	-2.30	.68	.8
3. Japan	1.07	1.00	1.21	- .10	- .10 <sup>0</sup>	- .8	- .9	- .9	1.04	.96
4. U.K.	3.38	3.53		- .33	- .01*	- .42	- .36	-7.55*	.64	1*
5. France	1.45	NA	2.06	- .11	.13	- .9	-1.45	1.45	-2.96	.98
6. Germany	.58	.67	.88	- .46	-1.04	-1.4	-1.33	-2.07	.57	.997
7. Italy	3.61	4.17	3.58	.08	- .12	+2.3	-2.75	.33	1.06	.1
8. Belgium	2.17	2.2	2.17	.25	.46	-1950	-3.20	-2.48	.49	.7
9. Netherlands	1.25	1.32	1.61	- .01	.33	- .42	- .5	- .21	-3.38	.994
10. Sweden	.75	.73		- .08	.08*	-1.44	-1.25	-1.71*	1.15	1*
11. Norway	.98	.95	.94	.11	.10	-1.38	- .91	- .78	- .72	.998
12. Denmark	3.42	3.40	3.37	-1.27	-1.19	- .94	-1.01	-1.00	- .2	.03
13. Austria	2.51	2.49		- .35	- .26*	-1.55	-1.06	-1.08*	- .345	0*
14. Ireland	6.58	6.54	7.01	.91	- .37	12.86	-1.19	- .41	.21	.94

\* Not ml estimates

**FIGURE 3.1**  
**Short-run Phillips Curves when the variance of the inflation rate is increasing over time.**



Footnotes for Chapter III

<sup>1</sup>See Friedman, Milton, "The Role of Monetary Policy," American Economic Review, (March: 1968): 1-17; and Phelps, Edmund, "Phillips Curve, Expectations of Inflation and Optimal Unemployment Over Time," Economica, (August, 1967): 254-81.

<sup>2</sup>See P. Cagan (1977) for detailed discussion of this point.

<sup>3</sup>Fischer, Stanley, "Long-Term Contracts, Rational Expectations, and the Optimal Money Supply Rule," Journal of Monetary Economics, (July, 1971): 191-205.

<sup>4</sup>Barro, Robert, "Unanticipated Money Growth and Unemployment in the U.S." American Economic Review, (March, 1977): 101-15.

<sup>5</sup>Friedman, M. and A. Schwartz, The Monetary Trends in the United States and the United Kingdom, forthcoming, (National Bureau of Economic Research).

<sup>6</sup>Friedman, M. and A. Schwartz, "The Great Contraction, 1929-33" in The Monetary History of the United States, (Princeton University Press, 1963): 299-419.

<sup>7</sup>Darby, Michael, "Three-and-a-Half Million U.S. Employees Have Been Mislaid: Or, an Explanation of Unemployment, 1934-1941," Journal of Political Economy, (February, 1976): 1-16.

<sup>8</sup>Lucas, Robert, "Some International Evidence on Output-Inflation Tradeoffs," American Economic Review, (June, 1973): 326-34.

<sup>9</sup>If  $\alpha$  was zero, then the only source of the aggregate shocks will be nominal. The public will not be fooled to think the rising absolute prices to be increasing in the demand for commodities relative to others, and the real sector will not be affected even in the short run.

<sup>10</sup>See Vining and Elwetowski (1976). They show strong evidence that the unweighted variance of the change in the relative prices is positively correlated with changes in the price level. This problem, nevertheless, is ignored by this assumption.

<sup>11</sup>Cagan, Phillip, "The Monetary Dynamics of Hyperinflation," in Studies in the Quantity Theory of Money, edited by M. Friedman, (The University of Chicago Press, 1956): 25-120.

<sup>12</sup>The OLS estimates are, however, biased and inconsistent since the independent variable  $dU$  is not independent of the error terms of

the equation. To show the dependence, write

$$dU(t) = B.dR + C.dA + D.d^2U + de(t)$$

Since  $de(t) = e(t) - e(t-1)$

therefore,  $dU(t)$  is not independent of  $e(t)$ .

<sup>13</sup>Gujarati, Damodar, Basic Econometrics, (McGraw-Hill, 1971): 376-378.

<sup>14</sup>Dhrymes, P. "Geometric Lag Structure II" in Distributed Lags Problems of Estimation and Formulation, (Holden-Day, 1971): 98-139.

### CONCLUSIONS

In this study, I first established that increasing variance of the actual inflation is positively correlated with the actual inflation and the unemployment rates. Two hypotheses were then formulated that attribute the secular increase in the unemployment rate to the inflationary process and, more particularly, to the variance of the inflation rate.

The first hypothesis stated that if the short run Phillips curve is convex, then the increasing variance of the inflation rate increases the average unemployment rate. The results of the tests of this hypothesis presented in Chapter II refute the hypothesis that the secular trend in the unemployment rate is due to the convexity of the Phillips curve.

The second hypothesis, based on Lucas' earlier work, stated that the slope of the Phillips curve becomes steep as the variance of the inflation rate increases, because increasing volatility serves the system of absolute prices useless for decisions affecting the unemployment rate. If the slope of the short run Phillips curve becomes steep over time, the average unemployment rate increases.

The statistical tests confirm the second hypothesis for most of the countries in the sample. Furthermore, it is statistically confirmed that the short run Phillips curve is negatively sloped. An attempt was also made to estimate the duration of the effects of the deviation of the actual from the expected inflation on the unemployment

rate. For most countries, the unemployment rates adjust well beyond two years when the actual is not equal to the expected inflation rate.

The increasing average unemployment rate for most countries, including the United States, Canada, Japan and Germany, can at least partially be explained by the increasing variation in the inflation rate.

#### Policy Implications

The obvious policy implication of the above conclusion is that government's stabilization policy first and foremost must aim to stabilize the inflation rate. If the contrary were true, that government policy aims to stabilize the unemployment rate at the expense of increasing the variance of the inflation rate, then the unemployment rate will further deteriorate over time.

The second policy implication, contrary to a widely accepted view, is that the accelerating actual inflation rate will not necessarily keep the unemployment rate at a low level. If the actual inflation rate is above the average inflation rate, there will be a movement along the Phillips curve reducing the unemployment rate; however, increasing variance of the inflation rate will have an offsetting effect by rotating the Phillips curve to the right, thus increasing the unemployment rate. The net effect of the accelerating inflation rate on the unemployment rate will depend on which of the two contrasting effects is more dominant.

### Suggestions for Future Research

The first question that still needs to be answered is the one raised by Professor M. Friedman in his Nobel Lecture: What are the microeconomic foundations of the determinants of the optimum level of employment which are affected by the increasing volatility of the inflation rate? It is my view that establishment of mere correlation between the permanent, or natural, component of the unemployment rate and the variance of the inflation rate is not sufficient in explaining this fundamental question.

Second, more ambitious empirical tests holding the variables affecting the labor force participation rate constant are required. Some international data on such variables are available for various countries.

Third, disaggregated commodity price data are necessary for more accurate estimate of  $\theta$  and expected inflation rate. The variance of the changes in the absolute price of commodities can be used to measure the impact of supply shocks to the economy.

Fourth, attempts must be made to improve the quality of the available international quarterly data on prices and unemployment rate. France, for example, did not have a quarterly price series until 1975. The poor regression results obtained for that country are partially due to the poor quality of their data. Furthermore, a homogeneous unemployment rate data must be developed such that pooled regressions can be run using cross sectional unemployment data.

Finally, the current debate among economists favoring fixed money rule versus flexible money rule must be resolved. In either case, the government's monetary policy must be known to the public.

Furthermore, more empirical research is required in estimating the lag structure involved from the implementation of a monetary policy to its effects on nominal wages and the price level. Only then the effects of government monetary policy on the absolute price of commodities can be sorted out from the effects of the changing supply and demand conditions on the relative price of commodities. In that case, not only the system of absolute prices will become more efficient, but the economy will be insulated from the changes in the nominal variables that at times cause prolonged unemployment and general depression.

## STATISTICAL APPENDIX

Derivation of the Expected Rate of Inflation

The inflation rate at any instant in time is the mean of the rate of change of the absolute price of commodities in  $n$  markets.

$$1) \quad \dot{P}_t = \alpha_1 \cdot P(1) + \dots + \alpha_z \dot{P}(n)$$

For simplification assume that each market is equal in size such that  $\alpha_1 = \alpha_3 = \dots = \alpha_z = 1/n$ . Therefore,

$$2) \quad \dot{P}_t = \frac{1}{n} \sum \dot{P}(i) \quad i = 1 \dots n$$

The expected rate of change of prices in any market is the rate of change of the average price level.

Assuming that the variance of the rate of change in the absolute prices is constant  $\tau^2$ , I can write, as in Lucas (1973) the rate of change of the absolute price in market ( $z$ ) as

$$3) \quad \dot{P}(z) = \dot{P}_t + z_t$$

$$\text{prob}(z) \sim N(0, \tau^2)$$

Information is conveyed to the economic agents in any market with one period lag. Such that the prior distribution of the expected inflation in market  $z$  is:

$$\text{prob} \{ \dot{P}_t(z) \} \sim N(\dot{P}_{t-1}, \tau^2)$$

$\tau^2$  is the variance of the  $\dot{P}(z)$  since:

$$E\{ \dot{P}_t(z) - \dot{P} \} = E(z_t^2) = \tau^2$$

$\tau^2$  is assumed to be constant over time.

The prior distribution of the inflation rate is also known. The mean of the inflation rate over time is  $\bar{P}$  and the variance  $\tau_t^2$ .

$$\text{prob} (\dot{P}_t) \sim N(\dot{P}_t, \tau_t^2)$$

where  $\bar{P} = \frac{\sum \dot{P}_{t-i}}{12}$   $i = 0, 1, \dots, 11$

My objective is to derive the posterior distribution of the inflation rate from the two known prior distributions. The mean of the posterior distribution is then the expected inflation. I employ Bayesian conditional probability to derive the first and the second moments of the posterior distribution.

The joint probability distribution of  $\dot{P}(z)$  and  $\dot{P}$  is

$$4) \quad \text{prob} \{ \dot{P}(z)_t, \dot{P}_t \} = \text{prob}(\dot{P}_t) \cdot \text{prob}\{ \dot{P}_t(z) | \dot{P}_t \}$$

The normal distribution of  $\dot{P}_t$  is

$$5) \quad \text{prob}(\dot{P}_t) = K_1 \cdot e\{-1/2\tau^2(\dot{P}_t - \bar{P})^2\}$$

The normal distribution of  $\dot{P}_t(z) | \dot{P}_t$  is

$$6) \quad \text{prob}\{ \dot{P}_t(z) | \dot{P}_t \} = K_2 \cdot e\{-1/2\tau^2(P_t(z) - P_t)^2\}$$

Therefore the joint probability function is:

$$7) \text{ prob}\{\dot{P}(z)_t, \dot{P}_t\} = K_1 \cdot K_2 \cdot e\{-1/2\{1/\sigma^2(\dot{P}_t - \bar{P}_t)^2 + 1/\tau^2(\dot{P}_t(z) - \dot{P})^2\}\}$$

Rewriting the exponential term:

$$8) -1/2\{1/\sigma_t^2(\dot{P}_t - \bar{P}_t)^2 + 1/\tau^2(\dot{P}_t(z) - \dot{P})^2\}$$

Expanding the squared terms:

$$9) -1/2\{1/\sigma_t^2(\dot{P}_t^2 - 2\dot{P}_t \cdot \bar{P}_t + \bar{P}_t^2) + 1/\tau^2(\dot{P}_t(z) - 2\dot{P}_t(z) \cdot \dot{P} + \dot{P}^2)\}$$

Collecting the like terms:

$$10) -1/2\{\dot{P}_t^2(1/\sigma_t^2 + 1/\tau^2) - 2\dot{P}_t(\bar{P}_t/\sigma^2 + \dot{P}_t(z)/\tau^2) + (\dot{P}^2/\sigma^2 + \dot{P}_t(z)^2/\tau^2)\}$$

Define:

$$1/a = 1/\sigma_t^2 + 1/\tau^2$$

and

$$b = \bar{P}_t/\sigma^2 + \dot{P}_t(z)/\tau^2$$

substituting the definitions in (10) into (9),

$$12) \quad -1/2a(\dot{P}_t^2 - 2ab\dot{P}_t + a^2b^2)$$

or

$$-1/2a(\dot{P}_t - ab)^2$$

The joint probability distribution, therefore, is

$$\text{prob}\{\dot{P}_t(z), \dot{P}_t\} = K_3 \cdot e\{-1/2a \cdot (\dot{P}_t - ab)^2\}$$

where  $K_3 = K_1 \cdot K_2$

The conditional probability of  $\dot{P}_t$  subject to information about  $\dot{P}(z)$  is

$$\text{prob}(\dot{P}_t | \dot{P}_t(z)) = \frac{\text{prob}(\dot{P}_t(z), \dot{P}_t)}{\text{prob}(\dot{P}_t(z))}$$

since  $\text{prob}(\dot{P}_t(z))$  is  $1/n$

$$13) \quad \text{prob}(\dot{P}_t | \dot{P}_t(z)) = K \cdot e\{-1/2a(\dot{P}_t - ab)^2\}$$

where  $K = n \cdot K_3$

$a$  = variance of the normal posterior distribution

$ab$  = mean of the normal posterior distribution

The expected value of inflation rate is the mean of the posterior distribution.

$$14) \quad E\{\dot{P}_t | \dot{P}_t(z)\} = ab \\ = \tau^2 / \tau^2 + \sigma_t^2 \cdot \bar{\dot{P}}_t + \sigma^2 / \sigma^2 + \tau^2 \cdot \dot{P}_t(z)$$

define  $\theta = \tau^2 / \tau^2 + \sigma_t^2 < 1$

Therefore the expected inflation in the (z) market is:

$$E\{\dot{P}_t | \dot{P}_t(z)\} = \theta \bar{\dot{P}}_t + (1-\theta) \dot{P}_t(z)$$

Since there are n markets, summing the expectations in n markets,

$$E\{\dot{P}_t | \dot{P}_t(1) \dots \dot{P}_t(n)\} = \theta \bar{\dot{P}}_t + (1-\theta) \cdot \Sigma \dot{P}_t(n) / n$$

and

$$E\{\dot{P}_t | \dot{P}_t(1) \dots \dot{P}_t(n)\} = \theta \bar{\dot{P}}_t + (1-\theta) \dot{P}_t$$

which is the formula for the expected inflation in the text.

DATA APPENDIX

The source of the data set used in this study is the University of Manchester--S.S.R.C. Research Programme. The following listing of the primary sources of data is based on their write-up. The fourteen countries are: United States, France, West Germany, Italy, Belgium, Netherlands, Sweden, Norway, Denmark, Austria and Ireland. The sample data are quarterly from 1957 I to 1974 IV.

1. Unemployment Series

Total number of registered unemployed were collected from "Main Economic Indicators" and adjusted on the basis of data presented in May 1971 and February 1973 issues of the "National Institute Economic Review".

The unemployment rate calculated for each country was then adjusted.

$$1. \quad u_t^* = U_t^* / E_t + U_t$$

$U_t^*$  is number of registered unemployed at time t using U.S. definition of unemployed.

$E_t$  is estimated total number of employees in employment in time t.

$U_t$  is the total registered unemployed in time t.

## 2. Inflation Data

The inflation rate is the logarithmic first difference of the nationally published retail price index. Problems of different weighting schemes used in calculating the price level in each country are ignored. The procedure employed was to collect unadusted monthly figures, re-set the base such that 1963=100, and take quarterly averages of the monthly data.

Sources of the national data and titles of series are:

- U.S.A. : Department of Labor Consumer Price Index: Survey of Current Business.
- U.K. : General Index of Retail Prices: Department of Employment Gazette
- Japan : Consumer Price Index: from 1963 to 1973 is taken from the Japanese sources, Basic Data for Economic Analysis. All others: Main Economic Indicators, O.E.C.D.
- Germany : Price index for cost of living (total expenditures) of four person workers' household with middle incomes: Statistical Bundesamt.
- Netherlands: Consumers' Price Index: Central Bureau voor de Statistich, "Maandschrift".
- Belgium : Index de Consumentierprijzen: Bulletines de Statistique.
- Source for the remaining countries is Retail Price Index: Main Economic Indicators O.E.C.D.

### 3. Volatility of Inflation

The measure of the volatility of the inflation rate was estimated:

$$1. \quad \dot{p}^t = \hat{a} + \hat{b}.t + \hat{c}.t^2$$

where  $\dot{p}^t$  is the estimated trend value of the inflation rate

$t$  is the time. For example,  $t = 1 = 1957$  II.

$$2. \quad v^t = | \dot{p} - \dot{p}^t |$$

where  $v$  is the absolute value of the residual in the first equation

$$3. \quad \sigma_t = \frac{\sum v^{t-i}}{12} \cdot 100 \quad i = 0, 1, 2, \dots, 11$$

The  $\sigma_t$  for each country is given in the following table.

### 4. Inflation and Unemployment Rates

The quarterly inflation and unemployment rates are plotted in Charts A.1 to A.14.

TABLE A1: Estimated Price Unpredictability

DATE		U.S. (1)	Canada (2)	Japan (3)	U.K. (4)	France (5)	Germany (6)	Italy (7)	Belgium (8)	Nthrls (9)	Sweden (10)	Norway (11)	Denmark (12)	Austria (13)	Ireland (14)
1959	4	.313	.405	.788	.688	1.616	.460	.825	.267	1.176	.534	.806	.872	1.506	1.070
1960	1	.319	.416	.743	.675	1.497	.463	.766	.303	1.155	.672	.810	.859	1.400	1.005
	2	.307	.390	.718	.670	1.377	.447	.702	.339	1.096	.672	.802	.783	1.121	.962
	3	.275	.419	.660	.650	1.368	.461	.681	.340	.923	.701	.774	.586	.920	.832
	4	.277	.397	.491	.649	1.193	.444	.654	.325	1.058	.702	.797	.507	1.074	.734
1961	1	.258	.377	.414	.622	.896	.443	.667	.317	1.061	.608	.791	.492	.952	.723
	2	.265	.332	.376	.609	1.010	.427	.630	.292	1.119	.607	.631	.514	.905	.735
	3	.249	.284	.478	.518	.922	.299	.573	.261	1.034	.594	.568	.554	.777	.721
	4	.230	.276	.637	.510	.923	.270	.482	.298	1.063	.552	.576	.600	.791	.661
1962	1	.205	.284	.573	.537	.821	.324	.452	.314	1.043	.644	.561	.673	.764	.746
	2	.207	.269	.574	.538	.674	.356	.481	.412	1.248	.627	.521	.715	.999	.833
	3	.196	.274	.548	.553	.600	.344	.473	.462	1.255	.611	.610	.679	1.142	.719
	4	.201	.242	.537	.591	.588	.381	.467	.483	1.311	.678	.605	.921	1.279	.680
1963	1	.187	.214	.784	.619	.644	.494	.696	.487	1.482	.510	.581	.873	1.389	.739
	2	.181	.211	.833	.618	.538	.499	.705	.463	1.585	.478	.611	.840	1.429	.744
	3	.198	.220	.861	.696	.550	.550	.705	.443	1.514	.468	.628	.973	1.508	.750
	4	.194	.219	.876	.662	.523	.578	.828	.504	1.360	.441	.638	1.008	1.379	.936

TABLE A1 (CONTINUED)

DATE	U.S. (1)	Canada (2)	Japan (3)	U.K. (4)	France (5)	Germany (6)	Italy (7)	Belgium (8)	Nthrls (9)	Sweden (10)	Norway (11)	Denmark (12)	Austria (13)	Ireland (14)	
1964	1	.183	.198	.849	.679	.454	.594	.887	.637	1.462	.440	.843	.986	1.366	.949
	2	.177	.173	.895	.716	.359	.577	.933	.707	1.553	.457	.820	.982	1.342	1.167
	3	.168	.162	.817	.662	.365	.586	1.016	.778	1.514	.439	.893	.910	1.304	1.167
	4	.159	.190	.711	.626	.255	.582	1.039	.752	1.530	.426	.861	.881	1.386	1.180
1965	1	.165	.190	.751	.602	.227	.562	1.009	.754	1.516	.297	.875	.815	1.296	1.105
	2	.172	.207	.782	.611	.249	.556	.925	.699	1.323	.235	.857	.783	1.402	1.020
	3	.174	.206	.881	.558	.281	.556	.910	.655	1.113	.403	.807	.970	1.261	.971
	4	.167	.197	.934	.525	.293	.526	.826	.641	1.060	.354	.843	.707	1.255	.973
1966	1	.166	.237	.711	.467	.226	.428	.593	.629	.950	.457	.804	.735	1.206	.962
	2	.187	.272	.653	.545	.213	.462	.563	.699	.882	.463	.750	.756	1.162	.959
	3	.186	.254	.727	.488	.177	.435	.612	.767	.878	.454	.717	.653	1.181	.945
	4	.184	.252	.738	.500	.177	.419	.476	.695	.935	.451	.703	.668	1.173	.818
1967	1	.210	.264	.728	.525	.179	.370	.438	.549	.785	.487	.503	.749	1.224	.886
	2	.191	.314	.808	.451	.175	.380	.411	.478	.592	.479	.515	.697	1.193	.669
	3	.211	.365	.860	.587	.186	.442	.348	.389	.529	.467	.446	1.085	1.194	.726
	4	.206	.376	.881	.577	.225	.529	.341	.379	.505	.551	.491	1.103	1.105	.754
1968	1	.202	.383	.807	.577	.269	.542	.362	.397	.494	.585	.462	1.162	1.146	.792
	2	.209	.369	.857	.526	.267	.544	.434	.391	.459	.656	.508	1.202	.842	.730
	3	.230	.362	.834	.564	.244	.589	.526	.390	.515	.545	.497	1.120	.851	.793
	4	.246	.363	.786	.565	.306	.596	.595	.395	.517	.610	.440	1.207	.687	.721

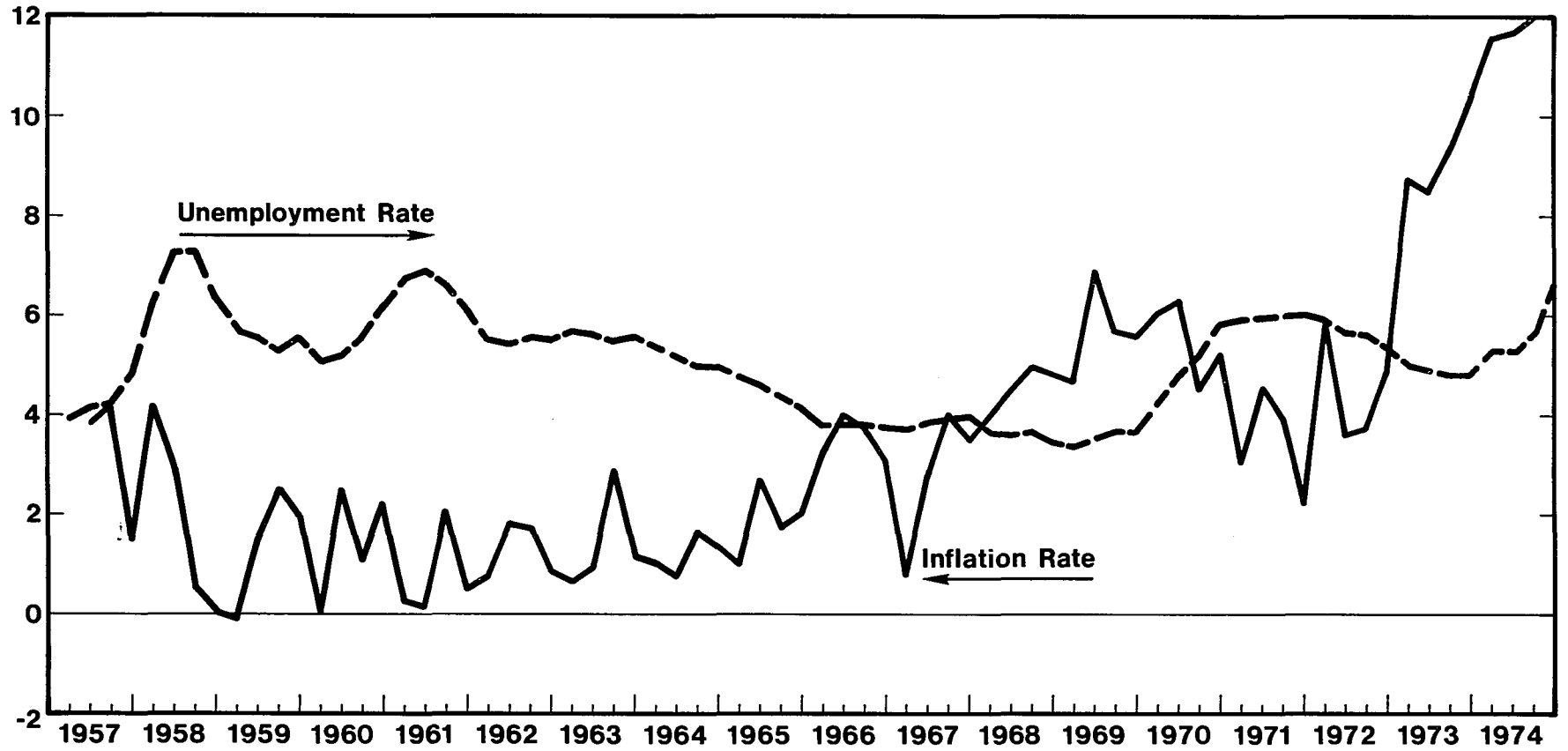
		TABLE A1 (CONTINUED)													
		U.S.	Canada	Japan	U.K.	France	Germany	Italy	Belgium	Nthrls	Sweden	Norway	Denmark	Austria	Ireland
DATE		(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
1969	1	.244	.322	.854	.594	.359	.558	.639	.348	.642	.522	.495	1.276	.665	.786
	2	.268	.358	.857	.516	.373	.551	.638	.265	.607	.554	.532	1.278	.629	.719
	3	.270	.343	.780	.576	.362	.559	.617	.205	.667	.554	.521	1.284	.496	.682
	4	.285	.376	.810	.591	.366	.578	.666	.215	.645	.591	.524	1.249	.513	.704
1970	1	.273	.371	.866	.560	.418	.651	.634	.221	.666	.689	.897	1.205	.386	.641
	2	.300	.349	.803	.589	.396	.664	.643	.257	.669	.681	.892	1.243	.347	.767
	3	.288	.344	.899	.510	.409	.652	.710	.312	.696	.662	.903	.878	.351	.704
	4	.283	.431	.830	.519	.391	.571	.679	.391	.672	.573	.853	.919	.368	.658
1971	1	.317	.474	.911	.565	.364	.622	.671	.361	.721	.720	.855	1.026	.365	.652
	2	.319	.466	.849	.600	.342	.577	.675	.343	.757	.783	.855	.935	.342	.669
	3	.331	.455	.895	.594	.351	.526	.666	.339	.744	.729	.857	.903	.373	.604
	4	.391	.520	.986	.657	.304	.524	.657	.374	.738	.652	.834	.857	.415	.640
1972	1	.386	.528	.918	.675	.277	.631	.619	.413	.679	.714	.793	.884	.356	.534
	2	.391	.458	1.063	.731	.267	.643	.643	.407	.760	.690	.755	.845	.328	.630
	3	.428	.491	1.150	.626	.265	.634	.614	.388	.648	.712	.730	.872	.356	.625
	4	.452	.452	1.085	.654	.332	.592	.573	.386	.629	.687	.725	.902	.350	.659

TABLE A1 (CONTINUED)

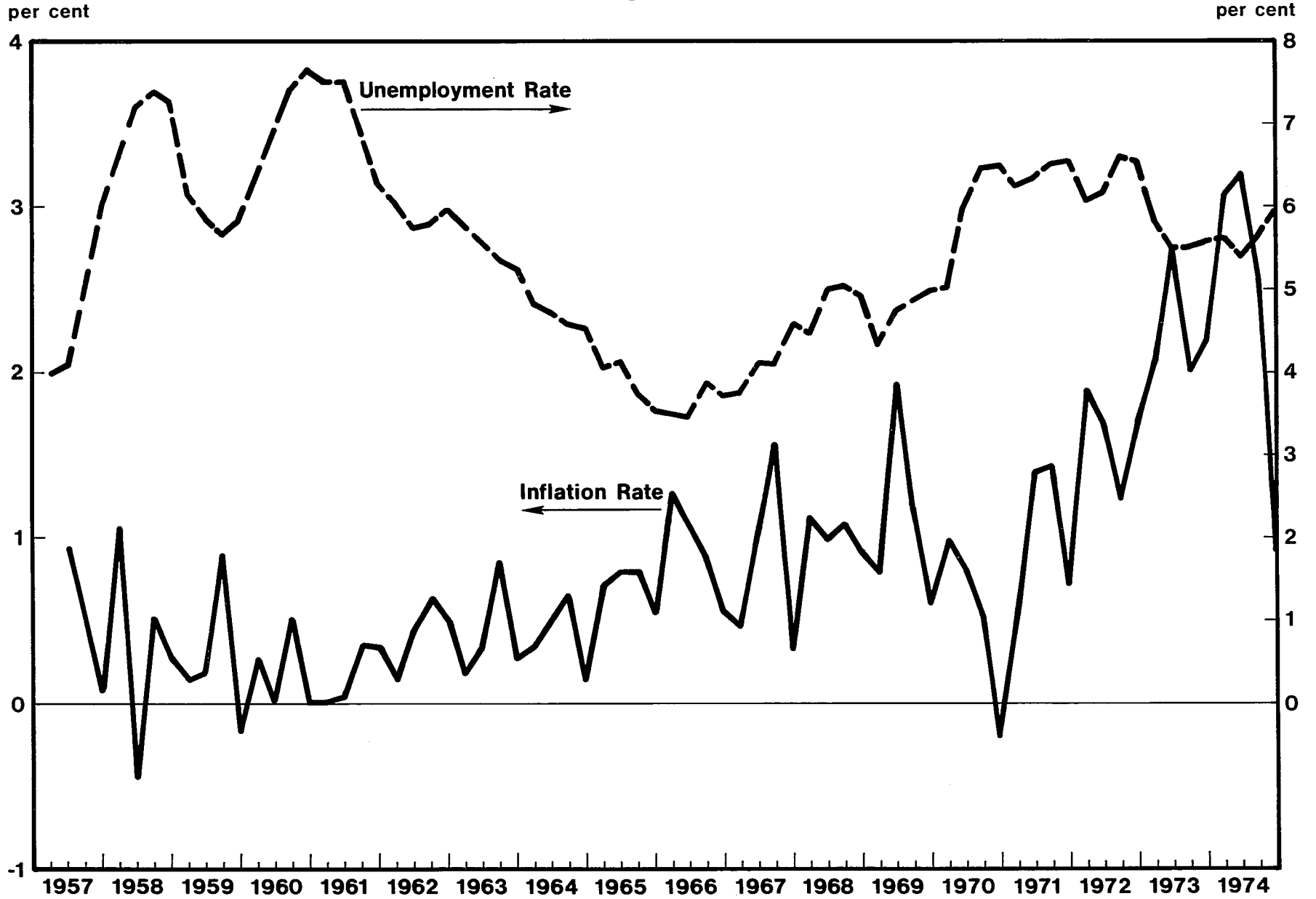
DATE		U.S.	Canada	Japan	U.K.	France	Germany	Italy	Belgium	Nthrls	Sweden	Norway	Denmark	Austria	Ireland
		(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
1973	1	.452	.458	1.150	.665	.316	.570	.606	.434	.668	.557	.349	.950	.374	.710
	2	.440	.498	1.092	.696	.309	.561	.619	.453	.755	.586	.337	.920	.391	.551
	3	.459	.439	1.024	.662	.294	.498	.594	.422	.723	.588	.352	.920	.418	.595
	4	.503	.325	1.397	.737	.337	.571	.678	.428	.702	.721	.336	1.016	.456	.644
1974	1	.517	.339	1.475	.805	.431	.480	.808	.558	.720	.595	.388	1.592	.502	.683
	2	.556	.425	1.429	.685	.479	.508	.954	.686	.708	.521	.338	1.623	.507	.800
	3	.578	.449	1.386	.687	.466	.511	1.113	.734	.733	.692	.316	1.576	.501	.759
	4	.630	.497	1.502	.726	.608	.587	1.232	.812	.868	.789	.358	1.545	.496	.773

### A1.1 U.S.

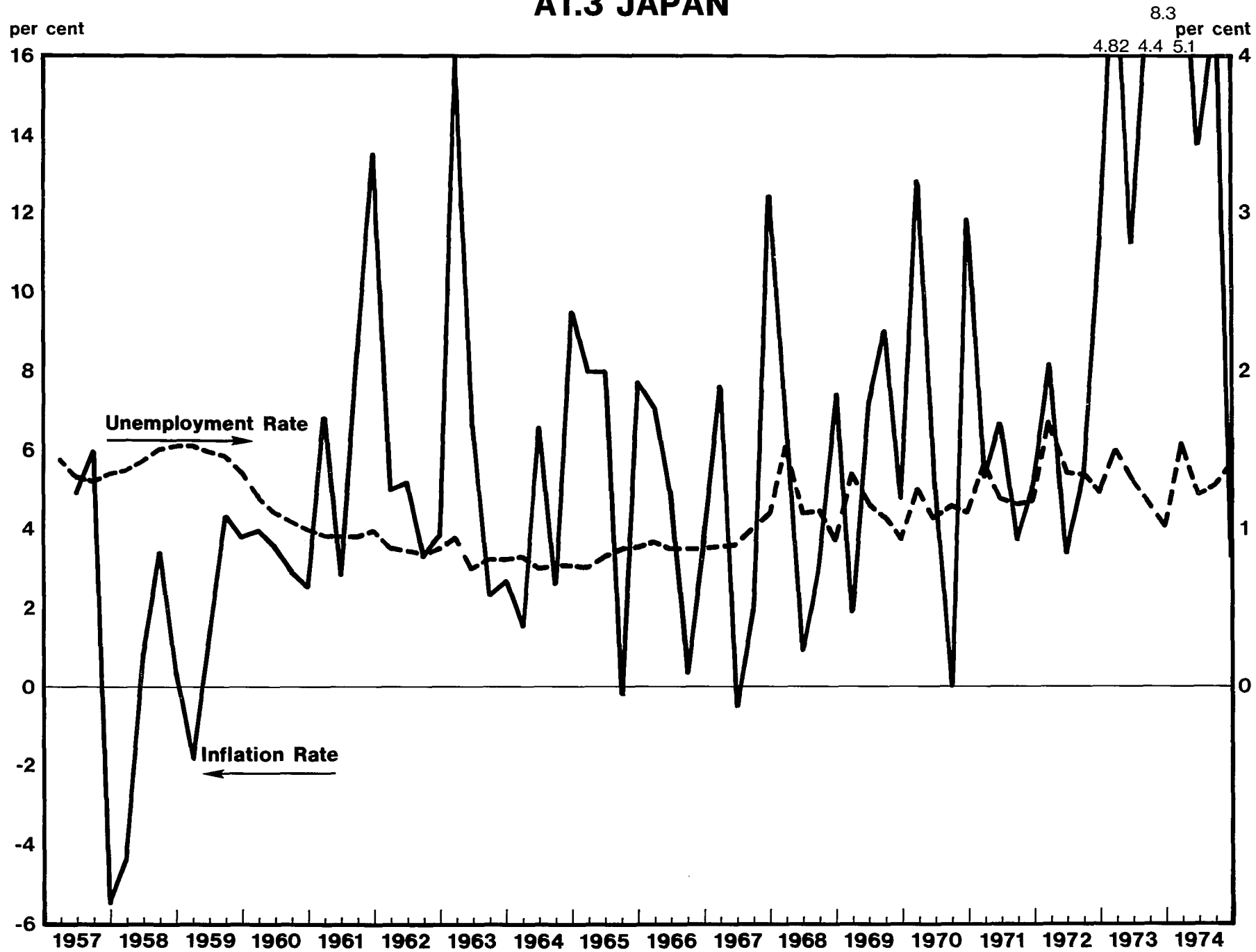
per cent



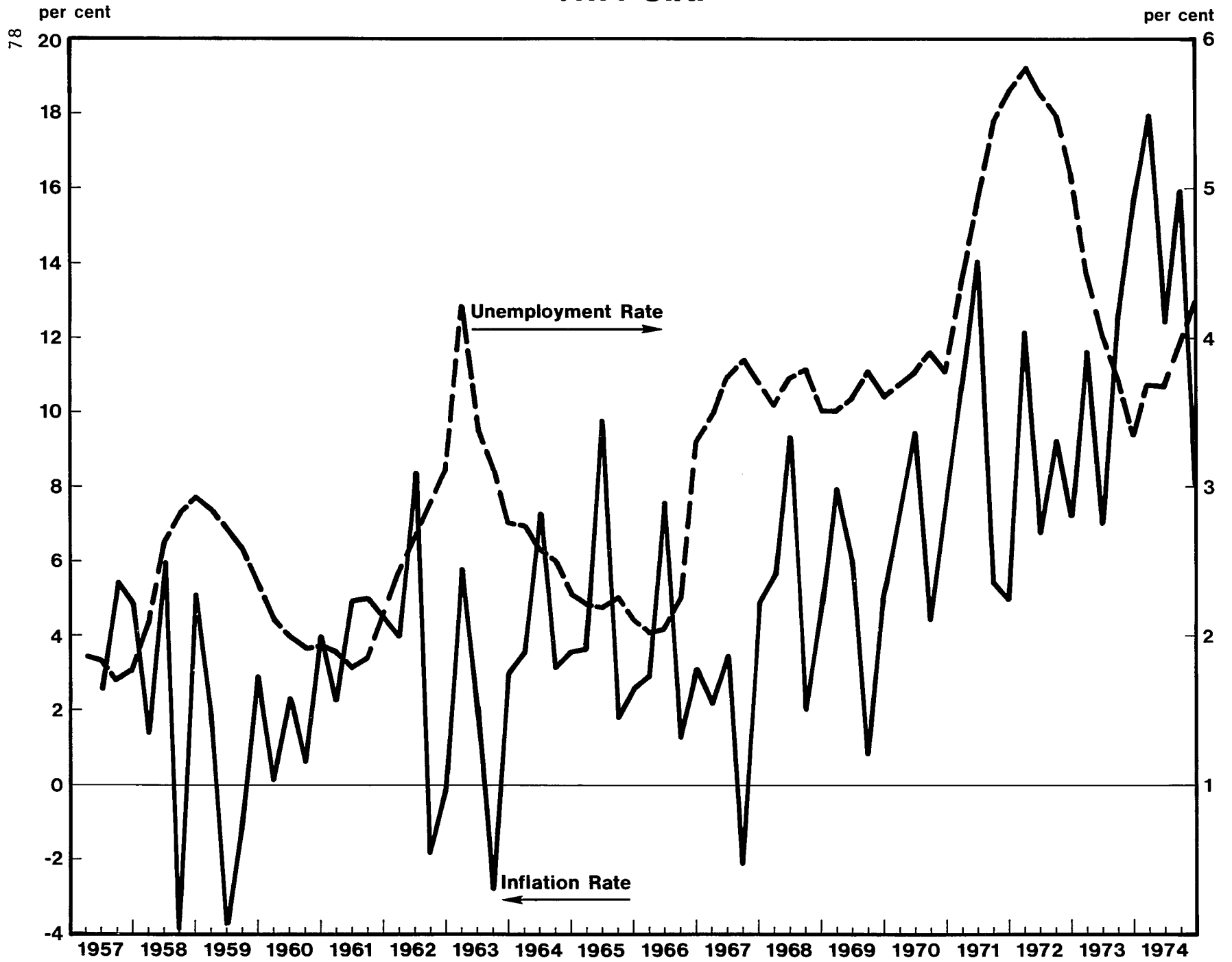
# A1.2 CANADA



# A1.3 JAPAN



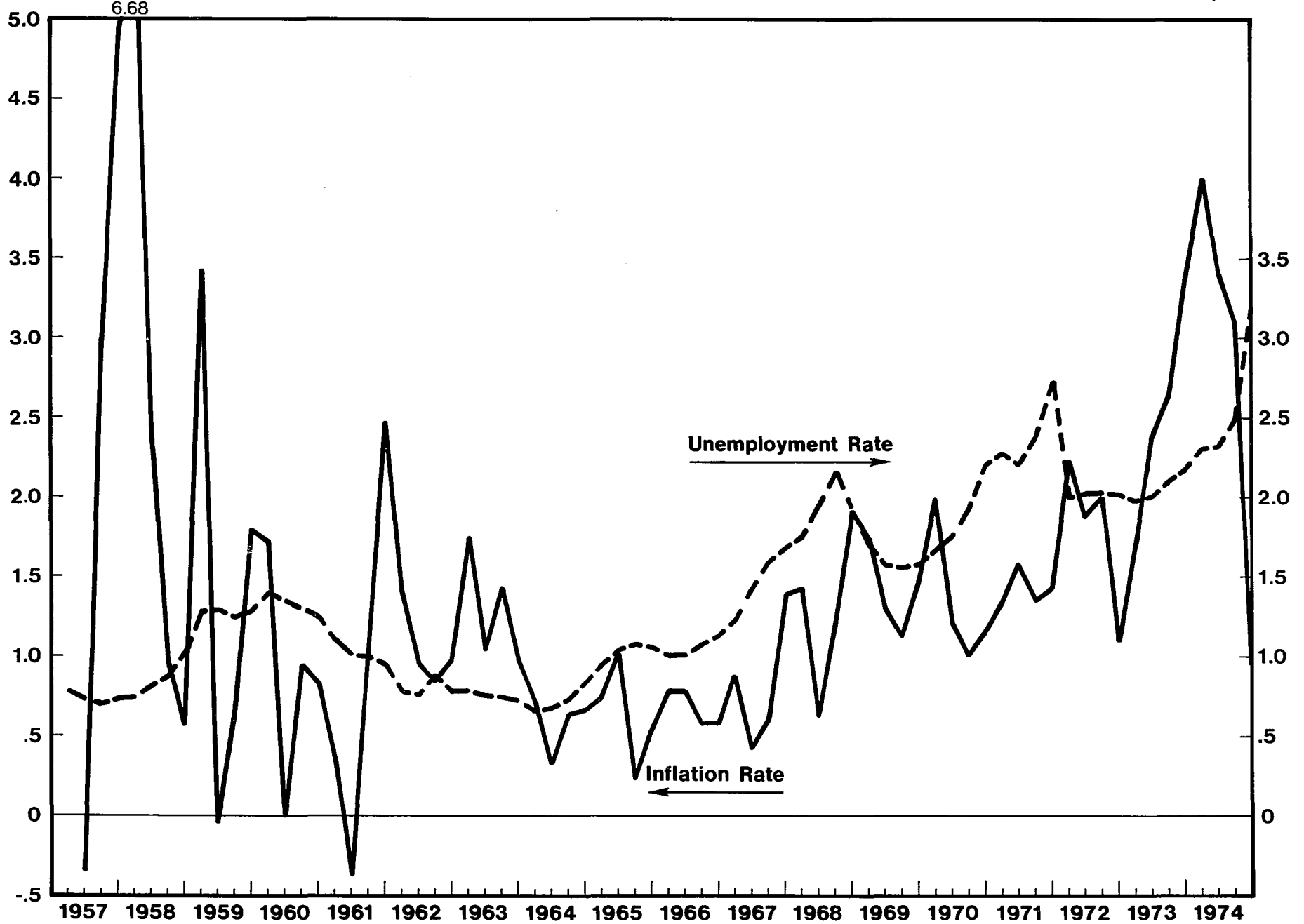
# A1.4 U.K.



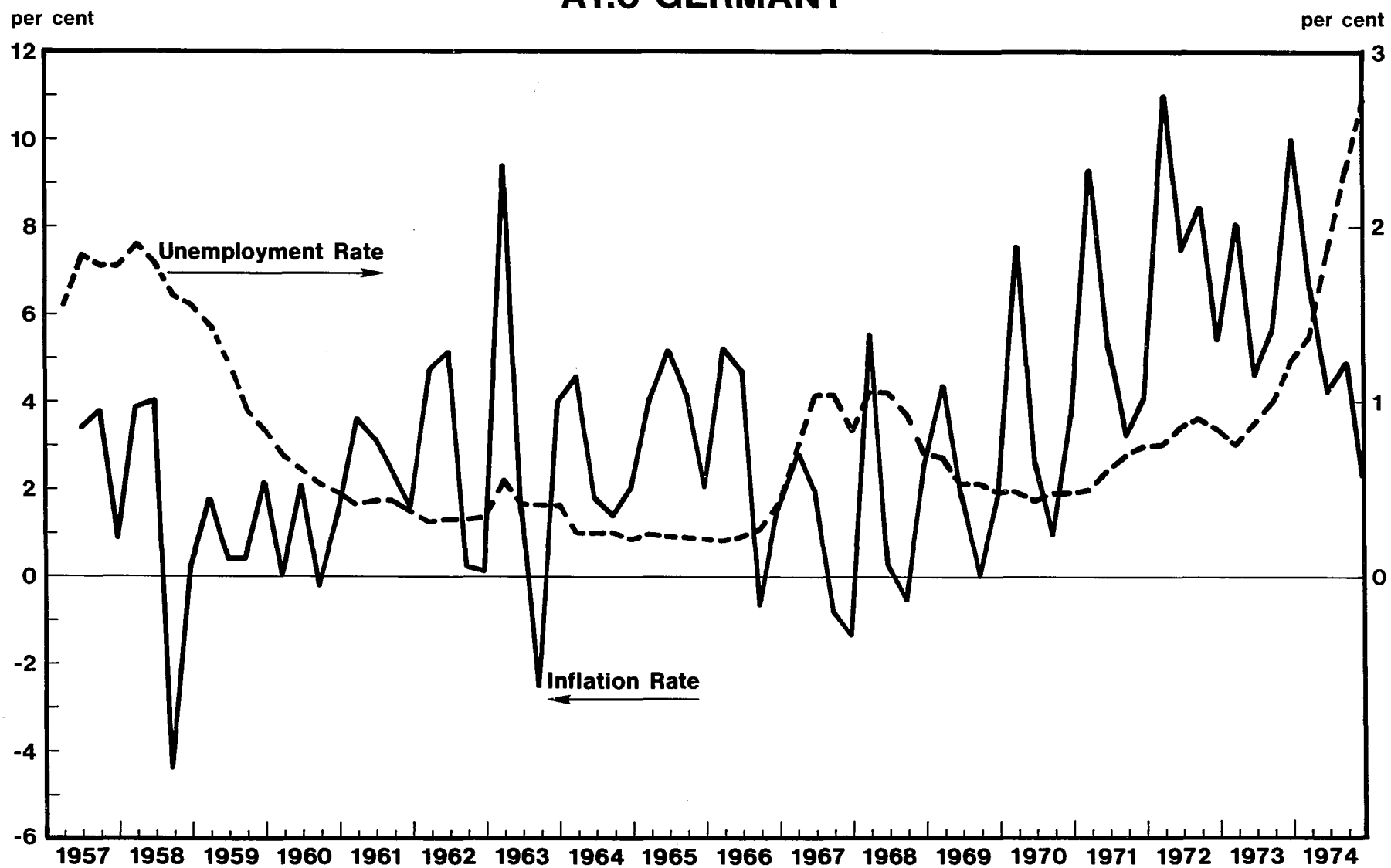
# A1.5 FRANCE

per cent

per cent

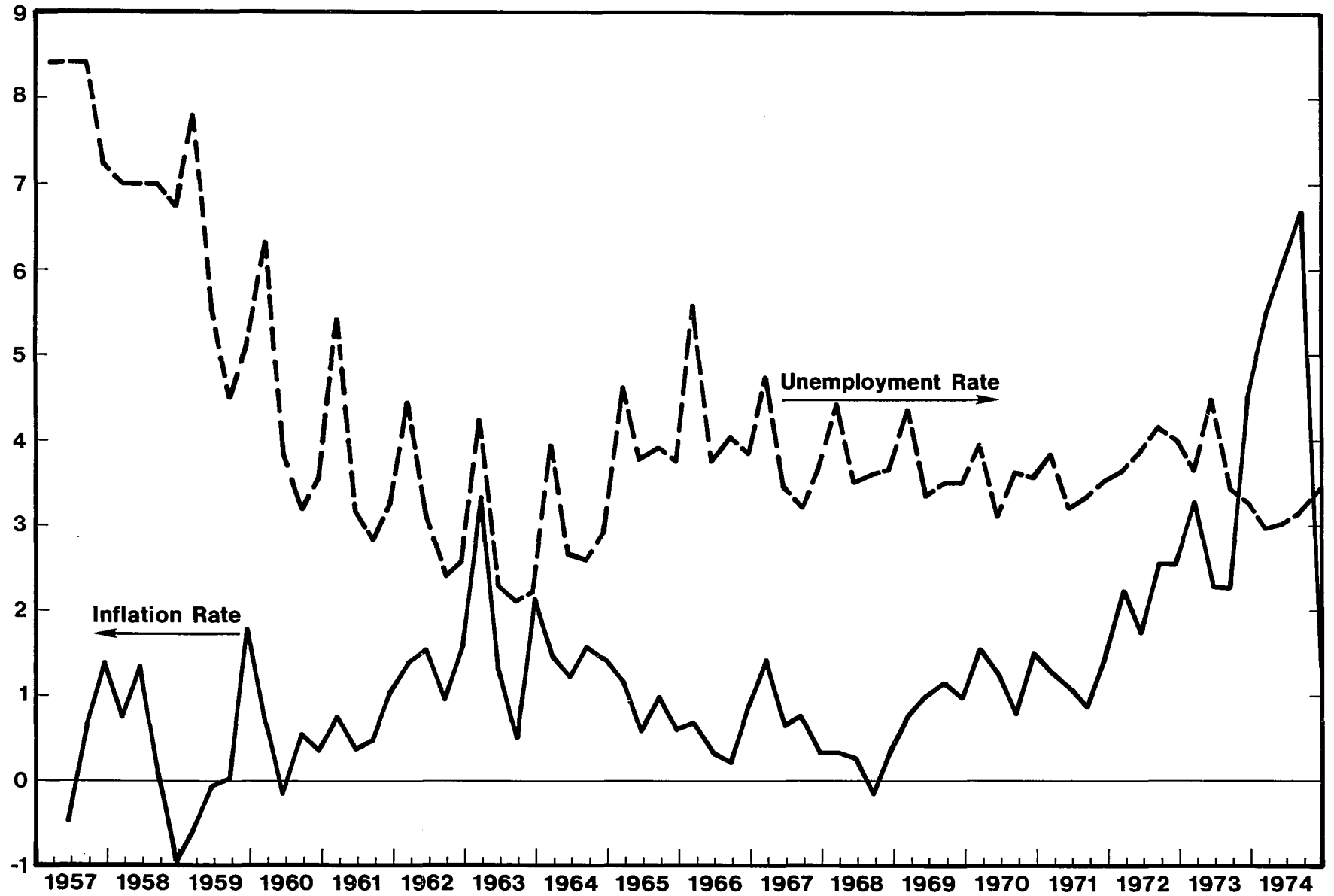


# A1.6 GERMANY

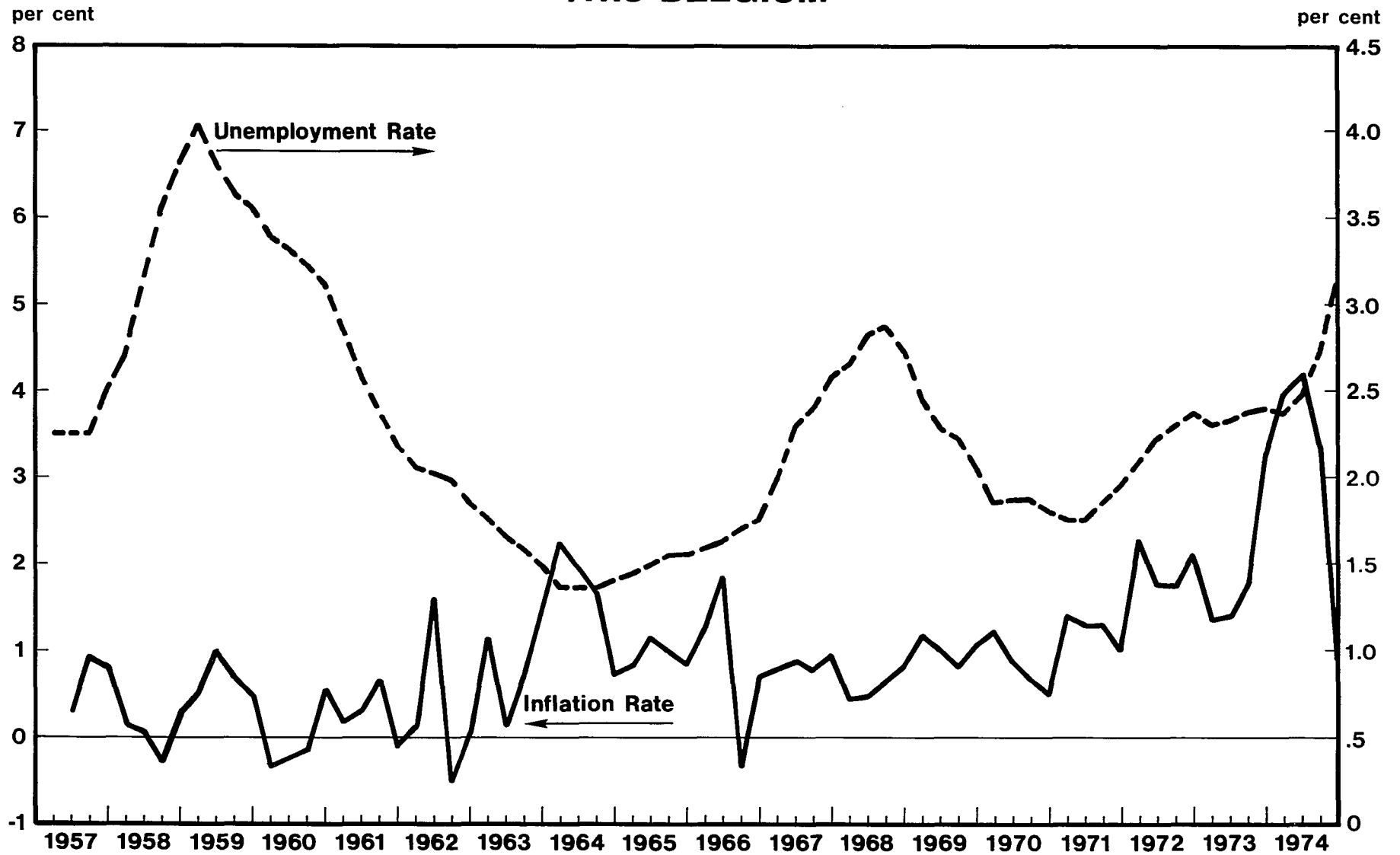


## A1.7 ITALY

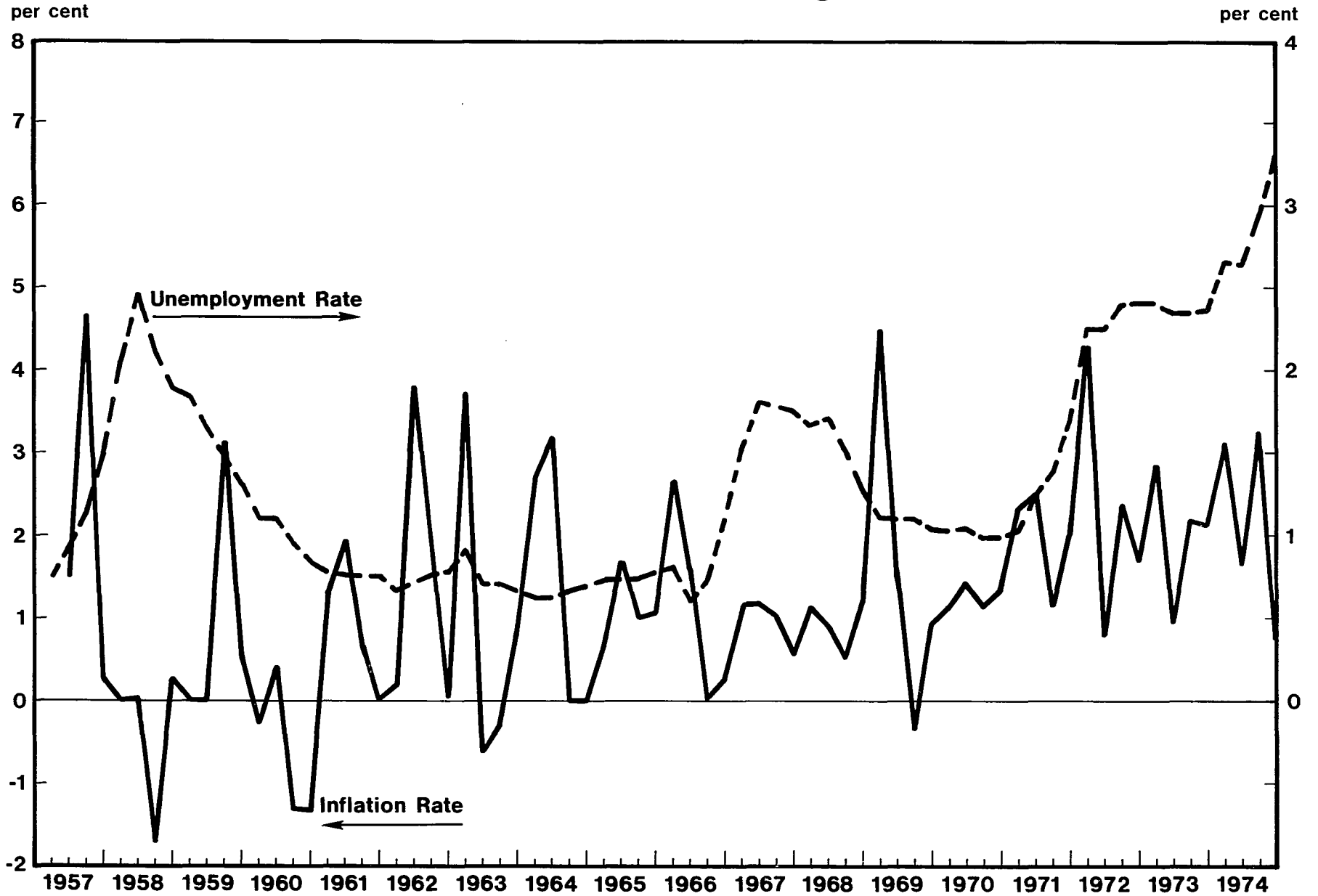
per cent



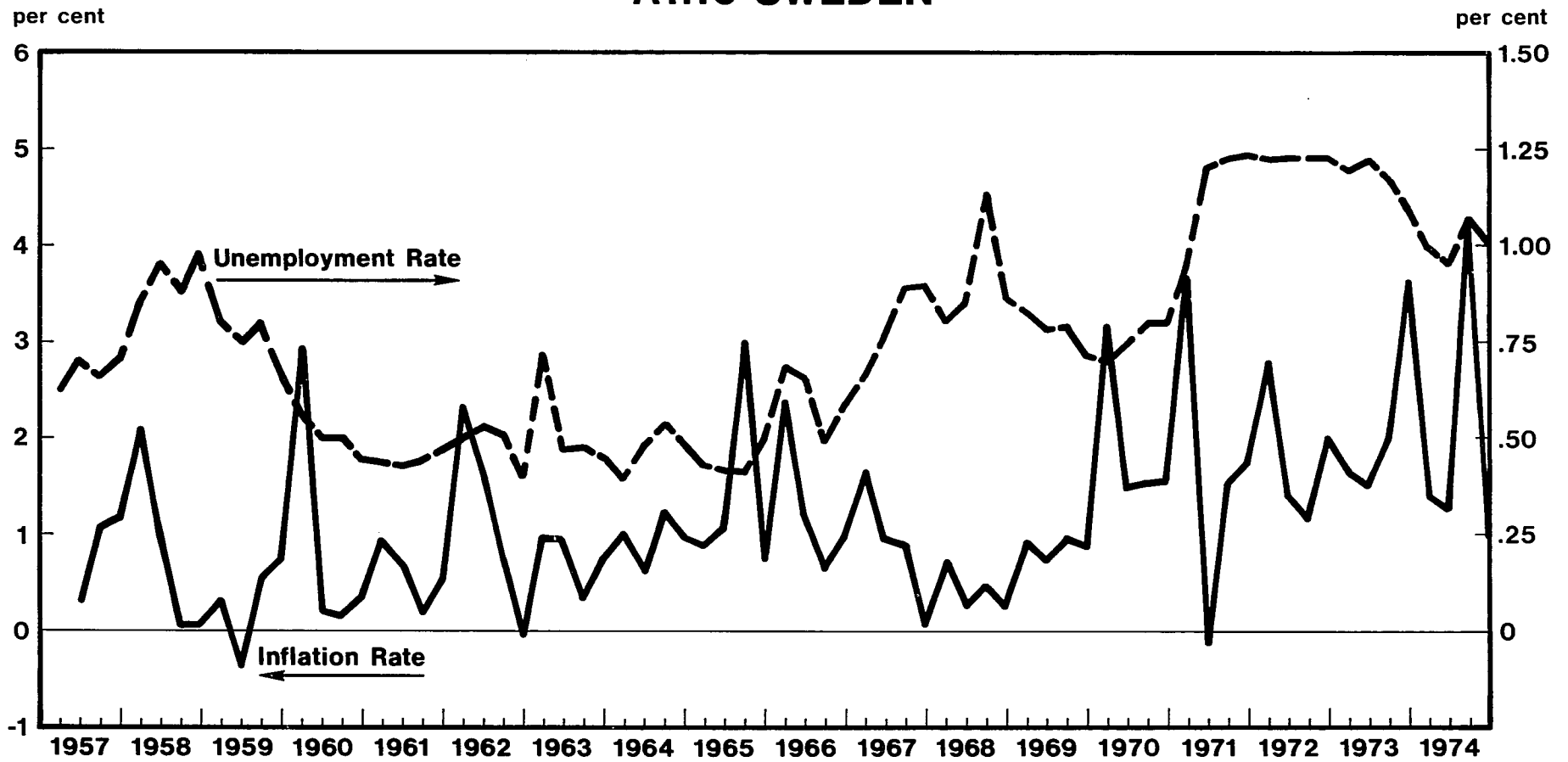
## A1.8 BELGIUM



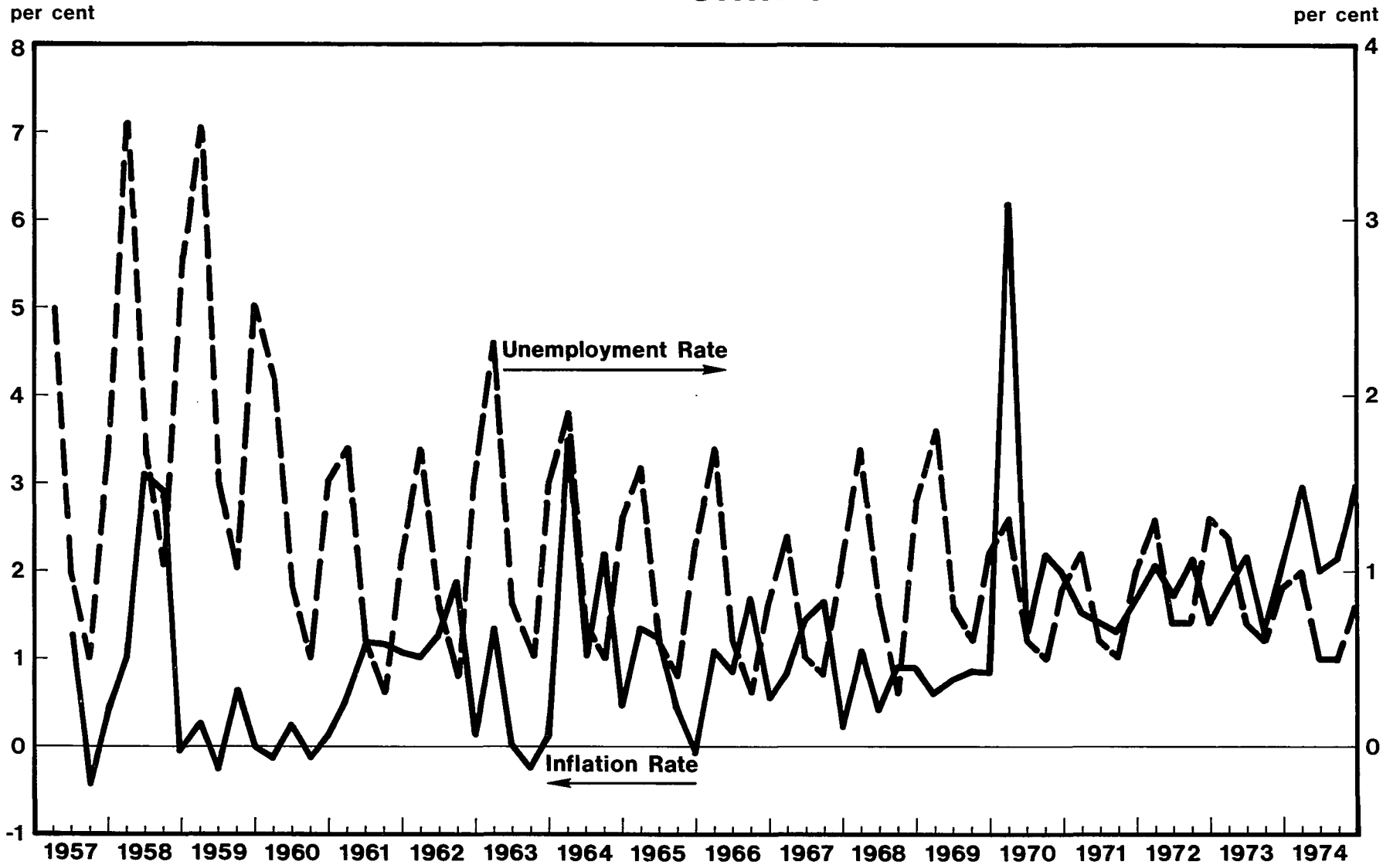
# A1.9 NETHERLANDS



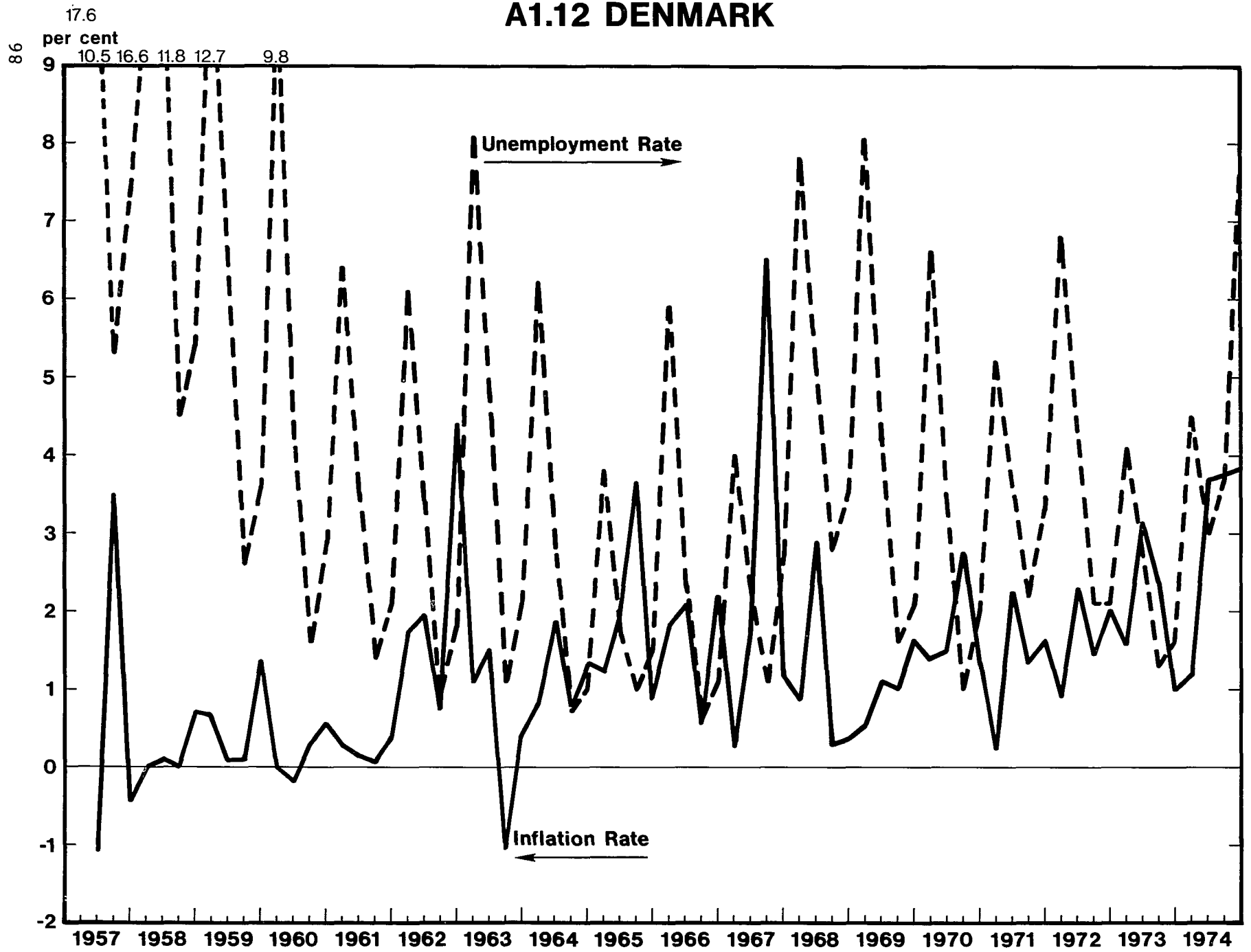
## A1.10 SWEDEN



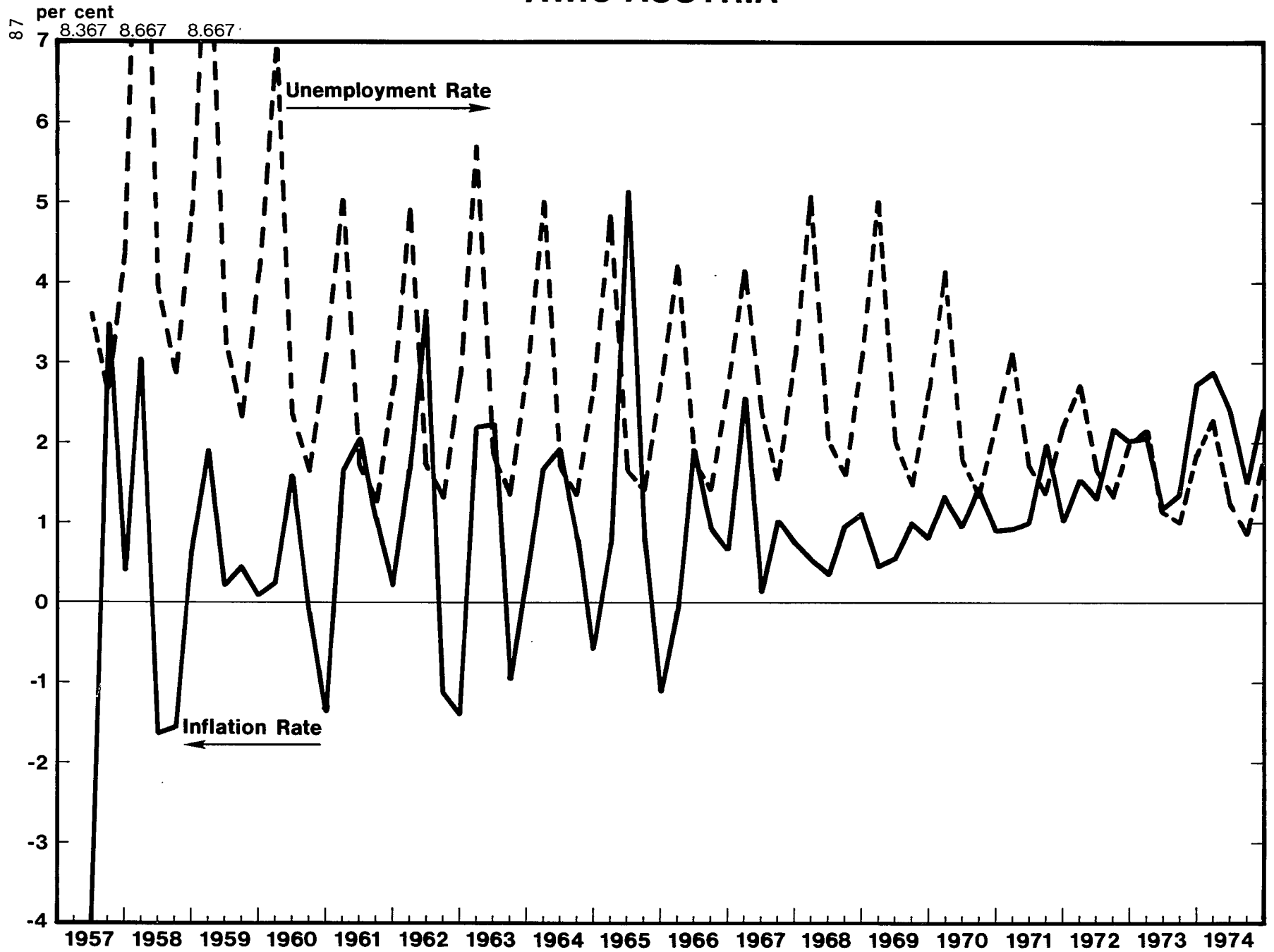
### A1.11 NORWAY



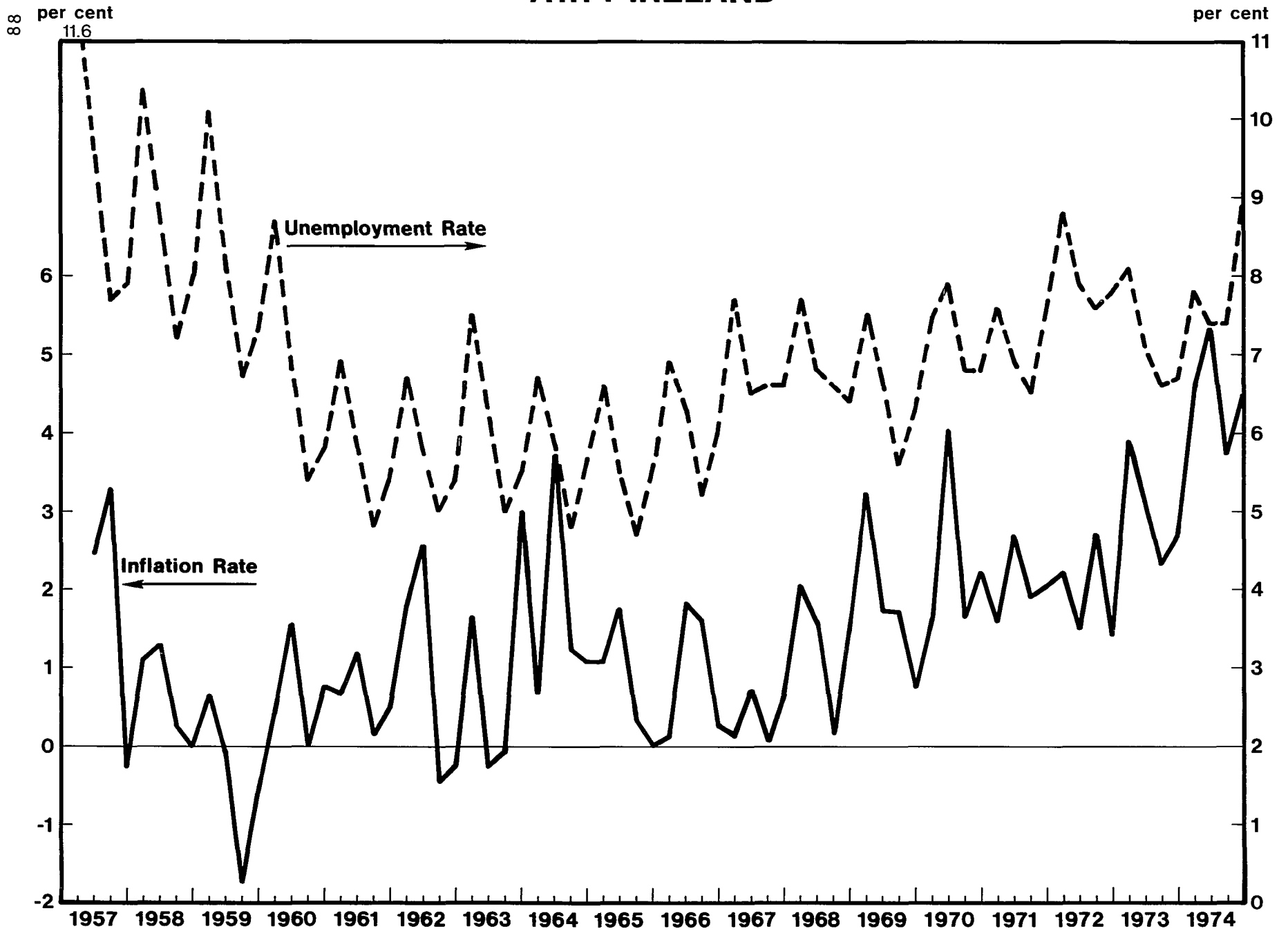
# A1.12 DENMARK



# A1.13 AUSTRIA



# A1.14 IRELAND



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